Water Management of the Regional Aquifer in the Sierra Vista Subwatershed, Arizona—2007 Report to Congress

U.S. Department of the Interior

Prepared in consultation with the Secretaries of Agriculture and Defense and in cooperation with the Upper San Pedro Partnership in response to Public Law 108-136, Section 321

U.S. Department of the Interior
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Preface

The Defense Authorization Act of 2004, Public Law 108-136, Section 321, stipulates the way in which Section 7 of the Endangered Species Act applies to the Fort Huachuca, Arizona military reservation. Section 321 of this Act further directs the Secretary of the Interior to prepare reports to Congress on steps to be taken to reduce the overdraft and restore the sustainable yield of ground water in the Sierra Vista Subwatershed:

> The Secretary of [the] Interior shall prepare, in consultation with the Secretary of Agriculture and the Secretary of Defense and in cooperation with the other members of the Partnership, a report on water use management and conservation measures that have been implemented and are needed to restore and maintain the sustainable yield of the regional aquifer by and after September 30, 2011. The Secretary of the Interior shall submit the report to Congress not later than December 31, 2004. . . . Not later than October 31, 2005, and each October 31 thereafter through 2011, the Secretary of the Interior shall submit, on behalf of the Partnership, to Congress a report on the progress of the Partnership during the preceding fiscal year toward achieving and maintaining the sustainable yield of the regional aquifer by and after September 30, 2011.

Pursuant to this requirement, an initial Section 321 report, submitted to Congress in 2005, established goals to achieve sustainability and indicated the various water management measures planned by Partnership members to meet the targeted reductions in aquifer use. The report that follows is an annual progress report, the third in a series of such reports that will be prepared from 2005 to 2011. The report utilizes the best information available at this time. Data from recently completed or ongoing Partnership research studies of the Sierra Vista Subwatershed were not fully available for inclusion in this report. In future years, these reports to Congress will rely on information from these studies and on data collected by a monitoring program tailored to Section 321 information needs. The authorship of this report is attributed collectively to the Upper San Pedro Partnership, a consortium of Federal, State, and local agencies, and nongovernmental organizations. Information for this report was supplied by several agencies including the Arizona Department of Water Resources, the Arizona Corporation Commission, the U.S. Geological Survey, the Agricultural Research Service, and other Upper San Pedro Partnership members.

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Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	4,047	square meter (m^2)
	Volume	
gallon (gal)	0.003785	cubic meter (m^3)
acre-foot (acre-ft)	1,233	cubic meter (m^3)
	Flow rate	
acre-foot per year (acre-ft/yr)	1,233	cubic meter per year (m^3/yr)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
gallon per day (gal/d)	0.003785	cubic meter per day (m^3/d)

Water Management of the Regional Aquifer in the Sierra Vista Subwatershed, Arizona—2007 Report to Congress

Submitted to Congress by the Secretary of the Interior, in consultation with the Secretary of Agriculture and Secretary of Defense, and in cooperation with the other members of the Upper San Pedro Partnership.

Executive Summary

Pursuant to the requirements of Section 321 of the Defense Authorization Act of 2004, Public Law 108-136, the Secretary of the Interior, in consultation with the Secretary of Agriculture and the Secretary of Defense, and in cooperation with other members of the Upper San Pedro Partnership, has prepared this third annual progress report assessing progress in calendar year 2006 toward a sustainable yield of ground-water withdrawal from the regional aquifer of the Sierra Vista Subwatershed, Cochise County, Arizona.

The initial Section 321 report, submitted to Congress in 2005, defined sustainability, established water-management targets, and identified various water-management measures planned by Partnership members to meet the targets. The initial sustainability goal was to eliminate annual storage depletions from the regional aquifer and begin accreting storage with the intent of beginning to replenish some of the cumulative storage depletion. On the basis of the best available information, the aquifer storage depletion is estimated to have been about 10,000 acre-feet in 2002 if then-established management measures are ignored. A management measure is a project or policy that yields water to offset the storage deficit. The deficit is projected to grow to about 13,000 in 2011 in the absence of management measures.

In this report, the definition of sustainability is redefined to consider several factors that include not only the water budget, but also measurements of the physical hydrologic system. Each of the factors used to assess sustainability is termed an 'indicator'. The indicators include the water budget, regional-aquifer water levels, near-stream ground-water levels, streamflows, spring discharge, and precluded future pumping in key areas. In future reports, threshold values that demarcate a numerical goal will be defined for each indicator if possible. The sustainability threshold for the water-budget indicator is defined as zero, with a value greater than zero indicating sustainability and a value less than zero indicating the level of withdrawal is not yet sustainable.

Data from the regional aquifer wells in 2001 and 2006 indicate that in areas of increasing population west of the San Pedro River, water levels have generally declined. Water levels near the river, particularly to the south end of the San Pedro Riparian National Conservation Area have generally been stable or risen. Streamflow at the U.S. Geological Survey gaging station near Charleston (09471000) reached a low value of 0.01 cubic feet per second (ft^3/s) on June 29, 2006. Flow ceased entirely at the site in July 2005. The 7-day low flow (the lowest of consecutive 7-day averages of flow) in June 2006 was 0.07 ft^3/s. This value was the lowest in the period of record for the gaging station. No analysis has been completed or published, however, that can quantitatively assess the reason, or reasons, for these low flows. Flow measured at Murray Spring, located within Curry Draw and downstream from the Sierra Vista wastewater recharge facility, has increased since monitoring began in 2003 with 32 gallons per minute (0.07 ft^3/s or 51 acre feet/year) in March 2003 and 122 gallons per minute (0.27 ft^3/s or 195 acre feet/year) in March 2006. In addition, the source of emanation has expanded from the original Murray Spring location to farther upstream in Curry Draw. The estimated amount of water recharged at the Sierra Vista wastewater recharge facility in 2006 was 2,230 acre feet. Recharge of water at the recharge facility may support flows in Curry Draw. Further investigation is required to identify the reason for the increased flows.

In order to mitigate the annual storage deficit, Partnership members have established various water-management measures. Some of these measures yield quantities of water that can be directly subtracted from the deficit; for example, a municipal wastewater recharge facility returns to the aquifer a quantity of water that would otherwise leave the system. Others management measures, including some conservation efforts and land-use policies yield quantities of water that are currently impossible to quantify. Finally, some water yields are "incidental" in that the yield occurred without implementation of a specific management measure. An example is the case where a farmer ceases to irrigate a field for reasons other than water conservation.

For calendar year 2006, calculations based on best estimates of actual management-measure yields and incidental yields from the sale of agricultural lands and increases in ephemeral-stream channel recharge measured or estimated in 2006 indicate that 9,600 acre-feet of water were yielded. When management-measure yields and an evaluation of pumping for 2006 in the Sierra Vista Subwatershed are combined in a water budget, a 2006 aquifer-storage deficit of about 5,200 acre-feet–a reduction of 2,300 acre feet from 2005–is indicated. The 2006 deficit value can not be directly compared to the deficits calculated in prior Section 321 reports owing to the use of an updated estimate of riparian evaporation and plant transpiration. The earlier estimate of evapotranspiration would have resulted in a calculated 2006 deficit of 2,100 acre feet. By comparison, the deficit reported for 2005 in the prior Section 321 report (using the earlier estimate of evapotranspiration) was 4,400 acre feet. In some cases management measures may prove more or less effective than originally planned. The Partnership has implemented a strategy of adaptive management such that management measures may be added to or eliminated from the plan, or modified as necessary to meet the goal of sustainability. In addition, the Partnership will adapt the criteria of sustainable yield as additional monitoring data become available.

Introduction

Ground water is the primary source of water for the residents of the Sierra Vista Subwatershed, Arizona, including Fort Huachuca, Bisbee, Sierra Vista, Huachuca City, Tombstone, and the rural residents of the Sierra Vista Subwatershed. Ground water is an essential component among the water sources that sustain the base flow of the San Pedro River and its associated riparian ecosystem, formally protected through an act of Congress as the San Pedro Riparian National Conservation Area (SPRNCA). Water outflow from the Sierra Vista Subwatershed, including water withdrawn by pumping, exceeds natural inflow to the regional aquifer within the Sierra Vista Subwatershed. As a result, ground-water levels in parts of the Sierra Vista Subwatershed are declining and ground-water storage is being depleted. In the absence of effective management measures, continued decline of water levels and associated depletion of storage will eventually diminish ground-water flow to the San Pedro River. The Defense Authorization Act of 2004 (Public Law, 108-136, Section 321, hereafter referred to as Section 321 and included as Appendix A) set goals and a timetable of 2011 for achieving, by various means, a sustainable level of ground-water use from the Sierra Vista Subwatershed. In addition, the Act formally recognizes the Upper San Pedro Partnership (Partnership) and clarifies the responsibilities of Fort Huachuca. The Partnership is specified as the regional cooperative organization for recommending policies and projects to mitigate water-use impacts in the Sierra Vista Subwatershed. Section 321 directs the Secretary of the Interior, in consultation with the Secretaries of Agriculture and Defense and in cooperation with the Partnership, to report on the water-use management measures (hereinafter referred to as water-management measures) that are being implemented and those needed to restore and maintain the sustainable yield of the regional aquifer by and after September 30, 2011.

The Partnership, formed in 1998, is a consortium of 21 local, State, and Federal agencies and private organizations whose collective goal is to ensure an adequate supply of water to meet the reasonable needs both of Sierra Vista Subwatershed residents and the San Pedro River. Some of the Partnership members are owners or managers of land and (or) are capable of implementing water-management measures. Other members include resource agencies with expertise in public policy, various scientific fields, and engineering. In pursuit of its goals, the Partnership has initiated and/or funded studies to better understand the regional hydrologic system, the riparian system, and recharge processes. The Partnership has also invested significant resources into systematically identifying, evaluating, and documenting water-management measures that will be used to attain sustainable yield of the regional aquifer. A complete listing of Partnership reports is contained in Appendix B. Additional information about the Partnership is available at: *http://www.usppartnership.com*.

Because the local ground-water system is complex, the consequences of ground-water use, and the effectiveness of alternative water-management strategies will only be better understood through ongoing research and monitoring efforts. The results of monitoring will provide information needed to improve management decisions as part of an adaptive management process. The term "adaptive" is used because decisions associated with sustainable yield must be made today in the absence of perfect knowledge about tomorrow's consequences. As new information becomes available, resource decisions can be amended or revised in subsequent years. For this reason, the continued operation of a well-designed monitoring program is important to provide useful feedback on the status and trends of aquifer conditions and the effectiveness of mitigation measures.

This report is the third of a series of annual progress reports due to Congress each year through 2011 to evaluate the success of Partnership water-management measures in attaining a sustainable yield of ground-water use in the Sierra Vista Subwatershed. As such, the report represents a manifestation of the adaptive-management process.

Purpose and Scope

The general purpose of this report is to address the reporting requirements of Section 321 for 2007 (reporting on calendar year 2006). To achieve that end, the report has three specific purposes: (1) to evaluate the implementation of water-management measures for the prior year (calendar year 2006), (2) to analyze the success of management measures in approaching a sustainable yield of ground-water use for the Sierra Vista Subwatershed, and (3) to present projected management measure yields in 2007–2011.

The information contained and goals enumerated in this report apply only to the Sierra Vista Subwatershed, which is part of the area drained by the San Pedro River (figure 1). The management boundaries of the Sierra Vista Subwatershed are defined as extending from the United States-Mexico border in the south to a northern divide drawn across the San Pedro Valley through the U.S. Geological Survey streamflow-gaging station, San Pedro River near Tombstone (station number 09471550). The hydrologic boundary extends to the headwaters of the San Pedro drainage in Sonora, Mexico, near Cananea (figure 1). The period of time considered in this report is 2006–2011.

Description of the Upper San Pedro Basin and the Sierra Vista Subwatershed

Physical System

The Upper San Pedro Basin[1] is a ground-water management unit that extends from the United States-Mexico border to a bedrock constriction called the Narrows about 11 miles north of

[1] The Upper San Pedro Basin is formally defined by statute in the Arizona Groundwater Management Act of 1980. The hydrologic boundaries of the Upper San Pedro Basin (a ground-water unit) and the San Pedro surface water

Benson, Arizona. The Sierra Vista Subwatershed is a 950 mi^2 area bounded on the west by the Huachuca Mountains and on the east by the Mule Mountains and Tombstone Hills. The southern boundary of the Sierra Vista Subwatershed is the United States-Mexico border, and the northern boundary is a watershed divide across the Upper San Pedro Basin which intersects the river at the gaging station near Tombstone about 1.5 miles downstream from the ghost town of Fairbank. The area within these bounds is an alluvium-filled valley with surfaces that slope gradually down from the base of the mountains to the San Pedro River, which flows north out of Mexico through the center of the valley. The basin's alluvial sediments constitute the Sierra Vista Subwatershed's regional aquifer.

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drainage do not coincide although the differences are minor. This report makes no attempt to resolve these differences in terminology.

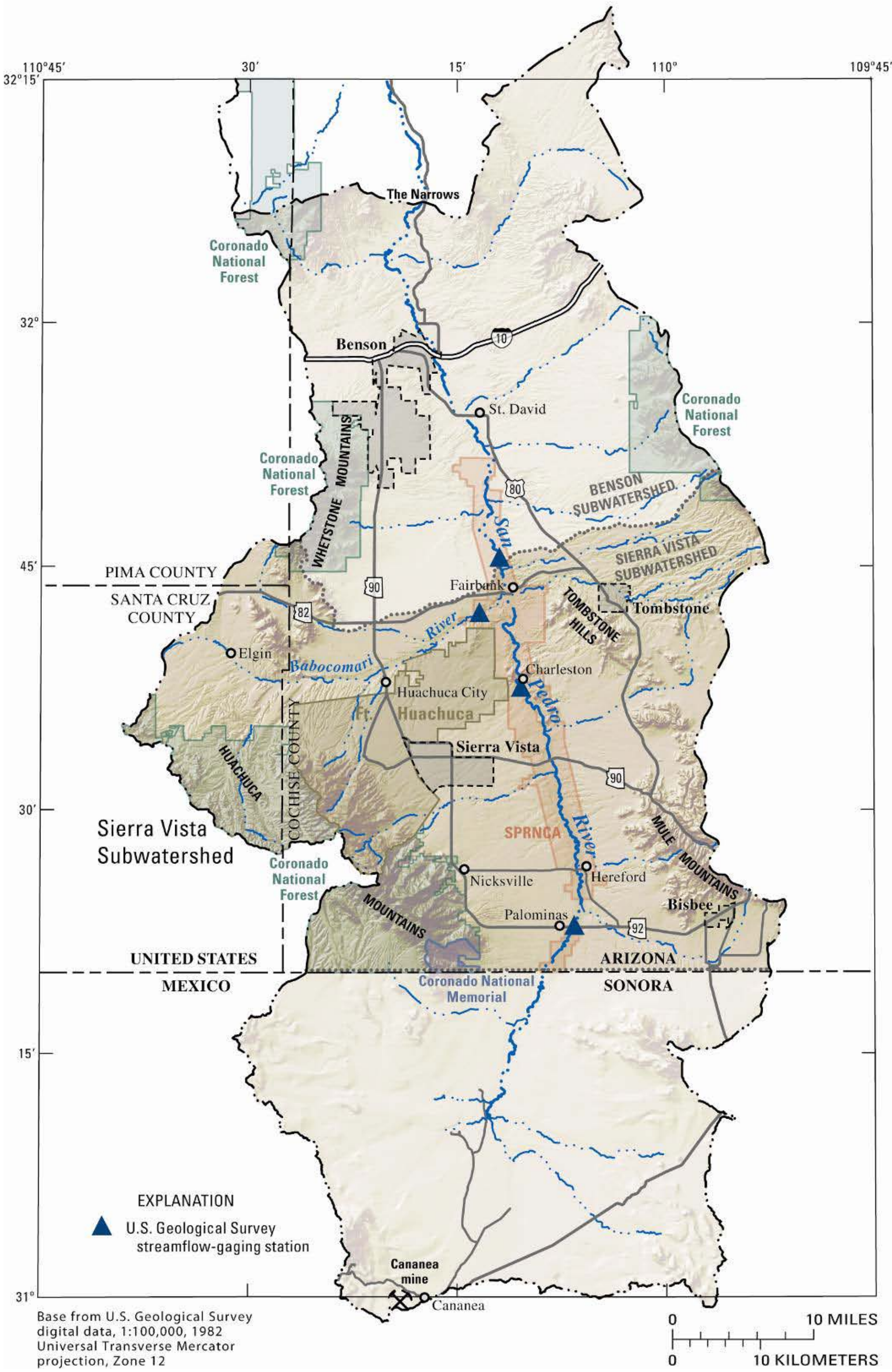

Figure 1. Location of the Sierra Vista Subwatershed, Upper San Pedro Basin, Arizona.

The Sierra Vista Subwatershed supports an ecologically diverse riparian system along the San Pedro River. In 1988, Congress designated portions of the river as the San Pedro Riparian National Conservation Area (SPRNCA; Public Law 100-696) to be managed by the Bureau of Land Management (BLM). The legislation directed the Secretary of the Interior to conserve, protect, and enhance the natural resources of this riparian system, which was the first riparian national conservation area in the country. The biological significance of the river stems from the ecosystem contrast between the riparian system and most of the surrounding area. The riparian system supports a diverse biota consisting of approximately 400 avian species, 81 mammalian species, and 43 species of reptiles/amphibians (Bureau of Land Management, 1989) and is a primary hemispheric corridor for migrating birds. The SPRNCA boundaries define a corridor along the San Pedro River up to 5 miles wide and extending about 35 miles north from the international boundary with Mexico (figure 1).

The climate of the Sierra Vista Subwatershed is semiarid; a basin-wide annual average rainfall of 16.1 inches was calculated using 1956 to 1997 records from four precipitation stations (Pool and Coes, 1999). The Agricultural Research Service interpolated a Sierra-Vista area 2006 precipitation of about 15 inches (Appendix C). Precipitation varies by location in the Sierra Vista Subwatershed and is typically greater on the basin-bounding mountain ranges than on the valley floor. About 65 percent of the annual precipitation arrives in late summer thunderstorms with the remainder generally arriving in winter storms (Goodrich and others, 2000).

Because precipitation in the Sierra Vista Subwatershed is concentrated in the mountains, most recharge to the regional aquifer system occurs at the periphery of the subwatershed, along the juncture between the mountains and basin floor (Pool and Coes, 1999). Water also enters the subwatershed as underflow from Mexico. Water that recharges along the mountain fronts moves toward lower elevation discharge locations. Within the subwatershed, natural ground-water discharge occurs mostly as outflow to the San Pedro River (base flow) and through consumption by the riparian vegetation along the river corridor (evapotranspiration). Some water also crosses the downstream boundary of the subwatershed as ground-water underflow.

