Update on the draft report: Efforts to achieve sustainable yield of groundwater in the Sierra Vista Subwatershed

Trying to put the goal of sustainable use into action on the ground

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

Outline

- ***Rough Draft Complete***
  - **Introduction**
  - **History of Research in the San Pedro River valley and Sierra Vista Subwatershed**
  - **Hydrogeologic setting of the Upper San Pedro Basin and the Sierra Vista Subwatershed**
  - **Socioeconomic setting of the Sierra Vista Subwatershed**
  - **History of the Upper San Pedro Partnership**

Outline

- ***Rough Draft Complete***
  - **Sustainability and the Sustainable Yield of Groundwater**
    - *History of sustainable yield*
    - *Current definition of sustainable groundwater use*
    - *Environmental consequences*
    - *Social consequences*
    - *Economic consequences*
  - **Indicators of Sustainable Groundwater Yield**
    - *Hydrological monitoring and environmental indicators in the Subwatershed*

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Outline

- ***Rough Draft Not Complete***
  - **Description and Assessment of indicators**
    - *Group 1, Subwatershed-wide indicators*
      - 1. Annual groundwater budget balance (BG, JC, BF, DC)
      - 2. Groundwater Conservation Efficiency (BG, JC; NEW)
      - 3. Regional aquifer water levels (BG, JC)
      - 4. Horizontal gradients (regional aquifer wells) (BG, JC ;NEW)
      - 5. Sum of areas with a groundwater depletion/total area (TJP; NEW)
      - 6. Sustainable Groundwater per Capita per year (BG, JC; NEW)
      - 7. Aquifer storage change measured with micro-gravity (JK)

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Outline

- ***Rough Draft Not Complete***
  - **Description and Assessment of indicators**
    - *Group 2, Riparian system indicators* (BG, JC)
      - 8. Near-stream alluvial aquifer water levels (BG, JC)
      - 9. Near-stream vertical gradients (BG, JC)
      - 10. Annual fluctuation of near-stream alluvial groundwater (BG, JC; NEW)
    - *Group 3, San Pedro River indicators*
      - 11. Streamflow permanence (BG, JC)
      - 12. Wet-dry mapping (DT; NEW)
      - 13. Base-flow discharge on San Pedro and Babocomari Rivers (JK; NEW)
      - 14. San Pedro River water quality (NP; NEW)
      - 15. Isotope analysis (JC, CE, KB; NEW)
    - *Group 4, Springs indicators*
      - 16. Springs discharge (TJP)

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Outline

- **Discussion: Evaluation of sustainable yield of groundwater in the Sierra Vista Subwatershed**
  - --general discussion and evaluation of how far along attempts to achieve sustainable yield are at in the SV Subwatershed. Consider regional successes and failures in addition to an overall, Subwatershed-wide evaluation
  - --a comprehensive figure used to evaluate sustainability in the Subwatershed such as but not necessarily the same as the color-code matrix used in the 2008 and 2009 321 Reports.

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Outline

- **Conclusion**
  - --Discuss how the community, through the USPP, has approached the effort to achieve sustainable yield, what the data tell us about where they have succeeded and where they have failed.
  - --Discuss other approaches on the edges of the radar, e.g., CAP/feasibility study
  - --Discuss other factors playing into the equation: population growth & increased GW pumping, ongoing reduction in GPCD in most parts of the Subwatershed, etc.
  - --Description of subsequent annual or semiannual progress report templates

