Aquifer-Storage Change and Land-Subsidence Monitoring in the Tucson Active Management Area

ARIZONA DEPARTMENT OF WATER RESOURSES

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Rob Carruth
with John Hoffmann and Don Pool

Cooperating Agencies: Arizona Department of Water Resources, City of Tucson Water Department, Town of Oro Valley, Metropolitan Domestic Water Improvement District, and Town of Marana

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History of Cooperation between USGS and Tucson Water Users

1979 – Initiated an investigation to determine the potential for aquifer compaction, land subsidence, and earth fissures in Tucson Basin and Avra Valley with City of Tucson Water Department

1996 – Initiated seasonal storage monitoring along with Metro Water $15k each from Oro Valley, Metro Water, and USGS

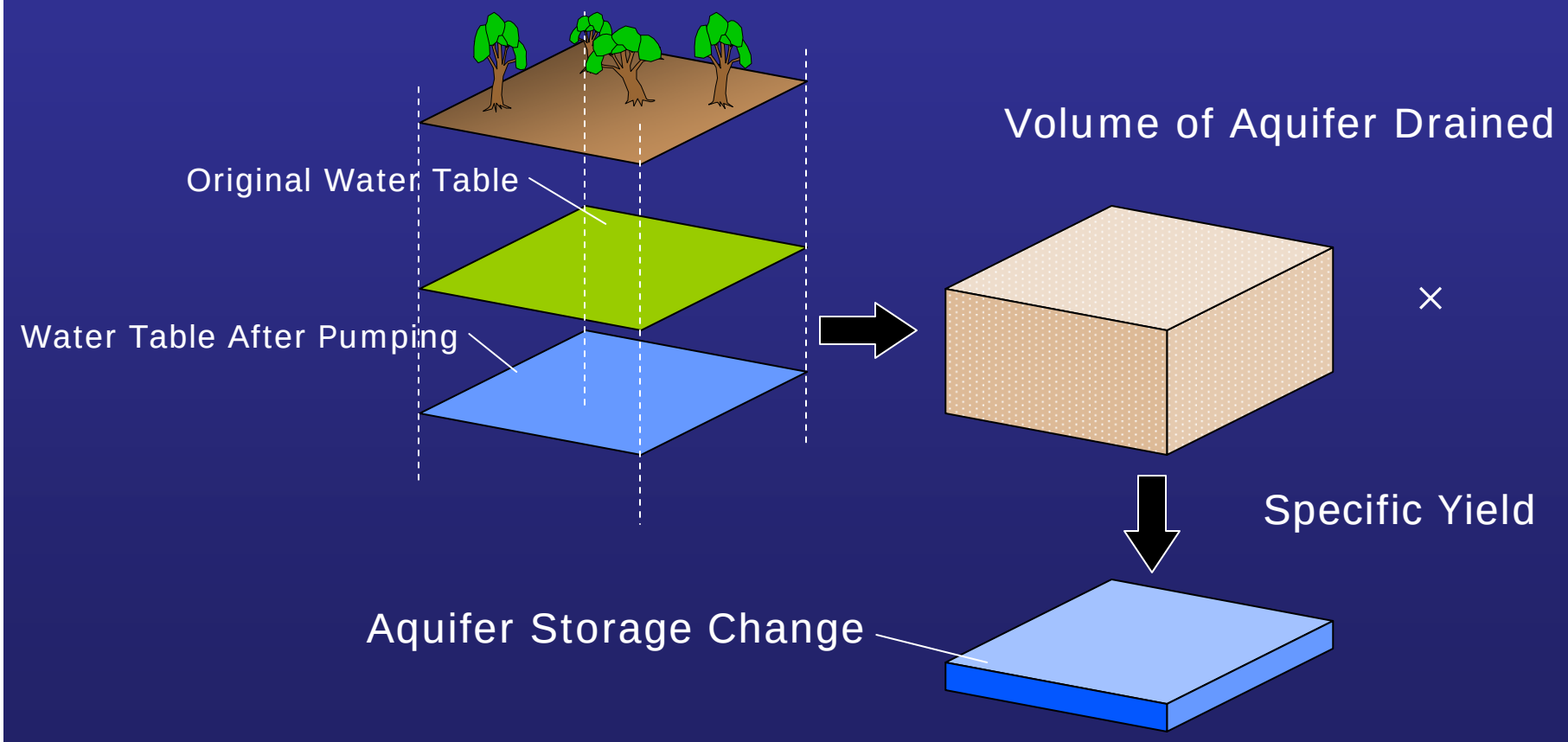
1998 – Augmented network with annual storage monitoring across the Tucson AMA with ADWR, Tucson Water Department, and Pima County

1999 – WRI Report 99-4067 “Aquifer-Storage Change in the Lower Canada del Oro subbasin, 1996-98”

2003 – Combined the 2 regional efforts into a single program and added Marana as a cooperator.

2007 – Reports for the periods 1998-2002 and 2002-2006 compiled and colleague reviewed.