In the subwatershed, the San Pedro River flows perennially (all year) in some reaches and intermittently in others. The ecologic condition of the riparian forest directly depends on the presence of shallow ground water within the flood plain, whereas the SPRNCA's aquatic habitats are directly dependent on stretches of perennial streamflow. This hydrologic context depends on consistent ground-water flow from the regional aquifer system to the stream (Pool and Coes, 1999).

The location of perennial streamflow is controlled by geology as well as by the amount and location of ground-water recharge and discharge. The primary perennial reach extends from about 7 miles south of the ghost town of Charleston to 1 mile north of Charleston, where the USGS streamflow-gaging station, San Pedro River at Charleston (station number 09471000), is located.

For many of the above-mentioned reasons, the subwatershed has been the subject of substantial scientific study over the last 15 years. Some of these studies have been sponsored by the Partnership and will provide valuable information for Section 321 reporting.

Cultural and socioeconomic setting

The Sierra Vista Subwatershed supports a human population of approximately 78,970 (estimated from Arizona Department of Economic Security, 2007) that is distributed among the unincorporated rural areas and the municipalities of Bisbee, Sierra Vista, Huachuca City and Tombstone. Sierra Vista, the Subwatershed's largest city, had a population of 44,870 (Arizona Department of Economic Security, 2007) including the permanent residents of the U.S. Army's Fort Huachuca.

The economy of the subwatershed is heavily dependent on Fort Huachuca, headquarters for the U.S. Army Intelligence Center, NETCOM, the Electronic Proving Ground and other DoD organizations. Fort Huachuca is the region's largest employer. The direct, indirect, and induced population in the subwatershed attributable to the Fort may be as much as 32,179 people (USFWS, 2007). Not only is Fort Huachuca the region's largest employer but it also controls approximately 78,000 acres in the Sierra Vista subwatershed much of which remains undeveloped. A recent economic impact analysis of Arizona's military installations estimates Fort Huachuca's impact as $2 billion statewide, the highest of the State's six installations.

The largest employer in the Subwatershed is the government sector. In addition to Fort Huachuca, Customs and Border Protection maintains a large presence. The University of Arizona South and Cochise College are also employers in the government sector. Retail, which is strongly affected by Mexico, and tourism driven by the region's western culture, heritage, and natural assets, have overtaken traditional industries of agriculture, ranching, and copper mining.

Conservation Culture

In recent years, local organizations and political jurisdictions have taken steps to promote a water-conservation culture in the region. Broadly speaking, this encompasses such activities as education and outreach efforts, incentive grants to replace water-wasting fixtures, municipal and county ordinances as well as policy changes. Many of these initiatives are captured by the City of Sierra Vista and Cochise County on their web sites (*http://www.sierravistawater.com/* for Sierra Vista, and *http://www.co.cochise.az.us/Water/Index.html* for Cochise County) where they each maintain water-conservation resources including tips, information, resources, and progress.

The conservation culture also extends to actions by members of the Partnership to manage the size of the problem into the future including the purchase of conservation easements, limiting development, or retiring agricultural use of various lands, and protecting hydrologically sensitive areas through growth management. Growth management tools used by members to limit development in uniquely sensitive locations are discussed elsewhere in this report. Quantifiable yields associated with these activities are difficult to determine in light of assumptions required.

The following information illustrates examples of the area's "conservation culture" as specific actions taken by Partnership members; it is not an all encompassing list.

Examples of Conservation Culture – City of Sierra Vista

- Established the Water Resources Center in the Office of the City Manager to coordinate and facilitate City water management plans and programs.
- Formed the Water Leadership Team (a committee of senior city staff including the City Manager, three Department Directors, and two Managers) to centrally plan, prioritize, and direct City conservation and mitigation programs
- Water use efficiency as determined by per capita water use has increased since CY2000 with per capita water use declining from 180 gpcd in 2000 to 145 gpcd in 2006.
- Reduced ground-water pumping in the city limits (including the Fort) to about 7300 acre-feet in 2006, the lowest since 2001.
- The City's toilet rebate program has, in its 7-year history, involved 750 households in the replacement of more than 1,200 high-flow toilets with new low-flow models. This program has saved 36 acre-feet of water (almost 12 million gallons) since its inception.
- Expanded residential rebate/incentive programs to include new rebates for cooler to air conditioner retrofits, and for the purchase of high-efficiency clothes washers.
- Established new water codes that include limiting the amount of turf in residential settings and prohibiting it at new commercial establishments; prohibiting the use of evaporative coolers as the primary source of cooling in new homes; prohibiting new golf courses unless they use

reclaimed water; requiring high-efficiency clothes washers in new commercial facilities; and requiring that washing machines and dishwashers supplied by builders in new residential construction meet Energy Star standards.

Examples of Conservation Culture – Cochise County

- Coordinates water policies through a water Coordinator who reports directly to the County Board of Supervisors.
- Established a subwatershed zoning district and a specific plan dealing with water exclusively for the Sierra Vista Subwatershed.
- Banned zoning density increases within 2 miles of the San Pedro River.
- Established new conservation codes including measures such as: hot water on demand, gray water plumbing, high-efficiency commercial laundry facilities, a ban on artificial water features (lakes, ponds, or fountains,) humidity sensors on outdoor irrigation, new turf restrictions, and limits on evaporative coolers.
- Enacted a Desert Hospitality Program to discourage unnecessary water use by restaurants (water served on request) and hotels (linens changed at the conclusion of the visit).
- Established a toilet rebate program that has replaced 341 high-flow toilets with new low-flow models resulting in an estimated conservation of about 19 acre feet of water annually.
- In a partnership with the Cochise Community Foundation and Cochise College, the County committed to tracking a series of Quality of Life (QOL) measures over the next decade. The QOL Index uses the San Pedro River as its indicator of Environmental Stewardship and will report out on changes in County water consumption.
- Provides financial and in-kind support to the University of Arizona Cooperative Extension Water Wise education program.

Examples of Conservation Culture – Fort Huachuca

- Operated the Fort Huachuca Water Wise conservation education program with an equivalent of one full time staff member.
- Achieved an 18 percent reduction in ground-water pumping through October of 2006 over 2005, and a 53 percent reduction over the last 24 years.
- Installed 119 waterless urinals in 2006 with an estimated savings of about 15 acre feet.
- Removed 295 evaporative coolers in 2006 resulting in about 14 acre feet of water savings.

- Made repairs to leaky sewer lines.
- Reused treated effluent for watering the Mountain View Golf course and Chaffee Parade Grounds.
- Engaged in negotiations to implement conservation easements.

Examples of Conservation Culture – Other

- The Partnership's business grant program invested $12,000 in 9 businesses to save 3.6 acre-feet/year.
- In 2006, Water Wise, a program of the University of Arizona cooperative extension service, held over 20 water conservation workshops, conducted 130 on-site visits to evaluate water use by homeowners and businesses, and had close to 3,000 face-to-face contacts to answer questions on water conservation best practices.
- The "Friday Report," a locally produced community radio talk show, features aspects of various water issues at least once or twice a month and provides residents with a deeper understanding of how water impacts much of the region's community development and projects.
- The National Forest Service thinned 150 acres of forest in the subwatershed for fire suppression purposes with a consequent reduction in upland evapotranspiration.

Essential Definitions

Two essential terms, "sustainable yield" and "overdraft," were defined in the initial Section 321 report specifically with regard to the Sierra Vista Subwatershed. These definitions are reiterated here to provide context for the discussions that follow. In addition, two additional terms are defined: "management measures", and "spatial water management."

Sustainable Yield

The Partnership has adopted the general definition offered by Alley and others (1999) for sustainable yield, which is "…managing [ground water] in a way that can be maintained for an indefinite period of time, without causing unacceptable environmental, economic, or social consequences." Therefore, a sustainable level of ground-water pumping for the subwatershed could be an amount between zero and a level that arrests storage depletion, with the understanding that to call a level of use sustainable (other than zero) will entail some consequences at some point in the future. What consequences are unacceptable are not yet fully defined, but will be decided as a collective result of stakeholder discussion, debate, and consensus. The role for science is to frame the range of options within which a goal can be established and to describe and predict the consequences of a given level of pumping.

The essential goal in achieving sustainable yield (more simply, sustainability) is to ensure that water of sufficient quantity and quality is available for the subwatershed's social, economic, and environmental needs. The Partnership has started to identify some specific elements of sustainable yield as shown in table 1. The ultimate definition of sustainability in numeric terms will likely be a complex consideration of many factors. The Partnership will be considering these factors in coming years as studies are completed and additional tools become available. An example of a complicating factor is that effects of pumping on flow in the river will vary through time, and as a function of spatial location in the subwatershed.

The term "safe yield" is not interchangeable with "sustainable yield" in this context; the two terms refer to different management goals. The State of Arizona defines safe yield as "a water management goal which attempts to achieve and thereafter maintain a long-term balance between the annual amount of groundwater withdrawn….and the annual amount of natural and artificial recharge…(A.R.S. § 45-562 (A))." Of key importance to the Sierra Vista Subwatershed is that safe yield does not consider the water required to sustain riparian ecosystems and streamflow and therefore is not used by the Partnership as a management concept.

Table 1. Initial criteria for sustainable yield

Social and economic	Environmental
• Sufficient water quantity for a growing human population • Fort Huachuca remains operational and able to assume new missions unless for reasons unrelated to water • Cost of living, specifically affordable housing and the cost of doing business, remains within the means of a diverse population • Maintain local participation in water management • Sustain water quality	• Ground-water levels in alluvial aquifer within the SPRNCA maintained • Stream base flow and flood flows maintained • Accrete aquifer storage • Riparian habitat and ecologic diversity maintained • Water quality sustained in SPRNCA • Overall riparian condition maintained • Springs in the SPRNCA continue to flow

Overdraft

The definition for overdraft used in this report is: ground-water consumption in excess of sustainable yield. This is consistent with the concept that pumping beyond a sustainable level is "over pumping."

Management Measures

The water- and land-controlling members of the Partnership have implemented a series of projects and policies that are intended either to reduce water consumption (conservation) or increase recharge to the aquifer system. Examples include water-conservation ordinances, conservation easements, and municipal wastewater reuse and recharge. Consideration is also being given to actions that can increase total water availability, such as rain-water harvesting and importation. These actions are referred to in this report as "water-management measures," and the yields from these measures are "management-measure yields."

Spatial Water Management

Spatial water management refers to decisions made in light of the fact that the location from which water is pumped from an aquifer influences where and when streamflow depletions will occur. The effect on streamflow by ground-water pumping is influenced by several factors including the aquifer properties and the distance from the stream that wells are located. As a general rule, pumping farther from a stream delays the onset of streamflow depletion (Alley and others, 1999). Spatial water management considers the effect of where pumping is occurring as part of decision making. An example is a management decision to move a group of supply wells located near a river and at the upstream end to a more distant and downstream location. The effect generally would be to protect upstream areas from streamflow depletion and delay the onset of streamflow depletion at downstream areas. Spatial water management is a technique that does not necessarily reduce total ground-water pumping. Instead, it is a strategy that can either be used to protect particular areas from streamflow depletion or to delay the effects of pumping farther into the future.

Strategy to Attain Sustainability

The Partnership has defined a strategy to attain a sustainable yield of ground-water withdrawals in the Sierra Vista Subwatershed. The strategy involves implementation of a variety of specific management measures that are designed to reduce the net impacts on the ground-water system. These measures can be categorized within the following groups: conservation, reuse, recharge, importation, engineered augmentation, redistribution, and spatial water management.

The identification and implementation of management measures by the Partnership and its members occurs within the context of adaptive management. The underlying premise is that the management process should improve through time, or 'adapt' as additional information about the success of prior measures becomes available. As monitoring and project data are evaluated, the Partnership will know better what existing measures work, and what additional measures may be needed to reach a sustainable level of ground-water withdrawals. An advantage of the adaptive-management process is that measures with a high level of certainty (in yield and funding) are implemented immediately, whereas less-certain measures are evaluated for later implementation.

The ultimate goal of water-use management in the subwatershed is attainment of a sustainable yield of ground-water withdrawals from the regional-aquifer system. A quantified yield has not yet, however, been defined as sustainable, partly because the yield that is sustainable depends not only on the definition by all stakeholders of unacceptable consequences, but, at least in the short term, on where ground water is pumped. Additionally, the impacts of drought and climate change may require a revision to the amount of ground water that can be sustainably removed from the ground-water system. As more is learned about the system, sustainable yield may need to be re-evaluated.

The knowledge gained in preparing prior Section 321 reports has made it clear that no single management measure or category of measures will achieve a sustainable yield. Instead, a multifaceted approach is required. Various management measures serve different purposes. Conservation measures, for example, improve water-use efficiency, while recharge and reuse of wastewater reduce the net withdrawals from the aquifer. Some techniques, such as spatial water management, do not necessarily reduce water use, but rather serve to 'buy time' by delaying the effects of pumping on streamflow depletion.

In 2006 and early 2007 the Partnership completed a key step toward populating a strategy to attain sustainability with specific project concepts. Specifically, the Partnership worked closely with the Bureau of Reclamation to develop a detailed problem statement with a specific goal to augment the area's water supply by approximately 10,000 acre feet/year by 2011 and 26,000 acre feet/year by 2050. This goal assumed a 2050 Subwatershed population of 170,000 using water at a gross per person rate equal to that estimated for 2002.

A variety of water supply augmentation alternatives were considered at an appraisal level by the Bureau of Reclamation including treatment of impaired waters from within the Subwatershed, engineered capture of urban-enhanced runoff, and importation of water from outside the Subwatershed. End uses for the water included serving municipal and industrial demand, and recharge in areas that would most benefit flows in the San Pedro River.

The Partnership worked through a screening process to compare and contrast the augmentation alternatives in order to recommend options to explore in greater detail. The screening process considered effectiveness (solving the problem), implementability (identifying technical and administrative constraints), and cost (capital, operation and maintenance). Several options were recommended for a feasibility report and further technical study, including capture and recharge of urban runoff, recovery and recharge of mine water, and importation of Central Arizona Project water. The results of the appraisal-level evaluation subsequent screening process are detailed in a Bureau of Reclamation report (Bureau of Reclamation, 2007).

Conservation

Conservation measures reduce the amount of water that would be pumped had such measures not been enacted; in essence, conservation is an increase in the efficiency of water use. Conservation does not, however, necessarily mean that total pumping will decline in the future because population may increase faster than conservation can reduce use. As a result, conservation may result in a reduced rate of pumping increase rather than a pumping reduction. Unfortunately, conservation is often not directly measurable – how much water would one have used if one had not conserved? An analysis of conservation can be made by comparing current per-capita pumping to per-capita pumping in an earlier year before conservation measures were implemented. A lower current per-capita pumping suggests that a population is using water more efficiently than before. Unfortunately, climate and other factors also play a role in water use so year-by-year per-capita use can be quite variable.

Several Partnership members have undertaken a variety of conservation projects. Examples of such projects include replacement of flush with waterless urinals, turf restrictions in new residential developments, prohibition of turf in commercial development landscaped areas, toilet rebates, requirement of gray-water plumbing and hot water on demand in new construction, and replacement of evaporative coolers with air-conditioning systems. Where it is possible to quantify water savings associated with these conservation measures, the results have generally indicated increased efficiency.

Recharge

Recharge management measures actively or passively increase the total aquifer recharge relative to natural quantities. The recharge could be derived from previously pumped water (municipal wastewater), in which case the net withdrawal of ground water is reduced. Alternatively, the source of recharge could be water that otherwise would have left the system by evaporation or runoff. The Partnership has embraced the implementation of a variety of recharge measures in pursuit of sustainability. The most significant examples (in terms of volume) of measures that return previously-pumped water to the aquifer are the wastewater treatment and recharge facilities of Sierra Vista and Fort Huachuca. These facilities collect wastewater through their respective municipal sanitary sewer systems, treat it, and discharge the treated effluent to shallow surface spreading basins for recharge. The City of Bisbee has now also implemented a wastewater treatment process that will result in increased ground-water recharge (and reduced pumping).

The Sierra Vista Subwatershed also includes recharge of “new” water, in the form of storm runoff, that would otherwise have evaporated or run off. In undeveloped arid to semiarid environments, most rainfall either evaporates directly or is utilized by plants (Scanlon, 1999). The recharge that does occur happens where water is concentrated, such as along the margins of mountain ranges or in ephemeral-stream channels. By increasing the amount of impervious land, urbanization has the effect of increasing both the peak discharge and total volume of runoff from storm events (Shuster and others, 2005). In the Sierra Vista Subwatershed, this increased runoff is ultimately directed into ephemeral-stream channels where the combination of generally pervious sediments and relatively high total water availability leads to aquifer recharge (GeoSystems Analysis, 2004).

Some of the increased recharge is passive; because the additional water from urbanized areas is directed into ephemeral-stream channels, recharge is increased. Recharge of urban-enhanced runoff, however, can also be purposefully increased through the construction of detention basins that slow the runoff of water in ephemeral-stream channels and thus encourage recharge.

The construction of detention basins for this purpose is a strategy that has, and will continue to be used by Partnership members, including Sierra Vista, Fort Huachuca, and Cochise County, to increase storm-water recharge in the Subwatershed. The Partnership intends to construct these detention basins to reduce peak discharge to predevelopment conditions so that the floodflow regime in the Subwatershed is not altered. Although this increased recharge from urbanization partially mitigates annual aquifer storage deficits, the Partnership does not suggest that urbanization increases recharge more than urbanization increases pumping, but rather that the increased recharge offsets a portion of the increased pumping.

Reuse

Another strategy adopted by Partnership members to attain sustainability is the reuse of wastewater. Much of the water that enters a point of initial use, for example a home, business, or industry, leaves with degraded quality but with a significant portion of the original quantity. Following treatment at a facility, the treated effluent can be allowed to evaporate in basins, discharged to a stream channel, recharged in an engineered recharge facility, or reused. Reuse prevents a portion of water from ever being removed from the aquifer. Owing to the fact that some losses are always incurred during recharge, reuse represents a potentially more efficient means of reducing overall ground-water use. The fact that the water is recycled, even though it is treated, limits its potential for reuse. Irrigation of existing turf is a common use of reclaimed water; in the Sierra Vista Subwatershed, wastewater currently replaces the pumping of ground water for irrigation of the Fort Huachuca Mountain View Golf Course and in the near future, will replace ground water for irrigation of the Turquoise Valley Golf Course in Naco, Arizona. Reuse only reduces ground-water demand, however, if existing uses of ground water are retired. If reused water is viewed as a source of water to initiate a new use, say a turf facility that would not otherwise exist, then the result is still a net increase in water and not a mitigation of existing ground-water use.

Importation

An additional means of reducing ground-water pumping within the Sierra Vista Subwatershed is to import sources of water from outside the Subwatershed boundaries, with the caveat that this imported water is used to replace existing demand. The U.S. Bureau of Reclamation, a Partnership member, conducted appraisal studies of several importation options. The various committees of the Partnership considered the options and in January 2007, the

Partnership Advisory Commission chose to pursue a feasibility study for delivery of Central Arizona Project water to the Subwatershed at a level of 20,000 to 40,000 acre feet annually. Such a delivery could directly replace existing ground-water uses or, as part of spatial management, could also be recharged at locations deemed beneficial to flows in the San Pedro River.