INDICATOR EVALUATION MATRIX

INDICATORS		2008	2009	2008–2009 DIFFERENCE	TREND 2002–2009	TREND EARLIEST DATA–2009
Regional Aquifer Water Levels		Feet below land surface–change since 2002		Difference (feet)		
	Ft. Huachuca	-3.10	-3.60	-0.50 ↓	↓	↓ (1995)
	Environmental Operations Park (EOP)	0.52	0.38	0.14 ↑	↑	↑ (2000)
	Southwest	-7.45	-0.55	6.9 ↑	≈	≈ (1973)
	East	-0.09	-0.08	0.01 ↑	≈	≈ (2000)
Alluvial Aquifer Water Levels		Feet below land surface–change since 2002		Difference (feet)		
	Palominas	3.15	NA	NA	NA	NA
	Hereford	0.53	NA			
	Hunter	2.16	NA			
	Central	1.86	NA			≈ (1995)
	North	-0.11	-0.88	-0.77 ↓	≈	NA
Near Stream Vertical Water Level Gradients		Feet/foot--gradient change since 2002		Difference (feet/foot)		
	Palominas	0.14	0.075	-0.06 ↓	≈	NA
	Hereford	0.0020	0.0016	-0.0004 ↓	↓	
	Hunter	NA	NA	NA	NA	
	Central	0.035	0.031	-0.004 ↓	≈	
	North	0.031	0.059	0.03 ↑	≈	
Springs		Annual median (gallons per minute)		Change (percent)		
WEST	Horsethief	10.89	9.87	-9.4 ↓	↑ (2005)	NA
	Murray	200.44	213.44	6.5 ↑	↑ (2003)	
	Moson	20.65	17.95	-13 ↓	≈ (2007)	
EAST	(Lewis Springs)	33.21	28.28	-14 ↓	≈ (2005)	
SOUTH	(McDowell-Craig Farm)	41.52	23.19	-44 ↓	≈ (2005)	
Streamflow permanence		Percent of year		Difference (percent of year)		
	Tombstone	84	47	-37 ↓	≈	↓
	Fairbank	88 (86-90)	58 (54-63)	-30 ↓	≈	NA
	Boquillas	100	100	0.0		
	Charleston Mesquite	82 (71-93)	75 (60-90)	-8 ↓	≈	
	Charleston	100	100	0.0		
	Moson	100	100	0.0		NA
	Lewis Springs	100	100	0.0		
	Hunter	92	91	-1 ↓	≈	NA
	Hereford	100	100	0.0	≈	
	Palominas	100	76	-24 ↓	≈	↓
Streamflow discharge		Cubic feet per second or Days		Difference (cfs or days)		
7-DAY WINTER LOW FLOW	Charleston	12.43	11.69	-0.74 ↓	≈	↓ (1936)
7-DAY SUMMER LOW FLOW	Charleston	0.65	1.64	0.99 ↑	≈	↓ (1936)
ANNUAL ZERO-FLOW DAYS	Tombstone	57	193	-136 ↓	≈	↓ (1968)
ANNUAL ZERO-FLOW DAYS	Palominas	1	87	-86 ↓	≈	↓ (1931)
Aquifer storage change (gravity)		Improved 4 · Unchanged 24 · Degraded 16	2008–2009	↓	↓ (2005)	NA
Annual storage deficit* (water budget balance ≥ 0 = sustainable)		Acre-feet -5,200	-6,100	-900 ↓	↓	↓

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

*After taking all revisions to the base water budget into account, the annual storage deficit increased 900 acre-ft from 2008 to 2009. The cummulative storage deficit also increased, but by the amount of the annual deficit, or 6,100 acre-ft. The amount added to the cummulative storage deficit since 321 reporting began in 2002 is about 60,000 acre-ft. When the annual water budget balance (storage deficit) in the Subwatershed reaches 0 or greater, the annual storage deficit indicator will be evaluated as "improving."

Description and Assessment of indicators

- *Group 1, Subwatershed-wide*
  - 1. Annual groundwater budget balance
  - 3. Regional aquifer water levels
  - 7. Aquifer storage change measured with micro-gravity
- *Group 2, Riparian system*
  - 8. Near-stream alluvial aquifer water levels
  - 9. Near-stream vertical gradients
- *Group 3, San Pedro River*
  - 11. Streamflow permanence
- Group 4, Springs indicators
  - 15. Springs discharge

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Description and Assessment of indicators

- 2. Groundwater Conservation Efficiency (GCE)
  - Total amount of sustainable, potable, groundwater available annually for pumping relative to the total amount of groundwater pumped.
  - Even though GCE can improve when the deficit increases (see GCEs for 2008 and 2011), it provides a measure of the effect of water conservation education programs and gw management on a region or municipality.
  - GCE = $\frac{Q_p - WBB}{Q_p}$,
  - Q_p = discharge from the system via pumping (negative)
  - WBB = water budget balance (deficits = negative).

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Description and Assessment of indicators

- 4. Horizontal gradients (regional aquifer wells)
  - Difference in WL's between two wells divided by the horizontal difference between the wells
  - As gradients decrease, rate of gw discharge to riparian system and the river will also decrease. Assumes WL's close to the river remain stable.
  - An increase in horizontal gradient between a well at some distance from the river and one near the river indicates progress toward sustainable yield
  - (1) Sierra Vista southeast: Antelope #3 – Deep B – Deep C
  - (2) Southeastern Fort Huachuca: MW3 – MW4 – MW5 – MW1
  - (3) Central Fort Huachuca: TW1 – TW8 – MW7
  - (4) Northern Fort Huachuca (Babocomari): TW4 – TW7 – TW6

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Description and Assessment of indicators

5. Sum of areas with a groundwater depletion/total area

- Area in which regional water level decline is observed divided by the area of the regional aquifer. For the purposes of the Sierra Vista Subwatershed, this would be the area of the cone(s) of depression divided by the Subwatershed area up to the base of the mountain fronts.

- Keeping track of the expansion of the cone of depression is critical to assessing the threat that capture will occur of both San Pedro River surface flow and riparian system evapotranspiration. Additionally, the cone of depression affects quality of life of Subwatershed residents and is thus information about its relative size and location is valuable.

