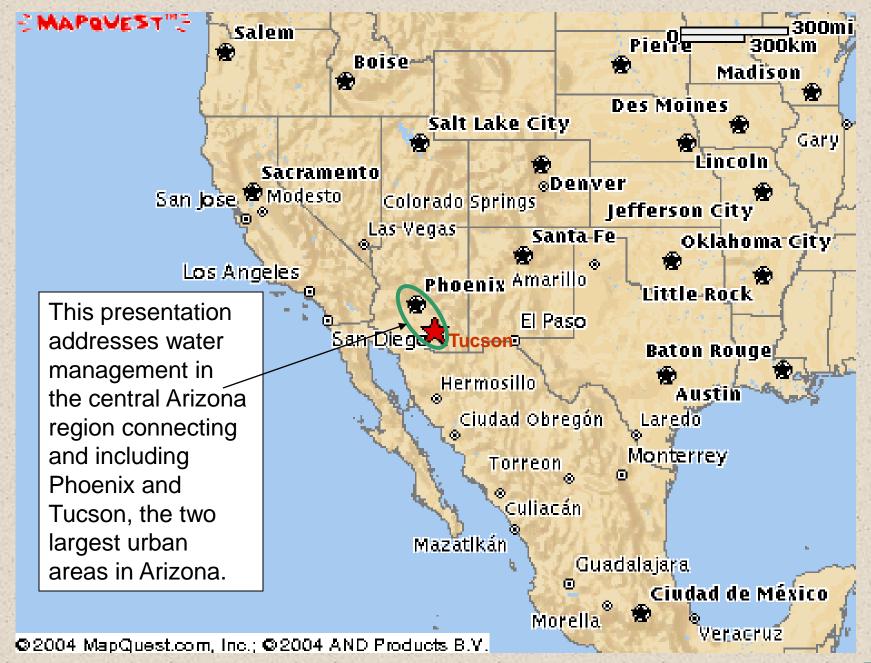


College of Agriculture and Life Sciences, The University of Arizona

# Groundwater Management in the Sonoran Desert of Arizona: The Importance of Surface Supplies and Recharge

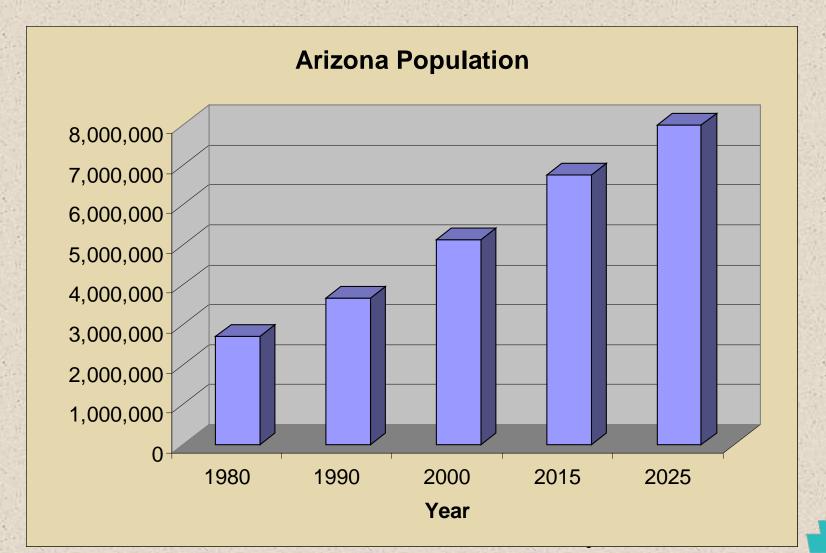
Engalec '04 March 2004
XII Encuentro National de Ganaderos Lecheros
Torreón, Coahuila México
Sharon B. Megdal, Ph.D.
University of Arizona
Water Resources Research Center
Tucson, Arizona USA
Email: smegdal@ag.arizona.edu







# Arizona is rapidly growing, with a large proportion of the population relying on groundwater





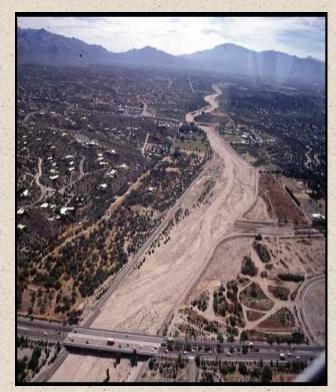
Tucson,like much of Arizona,is growing rapidly. It is located in the Sonoran Desert. The University of Arizona is located in Tucson.