Engineered Augmentation

Water supplies within the Sierra Vista Subwatershed can be bolstered by utilization of water that would leave the Subwatershed as runoff, plant transpiration, or evaporation in the absence of intervention. The recharge of urban-enhanced runoff through ephemeral-stream channels and detention basins augments supplies by adding water to the system without importing from beyond the Subwatershed boundaries; however, it is a passive process dependent on variable rainfall.

In 2006, the U.S. Bureau of Reclamation explored options to actively capture urban-enhanced runoff through the implementation of engineered collection systems with subsequent recharge or direct use of this water. Two of the options considered were implementation of storm-water collection and distribution systems at the scale of a neighborhood and of a business-park complex. A third option investigated was a large-scale (8-square mile) urban collection and recharge system with an estimated annual yield of 1,800 acre feet. The Partnership Advisory Commission chose to forward the large-scale concept to feasibility study by the Bureau of Reclamation. The neighborhood and business-park scale concepts were approved for possible implementation by Partnership members as appropriate.

Redistribution

The Bureau of Reclamation conducted an appraisal-level study to explore the option of removing water from the works of the Copper Queen mine near Bisbee, treating it, and transporting 2,600 acre feet of treated water annually for recharge near the SPRNCA. Ground water was withdrawn from the mine from 1906 through 1987 to facilitate mining operations. Following the cessation of mining operations, ground-water levels have been recovering. Eventually water may ‘daylight’ at the bottom of the large open pit. The idea that transporting water from the mine to a recharge location near the SPRNCA would be beneficial is based on the relatively large distance of the mine from the river and evidence that the geology of the area will minimize any negative effects to streamflow in the future (Southwest Groundwater Consultants, 2004). The Copper

Queen mine redistribution appraisal report was recommended by the Partnership Advisory Commission for continuation to feasibility analysis.

Spatial Water Management

Spatial water management recognizes that water removed from different places in the aquifer have different effects on streamflow. One option for spatial water management is to move ground-water extraction wells to areas where there is a relatively long lag time associated with the effects of pumping on streamflow. Although this technique will not address sustainability over the long term since any ground water extracted from the Subwatershed will eventually impact natural outflows (Alley and others, 1999), it may allow additional time to implement strategies that directly address the sustainable yield of ground water. General examples of spatial water management are formal Transfer of Development Rights, which allow developers to increase the density of housing in proposed residential developments by "transferring" the development from a hydrologically more sensitive areas to an area where ground water consumption from the new development will have a lesser impact on streamflow in the San Pedro River, and the establishment of conservation easements. A recently passed Cochise County ordinance that bans increases in zoning density within 2 miles of the San Pedro River is a specific example of a Partnership-member spatial-water management measure.

Specific management measures planned through 2011

The Partnership and its members maintain a roster of deficit reducing water-management measures that either are currently implemented and planned for continuation or are planned for implementation before 2011. The yields from these projects (table 2) make up the foundation of deficit reducing measures currently planned by Partnership members. The projects generally represent conservation, recharge, reuse, or land-management measures that are possible within the resource limitations of the members.

In keeping with the adaptive management process some future planned yields (2007 through 2011) have been modified from prior Section 321 reports to reflect improved knowledge and potential new projects (table 2). The future-year management measures and yields will evolve in each annual Section 321 report as needed to reflect the changing state of knowledge. Projected yields for 2007–2011 have been modified from the projections in prior Section 321 reports on the basis of improved knowledge about yields actually obtained in 2002–2006.

Table 2. Planned annual yields for 2007 through 2011 of Partnership member measures to reduce aquifer overdraft

[Yields are in acre-feet/year; ---, indicates no yield in year; Conservation yields in each year are relative to a zero yield in the baseline year of 2002; Recharge yields are total values and are relative to a baseline of zero acre feet]

		2007 Yield	2008 Yield	2009 Yield	2010 Yield	2011 Yield
Description	**Measure type**	**Planned**	**Planned**	**Planned**	**Planned**	**Planned**
Fort Huachuca						
Conservation measures[1]	Conservation	160	210	230	230	230
Effluent recharge	Recharge	530	510	490	490	490
Stormwater detention basins[2]	Recharge	120	550	570	580	580
Cochise County						
Conservation measures[3]	Conservation	110	110	120	120	120
Stormwater detention basins[4]	Recharge	30	30	30	30	30
Sierra Vista						
Conservation measures[1]	Conservation	300	300	310	310	320
Improved golf course efficiency	Conservation	15	15	15	15	15
Effluent recharge[5]	Recharge	2,150	2,210	2,270	2,340	2,410
Stormwater detention basins[2]	Recharge	80	190	360	400	420
Bisbee						
Conservation measures[1]	Conservation	20	30	40	50	60
Reduced ground-water pumping through effluent reuse	Conservation	170	470	480	485	485
Effluent recharge	Recharge	290	0	0	5	15
Huachuca City						
Conservation measures[1]	Conservation	5	10	10	10	20
Effluent recharged at Fort Huachuca	Recharge	---	---	---	200	200
Tombstone						
Conservation measures[1]	Conservation	5	10	10	10	20
Effluent recharge[6]	Recharge	130	130	130	130	130
Bureau of Land Management						
Mesquite reduction[7], and retirement of agricultural ground-water pumping[8]	Conservation	660	750	830	920	1,000
Urban enhanced ephemeral-stream channel stormwater recharge						
Increase in stormwater recharge in ephemeral channels by urbanization[9]	Recharge	2,300	2,300	2,300	2,300	2,300
Incidental Yields						
Retirement of agricultural pumping	Conservation	2,070	2,070	2,070	2,070	2,070
Total yields						
Total yield[10]		9,200	9,900	10,300	10,700	10,900

[1]Yield relative to 2002 baseline of zero. Conservation efforts started earlier than 2002 that continue to provide yields do not display a yield in the table because they are already incorporated in actual water-use figures. Yields for 2006–2011 are projected yields based on additional planned measures. To simplify presentation, various specific conservation projects are grouped together to report yields. Actual water use will vary from year to year owing to effectiveness of conservation, weather, and other factors.

[2]Projections for 2007–2011 differ from the 2004 and 2005 Section 321 reports owing to the application of an improved estimation technique developed by Stantec Consulting and Geosystems Analysis Inc. (2006). This technique was developed to provide a consistent method to calculate yields from Fort Huachuca, Sierra Vista, and Cochise County basins. Additional data and improved techniques will be employed as they become available to calculate yields.

[3] Conservation yield attributable to Cochise County can not be quantitatively projected owing to the large number of small unmetered wells. The reported yield is attributable to toilet-replacement rebates and assumed savings from code changes. Cochise County has enacted various code changes that should yield future water savings that will increase in proportion to population. Conservation measures enacted include: hot water on demand, gray water plumbing, high-efficiency commercial laundry facilities, a ban on artificial water features (lakes, ponds, or fountains,) humidity sensors on outdoor irrigation, new turf restrictions, and limits on evaporative coolers.

[4]Detention basin yield derived from a study of urban runoff and recharge in ephemeral-stream channels and detention basins by Stantec Consulting and Geosystems Analysis Inc. (2006).

[5]Approximately 1,000 acre feet/year in the wastewater treatment and recharge process is not currently accounted for and may recharge the aquifer in addition to the cited amounts. Efforts are underway to ascertain the fate of the unaccounted water.

[6]Effluent produced by residents of Tombstone that is released to and recharged in Walnut Gulch. Yield from Arizona Department of Water Resources (2005a).

[7]Water-use savings through management of invasive mesquite using various treatments. Mesquite reduction reduces water use by replacing mesquite with more shallowly rooted plants. Yield from mesquite reduction estimated by using an Agricultural Research Service model of riparian evapotranspiration in the SPRNCA.

[8]Retirement of irrigated agriculture or other high water-consumption uses by consensual agreement.

[9]Urbanization in semiarid climates can increase recharge by concentrating rainfall runoff in ephemeral-stream channels. Initial estimates provided by the Agricultural Research Service of natural recharge enhanced beyond predevelopment levels by urbanization—credit not claimed by any particular Partnership member. These preliminary estimates will be refined through ongoing research and monitoring programs. Increased water use due to urbanization likely exceeds increased recharge. The 2004 Section 321 report listed a value of 3,200 acre-feet/year for urban-enhanced ephemeral-stream channel recharge. Values for 2006–2011 have been reduced to 2,300 acre-feet/year owing to the use of new land-cover data in calculations; they are not intended to imply a decrease from current values. All urban-enhanced recharge estimates represent quantities expected in an average year—no current monitoring can provide year-specific values. Projections for 2006–2011 are based on 2001 land-cover data and do not account for increases that likely will occur as impervious-surface area increases.

[10]Total yields rounded to nearest 100 acre-feet. Yields based on the best current data and assumptions. Yield values differ from the prior Section 321 reports owing both to changes in implemented and planned projects and to the use of improved methods to reanalyze yields.

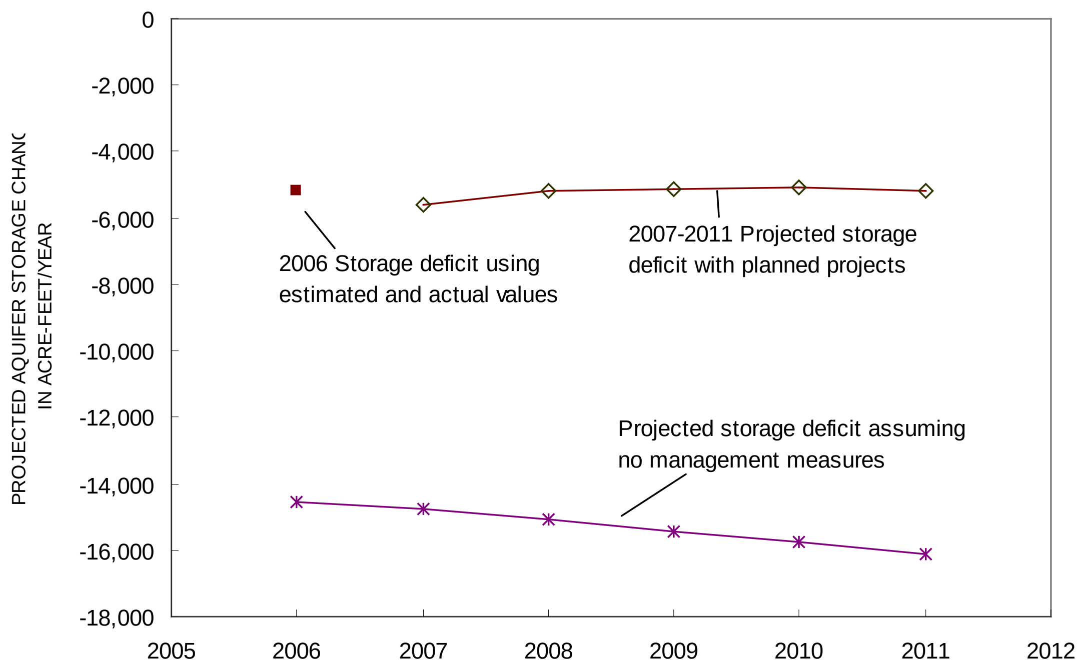

Figure 2. Effect of management measure yields (planned yields and estimates of actual yields) on annual aquifer storage change (calculated as the difference between projected annual aquifer-storage depletions if no management measures are taken and management-measure yields). (Deficit values can not be compared to prior Section 321 reports owing to the use of an improved estimate of riparian evapotranspiration [Scott and others, 2006]).

Assuming the currently projected yields are obtained, the projected aquifer storage deficit will not reach zero by 2011 by using only the current suite of management measures (figure 2). The estimation of future deficits includes a projection of population through 2011 based on the increase from the 2000 census (U.S. Census Bureau, 2000) to the 2005 population estimated by the Arizona Department of Economic Security (Arizona Department of Economic Security, 2006) . Each year the Arizona Department of Economic Security (AZDES) releases official estimates of prior-year population in incorporated areas and for whole counties. The AZDES population estimates do not report population by subwatershed, so for the purposes of Section 321 calculations it was assumed that the ratio of incorporated to unincorporated population remained the same as that for the last available data—the 2000 census.

The Partnership is actively investigating other management-measure approaches, including more effective rain-water harvesting techniques, to address the shortfall in yields. The current and future deficits depicted (figure 2) cannot be compared directly to similar results from prior Section 321 reports owing to the use in this report of a recently published (Scott and others, 2006) estimate of riparian evaporation and plant transpiration. The deficit currently projected is 3,100 acre feet larger than what would have been calculated using the earlier estimates of evapotranspiration.

The Partnership also recognizes the importance of spatial water management in protecting the base flows of the San Pedro River. Partnership-initiated science has begun to quantitatively define the relation between the location of a management action and the timing of effect on streamflow. An example of this recognition is the March 2006 enactment of a policy by the Cochise County Board of Supervisors to prohibit increased residential densities within 2 miles of the SPRNCA boundary. Assuming a given total rate of pumping, this effort will keep the most intense pumping a greater distance from the river thereby increasing the time before streamflow is reduced and giving additional time for planning. The Partnership is also considering locating some future recharge projects near the river where benefits to streamflow will be realized relatively quickly.

Strategy to Assess Sustainability

The language of Section 321 specifies that reports shall be prepared annually through 2011 discussing "the water use management and conservation measures that have been implemented and are needed to restore and maintain the sustainable yield of the regional aquifer by and after September 30, 2011." The Section 321 language leaves "sustainable yield" largely undefined other than to require that overdrafts from the aquifer be reduced. The Partnership recognized that while a "yield" refers only to an amount of water, "sustainable" is related in complex ways both to the physical environment and the socioeconomic system. Therefore, the Partnership adopted the definition stated previously "…managing [ground water] in a way that can be maintained for an indefinite period of time, without causing unacceptable environmental, economic, or social consequences."

To make the adopted definition of sustainable yield meaningful in the context of management decisions, consequences, and trends with respect to them, must be evaluated. The definition of specific indicators that relate to a consequence is helpful for evaluating status and trends. An indicator is something (such as a variable) that when measured provides useful information about a physical or socioeconomic system (Farrell and Hart, 1998). Measured values of indicators may be evaluated relative to a specific threshold or benchmark value that has an assigned meaning relative to sustainable yield; it is also possible that an indicator can be defined without an associated threshold. Examining the values of an indicator over a period of time allows an evaluation of how conditions are changing through time (trends), whether a critical value has been exceeded (threshold), and an idea how the indicator will look in the future (prediction).

The first Section 321 report and the subsequent annual reports considered a single quantifiable indicator – aquifer storage deficit calculated from the water budget. The calculated value of aquifer deficit in each year represents the numeric value of the indicator. A threshold for sustainable yield was defined relative to an aquifer storage deficit of zero; a zero or positive deficit (accreting aquifer storage) was defined as sustainable while a negative storage deficit was considered not sustainable. Although such an approach is easily applied and readily understood, it also does not consider aspects of sustainability such as spatial water-use management. For example, the subwatershed as a whole could achieve a water balance while localized pumping could still threaten sections of the San Pedro River.

The intent of the Partnership from the beginning of the Section 321 reporting process has been to define and report on a suite of sustainability indicators, including the aquifer storage deficit. Defining indicators and the associated thresholds is an ongoing process, and where possible, will be based on the best available science. The current report begins the process of defining indicators for the hydrologic system. The Partnership recognizes, however, that attainment of sustainability is contingent on no unacceptable consequences to the environment or to the socioeconomic system. Future reports may further refine sustainability indicators for additional environmental aspects and may also introduce socioeconomic indicators.

Riparian condition will be affected by a variety of factors, some of which can be controlled by human actions and some that can not. For example, naturally caused fires will modify riparian condition. The Partnership has committed to supporting the implementation of management measures that will influence hydrology, a key underlying control of riparian condition. Hydrology also varies because of both natural and human-caused factors. A graphical depiction (figure 3) reveals intrinsic interrelations between riparian condition, hydrology, and two drivers of hydrology, water management and climate. Riparian condition is controlled by hydrology, but may also influence hydrology as in the case, for example, where vegetation slows the runoff of floods and encourages recharge. The hydrology in turn is controlled primarily by a combination of natural factors, such as climate, and human actions such as ground-water pumping and various management measures to mitigate the effects of pumping. As a result of this chain of interrelated effects, sustainability indicators that are based on observations of hydrology or riparian ecology will respond both to human-caused and natural changes.

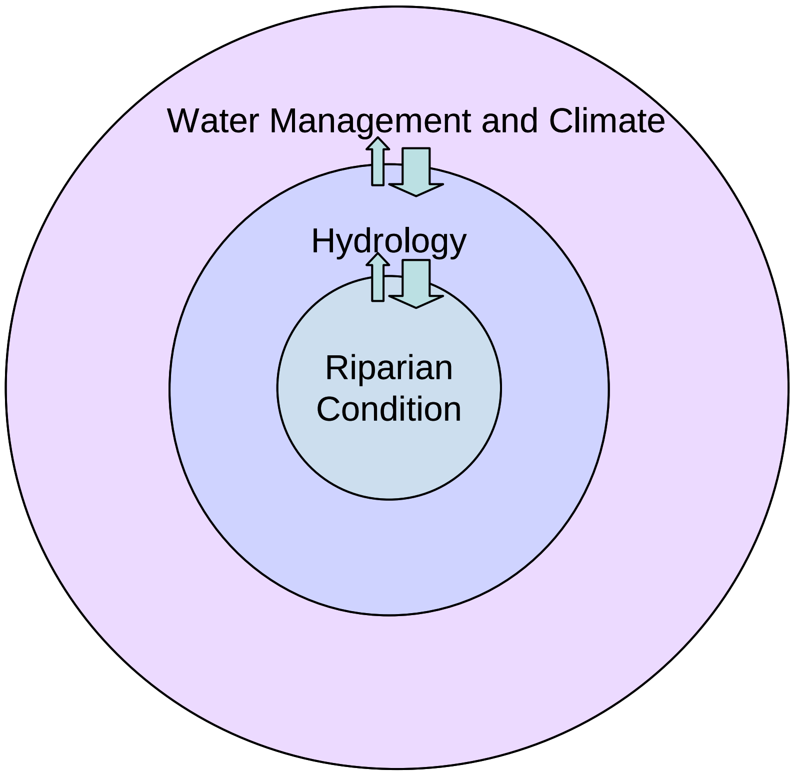

Figure 3. Conceptual relations between riparian condition, hydrology, and water-management measures and climate.

Ground-water indicators

The combination of completed scientific projects and an established monitoring program has yielded a base of information with which to define sustainability indicators relating to the ground-water system. This section defines indicators relating to regional-aquifer water levels and storage change, water levels in the San Pedro River stream alluvium, and hydraulic gradients.

