Water Management of the Regional Aquifer in the Sierra Vista Subwatershed, Arizona—2006 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

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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 second 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 member agencies.

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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)

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Water Management of the Regional Aquifer in the Sierra Vista Subwatershed, Arizona—2006 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 second annual progress report assessing progress in calendar year 2005 toward a sustainable yield of ground-water withdrawals 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 sustainability goal, at least initially, is to eliminate current 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 was estimated to have been about 10,000 acre-feet in 2002 if then-established management measures (for example, municipal wastewater recharge) are ignored. The deficit is projected to grow to about 13,000 in 2011 in the absence of management measures.

For calendar year 2005, 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 2005 indicate that 7,230 acre-feet of water were

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yielded. When management-measure yields and an evaluation of pumping for 2005 in the Sierra Vista Subwatershed are combined in a water budget, a 2005 aquifer-storage deficit of about 4,400 acre-feet is indicated.

It is important to recognize that 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 definition 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, the 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 member agency 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.

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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 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, including access to the Water Conservation Plan, 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 second 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.

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Purpose and Scope

The general purpose of this report is to address the reporting requirements of Section 321 for 2006 (reporting on calendar year 2005). To achieve that end, the report has three specific purposes: (1) to evaluate the implementation of projects proposed in the initial Section 321 report for the prior year (calendar year 2005), (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 2006-2011.

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 2005 – 2011.

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

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 Benson, Arizona. The Sierra Vista Subwatershed is 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 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.

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

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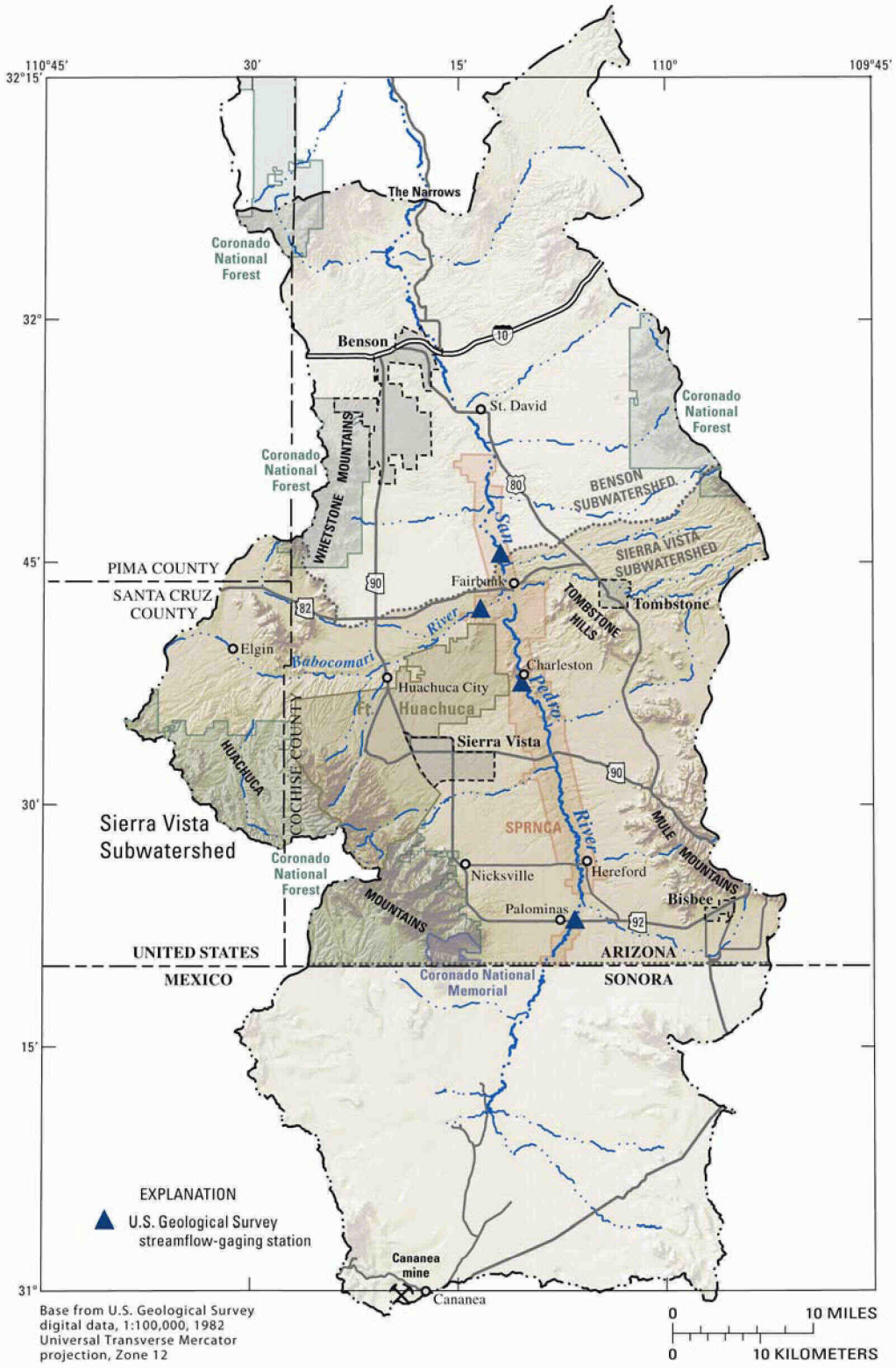

Figure 1. Location of the Sierra Vista Subwatershed, Upper San Pedro Basin, Arizona.

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The Sierra Vista Subwatershed supports a human population of about 77,422 (estimated from Arizona Department of Economic Security, 2006) 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 about 43,690 in 2005 (Arizona Department of Economic Security, 2006), including the permanent residents of the U.S. Army's Fort Huachuca.

The Sierra Vista Subwatershed also 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). 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.

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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 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.

Essential Definitions

Two essential terms, "sustainability" 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.

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 is to ensure that water of sufficient quantity and quality is available for the subwatershed's social, economic, and environmental needs.

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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.

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

It is important to note that the term "safe yield" is not interchangeable with "sustainable yield" in this context. 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.

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."

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Strategy of Sustainability Assessment

Assessment of success in attaining sustainability involves consideration of many factors, some that can be quantified, and some that can not. The initial Section 321 report utilized a simple water-budget approach to assess sustainability. Although such an approach is easily applied and readily understood, it also does not consider aspects of sustainability such as spatial water-use management. As a result, although this second annual report includes a water-budget approach, each succeeding annual Section 321 progress report will rely increasingly on an aquifer- and system-response approach to evaluate progress toward sustainability. An ongoing monitoring program is measuring the responses of the regional aquifer system to water-use management actions. The annual Section 321 progress reports will, however, continue to track estimated yields from management projects and to consider the yields relative to a subwatershed water budget.

Progress Toward Reducing the Subwatershed Ground-Water Storage Deficit in 2005

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.

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 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

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before. Unfortunately, climate and other factors also play a role in water use so year-by-year per-capita use can be quite variable. 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 2005 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 2005. Conservation was then calculated as the difference between actual pumping in 2005 and the pumping that would have occurred in 2005 if the estimated population used water at the 2002 per capita rate. The per capita pumping in Sierra Vista, for example, reduced from 174 gallons per capita per day (gpcd) in 2002 to 156 gpcd in 2005.

Recharge measures directly increase the amount of water returned to the aquifer. The wastewater recharge facilities of Sierra Vista and Fort Huachuca are examples of recharge measures. These facilities are intended to return a portion of water back to the aquifer system that had previously been pumped out. Recharge measures can also include the introduction of water to the aquifer, such as storm runoff, that would not otherwise have recharged. Some means of recharge result in yields that are more easily estimated than others. The effluent volume that enters a recharge basin, for example, is metered and the approximate losses to evaporation are easily calculated; the ultimate fate of recharged effluent — deep recharge to the regional aquifer, or shallow recharge to a perched aquifer — is more difficult to determine. Other means of recharge, such as through ephemeral-stream channels, are also difficult to estimate owing to uncontrolled conditions and the natural variability of several factors. 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 2004 Section 321 report.