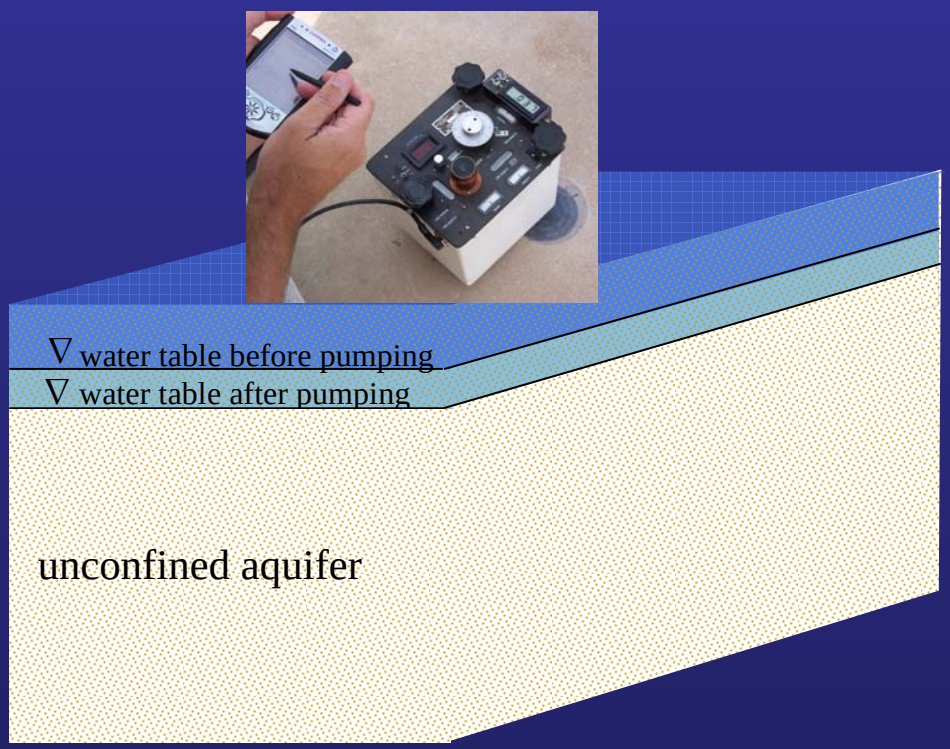
Aquifer Storage Change

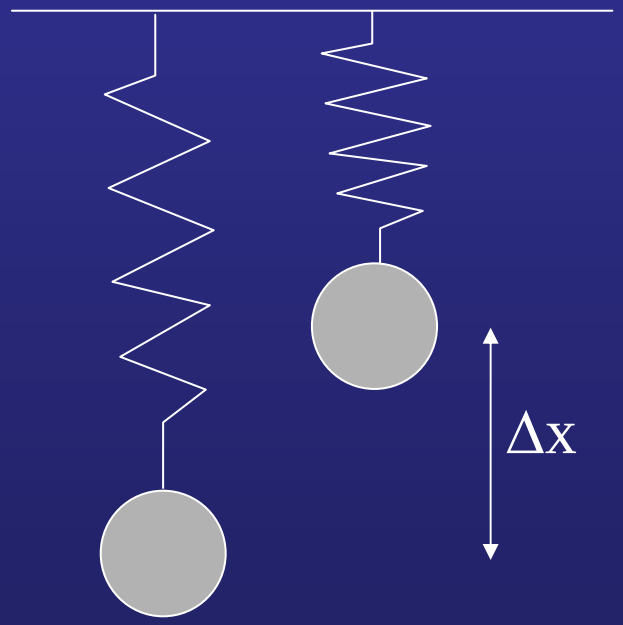


USGS
science for a changing world

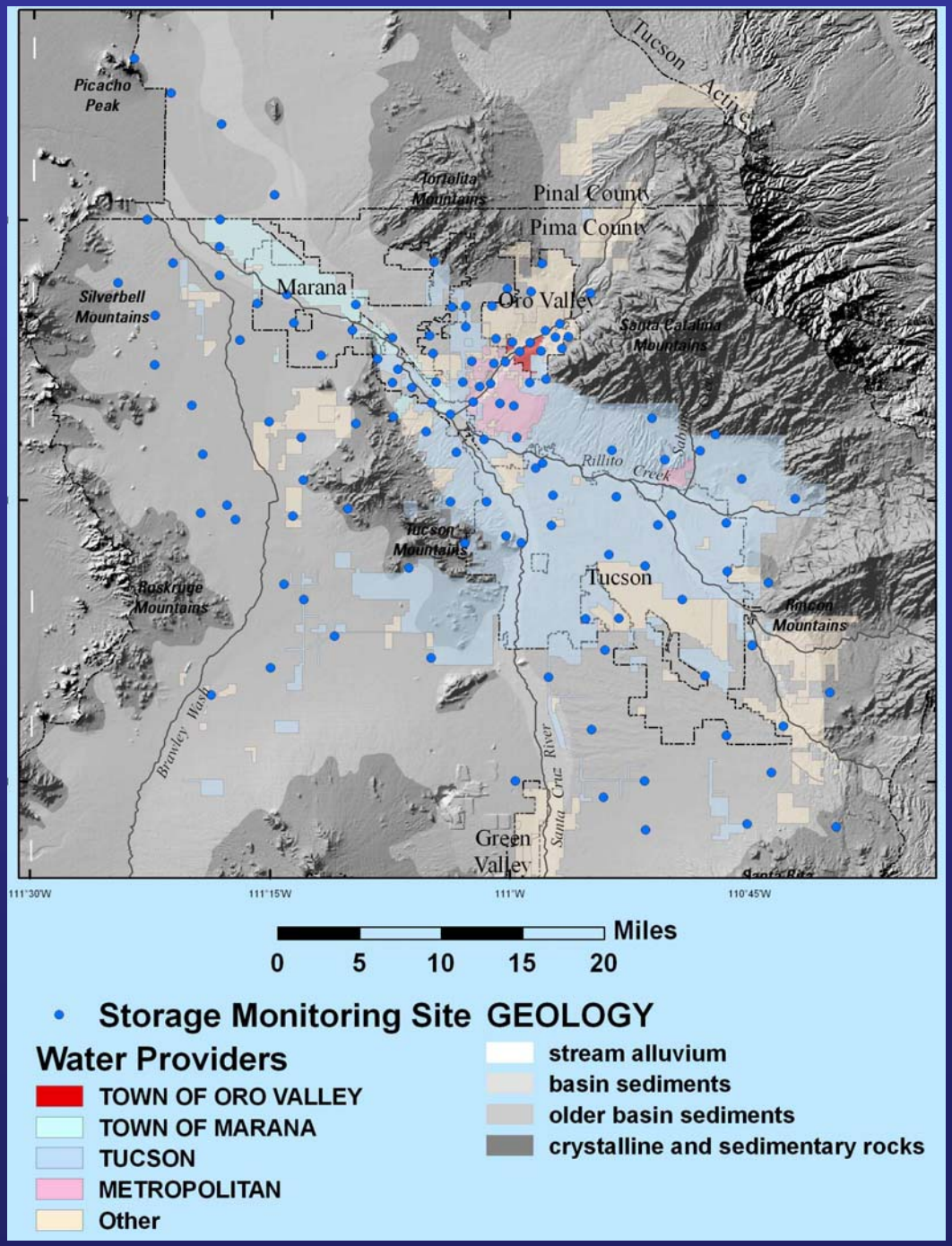
Gravity

The simplest type of gravimeter essentially measures the extension of a spring attached to a control mass.