Regional aquifer water levels and storage change

The most immediate and direct effect of ground-water pumping is declines in aquifer water levels. Declines in water levels beneath long-term pumping centers in the subwatershed have been measured over decades and indicate a general trend of loss in aquifer storage (Arizona Department of Water Resources, 2005b). As a direct measure of pumping effects, monitoring of water levels and aquifer storage change will serve a primary role in ascertaining the success of Partnership efforts to achieve a sustainable level of ground-water pumping in the subwatershed.

Water levels are measured to provide a sense of storage change; water-level decline indicates storage loss while water-level recovery indicates storage increase. Changes in water levels typically can not accurately be used to quantify storage change because the storage coefficient (ability of the soil to hold water) is generally not well known. Although water-level changes do not directly measure storage change, they are important for several reasons. They provide a direct indication of the direction of ground-water flow and of the hydraulic gradient driving this flow. Water levels have been measured at many locations in the subwatershed for decades and therefore provide a historical context within which to interpret changes. They are easily measured and measurements can be made with millimeter precision.

A regional-aquifer network of 30 wells (figure 4) has been monitored since about 2004 although records are longer or shorter depending on the well. Fifteen of these wells are monitored by the USGS through quarterly site visits and continuous data collection using dataloggers. The remaining 15 wells are on Fort Huachuca and have been monitored bimonthly by the Fort, USGS, or Arizona Department of Water Resources (ADWR) personnel. The distribution of these wells is concentrated in areas most likely to be influenced by pumping in the Sierra Vista/Fort Huachuca area, but the well locations also span from the mountain front to near the river. In addition, the ADWR conducts water-level sweeps in large numbers of wells approximately every 5 years.

Measurements of water levels in the monitoring-well network and additionally from the ADWR well sweeps constitute one set of sustainability indicators. Owing to the complexity of factors that affect water levels in wells, no single threshold value can be assigned to water levels in all of the wells. The Partnership is currently working to define thresholds.

The regional-aquifer monitoring network also includes measurements of ground-water storage change at about 45 stations using microgravity techniques. Gravity methods quantify changes in ground-water storage by measuring changes in total mass beneath a point on the Earth’s surface. When a gravity-measurement site remains undisturbed throughout a study period, a reasonable assumption can be made that the only change in mass through time is due to the removal or addition of underlying water (Pool and Eychaner, 1995). These measurements of storage change will also be included as indicators of sustainability.

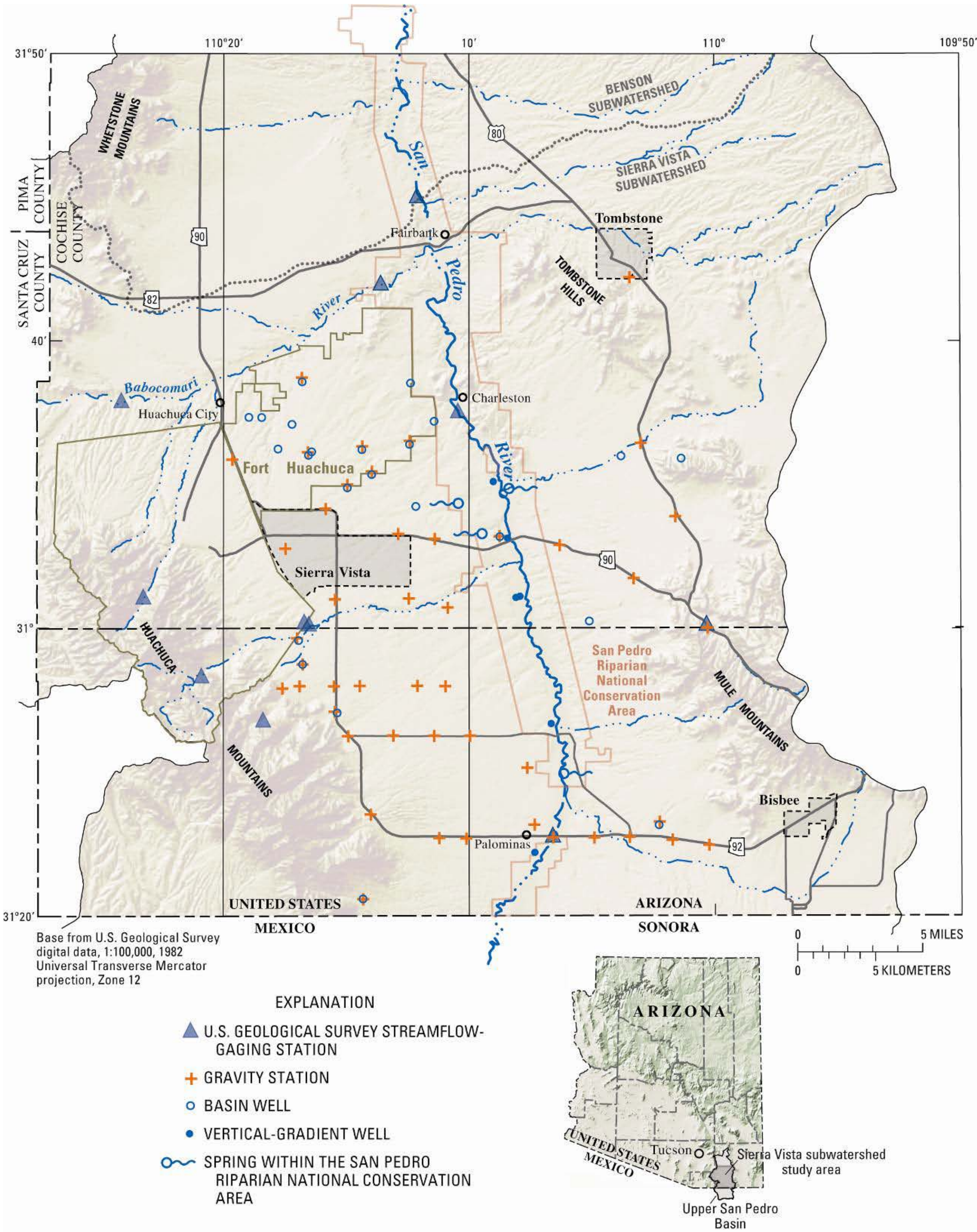

Figure 4. Locations of streamflow, ground-water level, spring, and microgravity monitoring locations in the Sierra Vista Subwatershed, Upper San Pedro Basin, Arizona.

Alluvial aquifer water levels

Much of the riparian vegetation along the San Pedro River can thrive only with direct access to shallow ground water in the stream alluvium near the river. Although declines in water levels anywhere in the aquifer system can have an eventual effect on the riparian system, the effect of declines in the stream-alluvium water levels on vegetation is relatively rapid.

A Partnership-initiated investigation was recently published that aimed to determine the relation between riparian vegetation variables and hydrologic conditions (Leenhouts and others, 2006). This study drew its conclusions on the basis of a variety of hydrologic measures, including ground-water levels in approximately 64 wells, and measurements of riparian vegetation and evapotranspiration. One outcome of the study was a map (figure 5) that divided the SPRNCA into 14 reaches and assigned a riparian condition class (dry, intermediate, or wet) to each reach. The condition-class assignment was based solely on the various measurements of riparian vegetation. The condition classes were then related to ground-water depth and streamflow permanence (the percentage of time in a year a stream flows), thus providing information about the hydrologic conditions that support particular riparian conditions. Specifically, the investigation found that the average maximum flood-plain (alluvium) ground-water depth in dry, intermediate, and wet condition-class reaches was 3.5 m, 3.0 m, and 1.7 m respectively (using water year 2002 data). The within-year average fluctuations of ground-water depth were 1.8 m, 0.9 m, and 0.3 m for dry, intermediate, and wet condition-class reaches respectively (again, for year 2002 data). The relation of streamflow permanence to riparian condition was also reported, with average flow permanence of 48, 78, and 100 percent for dry, intermediate, and wet classes in water year 2002 and 17, 63, and 98 percent in water year 2003.

From this information a specific set of ground-water and surface-water indicators can be defined pertaining to the hydrologic conditions along the San Pedro River. The ground-water indicators are the average and maximum ground-water depth, and within-year fluctuation in a subset of wells monitored in Leenhouts and others (2006). The surface-water indicator is streamflow permanence at a subset of the monitored sites. Although some riparian ground-water and streamflow data have been collected following the cessation of Leenhouts and others (2006) at the end of water year 2003, the full set of indicator wells and streamflow sites have not yet been fully defined.

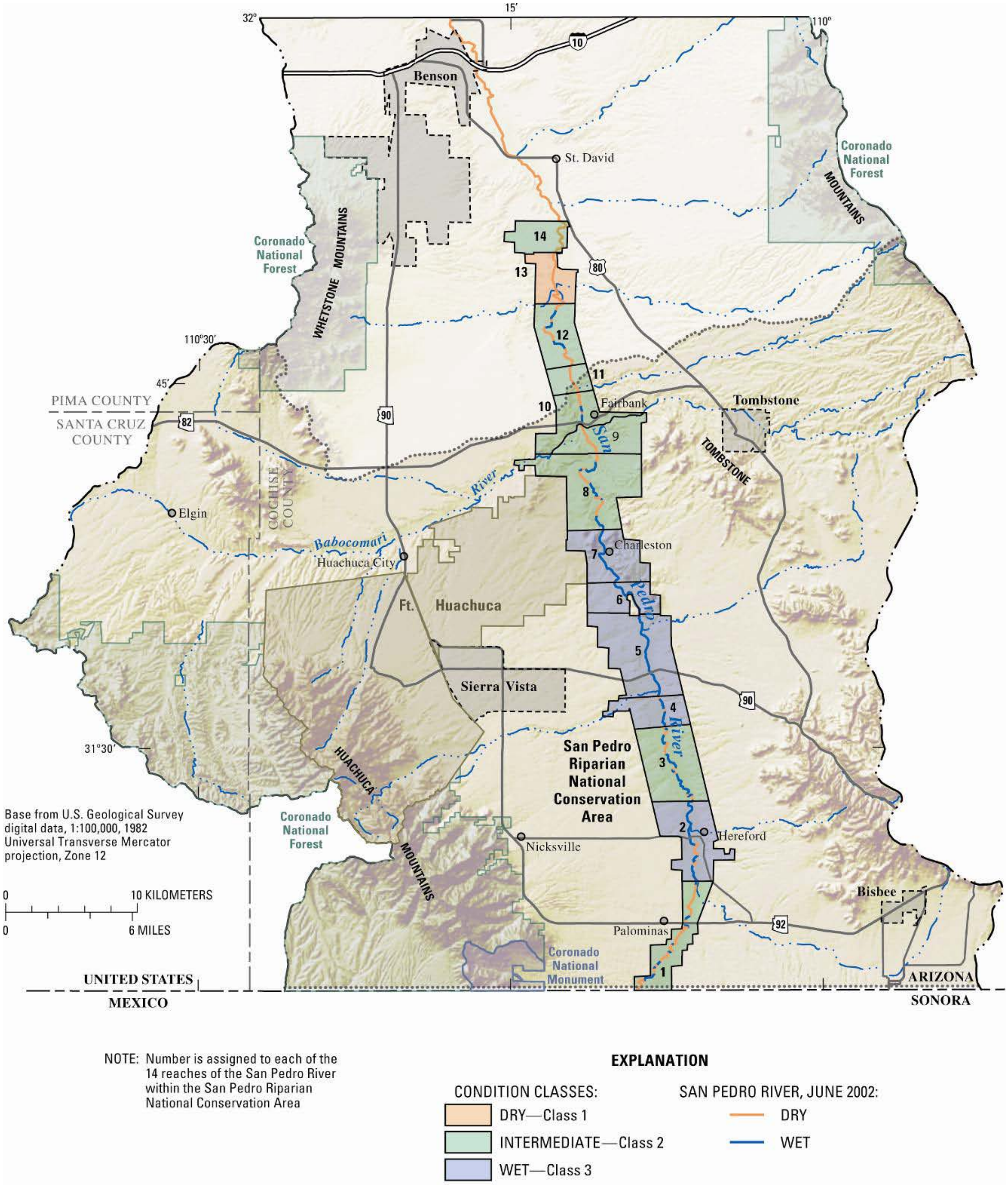

Figure 5. Riparian ecological condition class ranks for 14 reaches within the San Pedro Riparian National Conservations Area, Upper San Pedro Basin, Arizona (from Leenhouts and others, 2006).

The results in Leenhouts and others (2006), specifically the relations between riparian condition and hydrologic condition (Stromberg and others, 2006), set the ground work needed to define *thresholds* of sustainability in addition to indicators. Owing to the fact, however, that the relations were based on only a single year of ground-water data and two years of streamflow data, the Partnership will not adopt the published values as thresholds until additional data can indicate how much year-to-year variability occurs with each riparian condition class.

Vertical hydraulic gradients

Water flows from areas of higher water levels to lower water levels (or more precisely, from areas of higher energy to areas of lower energy). This difference in levels (divided by the distance between the points where the levels were measured) is a hydraulic gradient. In an aquifer, differences in water levels, or hydraulic head, can occur across both vertical and horizontal distances. Measurements of the changes in water levels provide a sensitive measure of changes in the force that moves water from one place to another. Some locations, such as at gaining reaches of the San Pedro River, have vertical hydraulic gradients that drive water upward from deeper parts of the aquifer into the stream system (Leenhouts and others, 2006). Vertical hydraulic gradients have been measured continuously at the Lewis Springs monitoring station near the juncture of highway 90 and the San Pedro River (figure 4) for about 10 years. These vertical gradient data serve as an additional indicator of sustainability in the suite currently defined.

Streamflow

The U.S. Geological Survey operates 9 streamflow-gaging stations in the Sierra Vista Subwatershed (figure 4) that collect data applicable for evaluating changes in the hydrologic system and progress toward sustainability. The periods of record vary from more than one hundred years at the streamflow-gaging station at Charleston (station number 09471000; continuous in time and location since 1935) to about 6 years at several stations. These data provide a spatially distributed look at how streamflow has varied since 2000. Stations located along the San Pedro River downstream of ground-water discharge locations help indicate changes in outflows from the regional aquifer system, whereas stations near the mountains indicate the relative amount of water available for recharge. The monthly streamflow records for each gaging station show the seasonal patterns imparted by the annual recurrence of summer precipitation events and winter cessation of evapotranspiration. Two specific indicators of sustainability adopted by the Partnership are the 7-day winter and summer low flows of the San Pedro River at Charleston. A 7-day low flow is the lowest value from a series of 7-day moving averages through a period of interest. The winter 7-day low flow period at Charleston is defined as January 15 through March 15 while the summer low flow is calculated using June data.

Springflow

In addition to stream base flow, springs represent another path through which water leaves the ground-water system and as such can act as indicators of how natural and human-induced changes to the hydrologic system are affecting the aquifer. Occasional measurements of spring flow were collected between 1988, when the SPRNCA was established, and 2003. Additional measurements were initiated in 2003, and a systematic network of quarterly measurements at 4 springs (figure 4) was initiated in response to Section 321 needs in early 2005. Discharge values measured at these springs are included as indicators of sustainability.

Precluded Future Use in Key Areas

Spatial water management addresses how future human water demands can best be managed to minimize the most immediate and direct impacts to base flows and alluvial ground-water levels. For example, pumping from areas close to streams and springs can generally be expected to affect the hydrology of the river system sooner than pumping from more distant areas.

Conservation easements are one mechanism by which future increases in pumping can be permanently precluded, especially within those areas close to the river that will have the most immediate impacts. An estimate of the amount of ground water that will not be pumped in the future as a result of the implementation of these easements was calculated as a means of tracking progress, and has been identified as one of the indicators of sustainability.

However, this indicator does not include the transfer (or relocation) of future ground water uses away from the river to those more distant (not a net reduction), such as would result in a transfer of development rights. Nor does it include any strategies or policies that limit future increases of development density over and above current approved levels. It only addresses the net reduction of current allowable development density.

It is also important to recognize that management of short-term impacts also needs to be coupled with implementation of additional long-term strategies that address the larger, overall groundwater deficit within the Subwatershed. Addressing both the balance of overall demand and supply with the avoidance of these shorter term, more acute impacts to the system, will all be necessary to accomplish sustainable yield.

Water Budget

In the preceding Section 321 reports, a water-budget approach was used to define an initial goal for attaining a sustainable yield of ground-water use. The goal was defined relative to a calculated annual aquifer-storage deficit of about 10,000 acre-feet/year for 2002. Specifically, the goal stated that: "The Partnership plans to offset net ground-water use [an amount] in excess of 10,000 acre-feet/year." This goal was based on the rationale that continued storage depletion would contribute to the cumulative storage deficit and increase the long-term risk of reduced base flows to the San Pedro River. Beginning to accrete storage initiates the process of reducing the cumulative deficit.

The water-budget approach used to create the initial goal for sustainability has some advantages. A water budget can be calculated relatively quickly using mostly existing information. A water budget is similar in some ways to a fiscal budget, and is easily expressed and understood by people with a variety of experience. Water budgets, however, also include significant limitations because they summarize a complex time-varying, three-dimensional flow system in a few numbers. As a result, a water budget cannot be used to evaluate spatial water-management aspects of sustainability. For example, it may be possible to pump ground water in a deficit condition in a particular area of the regional aquifer for a period of time without changing base flow in sensitive reaches of the riparian system, whereas pumping relatively small quantities of water near the river and upstream from sensitive reaches may have significant impacts over long reaches of stream. A water budget is also unable to forecast time-varying consequences to outflows caused by pumping. Removing water from an aquifer without replenishing it has the eventual effect of reducing the amount that flows out through the natural discharge locations. The timing of decrease in discharge, however, depends on properties of the aquifer, the intensity, timing, and location of pumping, and the proximity of pumping to recharge and discharge locations. A water budget also does not provide any measure of how pumping is changing water levels in the aquifer. Differences in water levels throughout an aquifer are the driving force that moves water through the system. Changing those levels modifies how ground water moves. An additional limitation to water budgets is that the storage deficit is calculated as the difference between inflows and outflows, resulting in a combination of the errors intrinsic to the inflow and outflow estimates.

In this Section 321 report, the aquifer storage deficit calculated from the water budget is included as an indicator of sustainability with a threshold of zero acre feet per year; a loss from storage being not sustainable, and a zero change or gain being sustainable.

Additional Factors

The Partnership has discussed the question of whether riparian variables should also be included as indicators of sustainability. The Bureau of Land Management has engaged in assessments of riparian Proper Functioning Condition (PFC) as part of its regular monitoring within the SPRNCA. A PFC analysis is a method for assessing the physical functioning of riparian and wetland areas relative to their ability to provide habitat through adequate water depth, duration, and temperature necessary for fish production, waterfowl breeding, and general biodiversity (Prichard and others, 1993). The underlying hydrologic conditions are key variables that affect the outcome of a PFC analysis, but are not the only variables. Land management practices, fires, and other factors will play a role as well. The Partnership may, in the future, elect to include PFC analyses of the SPRNCA as an indicator of sustainability.