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.

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In the initial Section 321 report, yields of net reduction in ground-water use were projected by category for each water-use controlling member of the Partnership. Section 321 specifically requests that the annual progress reports document the water-use management and conservation measures undertaken by water-use controlling members of the Partnership in the prior fiscal year, and the extent to which the measures reduced overdraft in the regional aquifer. The following discussion and table 2 compare planned management-measure yields with estimates of yields actually obtained for calendar year 2005. The fiscal year prior to the due date of this report to Congress (fiscal year 2006) 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 6,500 acre feet for 2005 was projected in the 2005 Section 321 progress report. The estimated actual yield for 2005 was 7,230 acre feet (table 2). 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.

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Table 2. Planned and estimated actual yields for 2005 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 2006; 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]

		2005 Yield	2005 Yield
Description	**Measure type**	**Planned**	**Actual**
Fort Huachuca			
Conservation measures[1]	Conservation	200	144
Reduced ground-water pumping through effluent reuse[1]	Conservation	54	(2)
Effluent recharge[3]	Recharge	610	437
Stormwater detention basins[4]	Recharge	370	49
Cochise County			
Conservation measures[5]	Conservation	60	60
Sierra Vista			
Conservation measures[1]	Conservation	290	700
Improved golf course efficiency		---	15
Effluent recharge[6]	Recharge	1,970	1,945
Stormwater detention basins[7]	Recharge	150	80
Bureau of Land Management			
Mesquite reduction[8]	Conservation	490	475
Urban enhanced ephemeral-stream channel stormwater recharge			
Increase in stormwater recharge in ephemeral channels by urbanization[9]	Recharge	2,300	2,300
Incidental yields			
Retirement of agricultural pumping[10]	Conservation	---	1,025
Total yields			
Total yield[11]		6,500	7,230

[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 2005 and the pumping that would have occurred using the 2002 gallons per capita per day for the associated population estimated for 2005 (Arizona Department of Economic Security, 2006). 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]Yields from effluent reuse are lumped with conservation and are not reported separately for this Section 321 report.

[3]Effluent recharge based on the 2005 Fort Huachuca biological opinion annual report (Fort Huachuca, 2006).

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[4]Recharge occurring because of stormwater detention basins on Fort Huachuca derived from Fort Huachuca biological opinion annual report (Fort Huachuca, 2006). Estimates in the report were based partially on monitoring data and therefore the yield is subject to the rainfall in 2005.

[5]Conservation yield attributable to Cochise County could not be calculated owing to the large number of small unmetered wells. The actual yield was assumed to equal the projected yield for 2005.

[6]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.

[7]Recharge occurring because of Sierra Vista's stormwater detention basins for 2005 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.

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

[8]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.

[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 prior Section 321 report listed a value of 3,100 acre-feet/year for urban-enhanced ephemeral channel recharge. The value for 2005 has been reduced to 2,300 acre-feet/year owing to the use of new land-cover data in calculations and do not suggest that actual recharge will decrease from current values. All urban-enhanced recharge estimates represent quantities expected in an average year—no current monitoring can provide year-specific values.

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

[11]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.

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Updated Information Included in This Report

The policy of the Partnership is to utilize the most recent official and (or) published information as part of any deficit and sustainability calculations. Updated information emerges regularly and the use of such information changes the results of the deficit estimates and projections. The following discussion describes three changes that have been implemented in this Section 321 report.

Improved Analysis of Urbanization and Detention-Basin Yields

In 2005, the Partnership funded a study (Stantec Consulting and Geosystems Analysis, 2006) to help identify locations where the installation of detention basins could most effectively increase recharge. An aspect of this study included a model-based reanalysis of recharge from existing detention basin structures. The actual detention basin yields for Sierra Vista in 2005 (table 2) differ from what had been projected owing to this reanalysis of recharge benefit. For Fort Huachuca, the actual yields differ from planned yields because field-collected data were utilized where available.

Updated Population Analysis

Each year the Arizona Department of Economic Security (AZDES) releases official estimates of prior-year population in incorporated areas and for whole counties. The calendar year 2005 AZDES population estimates (Arizona Department of Economic Security, 2006) revealed that the population projected for 2005 in the first two Section 321 reports differed from the AZDES estimates. Therefore, the AZDES population estimates for 2005 were used for this report in calculations of conservation and to project population from 2006 to 2011. 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 conservation yield for Sierra Vista (table 2) is based on the AZDES population estimate for 2005. That population was larger than had been projected for 2005 in earlier Section 321 reports and as a result, the conservation yield is increased. The reason for the increased yield is that a larger population than previously projected used a measured amount of water and therefore the amount used per person was smaller than it would have been for a smaller population.

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Pumping, Recharge, and Storage Deficit in 2005

A ground-water storage deficit of 4,400 acre feet in the Sierra Vista Subwatershed for 2005 was estimated by combining estimated total pumping with management-measure yields in a subwatershed water budget (table 3). The total pumping was the sum of uses by metered 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 2 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 2005, estimated conservation in ground-water pumping relative to 2002 gpcd usage was about 900 acre feet. Values for natural recharge and discharge are derived from an analysis by the ADWR (Arizona Department of Water Resources, 2005b)

Effect of Earlier Management Measures

Residents and policy makers in the Sierra Vista Subwatershed were aware of and actively seeking solutions to water issues prior to the enactment of Section 321. Many earlier conservation efforts yielded substantial reductions in net water use that are not represented in table 2 because of the 2002 baseline year used for Section 321 purposes. In other words, the net ground-water use in the subwatershed would have been greater in 2002 had earlier efforts not been undertaken. As an example, Fort Huachuca used about 420 acre-feet of effluent for golf course irrigation in 2002. Had the Fort not undertaken this conservation effort at an earlier time, pumping of ground water would have been about 420 acre-feet greater in 2002. Because this conservation is already a part of the water-use calculations for 2002, it can not be included as a specific credit. Other Partnership agencies have also enacted conservation measures that can not be credited specifically in table 2. These earlier efforts have reduced the daily per-capita water use in some areas of the subwatershed.

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Table 3. Water recharged to and withdrawn/discharged from the regional aquifer underlying the Sierra Vista Subwatershed in 2005

[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[1,8]	-7,700	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	-10,830	Ground-water extractions by water companies and municipalities
Pumping, rural/exempt well – gross	-4,900	Ground-water extractions by private wells
Pumping, industrial (turf, sand, and gravel) – gross	-1,430	Ground-water extractions for industrial and golf course uses
Pumping, irrigation – net[2]	-1,480	Ground-water extractions for agricultural use
Active management measures		
Reduction of riparian evapotranspiration	475	Management of invasive mesquite
Municipal effluent recharge[3]	2,380	
Detention basin recharge[4]	130	
Passive recharge resulting from human activities		
Incidental recharge[5]	2,310	
Urban-enhanced recharge[6]	2,300	
Aquifer storage change[7]	-4,400	Additions or reductions in stored aquifer water

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

[2]Pumping for irrigation is consumptive use only.

[3]Municipal effluent recharge is water returned to the aquifer through recharge facilities as reported by Sierra Vista (City of Sierra Vista, 2005) and Fort Huachuca (Fort Huachuca, 2005).

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

[5]Incidental recharge is an estimate of water returned to the aquifer from septic tanks, and turf watering.

[6]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.

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

[8]A Partnership sponsored study of riparian evapotranspiration (Scott and others, 2006) released in June 2006 contains an improved estimate of riparian ground-water use that is based on field measurements. The new estimate is not used in this year's Section 321 report water budget owing to insufficient time between the release of Scott and others (2006) and the preparation of this report for full and considered discussion by the Partnership.

