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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

Water Management of the Regional Aquifer in the Sierra Vista Subwatershed, Arizona—2009 Report to Congress

U.S. Department of the Interior
U.S. Geological Survey

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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 groundwater 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 (Department of the Interior, 2005).

The report that follows is an annual progress report, the fifth in a series of such reports to be prepared through 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. These reports to Congress will continue to rely on information from these studies (for example Kennedy and Gungle, in press) and on data collected by the 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 non-governmental 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, the Bureau of Land Management, the Bureau of Reclamation, and other Upper San Pedro Partnership members.

Conversion Factors

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)	325,851	gallon (gal)
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 (cfs)	448.812	gallon per minute (gpm)
gallon per minute (gpm)	1.6141	acre foot per year (acre-ft/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)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

°F=(1.8×°C)+32

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

°C=(°F-32)/1.8

Vertical coordinate information is referenced to the insert datum name (and abbreviation) here for instance, "North American Vertical Datum of 1988 (NAVD 88)."

Horizontal coordinate information is referenced to the insert datum name (and abbreviation) here for instance, "North American Datum of 1983 (NAD 83)."

Altitude, as used in this report, refers to distance above the vertical datum.

*Transmissivity: The standard unit for transmissivity is cubic foot per day per square foot times foot of aquifer thickness [(ft^3/d)/ft^2]ft. In this report, the mathematically reduced form, foot squared per day (ft^2/d), is used for convenience.

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C).

Water Management of the Regional Aquifer in the Sierra Vista Subwatershed, Arizona—2009 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.

Section 321 Reporting

Section 321 of the Defense Authorization Act of 2004, Public Law 108-136, requires each annual 321 report to include the following:

1. The quantity of the overdraft of the regional aquifer reduced during the reporting period;
2. Whether the reduction in (1) met the goal specified for the reporting period;
3. The water-use management and conservation measures undertaken by each water-use controlling member of the Partnership during the reporting period;
4. The extent of the contribution of such measures to the reduction of the overdraft;
5. The legislative accomplishments made during the reporting period in removing legal impediments that hinder the mitigation of water use by Partnership members.

These requirements are addressed in order, below. The fiscal year prior to the due date of this report to Congress (fiscal year 2009)—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. As with previous Section 321 reports, the previous calendar year (2008) was used instead.

1. The quantity of the overdraft of the regional aquifer reduced during 2008

In 2008, the quantity of the overdraft was reduced by 1,000 acre-ft, from 5,300 acre-ft in 2007 to 4,300 acre-ft in 2008 (fig. 1 and table 1). This storage deficit is discussed in more detail on p. A44 to A45 in Appendix A of this report.