Progress toward Sustainability

The assessment of progress toward sustainability in earlier Section 321 reports focused primarily on year to year changes in aquifer-storage deficit calculated by using a water-budget approach. The Partnership recognizes the importance of including all relevant information to assess progress. The relevant pieces of information are those that have been used to define indicators of sustainability. The following section presents the currently-available data. In some cases, a category of data, such as water levels in regional-aquifer wells, has been defined as an indicator of sustainability even through specific thresholds are not yet set.

For those indicators whose values are affected by climate, observed changes may have been caused by a combination of natural and human-induced changes; long periods of record may be required to uniquely define causality.

Ground-Water Indicators

Regional aquifer water levels and storage change

An analysis of historical trends is provided in Pool and Coes (1999), and in the ADWR's Active Management Area review report (Arizona Department of Water Resources, 2005a). In the regional aquifer system, a general and widely distributed decline of 0.3 to 0.5 ft/yr occurred from the 1940s through about the mid-1960s to early 1980s followed by a period of no decline or slight recovery. This trend is best illustrated in well D-23-22 18bbb (figure 6), which is located near Hereford and away from the primary historic pumping center of Sierra Vista-Fort Huachuca. Pool and Coes (1999) suggest that this regional pattern of decline followed by cessation of decline or recovery resulted from shifting climate patterns. Rates of water-level declines have been larger in the Sierra Vista-Fort Huachuca area as indicated by a hydrograph from public supply well D-21-20 34DCC1 and Fort Huachuca monitor well number 4 (figure 6). A well near the Huachuca mountains, Antelope number 2, indicates consistent declines since 2000. A long-term hydrograph from a well (site 312250110063901) along the San Pedro River near Palominas (figure 6) shows only a few feet of decline resulting from historic near-stream agricultural pumping, but the decline was sufficient to convert the then perennial stream reach to ephemeral.

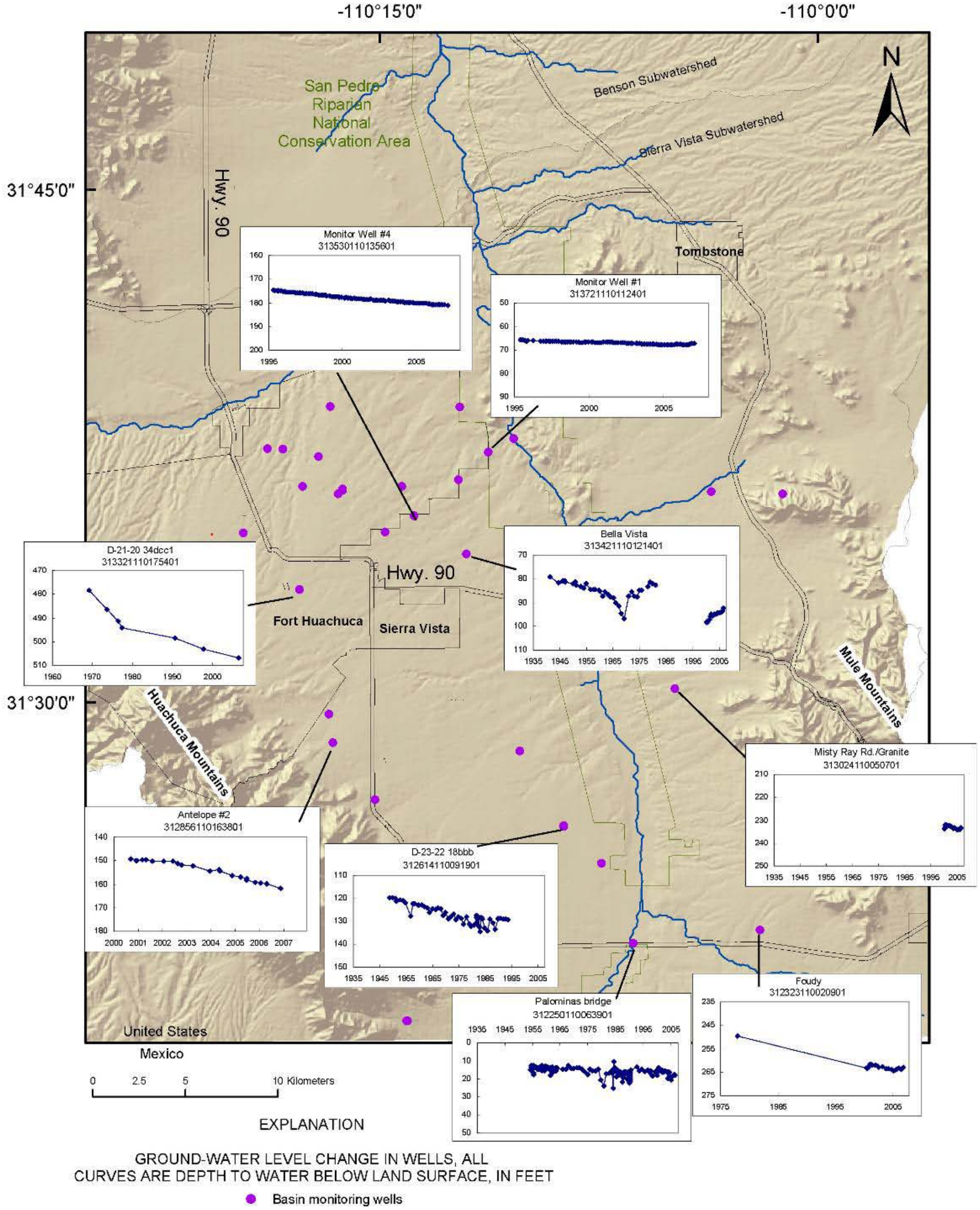

Figure 6. Long term ground-water level hydrographs at selected wells in the Sierra Vista Subwatershed, Upper San Pedro Basin, Arizona.

Data from spatially distributed production and observation wells show how water levels have changed across the Sierra Vista Subwatershed from 2001 to 2006 (figure 7). The Arizona Department of Water Resources periodically measures water levels in many wells across Arizona, including in the Upper San Pedro Basin. These measurements are generally single observations made at approximately the same time in a year, and therefore represent 'snapshots' of ground-water levels across broad areas. The ADWR conducted such measurements, or 'well sweeps' in 2001 and 2006 in the Subwatershed. The water level in any individual well may vary up or down by many feet depending on the recent pumping activity at that well, nearby recharge, and other factors. The difference between the 2001 and 2006 measurements at each well when broadly viewed as a collection of wells, however, provide a spatially-distributed view of how ground-water levels changed (figure 7). Areas with declines of greater than 1 foot are scattered across the Subwatershed, but are concentrated to the west of the San Pedro River and near the Babocomari River. Wells in which stable or greater than a 1-foot rise were largely located near the San Pedro River with a concentration near the Palominas/Hereford area. Rising levels northeast of Sierra Vista between the City and the river may represent the effects of recharge from the City of Sierra Vista's Environmental Operations Park, a management project designed to recharge the regional ground-water system.

Measurements of changes in microgravity have been made across a broad network of stations in the Sierra Vista Subwatershed (figure 8). Such measurements have been used to quantify changes in aquifer storage (Pool and Eychaner, 1995) and can be applied at locations lacking wells. Sufficient periods of record are required to recognize whether observed trends are caused by natural variability or human actions. The record in the Sierra Vista Subwatershed extends to about 2000 and a selection of measurements indicates that different locations exhibit different responses. A location near the Huachuca Mountains (Antelope 3) where recharge events tend to result in variable water levels shows about 100 microgals of gravity change, ranging from positive to negative values. Measured changes of about 13 microgals equal about 1 foot of free-standing water (Pool and Eychaner, 1995). Closer to the middle of the basin, near the site Palominas AA, the gravity signal exhibits relatively small variations.

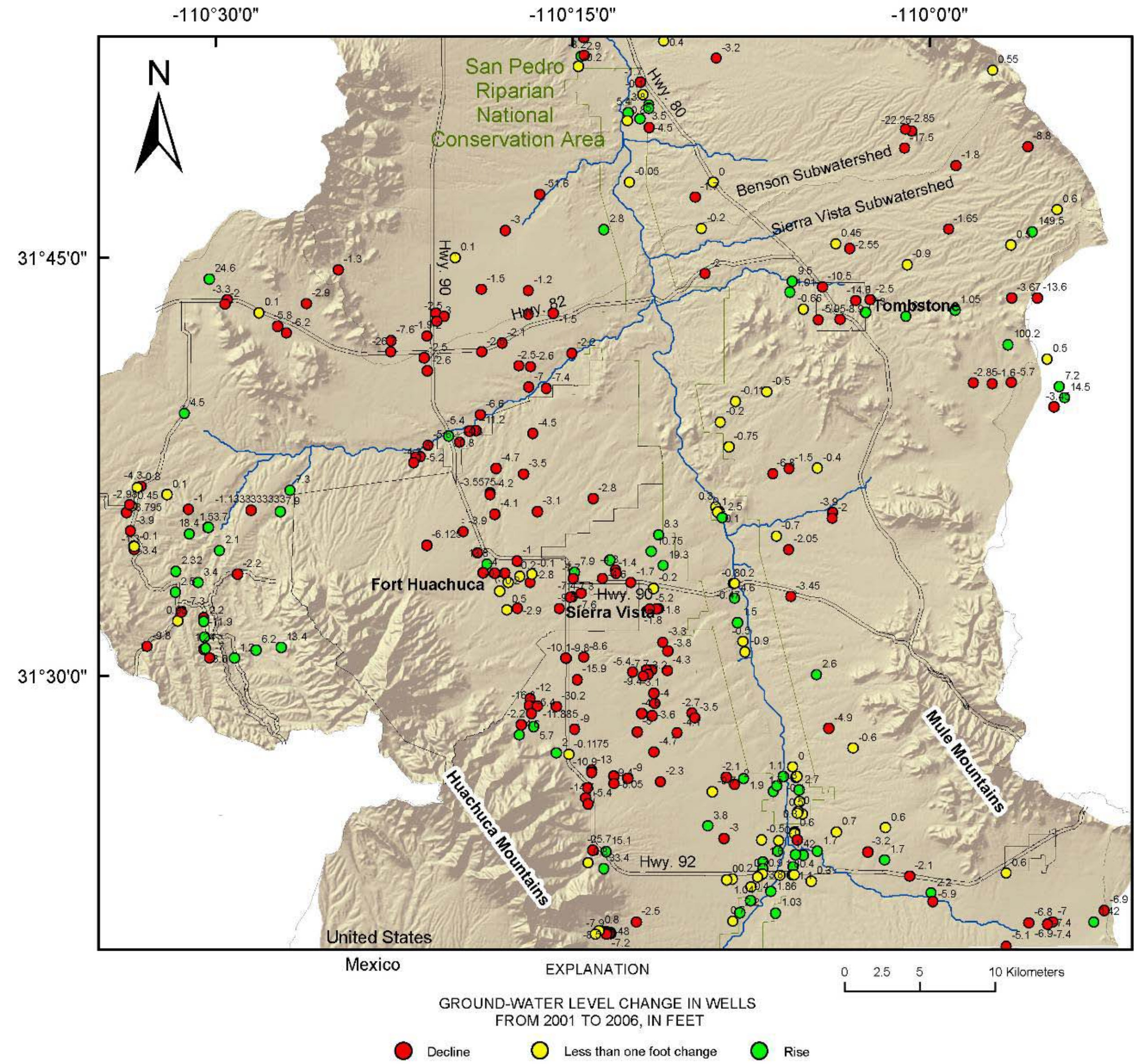

Figure 7. Changes in ground-water levels, 2001 to 2006, in the Sierra Vista Subwatershed, Upper San Pedro Basin, Arizona.

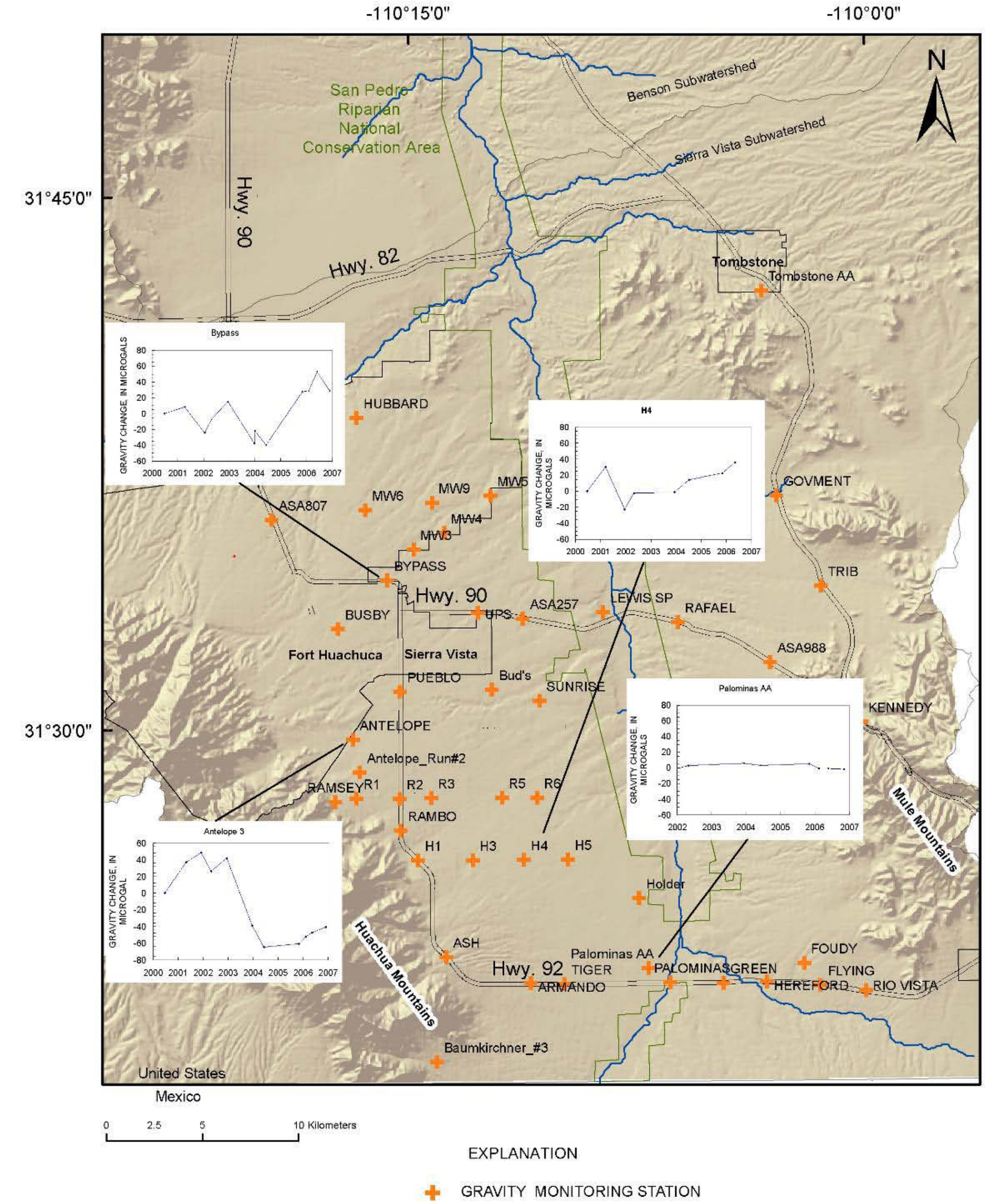

Figure 8. Microgravity monitoring locations and changes in gravity at selected locations, Sierra Vista Subwatershed, Upper San Pedro Basin, Arizona, 2000–2007.

Vertical hydraulic gradients

Changes in the hydraulic gradient measured between vertically separated (but horizontally collocated) wells near the San Pedro River help indicate changes in the tendency for water to flow between the stream and the ground-water system.

Ground-water levels measured at three locations along the San Pedro River, the Lewis Springs, Hereford, and Palominas monitoring sites (figure 9), illustrate a tendency in the direction of ground-water flow (up and toward or down and away from the river) and changes over the period of record. As calculated, positive gradients indicate a tendency for water to flow vertically upward toward the stream (Lewis Springs and Palominas) while negative gradients suggest downward flow (Hereford).

Streamflow

The U.S. Geological Survey operates 9 streamflow-gaging stations in the Sierra Vista Subwatershed (figure 10) that collect data applicable for evaluating changes in the hydrologic system and progress toward sustainability. The periods of record vary from more than one hundred years at the streamflow-gaging station at Charleston (station number 09471000) to about 6 years at several stations. These data provide a spatially distributed look at how streamflow has varied since 2000. Stations located at ground-water discharge locations, such as along the San Pedro River near Charleston, help indicate changes in outflows from the regional aquifer system, whereas stations near the mountains indicate the relative amount of water available for recharge. The monthly streamflow records for each gaging station show the seasonal patterns imparted by the annual recurrence of summer precipitation events and winter cessation of evapotranspiration. These records also show longer term changes.

Base flow at the Charleston gaging station varies seasonally (figure 11), typically with the lowest flow in June, and the highest flow in late winter. These seasonal variations have several causes, primarily related to changing rates of near-stream withdrawals such as by riparian vegetation. Longer-term changes may be caused by changes in the stream channel, and by climatic changes (Pool and Coes, 1999). A detailed analysis of trends in base flow at the Charleston gaging station may be found in Pool and Coes (1999) for the period 1936 through 1997.