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A detailed listing of area-by-area changes in consumptive water-water use for 1990 – 2002 is beyond the scope of this report. A general sense of the scale of changes, however, can be gained from information contained in table 4 of the Arizona Department of Water Resources' (ADWR) Upper San Pedro Basin Active Management Area review report (Arizona Department of Water Resources, 2005a). Net agricultural pumping (the consumptively used portion) was reduced from 2,800 acre-feet in 1990 to 2,500 acre-feet in 2002. The net[2] consumption of ground water for all non-agricultural uses[3] within the subwatershed in 1990 was 11,560 acre-feet compared with 13,900 acre-feet in 2002. During this same period, the ADWR estimates that population increased from 56,600 to 70,140. The resulting per-capita net use declined slightly from 182 to 177 gallons per person per day. Individual entities have also tracked specific reductions in water use, or decreases in per-capita use. Fort Huachuca reduced its total ground-water pumping from 2,760 acre-feet in 1990 to 1,525 acre-feet in 2002 (Arizona Department of Water Resources, 2005a); in the same period, its population declined from 9,210 to 8,413 (Arizona Department of Water Resources, 2005a). Gross water demand in Sierra Vista, based on a 1990 baseline of 202 gpcd and population of 21,915, was 4,960 acre-feet. Had the gpcd remained constant, gross demand would have increased to 7,160 in 2002 given the population of 30,700; conservation, however, reduced the projected increase in gross demand by 15 percent to 6,120 acre-feet (178 gpcd).

The lack of large improvement in average water-use efficiency in the subwatershed (182 gpcd in 1990 to 177 gpcd in 2002) in spite of improvements at Fort Huachuca and Sierra Vista reflects the increasing proportion of rural residents to the total population. In 1990, approximately 11 percent of the subwatershed's population was supplied water by exempt wells, whereas in 2002 16 percent was supplied in this manner. An estimate by the Arizona Department of Water Resources of per-capita consumptive use by the exempt-well supplied population was about 310 gpcd in 2002 (Arizona Department of Water Resources, 2005a). Examples of rural resident water uses that increase consumption relative to urban users are the irrigation of lands less than 2 acres and water supplies for large animals.

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[2] The net consumption is the estimated gross pumping minus any water unintentionally returned to the aquifer as reported by the ADWR (ADWR, 2005b). To avoid double counting of project yields, however, the 2002 ground-water use of 14,100 acre-feet does not consider effluent recharged by Sierra Vista and Fort Huachuca because those yields are included in the Section 321 plan tables. The ADWR did not account for any volume of stormwater recharge that is increased by urbanization.

[3] Includes residential, industrial, municipal, and recreational uses.

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Projected Yields and Deficits in 2006-2011

The Partnership maintains 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 4) make up the foundation of deficit reducing measures that current Partnership agency resources can support.

In keeping with the adaptive management process some future planned yields (2006 through 2011) have been modified from prior Section 321 reports to reflect improved knowledge and potential new projects (table 4). As an example of a new project, Cochise County now plans to install stormwater detention basins in areas where a Partnership sponsored study (Stantec Consulting and GeoSystems Analysis, 2006) identified a high potential for recharge. An example of an updated calculation is the modification of the method used to credit effluent reuse on Fort Huachua to more accurately reflect how increased conservation on the Fort's golf course can reduce effluent reuse. The future-year management measures and yields will evolve in each annual Section 321 report as needed to reflect the changing state of knowledge. The total management measure yields (table 4) when combined with projected pumping can be used to estimate annual aquifer storage change from 2005 to 2011 (figure 2). The projected aquifer storage change is calculated as the difference between the "no-action" aquifer storage losses and the management measure yields. The "no-action" storage loss is the deficit that is predicted to occur if no management measures were enacted and ephemeral-stream channel recharge was not increased by urbanization. Projected yields for 2006-2011 have been modified from the original projections in the 2004 Section 321 report on the basis of improved knowledge about yields actually obtained in 2002-2005.

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. The Partnership is actively investigating other management-measure approaches, including more effective rain-water harvesting techniques, to address the shortfall in yields.

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Table 4. Planned annual yields and estimates of actual annual yields for 2006 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]

		2006 Yield	2007 Yield	2008 Yield	2009 Yield	2010 Yield	2011 Yield
Description	**Measure type**	**Planned**	**Planned**	**Planned**	**Planned**	**Planned**	**Planned**
Fort Huachuca							
Conservation measures[1]	Conservation	100	130	250	250	250	250
Effluent recharge	Recharge	640	620	460	460	460	460
Stormwater detention basins[2]	Recharge	118	118	320	570	580	580
Cochise County							
Conservation measures[1]	Conservation	110	170	220	270	320	380
Stormwater detention basins[3]	Recharge	---	30	30	30	30	30
Sierra Vista							
Conservation measures[1]	Conservation	290	300	300	310	310	320
Improved golf course efficiency	Conservation	15	15	15	15	15	15
Effluent recharge	Recharge	2,090	2,150	2,210	2,270	2,340	2,410
Stormwater detention basins[2]	Recharge	80	80	190	360	400	420
The Nature Conservancy and Fort Huachuca							
Retirement of agricultural pumping[4]	Conservation	100	250	250	250	250	250
Bisbee							
Conservation measures[1]	Conservation	10	20	30	40	50	60
Reduced ground-water pumping through effluent reuse	Conservation	210	430	430	430	430	430
Effluent recharge	Recharge	---	---	120	130	140	150
Huachuca City							
Conservation measures[1]	Conservation	5	5	10	10	10	20
Effluent recharged at Fort Huachuca	Recharge	---	170	180	180	180	180
Tombstone							
Conservation measures[1]	Conservation	5	5	10	10	10	20
Bureau of Land Management							
Mesquite reduction[5], and retirement of agricultural ground-water pumping[3]	Conservation	580	660	750	830	920	1,000
Urban enhanced ephemeral-stream channel stormwater recharge							
Increase in stormwater recharge in ephemeral channels by urbanization[6]	Recharge	2,300	2,300	2,300	2,300	2,300	2,300
Incidental Yields							
Retirement of agricultural pumping	Conservation	1,750	1,750	1,750	1,750	1,750	1,750
Total yields							
Total yield[7]		8,410	9,210	9,830	10,470	10,760	11,030

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[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 2006-2011 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]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).

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

[5]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.

[6]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.

[7]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.

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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.

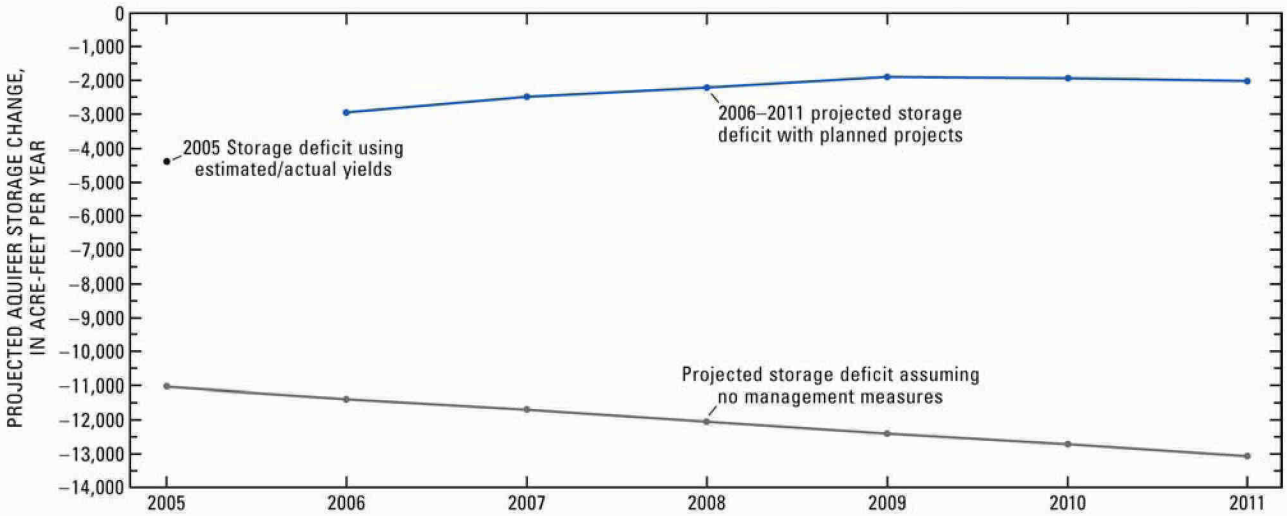

Figure 2. Effect of management measure yields (planned yields and estimates of actual yields) on annual aquifer storage change (calculated as the difference between projected annual aquifer-storage depletions if no management measures are taken and management-measure yields).