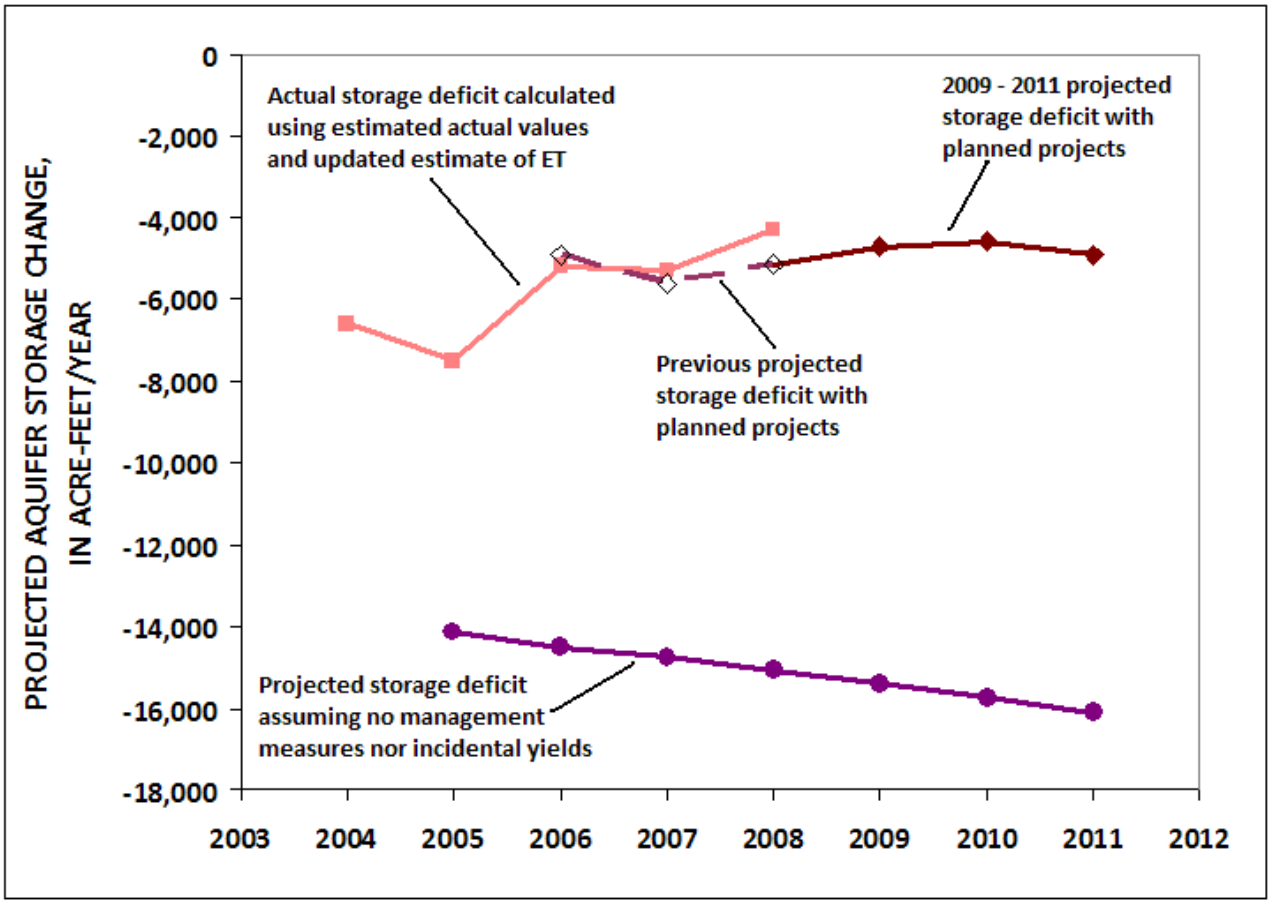

Figure 1. Effect of management-measure yields (planned yields and estimates of actual yields) on annual aquifer storage change (calculated as the difference between projected annual aquifer-storage depletions if no management measures are taken and management-measure yields). Deficit values shown, including those calculated for years prior to 2006, use an improved estimate of riparian evapotranspiration (Scott and others, 2006). Deficit values shown for years prior to 2006 are thus larger than values reported in Section 321 reports prior to 2007 (in other words, that report on data prior to 2006).

Table 1. Water recharged to and withdrawn/discharged from the regional aquifer underlying the Sierra Vista Subwatershed in 2008

[Water-budget volumes are in acre-ft/yr; inflows are assigned positive numbers, outflows are assigned negative numbers; all values are estimates based upon the best available data and computational methods]