$$g = -k\Delta x/\text{mass}$$

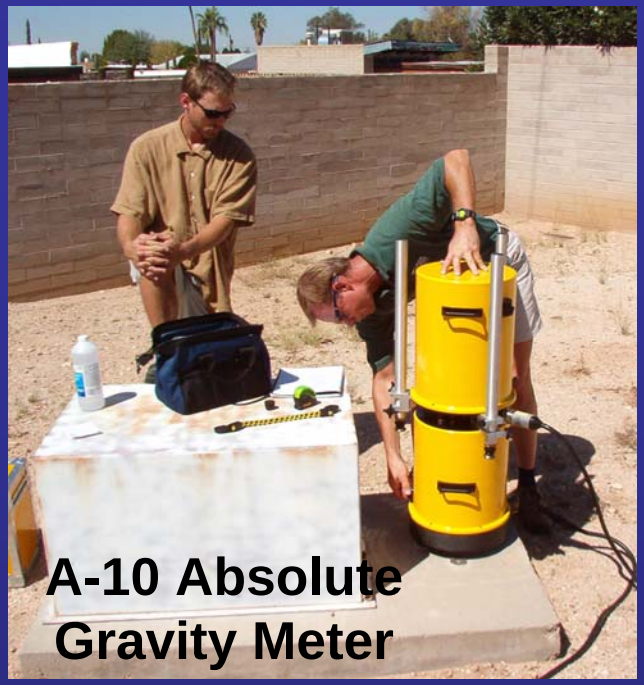


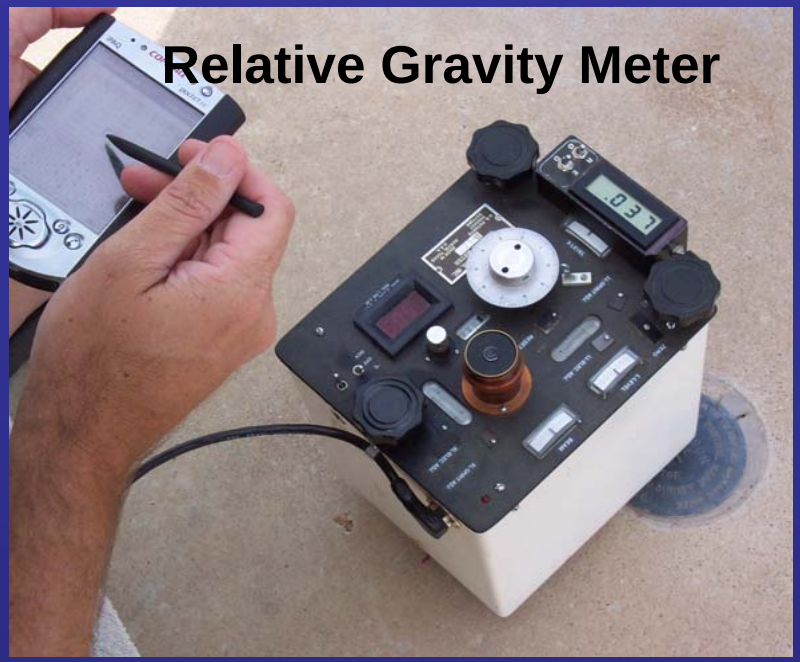
Aquifer-Storage Change and Subsidence Monitoring Stations in the TAMA

Directed by Arizona ground-water law to attain an annual balance between ground-water withdrawals (Q_{out}) and recharge (Q_{in}) by the year 2025

$$Q_{in} = Q_{out}$$

$$\Delta Storage = 0$$



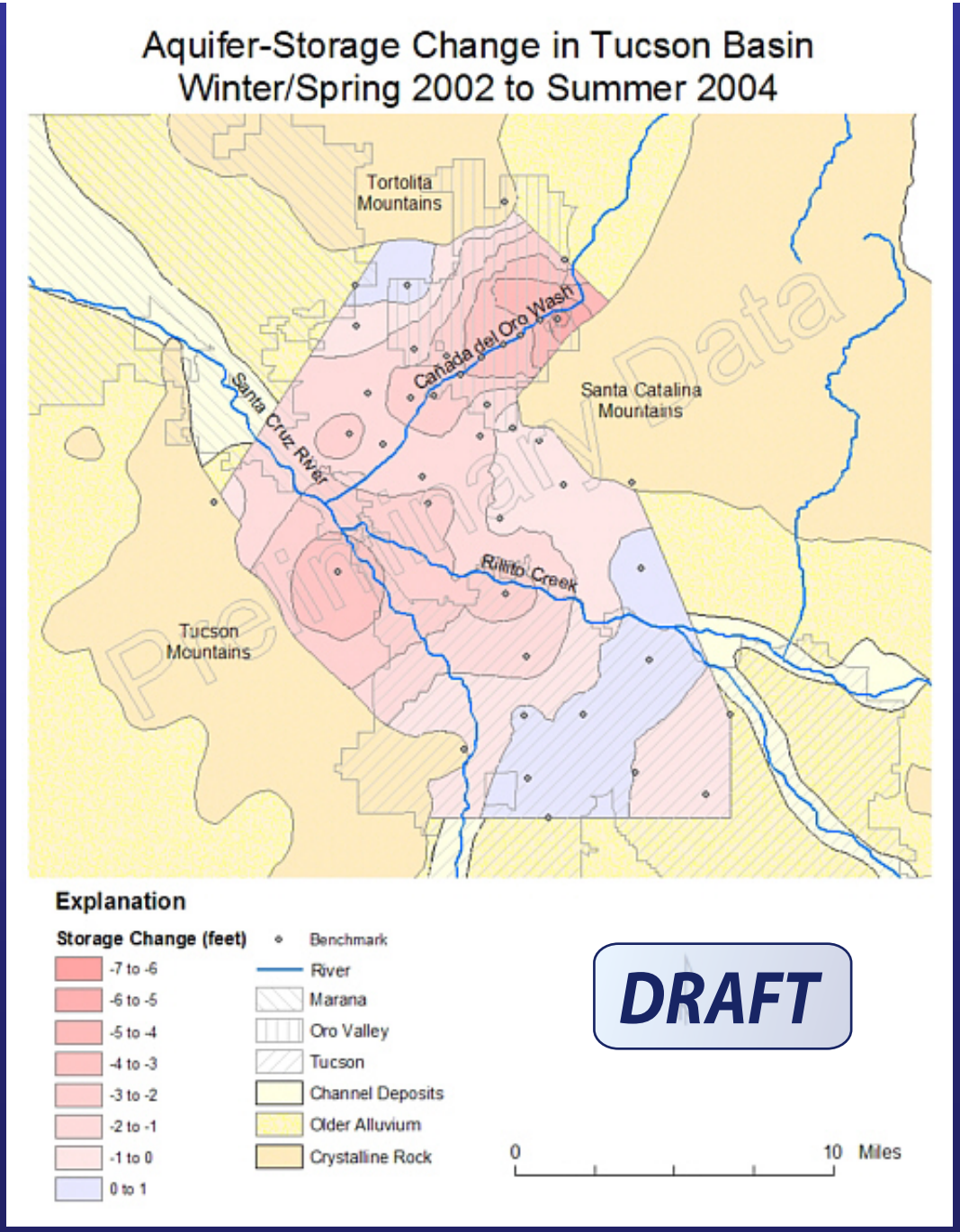


METHODS

Repeat gravity and GPS surveys

- Gravity – measures total mass (storage) change +/- 0.5 ft water
- GPS – measures aquifer-compaction (subsidence) portion of storage change +/- 0.07 ft water