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Long-Term Management Plan

The Partnership adopted an adaptive management strategy for solving water issues in the Sierra Vista Subwatershed. New possibilities for water-management measures are regularly evaluated for legal, logistic, and fiscal feasibility, and for potential yields. 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.

While the means to a goal are subject to regular reevaluation in the adaptive-management process, the goals themselves may also be refined. 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 also on where ground-water is pumped. The initial 321 report specified elimination of aquifer storage depletion as the goal. As more is learned about the system, the goals will be updated accordingly.

The Partnership is currently creating a long-term planning document that will be adapted periodically to reflect the latest knowledge about management-measure successes, as well as to include new management strategies. In addition, the plan will be adapted to meet the requirements of evolving goals. The Partnership's long-term plan will be the basis for identifying the management measures that will be evaluated in each annual Section 321 progress report.

Progress Toward Addressing 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 legislative accomplishments have 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

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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

Conservation Measures:

Code Changes

Impediment: 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).

2005 action: Although both the City of Sierra Vista and Cochise County are working on myriad code changes, no action has occurred at the state level to provide additional ordinance making powers as suggested above. House Bill (HB) 2329 local water use standards for landscaping was introduced but saw no legislative action. Senate Bill (SB) 1390 low water use landscaping for subdivisions was introduced but saw no legislative action.

2006 action: Cochise County Board of Supervisors adopted the Sierra Vista Subwatershed Water Conservation and Management Policy Plan in March. This plan limits density increases unless the subdivider incorporates water savings that mitigate any increase in usage over the current zoning. Additionally, it prohibits increasing densities within 2 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.

The Joint Planning Committee has developed a water conservation model ordinance that is being considered by all the cities in the subwatershed. The City of Sierra Vista is working on issues that would require developers "to bring the water with the development." No Arizona statutory changes have occurred.

Impediment: 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).

2005 action: SB 1336 establishes a rural water legislative study committee that is intended to address these and other issues. Legislation was signed by the Governor.

2006 action: The study committee has met periodically, but little action has been taken. The Arizona Department of Water Resources, in conjunction with the Governor's Office, has formed a Governor's Statewide Advisory Group. They are working on the potential process for such local/regional water management authority. SB 1484 was introduced that would have established a special taxing district to conduct water-resource management. The bill saw no action.

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Impediment: 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.

2005 action: HB 2173 Water Supply Notice; Subdivisions was introduced to respond to this issue. Final action on the bill has not happened.

2006 action: Several bills were introduced during this session. HB 2431 was passed and signed by the Governor. The original language was for disclosure of water adequacy; however, the language was changed to only require the seller to disclose how water is provided and that an adequate supply may not have been determined by ADWR.

Zoning

Impediment: Current state 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).

2005 action: HB 2262 was introduced that would require notice regarding water adequacy for 5-parcel splits. There is considerable opposition to changing the laws regarding 5-parcel lot splits and the bill has not progressed.

2006 action: SB 1255 was introduced that would require an affidavit of disclosure to be completed by the seller of a lot, or fractional interest that had previously undergone a land division into five or fewer lots, parcels or fractional interests in an unincorporated area of a county; defeated. The Cochise County Board of Supervisors adopted the Sierra Vista Subwatershed Water Conservation and Management Policy Plan in March. This plan limits density increases unless the subdivider incorporates water savings that mitigate any increase in usage over the current zoning. Additionally, it prohibits increasing densities within 2 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.

Conservation Easements

Impediment: Current law does not provide for Transfer Development Rights (TDRs) for counties, denying that management option to counties for anything other than encroachment of military airports.

2005 action: HB 2364 established the authority for counties to adopt ordinances implementing transfer of development rights under certain restrictions. Protection of "geologic features" is circumstance listed as reason to invoke transfer of development rights. Legislation has been signed by the Governor.

2006 action: Since the passage of the statute, Cochise County has been working with Pima County on a draft ordinance to implement TDRs.

Impediment: Current state law regarding the establishment of "irrigation non-expansion areas" applies to entire basins or

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subbasins, and cannot be applied to a subwatershed such as the Sierra Vista Subwatershed (ARS 45-432)

2005 action: No such authorizing legislation was introduced during the 2005 session. This could be discussed with the study committee established under SB 1336.

2006 action: HB 2462 was introduced in the Arizona Legislature; however, after its initial hearing it did not move further owing to opposition from the Chairman of the Senate Natural Resources Committee.

Impediment: Currently, there are no matching funds from state sources for conservation projects outside of the riparian zone to help address water management issues.

2005 action: No funding was budgeted by the legislature for FY06.

2006 action: SB 1251 was passed and signed by the Governor. This bill established the Agricultural Protection Fund, up to $4M, to protect critical agricultural land, including ranch land. Not funded in FY 2006 state budget.

Impediment: Current tax policy provides incentives for water consuming uses but not for water conserving uses on undeveloped lands (ARS 42-15004).

2005 action: No legislation was introduced on this subject for the 2005 session.

2006 action: No bills covering this issue were introduced.

Impediment: The priority date for a surface water right (including subflow) severed and transferred for instream flow can currently only be protected if the right is transferred to the State or its political subdivisions; the priority date cannot be protected by transfer to a Federal entity.

2005 action: No legislation was introduced on this subject for the 2005 session.

2006 action: No bills covering this issue were introduced.

Conservation Pricing

Impediment: 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)

2005 action: Guidelines for conservation pricing were drafted and provided for legislative drafting; however, it was determined that this avenue should be considered under the rural water legislative study committee.

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2006 action: No bills covering this issue were introduced; however, S1249 was passed and signed by the Governor that requires that the Arizona Corporation Commission be notified of a petition to form a water/wastewater improvement district when the boundaries of the proposed district affect the service area of a private water or sewer company under ACC jurisdiction.

Technology Incentives

Impediment: Currently, there are no matching funds from State sources for conservation projects outside of the riparian zone to help address water management issues.

2005 action: No funding was budgeted by the legislature for FY06.

2006 action: No funding was budgeted by the legislature for FY07.

Recharge/Reuse Measures:

Effluent Recharge/Reuse

Impediment: Currently, there are no matching funds from State sources for conservation projects outside of the riparian zone to help address water management issues.

2005 action: HB 2323 establishing tax credits for water conservation systems was introduced and later withdrawn.

2006 action: No bills covering this issue were introduced.

Impediment: Sufficient funding is not available for communities to meet EPA/ADEQ's high water-quality standards for effluent to be recharged through shallow basins.

2005 action: No funding was budgeted by the legislature for FY 06.

2006 action: No funding was budgeted by the legislature for FY 07.

Storm Water Recharge

Impediment: Currently Arizona limits the disposition and (or) use options for State trust lands. Such options could permit construction of optimally located recharge facilities.