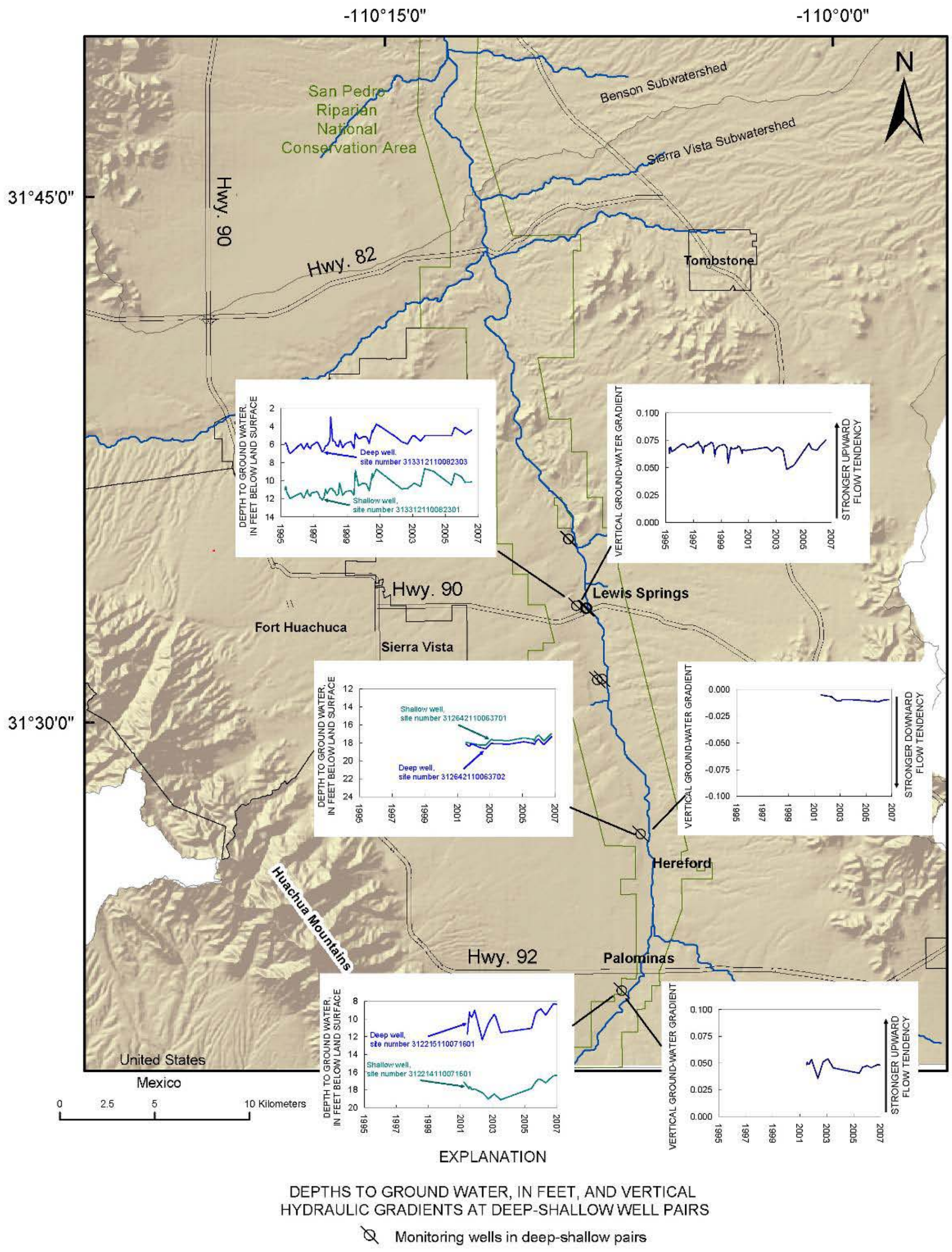

Figure 9. Ground-water level hydrographs and plots of vertical hydraulic gradients at selected wells in the Sierra Vista Subwatershed, Upper San Pedro Basin, Arizona.

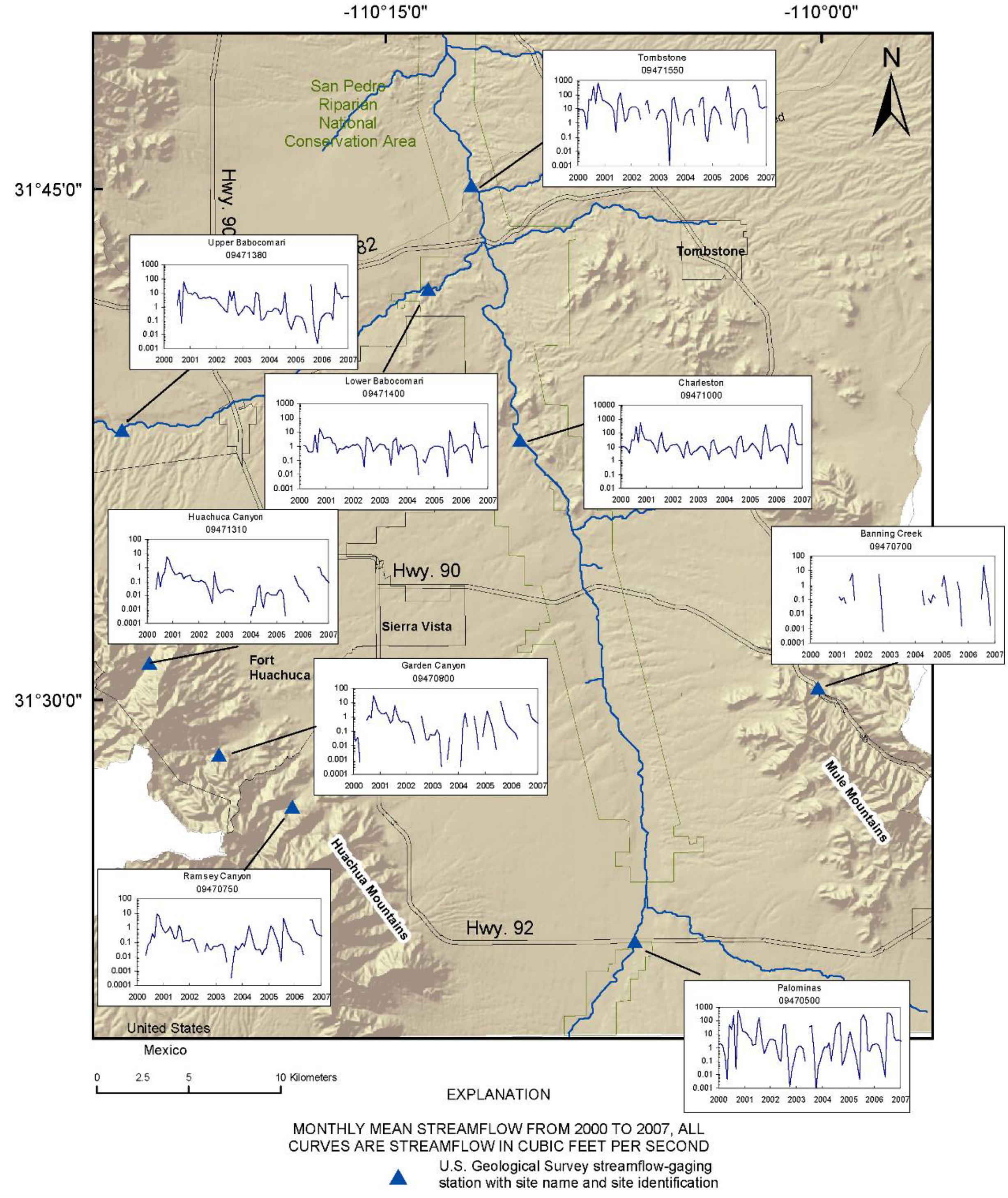

Figure 10. Monthly average streamflow at stream monitoring locations, Sierra Vista Subwatershed, Upper San Pedro Basin, Arizona, 2000–2006.

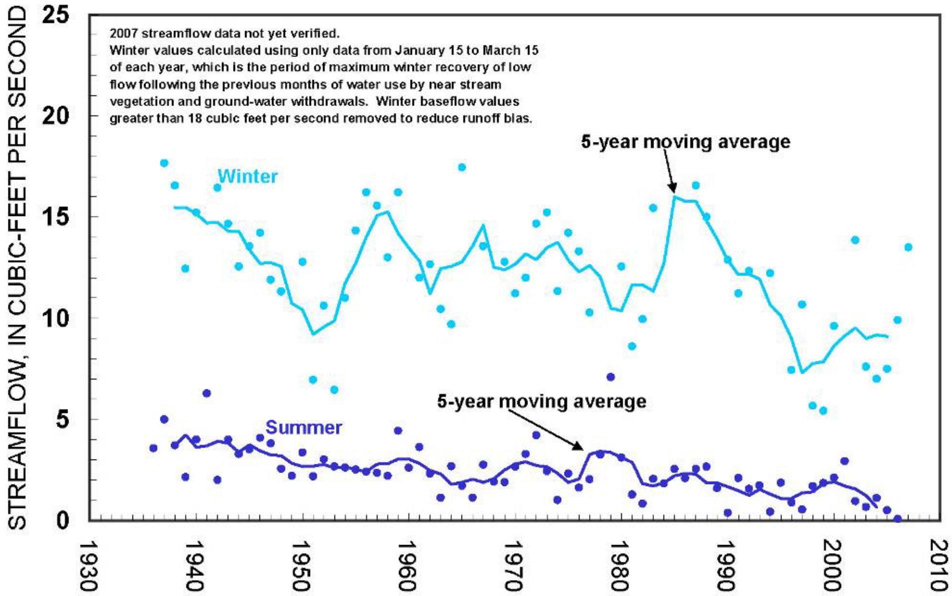

Figure 11. Seasonal 7-day low flow at the San Pedro River at Charleston streamflow-gaging station.

The conclusions in that report suggest that summer base flow has a decreasing long-term trend, but that winter base flow exhibits no significant trend after about 1951. In addition, Pool and Coes (1999) note that trends in both summer and winter base flow are closely related to wet-season runoff.

A detailed study of trends in annual total, peak, and low streamflow at Charleston (Thomas and Pool, 2006) noted that annual total flow decreased by more than 60 percent during the period 1913 to 2002 from 57,700 to 22,000 acre-feet/year. During the same period, annual low flows decreased from 7,900 to 4,300 acre-feet/year and summer low flows decreased from 900 to 300 acre-feet/year. Statistical tests of precipitation from the National Weather Service precipitation gage at Tombstone indicated no significant trends in winter, spring, and fall, but a significant downward trend in summer precipitation. After statistically removing the effect of the downward summer precipitation trend from the streamflow record, total streamflow still exhibited significant trends in June through December, low flows had significant trends in May through December, and storm runoff had significant trends in July through September. Thus while changes in precipitation contributed to trends in streamflow, a factor or factors other than precipitation also contributed to declining streamflows in the San Pedro River at Charleston. The larger number of months with streamflow trends compared with precipitation reflects a time-delayed relation; precipitation in a given month can affect streamflow several months later. The observed pattern in trends that remained after precipitation was considered – significantly downward in May through December, and not significant in January through April – led Thomas and Pool (2006) to suggest that seasonal near-stream ground-water withdrawals were major factors contributing to the trend. The authors conclude that these near-stream withdrawals could include both seasonal agricultural pumping and changes in riparian vegetation through the period of record; these two factors could not be separated using information available to the study. Changes in upland vegetation through the period of record from predominantly grassland to shrubland is indicated as a major factor causing the observed declines in runoff. Notably, Thomas and Pool (2006) state that ground-water pumping from the regional aquifer at a distance from the river was not a major factor in the low-flow declines owing to the timing of the declines and pattern of pumping; year-round withdrawals at a distance from the river would be expected to cause year-round trends. Fundamental principals of hydrology, however, indicate that withdrawals from an aquifer will result in eventual changes to natural inflows or outflows. The location where such changes will manifest depends largely on where pumping has occurred; a given location, such as the Charleston streamflow-gaging station, may not reflect the earliest impacts to the system.

The 7-day June and winter (defined as January 15 through March 15) low flows (figure 11) of the San Pedro River at Charleston serve as indicators of sustainability. The June low flow in 2006 was 0.07 cubic feet per second and was the lowest value recorded at the San Pedro at the Charleston station. The previous minimum value was 0.38 cubic feet per second in 1990 and the 10-year average (1997-2006) is 1.25 cubic feet per second. The 10-year average includes some years likely affected by storm runoff. The 2006 June low flow is less than the 2005 value (0.50 cubic feet per second) even though the San Pedro River ceased flowing in July in 2005. The cessation of flow in 2005 and record low June 7-day low flow value in 2006 were likely the result of a combination of factors that may include near-stream and regional-aquifer pumping, effects from an ongoing drought, changes in riparian water use, lower than average winter streamflows, or other causes. At the current time, no published analysis has attempted to attribute causes to the 2006 June low flow value and 2005 cessation of flow. The winter 7-day low flow for 2006 was 9.9 cubic feet per second compared with 7.5 cubic feet per second in 2005 and a 9-year average (winter

2001 removed from the 10-year average owing to the effects of a large series of storms in October of 2000) of 8.6 cubic feet per second.

Springflow

Springs represent another path through which water leaves the ground-water system and as such can act as indicators of how natural and human-induced changes to the hydrologic system are affecting the aquifer. Occasional measurements of spring flow have been made since 1988 when the SPRNCA was established. Additional measurements were initiated in 2003, and a systematic network of quarterly measurements at 4 springs (figure 12) was initiated in response to Section 321 needs in early 2005. Flow measured at Murray Spring, located within Curry Draw and downstream from the Sierra Vista wastewater recharge facility, has increased since monitoring began in 2003 with 32 gallons per minute (0.07 ft^3/s or 51 acre feet/year) in March 2003 and 122 gallons per minute (0.27 ft^3/s or 195 acre feet/year) in March 2006. In addition, the source of emanation has expanded from the original Murray Spring location to farther upstream in Curry Draw. The spring is about 2.5 km downgradient from the Sierra Vista wastewater recharge facility, at which an estimated 2,230 acre feet of water were recharged in 2006. Although the origin of increased flow may be related to recharge, a conclusive link has not been made. The relation between increased spring flow and effluent recharge is currently being investigated.

Precluded Future Use in Key Areas

Since 2000, the Bureau of Land Management, Fort Huachuca, and The Nature Conservancy have worked together to acquire conservation easements that permanently reduce the density of future development at key locations. Some of these same easements also retired existing agricultural pumping, and those benefits were previously reported as part of water budget estimates.

Conservation easements established since 2000 within the Palominas area include a total of approximately 3,242 acres, resulting in 809 fewer future homes. These tracts were zoned RU-4 (four acres per home), previously allowing for approximately 810 new homes. Given that one home is still permitted under these easements, the result is a net reduction of 809 future homes. Assuming a gpcd of 312 and 2.56 people per home (Arizona Department of Water Resources, 2005a) in the unincorporated areas, there will be a future annual water savings of 724 acre feet/year of groundwater pumping in this region owing to these projects.

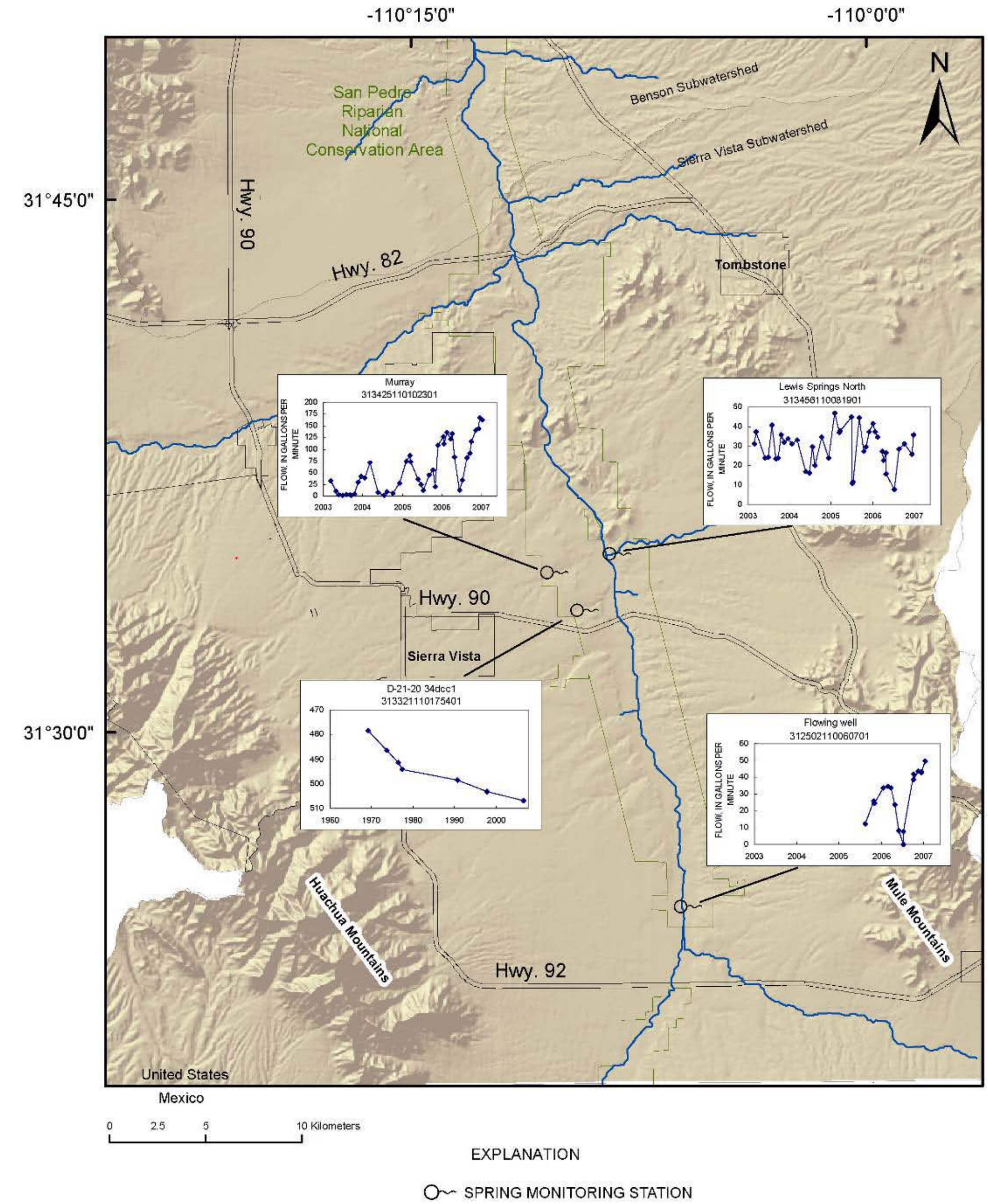

Figure 12. Measured flow at spring-monitoring locations, Sierra Vista Subwatershed, Upper San Pedro Basin, Arizona.

Water Budget

The initial Section 321 report outlined a set of management measures to be implemented in each calendar year through 2011 in order to attain a sustainable yield of ground water from the regional aquifer of the Sierra Vista Subwatershed. These measures can be characterized broadly as conservation and recharge, and categorized more specifically. For example, conservation includes public education, effluent reuse, code changes, and reductions in irrigated agriculture. Recharge includes the effluent and stormwater recharge projects that return or introduce various sources of water to the aquifer.

For this report, conservation yields were determined specifically for different Partnership members owing to differences in data availability. In rural Cochise County, for example, much of the ground water is pumped by unmetered private wells and the amount of pumping is estimated from the number of wells and an assumed per-well use. Because actual pumped volumes are unavailable, conservation was estimated for specific projects and summed to create grouped yields. Only yields from projects actually implemented in 2006 were counted. The estimated conservation yields were then assumed to represent actual water savings. For Sierra Vista and Fort Huachuca, sufficient data were available to calculate a per capita pumpage value for 2002 (the baseline year) and for 2006. Conservation was then calculated as the difference between actual pumping in 2006 and the pumping that would have occurred in 2006 if the estimated population used water at the 2002 per capita rate. The per capita pumping in Sierra Vista, for example, was reduced from 174 gallons per capita per day (gpcd) in 2002 to 153 gpcd in 2006.