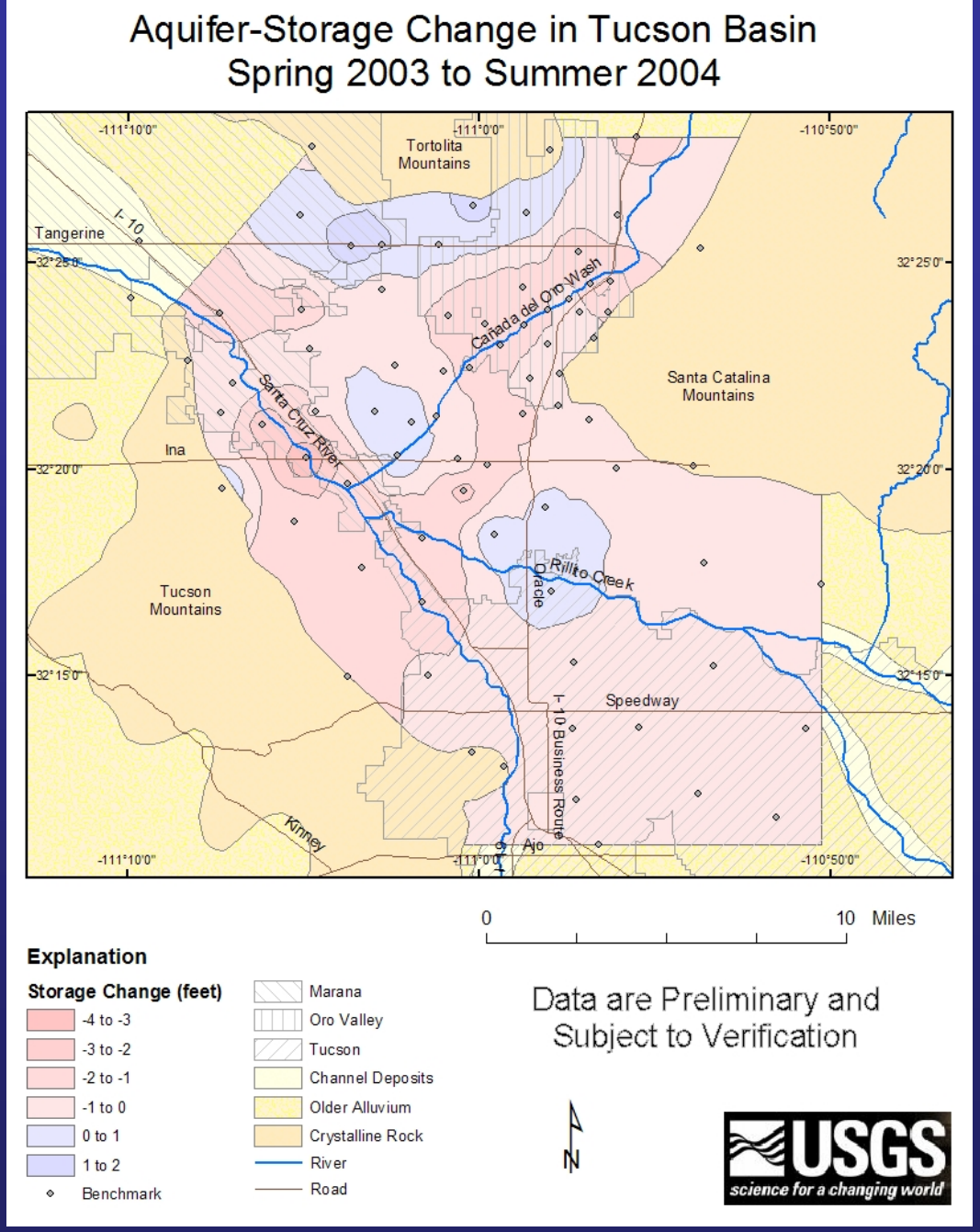
A10 Absolute Gravimeter



Storage Change in a portion of the Tucson Basin

2002 - 2004

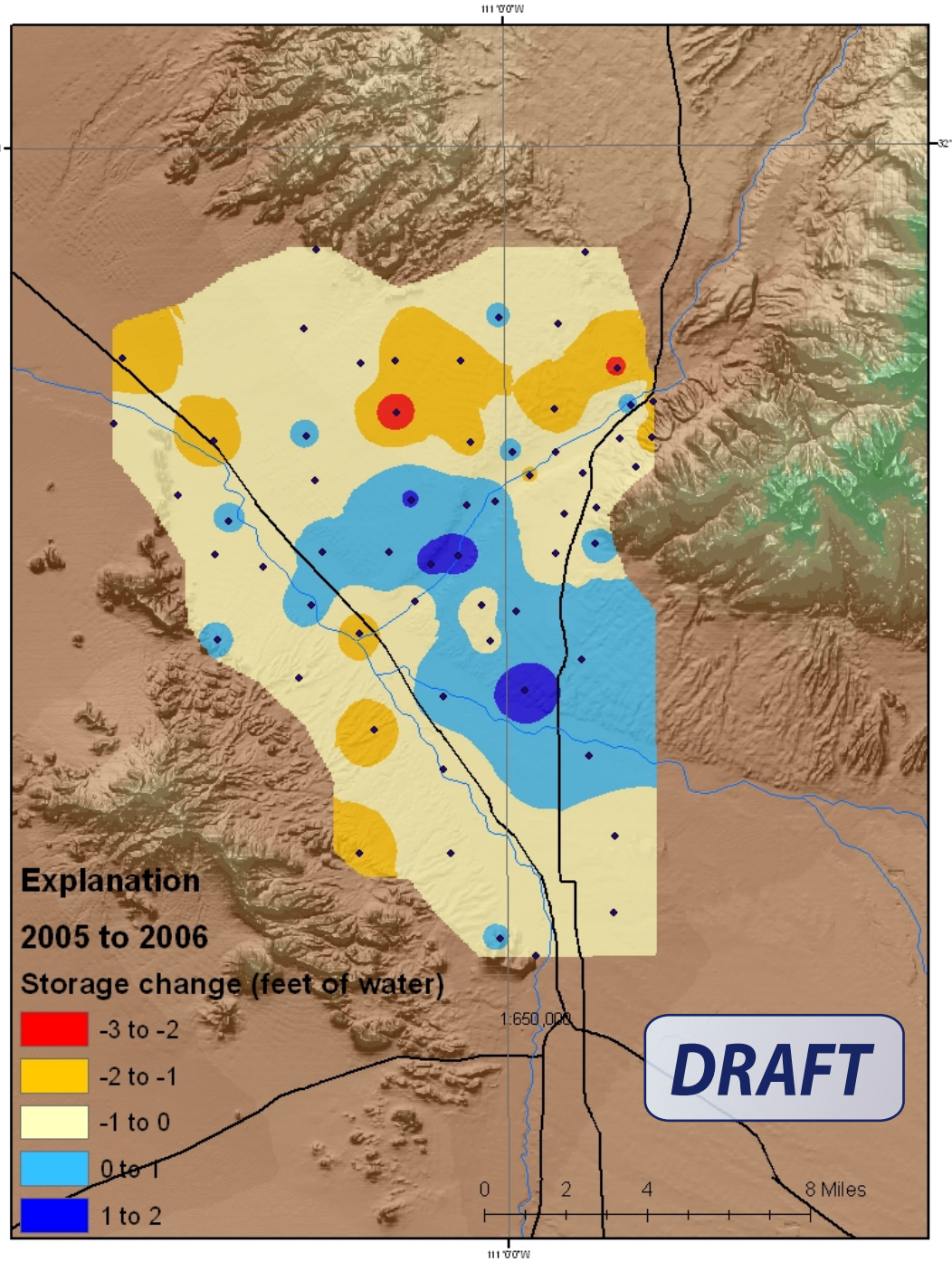
-160,000 acre-ft
~1/2 ft per year



Storage Change in a portion of the Tucson Basin

Spring 2003 – Summer 2004

-100,000 acre-ft
~1/2 ft per year



Storage Change in a portion of the Tucson Basin

Spring 2005 – Summer 2006

-60,000 acre-ft
~0.4 ft per year

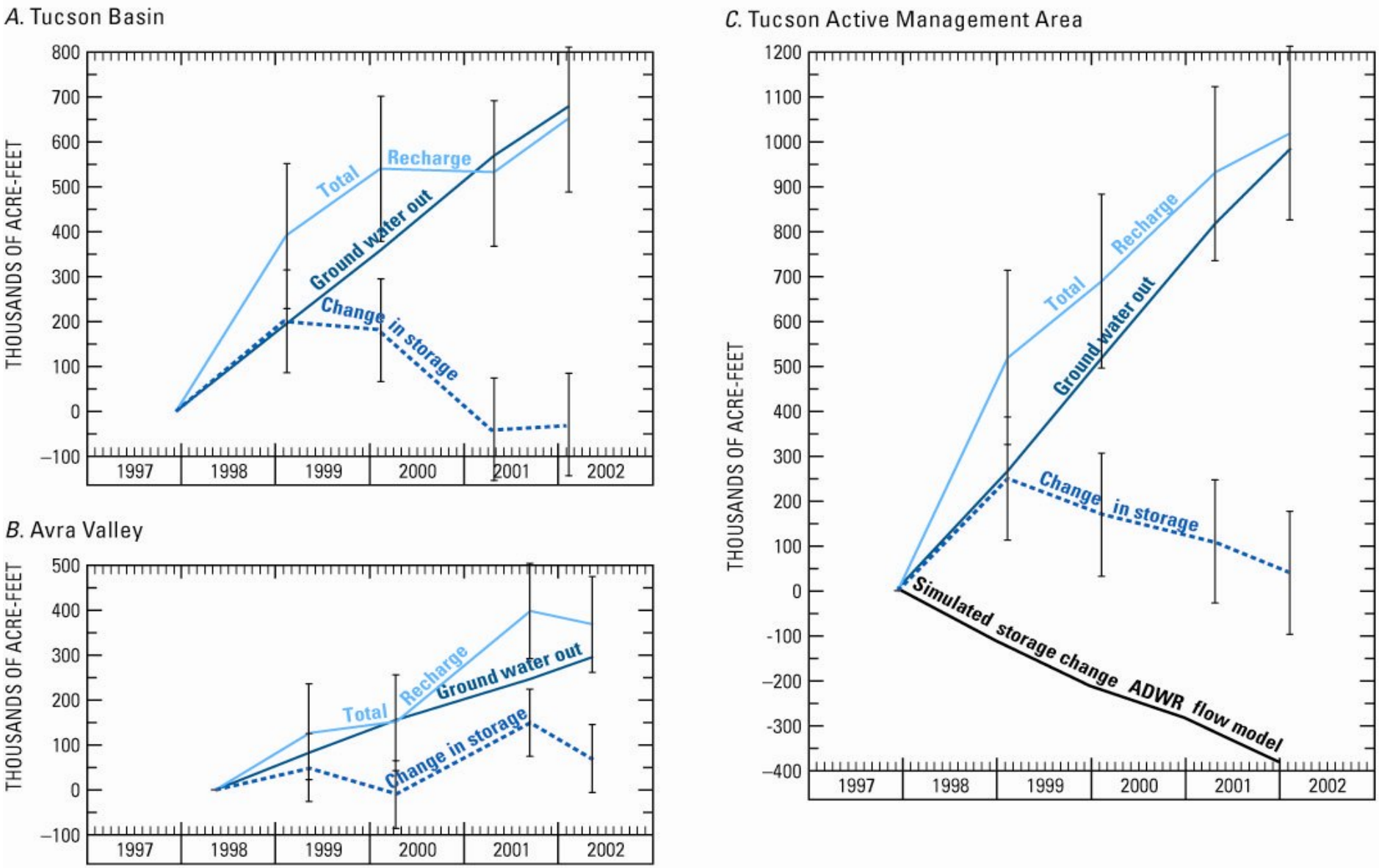


Figure 10. Cumulative ground-water budget within the monitored portions of the: *A*,Tucson Basin; *B*, Avra Valley; and *C*, Tucson Active Management Area, winter 1998 to spring 2002.

MONITORING NETWORK	WELL	GRAVITY STATION	SPECIFIC YIELD[9]	CORR. COEF.	WATER-LEVEL RANGE, FT.	STORAGE RANGE, FT. of WATER[10]
Tucson Basin	WR-52	WR-52	0.11	0.99	19.6	4.0
	B-92A	B-92A	1.18	0.98	3.4	5.7
	WR-175A	WR-175A	0.55	0.97	2.9	1.6
	WR-118A[1]	TUCSON AC	0.21	0.96	4.4	1.1
	C-22A	C-22A	0.25	0.96	6.9	1.8
	C-45	C-45	0.26	0.94	10.6	2.9
	A-54A	A-54A	0.27	0.94	15.2	4.7
	B-001A[2]	TUCSON AD	0.35	0.92	2.0	0.7
	A-50A	A-50A	0.49	0.91	11.3	4.1
	MW10	MW10	0.73	0.94	11.7	8.6