Water Resources Research Center – University of Arizona



 Central Arizona rainfall averages between 19 and 30 centimeters annually

- There are two rainy seasons
  - -Summer monsoons, moisture from the southeast
  - –Winter storms,moisture comes from the west





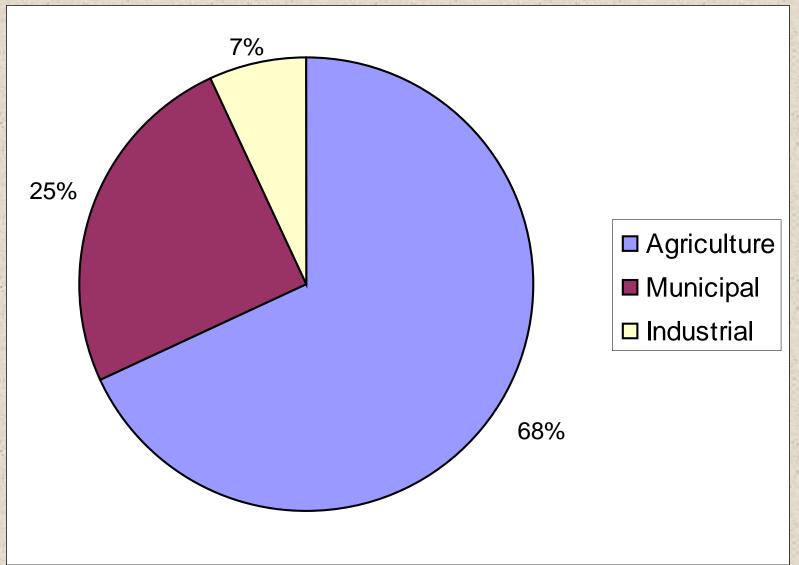


### Sources and Uses of Water In Arizona

- Arizona relies on groundwater, surface water, and treated wastewater (effluent) to meet its water needs.
- Important surface supplies are transported via canals. Dams are important parts of the surface water storage systems.
- Agricultural water use is close to 70 percent of statewide water use, but the municipal use is growing rapidly.
- Many communities in Arizona rely heavily on groundwater, although more recently (since the early 1990s) the Central Arizona Project has delivered Colorado River water to Central Arizona



## Arizona Uses of Water - 1998



Conversion	FACTORS
CONVERSION	FACIOR

To convert from customary unit	To metric unit	Multiply customary unit by	To convert to customary unit, multiply metric unit by
			,

acre-feet (ac-ft)	thousand cubic meters (m³ x 10³)	1.2335	0.8107
acre-feet (ac-ft)	hectare-meters (ha - m)	0.1234	8.107
thousand acre-feet (taf)	million cubic meters (m³ x 10°)	1.2335	0.8107
thousand acre-feet (taf)	hectare-meters (ha - m)■	123.35	0.008107

Not used often in metric countries, but is offered as a conceptual equivalent of customary western U.S. practice (a standard depth of water over a given area of land).

#### OTHER COMMON CONVERSION FACTORS

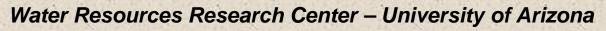
1 cubic foot=7.48 gallons=62.4 pounds of water 1 acre-foot=325,900 gallons=43,560 cubic feet

1 cubic foot per second (cfs)=450 gallons per minute (gpm) 1 million gallons=3.07 acre-feet

1 cfs=646,320 gallons a day=1.98 ac-ft a day 1 million gallons a day (mgd)=1,120 ac-ft a year

#### Source:

http://rubicon.water.ca.gov/pdfs/v2/v2metcon.pdf





### Arizona Sources of Water - 1998

One acre foot is 325,851 gallons of water. An acre foot of water is the amount that covers one acre of land with one foot deep water. It is equivalent to about 1.2335 thousand cubic meters.

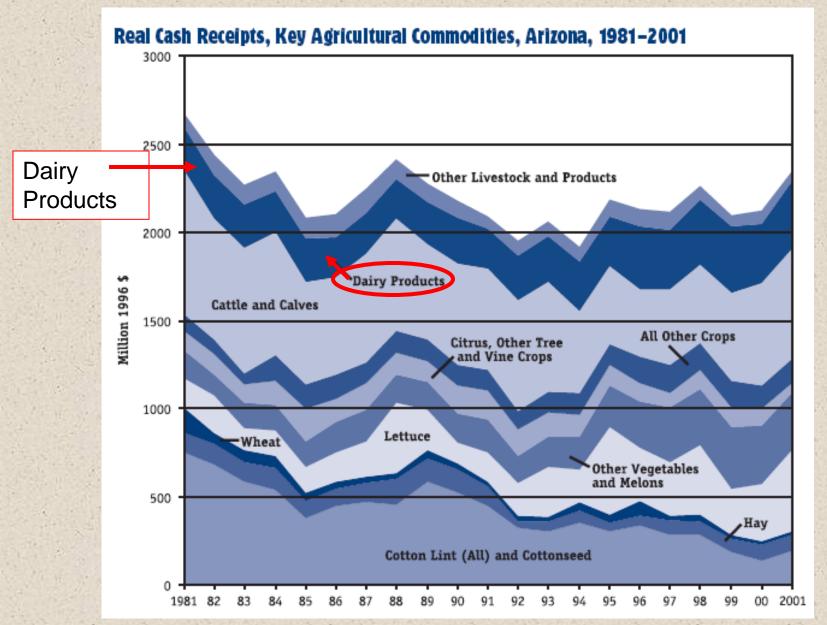
Water Sources	Acre Feet	Percent of Total
Surface Water		
Colorado River	1,398,000	20%
CAP – Water delivered through the constructed Central Arizona Project	1,025,000	15%
In-State Rivers	1,427,000	21%
Groundwater	2,922,000	41%
Reclaimed Water	178,000	3%
Total	6,950,000	100%