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
Groundwater inflow[1]	3,000	Subsurface inflow from Mexico
Groundwater outflow[1]	-440	Subsurface outflow at USGS San Pedro River near Tombstone streamflow-gaging station (09471550)
Stream base flow[1]	-3,250	Groundwater discharge to the river that flows out of the Subwatershed
Evaporation and plant transpiration[2]	-10,800	Groundwater consumed in the riparian system exclusive of evapotranspiration supplied by near-riparian recharge from precipitation or flood runoff
Sub-total	3,500	Natural aspects of system
Pumping		
Pumping, water companies and public supply– gross	-9,725	Groundwater extractions by water companies and municipalities (excluding golf courses)
Pumping, rural/exempt well – gross	-4,600	Groundwater extractions by private wells
Pumping, industrial (turf, sand and gravel, stock tanks, golf courses) – gross	-1,350	Groundwater extractions for industrial uses (including golf courses)
Pumping, irrigation – net[3]	-370	Groundwater extractions for agricultural use
Sub-total	-16,000	Pumping
Active management measures		
Reduction of riparian evapotranspiration	615	Management of invasive mesquite
Municipal effluent recharge[4,5]	2,700	
Detention basin recharge[6]	267	
Sub-total	3,600	Active management measures
Passive recharge resulting from human activities		
Incidental recharge[7]	2,200	
Urban-enhanced recharge[8]	2,300	
Sub-total	4,500	Passive recharge due to human activities
Total aquifer storage change[9]	**-4,400**	Additions or reductions in stored aquifer water

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

[2]Value of evapotranspiration (ET) is the average of the high and low estimates of Scott and others (2006).

[3]Pumping for irrigation is consumptive use only. Area considered is the groundwater basin portion of the Sierra Vista Subwatershed only. The area within the boundaries of the Sierra Vista Subwatershed includes more agricultural lands—primarily located in the head waters of the Babocomari River—than the area within the groundwater basin portion of the Subwatershed.

[4]Municipal effluent recharge is water returned to the aquifer through recharge facilities as reported by the City of Sierra Vista (Pat Bell, written commun., April 20, 2009), Fort Huachuca (Tom Runyon, written commun., June 5, 2009), City of Tombstone (Pat Kelly, written commun., June 16, 2009), and City of Bisbee (Russ McConnell, written commun., June 12, 2009).

[5]The City of Sierra Vista has known for some time that several hundred additional acre-ft of incidental recharge have been infiltrating through the bottoms of the wetlands ponds, although the amount of that additional recharge has not been known. A recent consultant's study of the city's recharge facility establishes 800 acre-ft/yr of incidental and additional recharge from the wetlands that is not reflected in the current recharge total. That number will be added to future recharge totals once appropriate coordination/validation has been completed by the city (Pat Bell, written commun., July 27, 2009).

[6]Recharge of stormwater within basins installed to mitigate flood peaks in urban ephemeral-stream channels.

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

[8] Urbanization in semiarid climates can increase recharge by concentrating rainfall runoff in ephemeral-stream channels. Estimate provided by the Agricultural Research Service. Recharge caused by urbanization only partially mitigates the increased pumping that accompanies increased urbanization.

[9]Value rounded to nearest 100 acre-ft/yr.

2. Whether the reduction in the deficit met the goal specified for the reporting period

The water budget goal for 2008 originally laid out in the 2004 321 Report (Department of the Interior, 2005) was to reduce the annual water budget deficit to 100 acre-ft by the end of 2008. The projected reduction in the deficit from 2007 to 2008 was 500 acre-ft (table 2). Since the publication of those figures, an improved estimation of population in the Subwatershed reduced the projected and actual 2008 deficit by about 550 acre-ft (Department of the Interior, 2007) and reduced the projected 2007 to 2008 deficit reduction to 410 acre-ft. An improved estimate of evapotranspiration further increased the deficit by 3,100 acre-ft (Scott and others, 2006). These changes result in a total revised 2008 annual deficit goal of 3,800 acre-ft. The actual annual deficit for 2008 was 4,300 acre-ft (table 2).

The deficit reduction from 2007 to 2008 is discussed in Appendix A, p. A44.