	C-99A	MW6	0.52	0.89	8.8	4.4
	MW13	MW13	0.35	0.87	12.2	4.3
	MW5	MW5	0.44	0.85	9.3	4.3
	CI-067A	MW4	0.67	0.77	6.0	3.5
	A-049A[3]	FD62	0.04	0.55	29.5	2.6
	D-4	D-4	0.13	0.54	7.2	1.9
	SC-17A[4]	XAVIER	0.05	0.52	6.7	0.7
	B-77A	B-77A	0.13	0.40	16.8	5.3
	E-9A	E-9A	0.12	0.38	2.8	1.6
	WR-53	WR-53	0.09	0.29	3.4	0.9
	SC-005A[5]	L75	0.01	0.21	14.1	0.8
	SC-25A	SC-25A	-0.10	-0.46	8.6	2.1
	B-76[6]	X419	-0.08	-0.63	9.0	1.2
	WR-147A[7]	MAGNETIC	-0.43	-0.78	2.4	1.3
	WR-142A	WR-142A	-0.46	-0.86	7.5	3.7
	B-7A	B-7A	-0.11	-0.97	6.8	0.7
Avra Valley	AV-13A	AV-13A	0.12	0.98	11.1	2.2
	AF-35A	AF-35A	0.07	0.96	18.3	1.4
	AV-25	AV-25	0.07	0.78	23.3	2.4
	WR-29A	WR-29A	0.19	0.75	6.9	2.0
	AF-25A	AF-25A	0.18	0.50	3.5	2.0
	AF-14[8]	AF-13	0.01	0.39	30.3	0.8
	AF-13	AF-13	0.01	0.37	35.6	0.8
	AF-1A	AF-1A	0.03	0.34	15.3	1.9
	AF-16A	AF-16A	0.03	0.19	6.5	1.6
	TA-13	TA-13	-0.12	-0.10	0.1	1.9
	WR-16B	WR-16B	-0.25	-0.64	2.1	1.2

1 Well WR-118A is about 1000 ft from gravity station TUCSON AC.
2 Well B-001A is about 3500 ft from gravity station TUCSON AD.
3 Well B-049A is about 3600 ft from gravity station FD62.
4 Well SC-17A is about 200 ft from gravity station XAVIER.