- Use consistent set of wells and contouring approach (e.g., kriging or spline). Point at which a lowered water table becomes a "depletion problem" can be somewhat subjective. For the purposes of this paper, any evidence of a broad cone of depression is indicative of negative impacts on the groundwater supply.

- ADWR well sweeps not 100% consistent from sweep to sweep, but will provide the most relatively consistent data set with the greatest number of data points available.

- Divide (2) by (3) to get Groundwater Depletion Problem Per Subwatershed Area:
- $GDPPSA = \frac{Ac}{Asw-BR}$, where: A_c is area of the cone(s) of depression, A_{sw} is area of the Subwatershed, and BR is area of bedrock/non-viable regional aquifer (mountain block).
- May also want to calculate distance from riparian system and (or) rate of expansion.

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Description and Assessment of indicators

- 6. Sustainable Groundwater per Capita per year
  - Allows for tracking of total sustainable groundwater supplies available to the human population. Pumping beyond the SGC is unsustainable. This is the only indicator that considers sustainability from a groundwater availability perspective. The SGC is sensitive to changes in population and the water budget balance.
  - $SGC = \frac{Q_p - WBB}{P_{sw}} \quad (= \frac{Q_s}{P_{sw}})$
  - where Q_p = total gw pumped in the given year
  - WBB = water budget balance (deficit = negative)
  - P_{sw} = population in the given year.

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Description and Assessment of indicators

- 10. Annual fluctuation of near-stream alluvial groundwater
  - The mean annual range of water level elevations in alluvial aquifer wells found in each reach.
  - Closely related to riparian system health and thus sustainable groundwater yield
  - Requires continuous measurement of water levels in near-stream wells in each of the 10 river reaches, recording at least every 6 hours if not more frequently.
  - Fluctuations are averaged values across the flood plain (fluctuations are smaller near the river and greater near the flood-plain perimeter).
  - Water levels have been measured and data is on hand (either stored locally at the AzWSC or in GWSI and ADAPS) up through September, 2012

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Description and Assessment of indicators

- 12. Wet-dry mapping
  - Evaluation of the entire stream reach to determine total wetted stream length and is undertaken during the driest part of the year (third weekend in June).
  - Comprehensive snapshot at the same time every year, thus complimenting the other indicators which tend to evaluate a limited number of locations frequently or continuously. Allows for comparisons of year-to-year variability
  - During dry season depends on shallow groundwater near and discharging to the river. Increasing dry river length would indicate a trend away from sustainable groundwater use.
  - It may be the case that it can also be used as an effective proxy for Stream flow permanence.
  - Mapping takes place third weekend in June. Consistently wet reaches considered perennial.
  - For the purposes of this report it will be more valuable to consider these data based on the ten river reaches identified by Stromberg and others (2006)).

Description and Assessment of indicators

- 14. San Pedro River water quality
  - Evaluation of a suite of water quality parameters for the San Pedro River.
  - Aquatic habitat health can readily degrade as a result of contaminants or excessive nitrogen or other compounds in the stream or gw, indicating gw use or management may not be sustainable relative to the aquatic health of the river.
  - USGS NAWQA sampling is conducted at Charleston, downstream of Curry Draw. Curry Draw is likely a treated effluent dominated stream (via groundwater discharge 1 km down gradient of treated effluent recharge ponds).
  - The headwaters of the San Pedro River are in Cananea, Sonora, Mexico, adjacent to a large open pit copper mine. The City of Cananea does not have a waste water treatment facility at this time. Both the copper mine and raw sewage have been sources of contamination in the past.
  - The city of Naco, Sonora, Mexico is on the international border adjacent to the city of Naco, Arizona, USA, and in the upper Greenbush Draw drainage. Greenbush Draw is a large, ephemeral channel that discharges into the San Pedro River a few miles east of Palominas, Arizona. Raw sewage from Naco, Sonora, has been discharged into Greenbush Draw in the past. Various groups have been working with the community in recent years to install waste water treatment.

Description and Assessment of indicators

- 15. Analysis of Isotope Data

- Comparison of isotopic signature ($\delta^{2}H$ and $\delta^{18}O$) of samples from the San Pedro River with the signature in regional aquifer wells, and to evaluate any related trends.

- Evaluate whether source water in San Pedro River is changing as a means to recognize when the cone of depression has begun to capture San Pedro River surface flow.

- Isotopic composition of rainfall influenced by the temperature at which it forms; higher altitude rainfall is generally more depleted in heavier isotopes than lower altitude rainfall.

- Once precipitation becomes recharge, the isotopic signature generally does not change.

- If surface water in the San Pedro River shifts from gaining to losing, or from regional-aquifer dominated discharge to alluvial-aquifer (bank storage) dominated discharge, it could be expected that the isotopic signature would likewise trend.

- Isotopes are collected at each mainstem gaging station

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