Table 2. Original and revised 2008 water budget deficit goals and actual water budget deficit

[in acre-ft/yr]

Original 2007 to 2008 deficit reduction goal from 2004 321 Report	Revised 2007 to 2008 deficit reduction goal	Actual 2007 to 2008 deficit reduction	Original 2008 annual deficit goal from 2004 321 Report	Revised 2008 annual deficit goal	Actual 2008 annual deficit
500	410	1,000	100	3,800	4,300

3. Water use management and conservation measures undertaken by each water-use controlling member of the Partnership

The water use management and conservation measures undertaken by each water-use controlling Partnership member in 2008 are detailed in table 3. The actual yields from the measures undertaken in 2008 are 100 acre-ft less than the 2008 planned yields. Note that the water budget shown in table 1 is calculated using combined estimated total pumping with management-measure yields, but excluding conservation measures. The estimated conservation measures shown in table 3 are intrinsically included in any reductions in groundwater pumping included in table 1. Because these conservation measures are often rough estimates, the totals in table 3 have a large margin of error. Management and conservation measures are discussed in Appendix A, p. A12–A15.

4. Extent of contribution of management and conservation measures to the reduction of the overdraft

The contribution of management and conservation measures to the reduction of the overdraft in 2008 equaled about 10,800 acre-ft (the difference between the "Projected storage deficit assuming no management measures…" and the "Actual storage deficit…" in fig. 1). The deficit without management and conservation measures projected in 2004 for 2008 (adjusted for a revised population estimate from 2005) was 15,100 acre-ft. The deficit calculated for 2008 using the water budget method is 4,300 acre-ft (table 1).

5. Legislative accomplishments

No additional legal barriers to implementation of management measures occurred in 2008. For the first time in the history of 321 reporting, the Partnership did not make any additional progress in addressing the previously existing legal impediments. This is at least in part a result of the Arizona State

Legislature's preoccupation with the State's fiscal budget this year, brought on by the economic downturn at the end of 2008 and early 2009. Little legislation passed the State Legislature this year outside of items directly related to the State's fiscal health.

See Appendix D for details of legal impediments and legislative accomplishments from the 2008 and earlier 321 Reports.

Indicators of Progress toward Sustainable Yield

It is important to understand that the overall situation in the regional aquifer of the Sierra Vista Subwatershed today is not improving; rather, it is getting worse at a rate slower than in 2002 (and 2007). Though the annual overdraft of the aquifer has been greatly reduced from the 15,084 acre-ft anticipated for 2008 when first estimated in 2004 (includes significant revisions in 2005 and 2007) to 4,300 acre-ft today, this is still another 4,300 acre-ft of water that has been removed from storage in addition to the hundreds of thousands of acre-ft that have been removed from storage since groundwater pumping commenced in earnest in the first half of the 20th century. This year's annual storage deficit is a thousand acre-ft less than in 2007, but until the aquifer begins to actually accrete storage (i.e., the annual water budget becomes greater than 0) there will be no reduction in the cumulative deficit. Table 4 presents 6 of the 8 indicators of sustainability the Partnership has agreed to track1 and shows whether each indicator (1) has improved or degraded since last year (2007), (2) shows improving or degrading short-term trends for the period of 321 reporting, 2002–08, (3) shows improving or degrading long-term trends beginning with the earliest useful data available through 2008. This should progress toward the goal of sustainable yield of groundwater in the Subwatershed at this time. It should be noted, however, that the response time to management and conservation measures for many of the indicators

[1] Because of the volume of data and the time required to assess those data, two indicators (alluvial aquifer groundwater elevations and near-stream vertical hydraulic gradients) were not incorporated into the Subwatershed assessment this year; both will be included next year, in the 2010 321 Report.