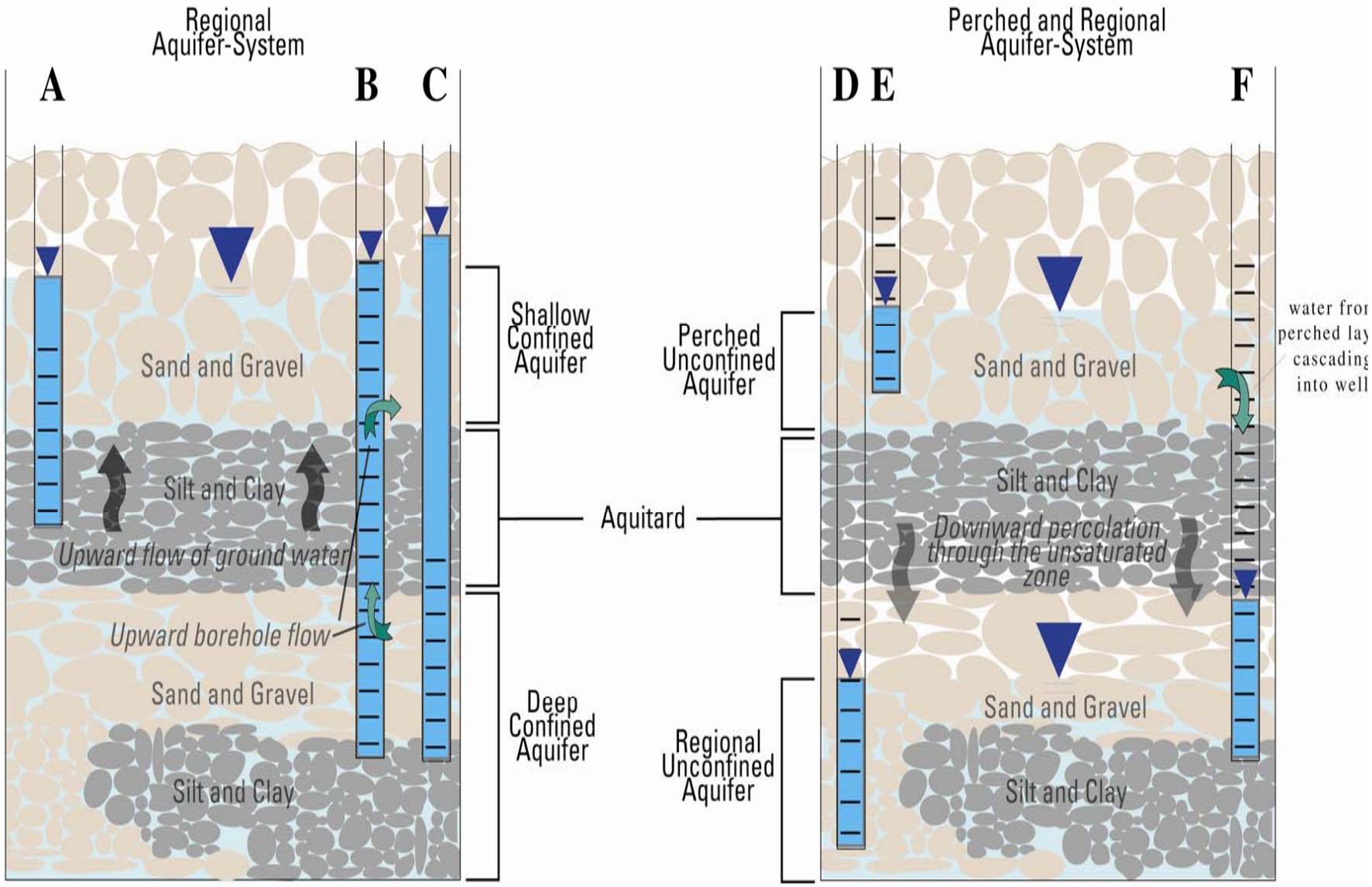
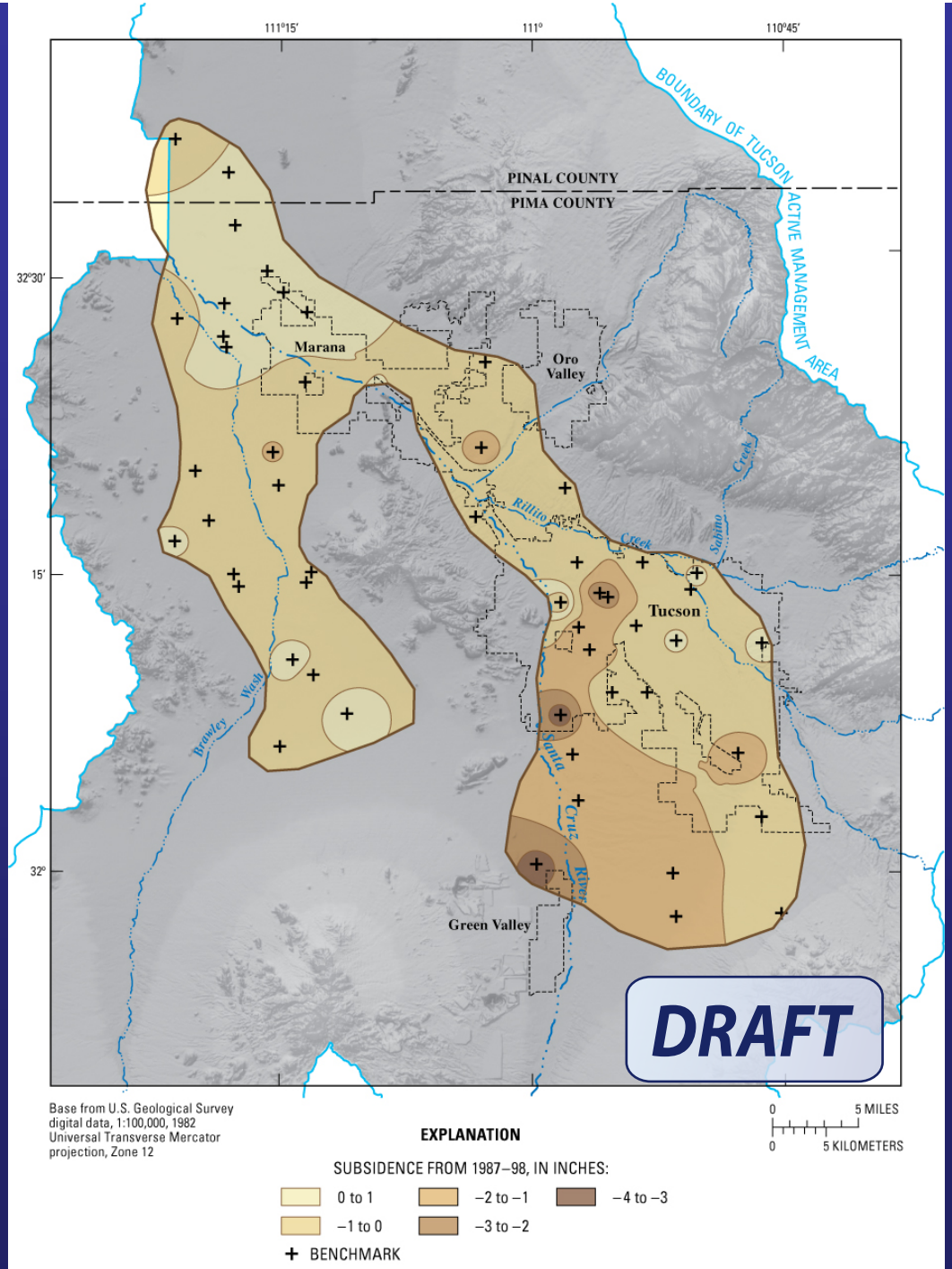