The Partnership is continually striving to develop improved estimates of recharge and conservation yields. As a result some yields reported here differ from same-category yields reported in the prior Section 321 reports.

Planned and Actual Management Measure Yields

The effect of conservation and recharge, once estimated, may be combined to calculate a total yield of management measures — this combined yield describes the reduction in net ground-water use in the Sierra Vista Subwatershed compared with the use that would have occurred in the absence of management measures.

The following discussion and table 3 compare planned management-measure yields with estimates of yields actually obtained for calendar year 2006. The fiscal year prior to the due date of this report to Congress (fiscal year 2007) specified in Section 321 as the reporting period was still underway during the preparation of this report and therefore was not a useable reporting period. A combined deficit-reducing yield of 8,410 acre feet for 2006 was projected in the 2006 Section 321 progress report (reporting on year 2005). The estimated actual yield for 2006 was 9,600 acre feet (table 3). This overall yield includes active Partnership member projects as well as incidental yields from increased recharge caused by urbanization and a decrease in agricultural pumping caused by the sale of agricultural property. Urbanization in arid climates can increase recharge by directing additional stormwater runoff to ephemeral stream channels where the ratio of recharge to evaporation is increased. The Partnership does not suggest that urbanization increases recharge more than urbanization increases pumping, but rather that the increased recharge offsets some of the increased pumping. Please see the 2004 Section 321 report (http://water.usgs.gov/Section321.2004_050705.pdf) for additional details.

Table 3. Planned and estimated actual yields for 2006 of Partnership member measures to reduce aquifer overdraft and of increased recharge from urbanization

[Yields are in acre-feet/year; ---, indicates no yield in year; Numbers compiled in March–June 2007; Conservation yields in each year are relative to a zero yield in the baseline year of 2002; Recharge yields are total values and are relative to a baseline of zero acre feet]

Description	Measure type	2006 Yield Planned	2006 Yield Actual
Fort Huachuca			
Conservation measures[1]	Conservation	100	415
Effluent recharge[2]	Recharge	640	410
Stormwater detention basins[3]	Recharge	120	185
Cochise County			
Conservation measures[4]	Conservation	110	110
Sierra Vista			
Conservation measures[1]	Conservation	290	840
Improved golf course efficiency		15	45
Effluent recharge[5]	Recharge	2,090	2,230
Stormwater detention basins[6]	Recharge	80	130
The Nature Conservancy and Fort Huachuca			
Retirement of agricultural pumping[7]	Conservation	100	0
Bisbee			
Conservation measures	Conservation	10	10
Reduced ground-water pumping through effluent reuse	Conservation	210	---
Effluent recharge[8]	Recharge	---	250
Huachuca City			
Conservation measures[1]	Conservation	5	5
Tombstone			
Conservation measures[1]	Conservation	5	5
Effluent recharge[9]	Recharge	130	130
Bureau of Land Management			
Mesquite reduction[10]	Conservation	580	475
Urban enhanced ephemeral-stream channel stormwater recharge			
Increase in stormwater recharge in ephemeral channels by urbanization[11]	Recharge	2,300	2,300
Incidental yields			
Retirement of agricultural pumping[12]	Conservation	1,750	2,070
Total yields			
Total yield[13]		8,400	9,600

[1]Yield relative to 2002 baseline of zero. Conservation efforts started earlier than 2002 that continue to provide yields do not contribute to a reported yield because they are already incorporated in the baseline actual water-use figures. Yield calculated as the difference between pumping reported by the agency for 2006 and the pumping that would have occurred using the 2002 gallons per capita per day for the associated population estimated for 2006 (Arizona Department of Economic Security 2007). To simplify presentation, various specific conservation projects are grouped together to report yields. Actual water use will vary from year to year owing to effectiveness of conservation, weather, and other factors. Numerous specific conservation measures as Fort Huachuca and codes in Sierra Vista have been enacted and the conservation yield reported includes combined yields from those actions.

[2]Effluent recharge based on the 2006 Fort Huachuca biological opinion annual report (Fort Huachuca, 2007).

[3]Recharge occurring because of stormwater detention basins on Fort Huachuca derived from Fort Huachuca biological opinion annual report (Fort Huachuca, 2007). Estimates in the report were based partially on monitoring data and therefore the yield is subject to the rainfall in 2006.

[4]Conservation yield attributable to Cochise County could not be calculated owing to the large number of small unmetered wells. The reported yield of 110 acre feet is attributable to toilet-replacement rebates and assumed savings from code changes. Cochise county undertook various code changes that should have yielded water savings, but that can not be quantified owing to lack of available metered water-use data. Conservation measures included in the codes include: hot water on demand, gray water plumbing, high-efficiency commercial laundry facilities, a ban on artificial water features (lakes, ponds or fountains,) humidity sensors on outdoor irrigation, new turf restrictions, and limits on evaporative coolers.

[5]Recharge values based on data provided to the Arizona Department of Water Resources by the Sierra Vista Public Works Operations Division. Recharge values are based on metered inflows to infiltration basins minus an estimate of evaporative loss. Approximately 1,000 acre feet/year in the wastewater treatment and recharge process is not currently accounted for and may recharge the aquifer in addition to the cited amounts. Efforts are underway to ascertain the fate of the unaccounted water.

[6]Recharge occurring because of Sierra Vista's stormwater detention basins for 2006 based on a Sierra Vista calculation derived from a Partnership sponsored study of runoff and recharge (Stantec Consulting and Geosystems Analysis Inc., 2006). This technique was developed to provide a consistent method to calculate yields from Fort Huachuca, Sierra Vista, and Cochise County basins. Additional data and improved techniques will be employed as they become available to calculate yields.

[7] Retirement of irrigated agriculture or other high water-consumption uses by consensual agreement.

[8] Recharge of municipal wastewater released into Greenbush draw from June 1 to December 31, 2006. Yield figures derived from personal communication with Russ McConnell of Bisbee Public Works (2007).

[9]Effluent produced by residents of Tombstone that is released to and recharged in Walnut Gulch. Yield from Arizona Department of Water Resources (2005a). This yield was not specifically listed in the prior Section 321 reports, but was included in the water budget as general incidental recharge.

[10]Water-use savings through management of invasive mesquite using various treatments. Mesquite reduction reduces water use by replacing mesquite with more shallowly rooted plants. Yield from mesquite reduction estimated using an Agricultural Research Service model of riparian evapotranspiration in the San Pedro Riparian National Conservation Area.

[11]Urbanization in semiarid climates can increase recharge by concentrating rainfall runoff in ephemeral-stream channels. Initial estimates provided by the Agricultural Research Service of natural recharge enhanced beyond predevelopment levels by urbanization—credit not claimed by any particular Partnership member. These preliminary estimates will be refined through ongoing research and monitoring programs. Increased water use due to urbanization likely exceeds increased recharge. All urban-enhanced recharge estimates represent quantities expected in an average year—no current monitoring can provide year-specific values.

[12]Yield did not result from any specific Partnership member actions.

[13]Total yields rounded to nearest 100 acre-feet. Yields based on the best current data and assumptions. Yield values differ in places from the prior Section 321 reports owing both to changes in implemented and planned projects and to reanalysis of yields using improved methods. Total yield (planned and actual) value does not include Tombstone wastewater recharge as in prior reports that recharge was tabulated in general incidental recharge. The ultimate aquifer-storage deficit calculation, however, does include the Tombstone wastewater recharge value.

Measures without quantified yields

In some cases, such as for rural areas where pumping is not metered, conservation management measures have been enacted that do not have a yield reported owing to the difficulty in quantifying the yield. Various efforts by Cochise County are expected to result in increased conservation savings. In addition, methods such as Transfer of Development Rights have been implemented as part of the strategy of spatial water management.

The Sierra Vista Subwatershed Water Conservation Management Plan adopted by Cochise County in 2006, requires that requests for rezoning to support increased density for housing above that which is allowed for in current zoning (already factored into growth and water budget projections used by the USPP) must be submitted under the formal subdivision approval process. The plan further stipulates that developers must take actions to limit water use by planned developments to that amount projected to have been used under the former, lower density zoning. Thus, increases in density are no longer increases in projected water use in the unincorporated areas of the Subwatershed.

In 2006 Cochise County established a zoning overlay district within the Sierra Vista Subwatershed. Water-conservation provisions of the zoning overlay for new-home construction include: hot water on demand, installed “stub-outs” for gray water plumbing, high-efficiency commercial laundry facilities, a ban on artificial water features (lakes, ponds or fountains,) humidity sensors on outdoor irrigation, new turf restrictions, and limits on evaporative coolers.

The County’s overlay zone also amends the Subdivision Regulations requiring future subdivisions within the unincorporated areas of the Sierra Vista Subwatershed to be served by a water company or water district rather than unregulated individual wells. Current assumptions about water demand by individual well owners suggest that users served by a water company use less water, possibly owing to the billing for deliveries. Additional benefits to having water delivered by a water company is that usage can be metered and the water utility could implement strategies to reduce use.

Formal Transfer of Development Rights away from hydrologically more sensitive areas to areas of lesser impact on streamflow is one tool, or factor, for a developer to use in justifying density increases within the sub-watershed. The overlay zone also amends the Zoning Regulations' rezoning criteria to reflect this potentially significant factor.

The county effort with respect to the overlay zoning district is meant to avoid exacerbation of the aquifer storage deficit by new growth. Specific savings in terms of the water budget may not be quantifiable or reportable as a direct, immediate reduction in the water deficit as a result of these measures. Common sense water policies and public education do, however, contribute to the local "culture of conservation".

Various conservation efforts of Sierra Vista and Fort Huachuca are also not included in table 3 owing to the timing of their implementation. The Section 321 reports use a 2002 baseline year for calculations. Any conservation efforts initiated prior to that year are intrinsically included in the baseline value and can not be separately counted. Nevertheless, water usage would currently be higher in the absence of those measures.

Storage Deficit in 2006

A ground-water storage deficit of 5,200 acre feet in the Sierra Vista Subwatershed for 2006 was estimated by combining estimated total pumping with management-measure yields in a subwatershed water budget (table 4). This value can not be directly compared to the deficits calculated in prior Section 321 reports owing to the use of an updated estimate of riparian evaporation and plant transpiration.

Values for natural recharge and some values of natural discharge are derived from an analysis by the ADWR (Arizona Department of Water Resources, 2005b). A significant departure from prior Section 321 reports is the use of a new value for riparian evaporation and plant transpiration (ET) derived from results published as part of Partnership-initiated research (Scott and others, 2006). This value represents an estimate for the riparian ET within the Subwatershed that is based on field measurements. Scott and others (2006) reported a range of riparian ET for the Subwatershed of 9,600 to 12,055 acre feet/year. For this Section 321 report, the previously used ET value of 7,700 acre feet/year derived from Arizona Department of Water Resources (2005b), has been replaced with the average of the range reported in Scott and others (2006), a value of 10,800 acre feet/year.

Replacing the previously used ET value with the updated number has the effect of increasing the calculated aquifer-storage deficit by 3,100 acre feet/year. This difference does *not* mean that the actual deficit has increased by 3,100 acre feet compared to the prior year. It does mean that the calculated deficit is larger because estimate of natural discharge is larger than previously estimated. A storage deficit calculated using the previously estimated riparian evapotranspiration value (of 7,700 acre feet annually) would be 2,100 acre feet in 2006. By comparison, the deficit reported for 2005 in the prior Section 321 report (using the earlier estimate of evapotranspiration) was 4,400 acre feet.

The total pumping was the estimated sum of uses by private water companies, municipalities, Fort Huachuca, golf courses, rural residents using exempt wells, agriculture, and industry. The effectiveness of conservation measures is intrinsically included in values for total pumping and is not part of the deficit calculation. Estimates for conservation yields, however, are included in table 3 to indicate how much water was likely saved compared to a condition where conservation efforts were not undertaken. An exception is conservation through reduction of mesquite near the San Pedro River; it is independent of ground-water pumping and therefore tabulated separately. In 2006, estimated conservation in ground-water pumping relative to 2002 gpcd usage was about 1,400 acre feet.

Table 4. Water recharged to and withdrawn/discharged from the regional aquifer underlying the Sierra Vista Subwatershed in 2006

[Water-budget volumes are in acre-feet/year; inflows are assigned positive numbers, outflows are assigned negative numbers]

Component	Estimated volume	Description
Natural aspects of system		
Natural recharge[1]	15,000	Inflow largely from percolating waters on and around mountains and through ephemeral channels
Ground-water inflow[1]	3,000	Subsurface inflow from Mexico
Ground-water outflow[1]	-440	Subsurface outflow at USGS San Pedro River near Tombstone streamflow-gaging station (09471550)
Stream base flow[1]	-3,250	Ground-water discharge to the river that flows out of the subwatershed
Evaporation and plant transpiration[2]	-10,800	Ground water consumed in the riparian system exclusive of evapotranspiration supplied by near-riparian recharge from precipitation or flood runoff
Pumping		
Pumping. water companies and public supply– gross	-10,610	Ground-water extractions by water companies and municipalities
Pumping, rural/exempt well – gross[3]	-4,390	Ground-water extractions by private wells
Pumping, industrial (turf, sand, and gravel, stock tanks) – gross	-1,490	Ground-water extractions for industrial and golf course uses
Pumping, irrigation – net[4]	-430	Ground-water extractions for agricultural use
Active management measures		
Reduction of riparian evapotranspiration	475	Management of invasive mesquite
Municipal effluent recharge[5]	3,030	
Detention basin recharge[6]	310	
Passive recharge resulting from human activities		
Incidental recharge[7]	2,090	
Urban-enhanced recharge[8]	2,300	
Aquifer storage change[9]	-5,200	Additions or reductions in stored aquifer water

[1]Flow volume estimated by the Arizona Department of Water Resources (2005b).

[2]Value of evapotranspiration (ET) is the average of the high and low estimates of Scott and others (2006). This value replaces the 7.700 acre feet/year estimate used in previous Section 321 reports (derived from Arizona Department of Water Resources, 2005b). The increase of 3,100 acre feet annually does not necessarily suggest that actual ET has increased, but rather that the estimate of ET has increased.

[3]Value is lower than in previous Section 321 report owing to use of a revised calculation technique consistent with that of the Arizona Department of Water Resources (2005a). Exempt-well population derived from Arizona Department of Economic Security 2006 data. Earlier reports calculated population as number of exempt wells times 4.72 people per well (from Arizona Department of Water Resources, 2005a).

[4]Pumping for irrigation is consumptive use only. Area considered is the ground-water basin portion of the Sierra Vista Subwatershed only. The area within the boundaries of the Sierra Vista Subwatershed includes more agricultural lands than the area within the ground-water basin portion of the Subwatershed. These agricultural lands are primarily located in the head waters of the Babocomari River.

[5]Municipal effluent recharge is water returned to the aquifer through recharge facilities as reported by Sierra Vista (City of Sierra Vista, 2007), Fort Huachuca (Fort Huachuca, 2007), City of Tombstone (Arizona Department of Water Resources, 2005a), and City of Bisbee (personal communication, Russ McConnell, 2007)

[6]Recharge of stormwater within basins that have been installed to mitigate increased flood peaks in ephemeral-stream channels resulting from urbanization.

[7]Incidental recharge is an estimate of water returned to the aquifer from septic tanks, and turf watering. Value reduced from prior Section 321 report owing to revised technique for calculating exempt-well pumping.

[8]Urbanization causes enhanced recharge by concentrating storm runoff in ephemeral-stream channels. Recharge in arid and semi-arid environments is more likely to occur if runoff from precipitation reaches permeable stream-channel sediments. Recharge caused by urbanization only partially mitigates the increased pumping that accompanies increased urbanization.

[9]Value rounded to nearest 100 acre-feet/year.

Legal Impediments

Consistent with the requirements of Section 321, the initial report included a list of potential legal barriers to the implementation of certain management measures. Section 321(d)(2)(C) further requires that annual reports include a discussion of what progress has been made in addressing these legal impediments. To meet this reporting requirement, the following list restates the legal impediments discussed in the initial Section 321 report and includes the current status of proposals to address these barriers. Recognizing that changes in applicable legal standards have broad-based policy effects that are beyond the scope of this report, this discussion of legal impediments carries no explicit or implicit recommendation or endorsement for any legislative action by any Partnership member or Federal, State, local, or other entity.

Water-Management Measures and Legal Impediments have been identified in three major categories: ***Conservation Measures, Recharge/Reuse Measures,*** and ***Augmentation/ Importation Measures.*** Within each major category specific issues have been determined to be important to meeting the stated goal of sustainability. Individual member entities have worked on those issues under their jurisdiction during the past four years. Additionally, the Partnership has tracked legislation as it has been introduced in the Arizona Legislature along with any final action or inaction taken.

Conservation Measures—Code Changes: Limited authority exists for local (city, county) action with respect to modifying human behavior subsequent to final building inspection or for actions not related to development (i.e., water wasting ordinances). Since 2004 Cochise County and the City of Sierra Vista have worked on and/or passed myriad code changes. The Sierra Vista Subwatershed Water Conservation and Management Policy Plan was adopted in 2006 by Cochise County Board of Supervisors. The Plan limits density increases unless the subdivider incorporates water savings that mitigate any increase in usage over the current zoning. It prohibits increasing densities within two miles of the San Pedro Riparian National Conservation Area and caps densities to one unit per acre unless effluent is recharged or densities are transferred from elsewhere. A companion ordinance was also adopted by the County in late 2006 mandating certain water saving devices. The Joint Planning Committee (comprised of representatives from each local government within the subwatershed) developed a water conservation model ordinance that was approved by the Partnership and subsequently distributed to the governing bodies of the four municipalities for their consideration. The Sierra Vista City Council amended their existing water conservation ordinance in June 2007 to incorporate many of the model ordinance provisions. These include a further limitation of 10 percent on commercial use of turf; requiring the use of Energy Star rated clothes washers and dish washers under certain circumstances; and the prohibition of potable water for golf course irrigation. No legislative action at the state level has occurred that would provide local governments with additional authority in this area of concern with the exception of the repeal of the State Plumbing Code thus authorizing all cities and counties the ability to adopt individual codes.

Current state law does not provide any effective mechanisms for local/regional water management authority, or local ability to create funding mechanisms outside of Active management Areas (AMAs) (ARS 45-1942). Since 2004 there have been multiple committees, both legislative and at the department level (ADWR), established to study and identify a means by which such a mechanism could be developed with broad based support. During 2006-2007 a Statewide Water Advisory Group (SWAG) met numerous times to discuss and develop potential solutions to the issue of rural water concerns throughout the state. During the 2007 legislative session, House Bill 2300 was passed outlining the process for the establishment of the Upper San Pedro Water District. This action is considered to be groundbreaking in that, if approved by the voters of the District, facilities can be constructed that will augment existing water supplies and assist in reaching sustainable yield as required by Section 321. Additionally, House Bill 2692, "Water Supply Development Revolving Fund" was passed and signed by the Governor. This bill provides funding assistance for water supply development projects if the county or municipality adopts the Water Adequacy requirements under Senate Bill 1575.