2005 action: A private initiative has been drafted that would allow for some State Trust Land exchanges that could assist with this issue.

2006 action: The initiative mentioned in 2005 will be on the General Election ballot in November 2006.

Augmentation/Importation Measures:

Augmentation/Importation Strategies

Impediment: Currently Arizona limits the disposition and/or use options for State Trust Lands. Such options could permit construction of optimally located augmentation projects.

2005 action: A private initiative has been drafted that would allow for some State Trust Land exchanges that could assist with this issue.

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2006 action: The initiative mentioned in 2005 will be on the General Election ballot in November 2006. A competing referendum will also be forwarded to the voters.

Impediment: 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.'

2005 action: HB 2174 was introduced which under drought emergency conditions would have allowed for such transfers temporarily. Under a 'strike everything' action, bill was changed into a funding bill that has been signed by the Governor.

2006 action: HB 2436 was introduced which would allow water transfer under emergency conditions.

Impediment: Currently, the Central Arizona Project (CAP) does not extend into the Sierra Vista Subwatershed, and its allocations do not pertain to the Upper San Pedro Basin. The enabling legislation expired in 1988; new legislation would be required for this option.

2005 action: Although no new legislation was introduced, the city of Sierra Vista is considering filing a letter of intent to use CAP water under an existing reallocation process.

2006: The City of Sierra Vista, through their attorney, filed a letter of intent with the Arizona Department of Water Resources for a CAP allocation. The Partnership, in cooperation with the Bureau of Reclamation (BOR), have been working on a screening process for alternative water source projects including the CAP. U.S. House Bill HR5460 was introduced in May 2006 that, if passed, would authorize the BOR to complete a feasibility study on an, as yet unnamed project.

Impediment: 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 Act, Public Law No. 108-451 (2004), provides Congressional approval for a settlement, but no judicial decree has yet been entered.

2005 action: HB 2728 Water Settlement Act was introduced which implements congressional passage of the Indian Settlement Act. This has been signed by the Governor.

2006 action: The Arizona Legislature passed and the Governor signed HB 2835 that implements portions of the Settlement Act.

Additional actions:

2005 action: Two bills were introduced and moved through the legislative process during the 2005 session that could have a favorable outcome for water conservation:

HB 2277 Water Providers; Water Plans was passed and signed by the Governor requiring public water systems to prepare supply, drought-preparedness and conservation plans.

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HB 2323: Tax Credits; Water Conservation Systems. Provides a tax credit for individuals installing water conservation systems, builders constructing homes with water conservation systems, and corporations constructing homes with water conservation systems.

Both bills were signed by the Governor.

One bill was introduced that would provide some necessary funding for ADWR but only for expenses and costs for determining and declaring adequate and assured water supplies:

HB 2174 Assured Water Supply; Fund; Committee provides funding to an Administrative Fund to help support ADWR's work. The bill was passed and signed by the Governor.

2006 action: Several appropriation bills are awaiting action in the FY07 budget bill for Arizona.

HB 2463 authorized partial reimbursement to local governments for the development of regional ground-water plans; bill failed to get approval.

HB 2775 requires the establishment of a statewide, automated ground-water monitoring system; bill failed to get approval.

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Monitoring Data in Support of Sustainability Evaluation

In the first Section 321 report, 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 replenishing 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 can not 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 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. 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 result of most interest in the Sierra Vista Subwatershed, the storage deficit, is the calculated difference between inflows and outflows. As a result the error in the deficit calculation combines the errors intrinsic to the inflow and outflow estimates.

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Several deficiencies in the water-budget approach are eliminated by directly monitoring changes in the aquifer. Instead of calculating storage change from other inflow and outflow values, it can be measured directly using microgravity techniques. Changes in water levels, hydraulic gradients, and natural outflows can be measured as well. A limitation of direct monitoring is that periods of record longer than a year are needed to determine what changes result from human activity, and what changes would have occurred naturally.

Data from regional-aquifer and streamflow monitoring will play an increasingly important role in verifying overdraft reductions in each succeeding annual progress report. Some initial data are presented here to set the framework for the more detailed analyses that will be used for evaluation of progress toward sustainability. Two specific data sources are indicated in Section 321: (1) "The San Pedro base flow monitoring record of the Charleston flow gauge of the United States Geological Survey", and (2) "Current surveys of the groundwater levels in area wells as reported by the Arizona Department of Water Resources and by Federal agencies."

These sources of information are essential for evaluating sustainability. It is important to recognize, however, that an overly simplistic analysis can be misleading. For example, base flow at the Charleston gaging station could potentially be influenced by pumping, but may also change because of climatic factors. Similarly, changes in ground-water levels may be linked to pumping, but might also be influenced by a significant recharge event. These issues are exacerbated if one examines short periods of record. The analysis necessary to resolve these issues will be performed and reviewed outside of the annual Section 321 progress report, with the results cited in future annual reports.

Streamflow data have been collected by the U.S. Geological Survey in the Sierra Vista Subwatershed since the early 1900s. In about 2000, a more comprehensive data-collection effort was initiated that includes measurements of streamflow, ground-water levels, vertical hydraulic gradients, aquifer storage change, and spring discharge (figure 3).

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) to about 6 years at several stations.

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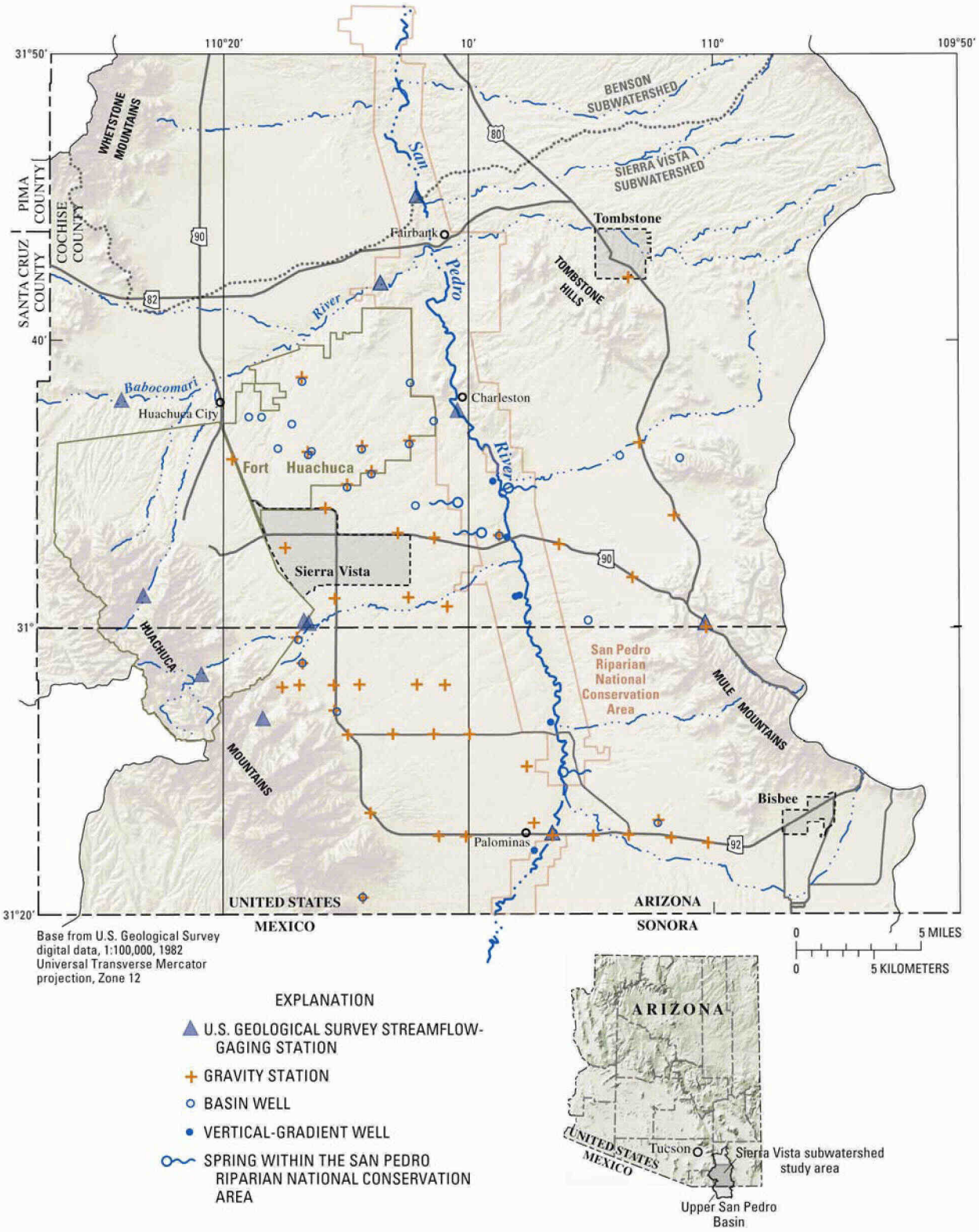