Table 3. Planned and estimated actual yields for 2008 of Partnership member measures to reduce aquifer overdraft and of increased recharge from urbanization

[Yields are in acre-ft/yr; numbers compiled March—June 2009 based on data provided by respective jurisdictions or in conjunction with USGS; 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-ft]

Description	Measure type	2008 Yield Planned	2008 Yield Actual
Fort Huachuca			
Conservation measures[1,2]	Conservation	185	890
Effluent recharge[3]	Recharge	505	211
Stormwater detention basins[4]	Recharge	120	46
Cochise County			
Conservation measures[5]	Conservation	110	110
Stormwater detention basins	Recharge	30	30
Sierra Vista			
Conservation measures[1,2]	Conservation	800	1,600
Improved golf course efficiency	Conservation	15	15
Effluent recharge[6]	Recharge	2,200	1,881
Stormwater detention basins[7]	Recharge	190	191
Bisbee			
Conservation measures	Conservation	30	20
Reduced groundwater pumping through effluent reuse	Conservation	470	0
Effluent recharge[8]	Recharge	0	475
Huachuca City			
Conservation measures[2]	Conservation	10	60
Tombstone			
Conservation measures[2]	Conservation	10	10
Effluent recharge[9]	Recharge	130	90
Bureau of Land Management			
Mesquite reduction[10] and retirement of agricultural groundwater pumping	Conservation	760	615
Urban enhanced ephemeral-stream channel stormwater recharge			
Increase in stormwater recharge in ephemeral channels by urbanization[11]	Recharge	2,300	2,300
Incidental yields			
Retirement of agricultural pumping[12]	Conservation	2,070	2,070
Total yields			
Total yield[13]		9,800	9,700

[1]Fort Huachuca is wholly contained within the boundaries of the City of Sierra Vista, and Fort Huachuca's conservation yields are included in the Sierra Vista yields included in table 3. The Planned and Actual Total Yields found at the bottom of this table do not include the values from the Fort Huachuca Conservation Measures line. Fort Huachuca's yields were double counted in previous 321 reports and this accounts for the 100 acre-ft discrepancy in 2008 Planned Total Yield data from the 2008 and 2009 321 Reports.

[2] 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 2008 and the pumping that would have occurred using the 2002 gallons per capita per day for the associated population estimated for 2008 (Arizona Department of Commerce, 2009).

[3] Tom Runyon, Fort Huachuca Hydrologist, written commun., June 5, 2009.

[4] Recharge from stormwater detention basins on Fort Huachuca. Estimate derived from Fort Huachuca biological opinion annual report (Fort Huachuca, 2009). Report estimates based partially on monitoring data and therefore yield is subject to 2008 rainfall.

[5] Conservation yield attributable to Cochise County could not be calculated owing to the large number of small unmetered wells. The reported yield of 110 acre-ft is attributable to toilet-replacement rebates and assumed savings from code changes. Cochise County undertook various code changes that should have yielded water savings, but that cannot be quantified owing to lack of available metered water-use data, for example, hot water on demand, gray water plumbing, high-efficiency commercial laundry facilities, ban on artificial water features, humidity sensors on outdoor irrigation, new turf restrictions, limits on evaporative coolers.

[6] Pat Bell, City of Sierra Vista, written commun., April 20, 2009. Recharge values are based on metered inflows to infiltration basins minus estimated evaporative loss. A recent consultant's study of the city's recharge facility establishes 800 acre-ft/yr of incidental and additional recharge from the wetlands that is not reflected in the current recharge total. That number will be added to future recharge totals once appropriate coordination/validation has been completed by the city (Pat Bell, City of Sierra Vista, written commun., July 27, 2009).

[7] Recharge of stormwater in 2008 in the City of Sierra Vista's stormwater detention basins. Values 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.

[8] Russ McConnell, Bisbee Public Works, written commun., June 12, 2009. Recharge from effluent released into Greenbush Draw; 95% of total effluent discharged is assumed to recharge the groundwater system.

[9] Pat Kelly, Tombstone Public Works, written commun., June 16, 2009. Recharge from effluent produced by residents of Tombstone that is released into Walnut Gulch; 95% of total effluent discharged is assumed to recharge the groundwater system.

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

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

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

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

will be, at a minimum, years and in many cases decades or longer; capture of natural discharge from the system continues for long periods of time even when pumping is entirely discontinued (Bredehoeft and Durbin, 2009; Leake and others, 2008).