Current state law is ambiguous regarding appropriate actions by counties when ADWR determines "water inadequacy." (ADWR's "groundwater adequacy certificate" considers only availability for human use, not ecological considerations). Recent case law appears to prohibit county government from denying subdivision approval for lack of water adequacy. During the 2007 legislative session Senate Bill 1575, "Water Adequacy Amendments" was passed and signed by the Governor. This bill authorizes a county or municipality to adopt by unanimous vote an ordinance requiring an adequate water supply before any subdivision may be approved. This action, in conjunction with the establishment of the Upper San Pedro Water District, requires the Director of the Arizona Department of Water Resources to adopt rules for water adequacy that are consistent with the sustainability goal of the District.

Conservation Measures—Zoning: Current law limits counties from applying subdivision standards (with respect to water resource management) to lot splits of five or fewer (ARS 11-806/11-809). There has been no change adopted or contemplated to resolve this issue.

Conservation Measures—Easements: The issue identified was that the current law does not provide for the use of Transfer Development Rights (TDR) for counties. This denies counties the use of that management option. In 2005, HB 2364 became law giving counties the authority to adopt a TDR ordinance. Cochise County worked with Pima County to develop such an ordinance. During this process the Partnership has established a TDR Work Group to assist in the development of 'key locations' that will identify the 'giving' properties portion of the transfer equation. The Partnership believes that such transfers are a best served through private arrangements. It is felt that this impediment has been resolved.

Current state law regarding the establishment of 'irrigation non-expansion areas (INA)' applies to entire basins or sub basins, and cannot be applied to a subwatershed such as the Sierra Vista Subwatershed (ARS 45-432). An attempt was made to pass legislation in 2006 that would have established an INA only for the SV Subwatershed. It failed to gain the necessary legislative support. With irrigated agriculture on the decline in the SV Subwatershed, this issue has not been pursued.

The impediment of no matching funds from state sources for conservation projects outside of the riparian zone to help address water management issues was partially resolved in 2006 through the establishment of the Agricultural Protection Fund. So far there has been no appropriation for this Fund. In the 2007 Legislative Session, House Bill 2692, "Water Supply Development Revolving Fund" was passed and signed by the Governor. This bill provides for funding assistance for water supply development projects if the county or municipality adopts the Water Adequacy requirements under Senate Bill 1575.

Current tax policy provides incentives for water consuming uses but not for water conservation uses on undeveloped lands (ARS 42-15004). There has been no action taken on this measure during the past three years of this report. Passage of House Bill 2300 in 2007 provides an opportunity for the voters within the Upper San Pedro Water District to implement a use tax on customers of municipal water providers that could offer an incentive to conserve.

Conservation Measures—Conservation Pricing: The Arizona Corporation Commission (ACC), Arizona's public utilities commission, is limited in its ability to consider area-wide conservation pricing for the private and individually-owned water providers who serve about 90 percent of the area's population (ARS 4-257). Although guidelines for the drafting of legislation were considered, no bills have been introduced on this subject due to a lack of legislative support.

Conservation Measures—Technology Incentives: Currently, there are no matching funds from state sources for conservation projects outside of the riparian zone to help address water management issues. House Bill 2692, "Water Supply Development Revolving Fund" was passed and signed by the Governor in 2007. This bill provides for funding assistance for water supply development projects if the county or municipality adopts the Water Adequacy requirements under Senate Bill 1575.

Recharge/Reuse Measures—Effluent Recharge/Reuse: Currently, there are no matching funds from state sources for conservation projects outside of the riparian zone to help address water management issues. Additionally, sufficient funding is not available for communities to meet EPA/ADEQ's high water-quality standards for effluent to be recharged through shallow basins.
House Bill 2692, "Water Supply Development Revolving Fund" was passed and signed by the Governor in 2007. This bill provides for funding assistance for water supply development projects if the county or municipality adopts the Water Adequacy requirements under Senate Bill 1575.

Recharge/Reuse Measures—Storm Water Recharge: Currently Arizona limits the disposition and (or) use options for State trust lands. Such options could permit construction of optimally located recharge facilities. Although no action has occurred to change this issue, the Partnership's Technical Committee is working with the existing ground-water modeling program to identify 'key locations' for possible recharge. A representative of the Arizona State Land Department participates in the Partnership and dialogue is on-going.

Augmentation/Importation Strategies: Currently Arizona limits the disposition and (or) use options for State trust lands. Such options could permit construction of optimally located recharge facilities. Although no action has occurred to change this issue, the Partnership's Technical Committee is working with the existing ground-water modeling program to identify 'key locations' for possible recharge. A representative of the Arizona State Land Department participates in the Partnership and dialogue is on-going.

Current State law generally prohibits interbasin transfer of ground water, and intrabasin transfer of ground water between subbasins may be subject to the payment of 'damages.' In 2006 the Governor signed HB 2436 that allows groundwater to be transported away from a groundwater basin that is outside an active management area (AMA) under specific emergency circumstances and on a temporary basis. House Bill 2300 establishing the Upper San Pedro Water District prohibits this from occurring in the Sierra Vista Subwatershed.

The outcome of the Gila River Adjudication, which has been ongoing for 25 years, may render some projects unfeasible. Arizona's definitions regarding surface water, ground water, and the potential connections between them are subject to the judicial proceedings in the Gila River Adjudication. The Arizona Water Settlements Action, Public Law No. 108-451 (2004) provides Congressional approval for a settlement, but no judicial decree has yet been entered. During the legislative sessions of 2005 and 2006 HB 2728 and HB 2835 were passed and signed by the Governor implementing the required portions of the Settlement Act. However, there continue to be on-going adjudications between parties other than Gila River Tribal Communities.
In 2007 the United States Supreme Court denied a request to review the 2005 decision of the Arizona Supreme Court regarding subflow issues. As a result, the Arizona Department of Water Resources is charged with the mapping of the subflow zone for the San Pedro River Watershed and is working with The U.S. Geologic Survey in mapping the Holocene alluvium to determine the delineation between surface water and ground water. This work could have major impacts on groundwater well locations.

Additional Actions Taken: Since 2005 several bills have been passed that provide some benefit to the subwatershed: 1) a requirement that all public water systems prepare supply, drought-preparedness and conservation plans; and 2) tax credits for individuals and builders installing water conservations systems.

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Glossary

Base flow

The sustained flow in a stream that comes from ground-water discharge or seepage.

Consumptive use

The portion of ground water pumped that is not returned to the aquifer as recharge.

Deficit
Synonymous with aquifer storage loss.

Management target
A quantified goal to reduce net ground-water consumption as part of reaching sustainable yield. The Partnership has chosen, as a management target, to eliminate aquifer storage depletion and begin accreting storage.

Net ground-water consumption
Ground water removed from the regional aquifer of the subwatershed that is not returned through incidental or artificial recharge or replaced through enhanced recharge.

Overdraft
Net ground-water consumption from the regional aquifer of the subwatershed in excess of sustainable yield.

Partnership

An abbreviation of the Upper San Pedro Partnership which is a collaboration of public agencies and organizations that own or control land, or water use, in the Sierra Vista Subwatershed portion of the Upper San Pedro River Basin, and that have the authority and resources to identify reasonable, feasible, cost-effective projects and policies, and the ability to actually implement them. Federal, State, and local governmental and nongovernmental entities whose mission is to create a water-management plan that meets the needs both of Sierra Vista Subwatershed residents and of the San Pedro Riparian National Conservation Area (SPRCNA).

Regional aquifer
The regional aquifer is defined as the aquifer underlying the Sierra Vista Subwatershed.

Recharge, artificial
Ground-water recharge of municipal effluent in specifically engineered recharge facilities.

Recharge, enhanced
The increase in naturally occurring ground-water recharge through ephemeral channels due to urbanization.

Recharge, incidental
Ground-water recharge from sources not specifically engineered to generate recharge such as septic tanks, golf courses, and agricultural operations.

Riparian
Vegetation, habitat, or ecosystems that depend on surface and/or subsurface water flow.

Storage change

The change in the volume of water stored in an aquifer through time. Storage change results from a difference between inflows and outflows. It is often expressed as an annual volume.

Storage depletion

A decrease in aquifer storage.

Sustainable yield
The level of ground-water use that can be maintained for an indefinite period of time without causing unacceptable environmental, economic, or social consequences.

Appendix A – Public Law 108-136 (Section 321)

SEC. 321. COOPERATIVE WATER USE MANAGEMENT RELATED TO FORT HUACHUCA, ARIZONA, AND SIERRA VISTA SUBWATERSHED.

(a) LIMITATION ON FEDERAL RESPONSIBILITY FOR CIVILIAN WATER CONSUMPTION IMPACTS.—
(1) LIMITATION.—For purposes of section 7 of the Endangered Species Act of 1973 (16 U.S.C. 1536), concerning any present and future Federal agency action at Fort Huachuca, Arizona, water consumption by State, local, and private entities off of the installation that is not a direct or indirect effect of the agency action or an effect of other activities that are interrelated or interdependent with that agency action, shall not be considered in determining whether such agency action is likely to jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modification of designated critical habitat.

(2) VOLUNTARY REGIONAL CONSERVATION EFFORTS.—Nothing in this subsection shall prohibit Federal agencies operating at Fort Huachuca from voluntarily undertaking efforts to mitigate water consumption.

(3) DEFINITION OF WATER CONSUMPTION.—In this subsection, the term ‘‘water consumption’’ means all water use off of the installation from any source.

(4) EFFECTIVE DATE.—This subsection applies only to Federal agency actions regarding which the Federal agency involved determines that consultation, or reinitiation of consultation, under section 7 of the Endangered Species Act of 1973 (16 U.S.C. 1536) is required with regard to an agency action at Fort Huachuca on or after the date of the enactment of this Act.

(b) RECOGNITION OF UPPER SAN PEDRO PARTNERSHIP.—Congress hereby recognizes the Upper San Pedro Partnership, Arizona, a partnership of Fort Huachuca, Arizona, other Federal, State, and local governmental and nongovernmental entities, and its efforts to establish a collaborative water use management program in the Sierra Vista Subwatershed, Arizona, to achieve the sustainable yield of the regional aquifer, so as to protect the Upper San Pedro River, Arizona, and the San Pedro Riparian National Conservation Area, Arizona.

(c) REPORT ON WATER USE MANAGEMENT AND CONSERVATION OF REGIONAL AQUIFER.—

(1) IN GENERAL.—The Secretary of [the] Interior shall prepare, in consultation with the Secretary of Agriculture and the Secretary of Defense and in cooperation with the other members of the Partnership, a report on the water use management and conservation measures that have been implemented and are needed to restore and maintain the sustainable yield of the regional aquifer by and after September 30, 2011. The Secretary of the Interior shall submit the report to Congress not later than December 31, 2004.

(2) PURPOSE.—The purpose of the report is to set forth measurable annual goals for the reduction of the overdrafts of the groundwater of the regional aquifer, to identify specific water use management and conservation measures to facilitate the achievement of such goals, and to identify impediments in current Federal, State, and local laws that hinder efforts on the part of the Partnership to mitigate water usage in order to restore and maintain the sustainable yield of the regional aquifer by and after September 30, 2011.

(3) REPORT ELEMENTS.—The report shall use data from existing and ongoing studies and include the following elements:

(A) The net quantity of water withdrawn from and recharged to the regional aquifer in the one-year period preceding the date of the submission of the report.

(B) The quantity of the overdraft of the regional aquifer to be reduced by the end of each of fiscal years 2005 through 2011 to achieve sustainable yield.

(C) With respect to the reduction of overdraft for each fiscal year as specified under subparagraph (B), an allocation of responsibility for the achievement of such reduction among the water-use controlling members of the Partnership who have the authority to implement measures to achieve such reduction.

(D) The water use management and conservation measures to be undertaken by each water-use controlling member of the Partnership to contribute to the reduction of the overdraft for each fiscal year as specified under subparagraph (B), and to meet the responsibility of each such member for each such reduction as allocated under subparagraph (C), including—

(i) a description of each measure;
(ii) the cost of each measure;
(iii) a schedule for the implementation of each measure;
(iv) a projection by fiscal year of the amount of the contribution of each measure to the reduction of the overdraft; and
(v) a list of existing laws that impede full implementation of any measure.

(E) The monitoring and verification activities to be undertaken by the Partnership to measure the reduction of the overdraft for each fiscal year and the contribution of each member of the Partnership to the reduction of the overdraft.

(d) ANNUAL REPORT ON PROGRESS TOWARD SUSTAINABLE YIELD.—

(1) IN GENERAL.—Not later than October 31, 2005, and each October 31 thereafter through 2011, the Secretary of the Interior shall submit, on behalf of the Partnership, to Congress a report on the progress of the Partnership during the preceding fiscal year toward achieving and maintaining the sustainable yield of the regional aquifer by and after September 30, 2011.
(2) REPORT ELEMENTS.—Each report shall include the following:
(A) The quantity of the overdraft of the regional aquifer reduced during the reporting period, and whether such reduction met the goal specified for such fiscal year under subsection (c)(3)(B).
(B) The water use management and conservation measures undertaken by each water-use controlling member of the Partnership in the fiscal year covered by such report, including the extent of the contribution of such measures to the reduction of the overdraft for such fiscal year.
(C) The legislative accomplishments made during the fiscal year covered by such report in removing legal impediments that hinder the mitigation of water use by members of the Partnership.

(e) VERIFICATION INFORMATION.—Information used to verify overdraft reductions of the regional aquifer shall include at a minimum the following:

(1) The annual report of the Arizona Corporation Commission on annual groundwater pumpage of the private water companies in the Sierra Vista Subwatershed.
(2) The San Pedro base flow monitoring record of the Charleston flow gauge of the United States Geological Survey.
(3) Current surveys of the groundwater levels in area wells as reported by the Arizona Department of Water Resources and by Federal agencies.

(f) SENSE OF CONGRESS.—It is the sense of Congress that any future appropriations to the Partnership should take into account whether the Partnership has met its annual goals for overdraft reduction.

(g) DEFINITIONS.—In this section:
(1) The term ''Partnership'' means the Upper San Pedro Partnership, Arizona.
(2) The term ''regional aquifer'' means the Sierra Vista Subwatershed regional aquifer, Arizona.
(3) The term ''water-use controlling member'' has the meaning given that term by the Partnership.

Appendix B – List of Partnership Reports and Other Documents Consulted to Calculate Management-Measure Water Yields

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Brown and Caldwell Consultants, 2006, City of Bisbee reuse/recharge options for treated effluent discharged from the San Jose wastewater treatment facility: Brown and Caldwell Consultants, variously paged.

Partnership planning documents consulted for report preparation

USPP Semi-annual Report - progress through January 2000. USPP Administrative Committee. February 9, 2000.

Upper San Pedro Partnership Progress Report. USPP Administrative Committee. January 2001

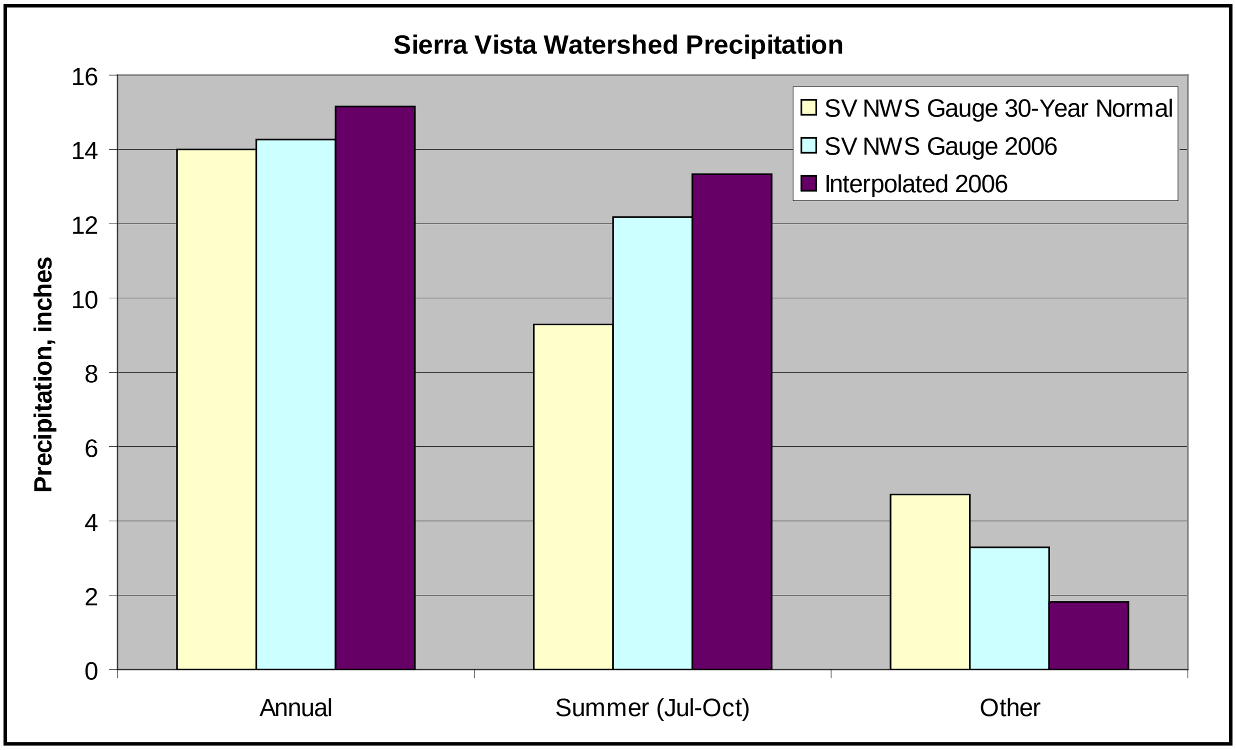
Water Conservation Plan- 2002 Progress Report. USPP Administrative Committee. January 2002

A Working Water Conservation Plan. USPP. February 12, 2003

2004 Water Management and Conservation Plan. USPP. February 11, 2004

2005 Water Management and Conservation Plan. USPP. March 9, 2005

Appendix C – Precipitation in the Sierra Vista Subwatershed



Appendix D – Agency Representation in the Upper San Pedro Partnership

Local Agencies

Cochise County
Sierra Vista
Huachuca City
Bisbee
Tombstone

Arizona State Agencies

State Land Department
Department of Water Resources
Department of Environmental Quality
Arizona Association of Conservation Districts

Federal Agencies

U.S. Geological Survey
USDA Agricultural Research Service
U.S. Fish and Wildlife Service
Bureau of Reclamation
Fort Huachuca
Bureau of Land Management
U.S. Forest Service
National Park Service

Non-Governmental Agencies

The Nature Conservancy
National Audubon Society
Bella Vista Ranches
Hereford National Resource Conservation District