Figure 3. Locations of streamflow, ground-water level, spring, and microgravity monitoring locations in the Sierra Vista Subwatershed, Upper San Pedro Basin, Arizona.

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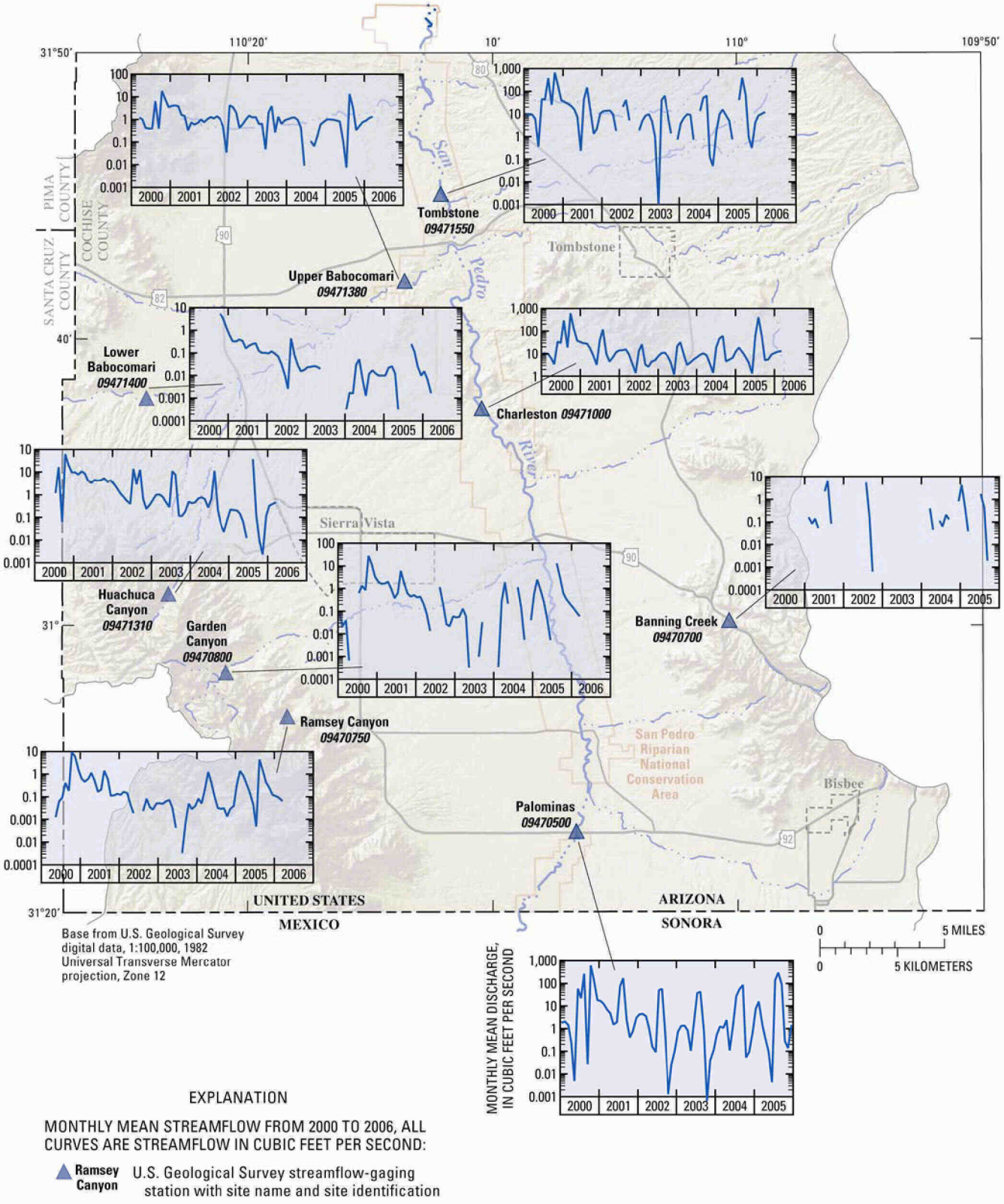

Figure 4. Monthly average streamflow at stream monitoring locations, Sierra Vista Subwatershed, Upper San Pedro Basin, Arizona, 2000–2006.

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, 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 that will serve as part of the basis for the comprehensive interpretation of field data in future Section 321 reports.

Base Flow at San Pedro River at Charleston

Base flow at the Charleston gaging station varies seasonally (figure 5), with the lowest flow in early summer, 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.

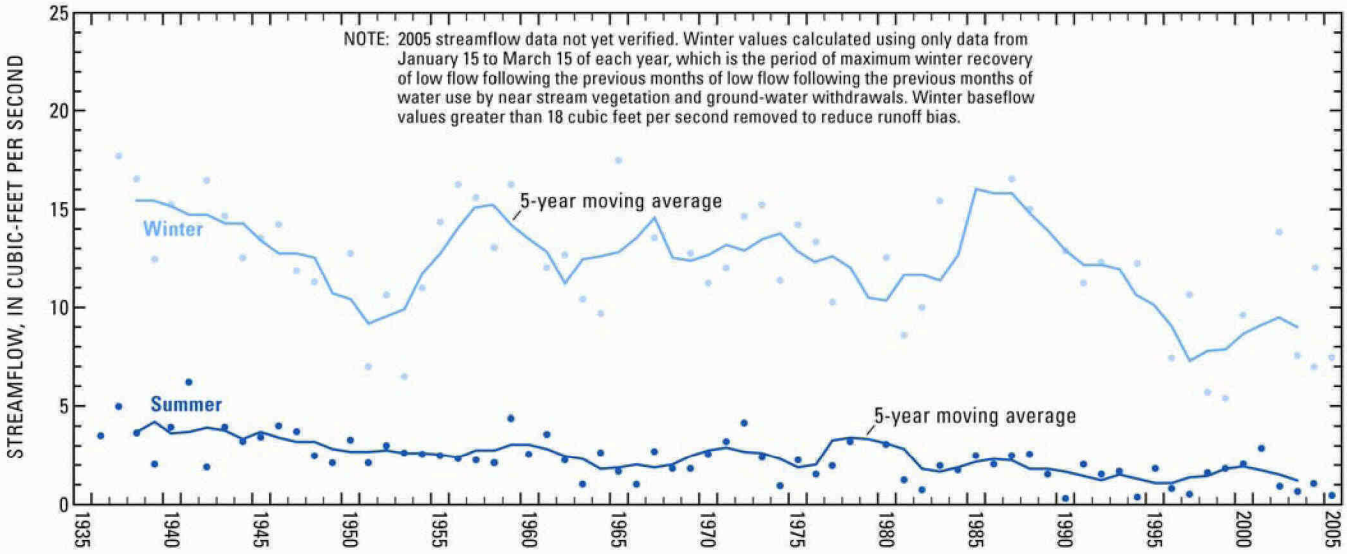

Figure 5. Seasonal 7-day low flow at the San Pedro River at Charleston streamflow-gaging station.