Table 4. Evaluation matrix for indicators of progress toward sustainable yield of groundwater use in the regional aquifer of the Sierra Vista Subwatershed, Upper San Pedro Basin, Arizona.

[Values observed in 2007 and 2008 are reported in their respective columns; "2007–2008 DIFFERENCE" column evaluates 2007–08 change for each indicator; box color and arrows highlight whether indicator has improved (green, ↑), remained unchanged (orange, ≈), or degraded (red, ↓) since 2007; "2002–2008" column evaluates short-term trend in each indicator over period of 321 reporting; "EARLIEST DATA–2008" column evaluates long-term trend in each indicator, from earliest useful data to 2008 (see plots in Appendix A); dates in parentheses indicate first year of record evaluated; NA, not available (data record does not include enough points to make trend evaluation meaningful); cfs, cubic feet per second]

INDICATOR EVALUATION MATRIX

INDICATORS		2007	2008	2007–2008 DIFFERENCE	TREND 2002–2008	TREND EARLIEST DATA–2008
Regional Aquifer Levels		Feet below land surface--change since 2002		Difference (feet)		
	Ft. Huachuca	-3.28	-3.32	-0.04 ↓	↓	↓ (1995)
	Environmental Operations Park (EOP)	-0.11	-0.04	0.07 ↑	≈	↓ (1995)
	Southwest	-7.24	-7.45	-0.21 ↓	↓	≈ (1973)
	East	-0.28	-0.09	0.19 ↑	≈	≈ (2000)
Springs		Annual median (gallons per minute)		Change (percent)		
WEST	Horsethief	4.94	10.89	120 ↑	≈ (2005)	NA
	Murray	140.35	200.44	43 ↑	↑ (2003)	
	Moson	19.07	20.65	8 ↑	NA	
EAST	(Lewis Springs)	30.97	33.21	7 ↑	≈ (2005)	
SOUTH	(McDowell-Craig Farm)	21.47	41.52	93 ↑	≈ (2005)	
Streamflow permanence		Percent of year		Difference (percent of year)		
	Tombstone	69.6	84.4	14.8 ↑	↑	↓
	Fairbank	63.8	85.5	21.7 ↑	NA	NA
	Boquillas	100.0	100.0	0.0		
	Charleston Mesquite	91.5	91.8	0.3 ↑		
	Charleston	100.0	100.0	0.0		
	Moson	100.0	100.0	0.0	NA	NA
	Lewis Springs	100.0	100.0	0.0		
	Hunter	90.7	92.3	1.6 ↑	NA	NA
	Hereford	95.1	100	4.9 ↑		
	Palominas	100	100	0.0	↑	↓
Streamflow discharge		Cubic feet per second *or* Days		Difference (cfs *or* days)		
7-DAY WINTER LOW FLOW	Charleston	13.90	12.40	-1.50 ↓	≈	≈ (1936)
7-DAY SUMMER LOW FLOW	Charleston	0.37	0.65	0.28 ↑	↓	↓ (1936)
ANNUAL ZERO-FLOW DAYS	Tombstone	111	57	54 ↑	↑	↓ (1968)
ANNUAL ZERO-FLOW DAYS	Palominas	0	1	-1 ↓	↑	↓ (1931)
Aquifer storage change (gravity)		Improved 2	Unchanged 16	Degraded 19 2007–2008 ↓	≈ (2005)	NA
Annual storage deficit*		Acre-feet				
(≥ 0 = sustainable)		-5,300	-4,300	↓	↓	↓

EXPLANATION: IMPROVING (↑) | UNCHANGED (≈) | DEGRADING (↓)

*While the annual 2008 Subwatershed deficit was 1,000 acre-ft less than in 2007, the cumulative storage deficit continued to increase (by 4,300 acre-ft in 2008). When the annual deficit in the Subwatershed reaches 0 or above, the annual storage deficit indicator will be evaluated as "improving."

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