Figure 4. Selected representations of common relations between hydraulic head, screened Intervals, water levels in wells, and water tables in the Tucson Active Management Area.



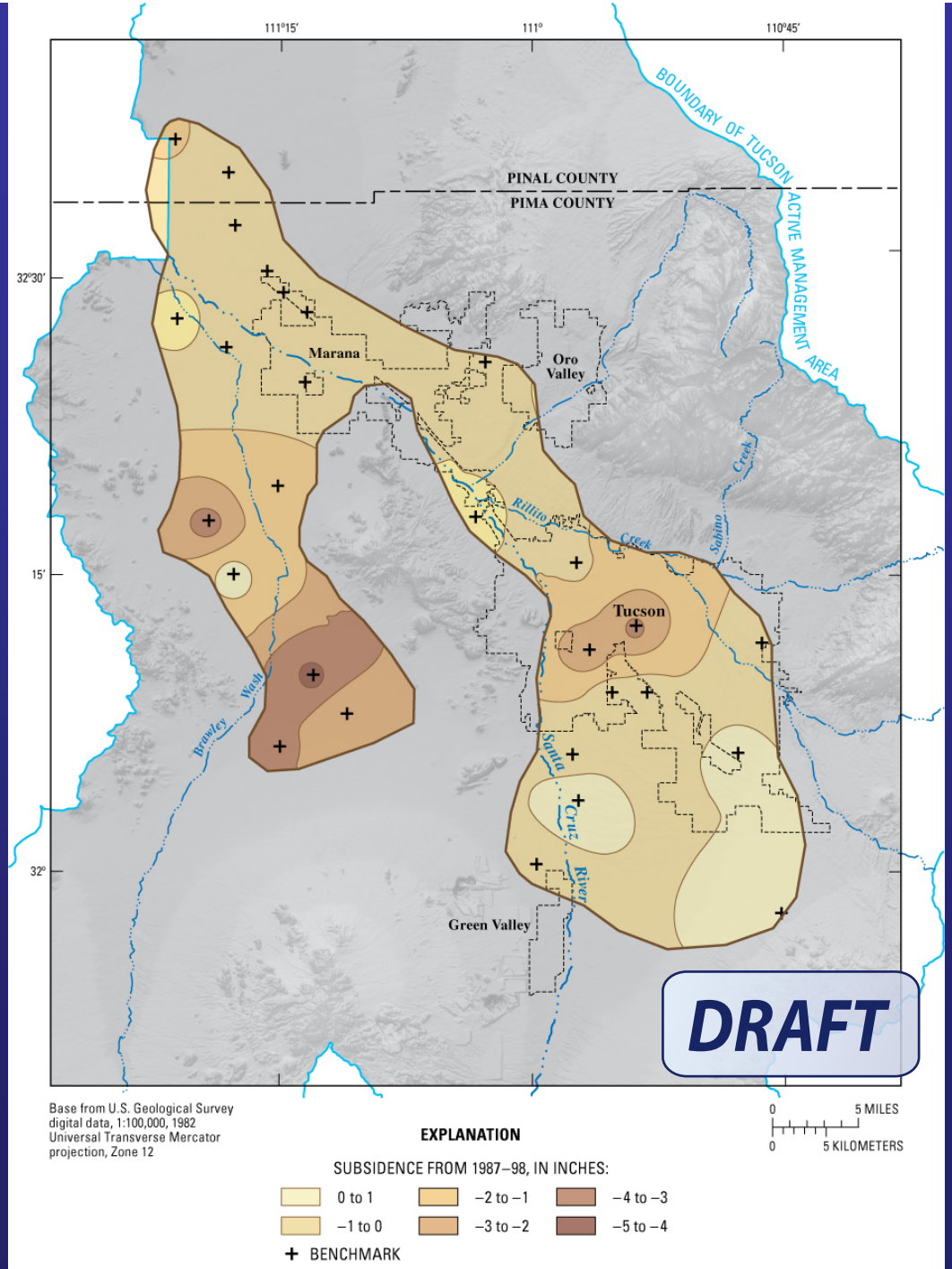
Land Subsidence in the TAMA

1998 - 2002

Maximum subsidence

~ 3.5 inches Tucson Basin

~ 1.1 inches Avra Valley



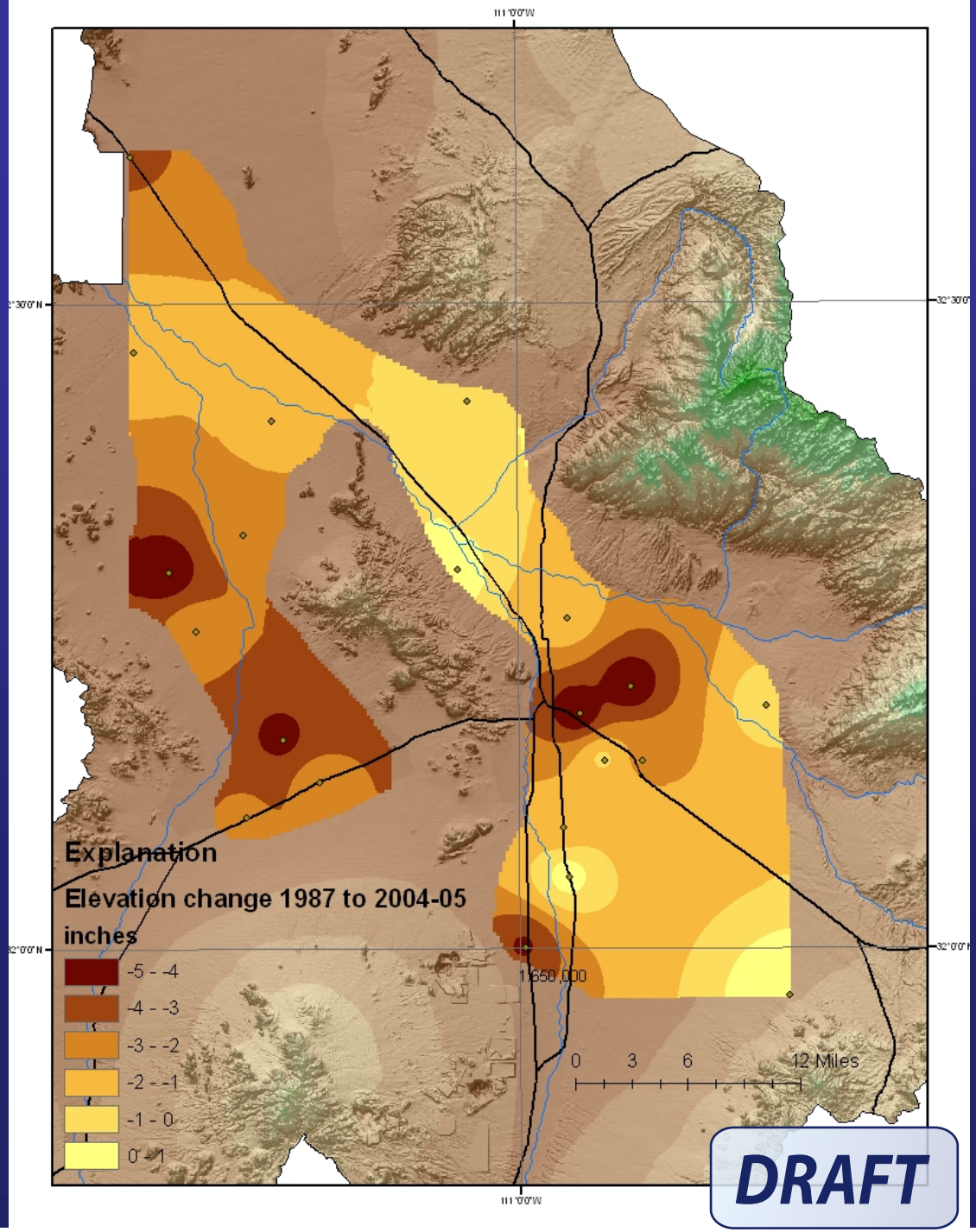
Land Subsidence in the TAMA

2002 - 2004

Maximum subsidence

~ 3.2 inches Tucson Basin

~ 4 inches Avra Valley.

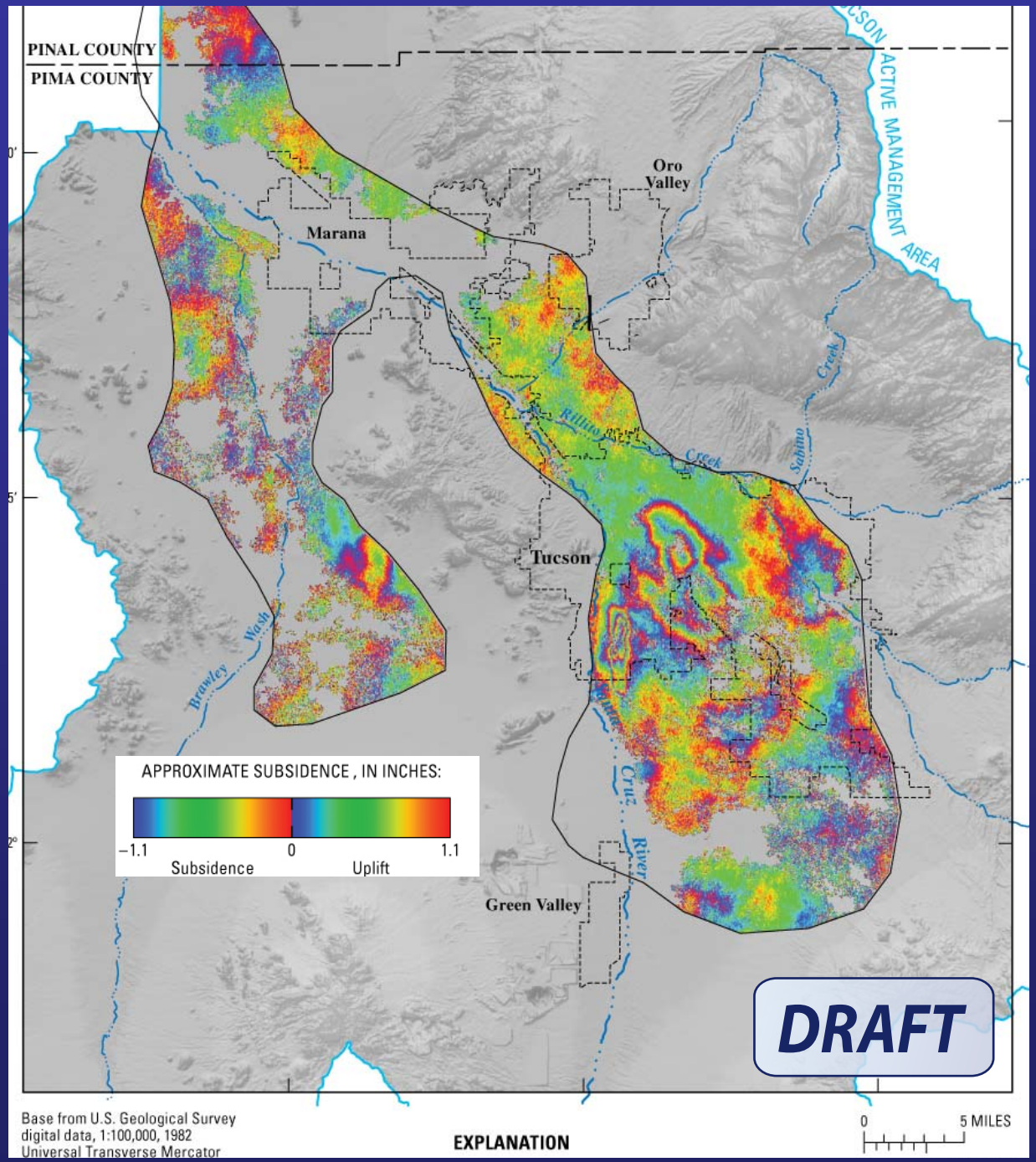


Land Subsidence in the TAMA

1987 to 2004-05

Maximum subsidence

~ 5 inches Tucson Basin and Avra Valley.



InSAR

in the TAMA

February 2003 to October 2006

Maximum subsidence

~ 1.5 inches Tucson Basin

Aquifer-Storage Change and Land-Subsidence Monitoring in the Tucson Active Management Area

Considerations for continued program:

- Review of existing network and target areas of interest
  - pumpage
  - storage change
  - land subsidence
  - artificial recharge
- Increase incorporation of A-10 absolute gravity meter into the program
  - Improve gravity survey accuracy and efficiency
- Utilize InSAR technology
  - Improved spatial resolution of land-surface deformation
  - Used in concert with GPS for control
- Utilize continuous-operating GPS receivers
  - Improve definition of seasonal deformation

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Thank You !