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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.

Examination of the long-term record for base flow at Charleston does indicate, however, that variability is high from year to year, and that analysis of changes in any particular year could be misleading. Interpretations made of changes in base flow will be made in the context of climate, human activities, and measured changes in aquifer water levels and storage. It is worthy to note that zero flow was measured at Charleston for the first time in the period of record on July 6, 2006.

Spring 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 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 6) were initiated in response to Section 321 needs in early 2005. Discharge at one spring, Murray spring, has increased during the period of data collection. This spring is about 2.5 km downgradient from the Sierra Vista wastewater recharge facility. 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.

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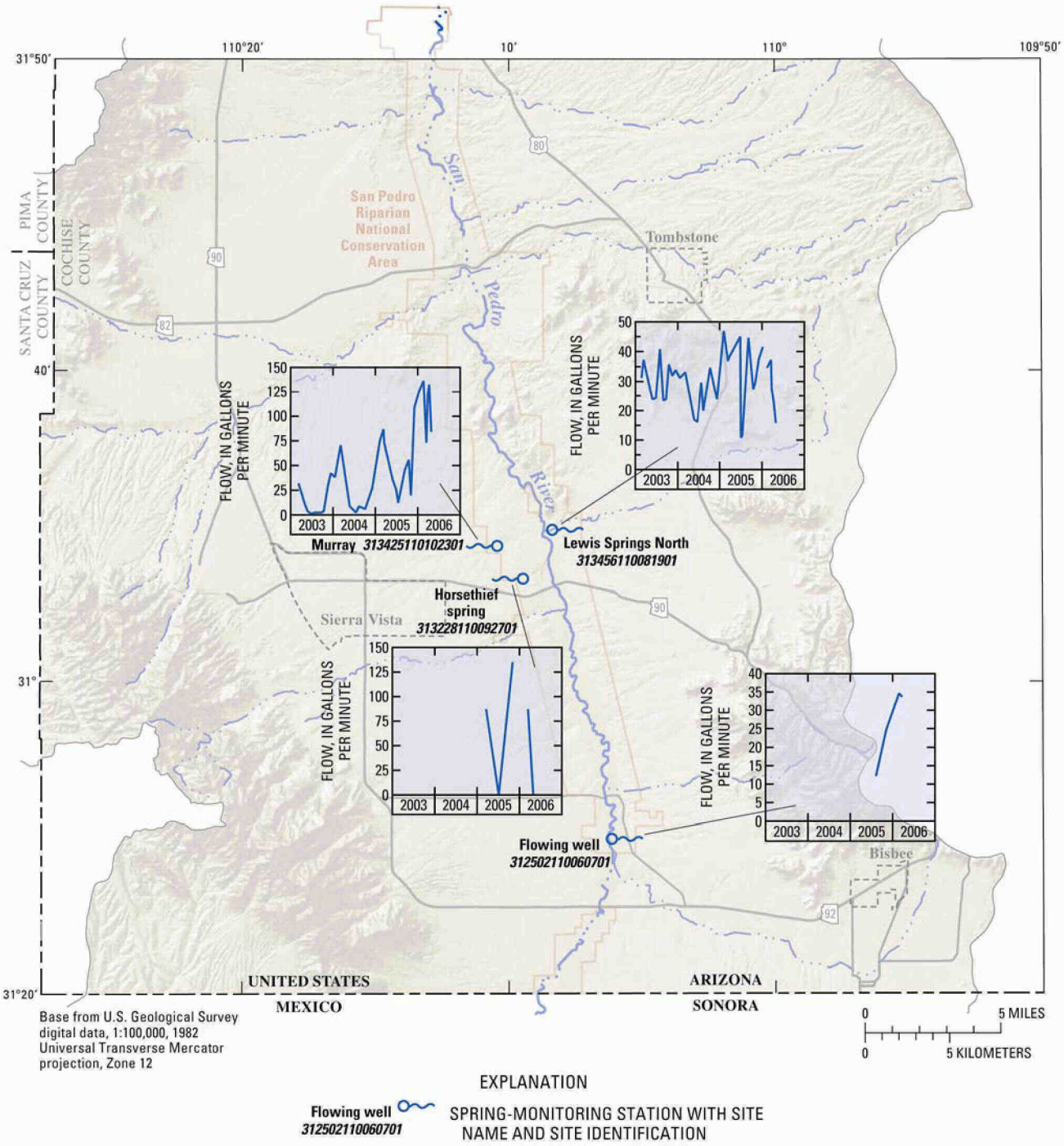

Figure 6. Measured flow at spring-monitoring locations, Sierra Vista Subwatershed, Upper San Pedro Basin, Arizona.

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Water Levels in the Aquifer

Changes in ground-water levels indicate changes in aquifer storage. Rising water levels represent increasing storage, whereas falling water levels mean storage is declining. Like base flow, ground-water levels can change both because of climate and because of pumping. Although streamflow measurements are limited to the locations of the few gaging stations, wells where ground-water levels may be measured are widely distributed across the Sierra Vista Subwatershed. Some wells are closer to pumping centers, where changes caused by withdrawals are more likely to be observed, and some are near recharge locations, where natural climate variability may dominate water-level changes.

Trends in aquifer water levels are analyzed in Pool and Coes (1999), and in the ADWR's Active Management Area review report (Arizona Department of Water Resources, 2005a). The summary provided here is drawn from those sources. 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 7), 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 (figure 7). A long-term hydrograph from a well along the San Pedro River near Palominas (figure 7) shows only a few feet of decline resulting from historic near-stream agricultural pumping, but the decline was sufficient to convert a perennial stream reach to ephemeral. Data from spatially distributed monitor wells show how water levels have changed across the Sierra Vista Subwatershed (figure 7).

Long-term hydrographs show that changes in the aquifer system are caused by natural and human-caused factors over relatively large spans of time. The amount of time since the adoption of Section 321 has been insufficient to evaluate aquifer responses to management measures undertaken by the Partnership, but future annual reports will increasingly utilize monitoring data in the evaluation of management-measure success in attaining sustainability.

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Aquifer Storage Change

Ground-water storage change is be determined directly by measuring changes in microgravity. 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. Microgravity measurements are generally sufficiently precise to detect a change of 15 cm of free-standing water. In an unconfined aquifer, the corresponding water-level change is larger than the equivalent change in free-standing water by a factor of 1 over porosity. The difference arises because volume is occupied by aquifer sediments so adding or subtracting a given mass of water requires more volume in porous media than in open space. A typical range of porosity for aquifer sediments is 0.05 to 0.30. A significant advantage of gravity measurements is that measurements can be made with equal ease in developed and undeveloped areas thereby allowing comparison of changes between these two area types. New stations can be established at a low cost allowing easy adaptation of the gravity monitoring network.

Variations in microgravity are available across much of the current gravity network since about 2000 (figure 8). These measurements will be synthesized with water-level data to evaluate aquifer storage change across the Sierra Vista Subwatershed.

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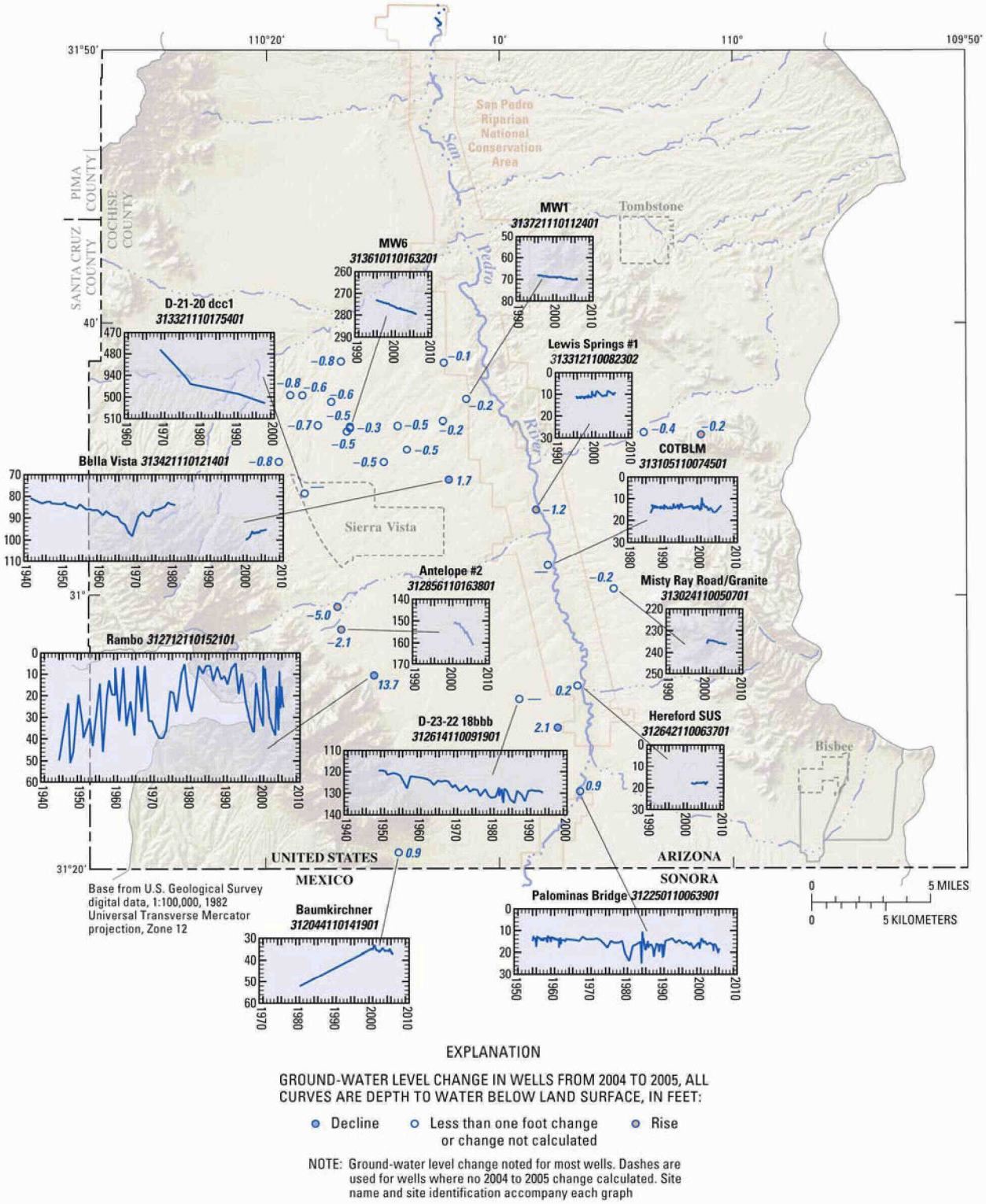

Figure 7. Changes in ground-water levels from 2004 to 2005 at selected wells with associated long-term hydrographs, Sierra Vista Subwatershed, Upper San Pedro Basin, Arizona.

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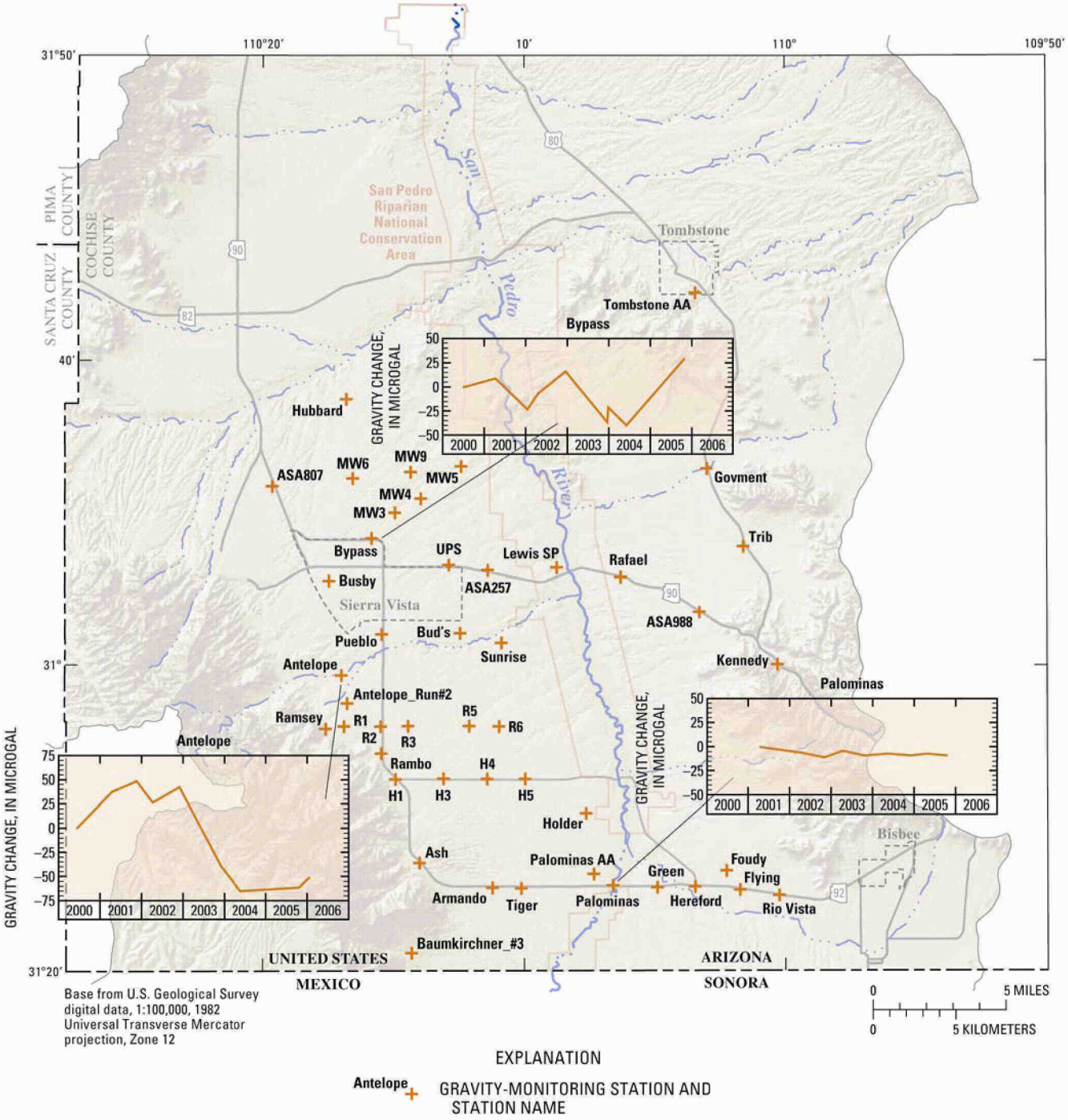

Figure 8. Microgravity monitoring locations and changes in gravity at selected locations, Sierra Vista Subwatershed, Upper San Pedro Basin, Arizona, 2000–2006.

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FCSPRNCA1282

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.

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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.

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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.

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(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.

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(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.

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

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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

FCSPRNCA1289