# Arizona has been an innovator in groundwater management

- Groundwater Management Act of 1980 (GMA) introduced groundwater regulation to certain parts of Arizona.
- An important addition to the GMA was the introduction of the recharge and recovery program.
- Before going into aspects of the management of groundwater in central Arizona that may be of interest, let me provide a little bit of information on Arizona dairy activity...





Source, Arizona Review, Spring 2003 Data: Arizona Agriculture Statistics Service



## 2002 Arizona Dairy Industry

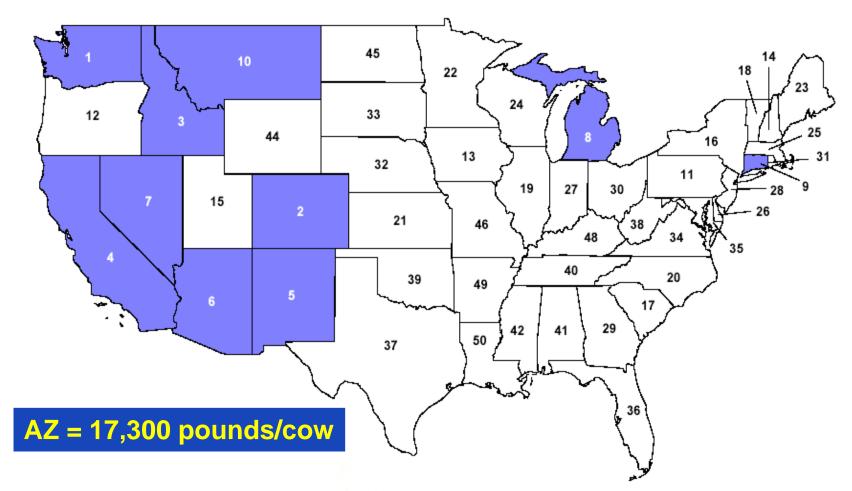
Arizona Dairy Industry Information and Photos Courtesy of Matt VanBaale, Ph.D. Extension Dairy Specialist/Assistant Professor Department of Animal Sciences, University of Arizona

- Ranked number 2 in cows/herd: cows per herd exceeds 1022
- 150,000 total head
- Maricopa county ranked 5<sup>th</sup> nationally
  - Producing > 240,000,000 lbs. of milk
    - This represents approximately 80% of AZ's CAFO (Concentrated Animal Feeding Operation)

**Compiled from: USDA National Agriculture Statistics** 

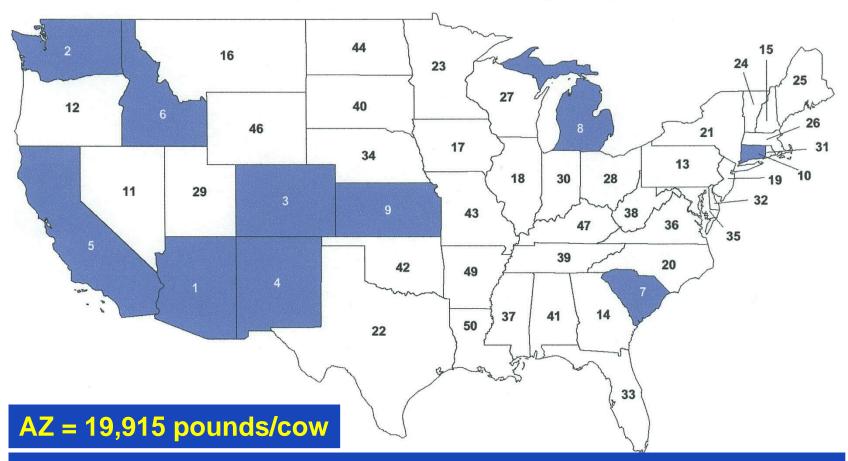


## 2001 Milk Production Per Cow Ranking Top Ten States Highlighted



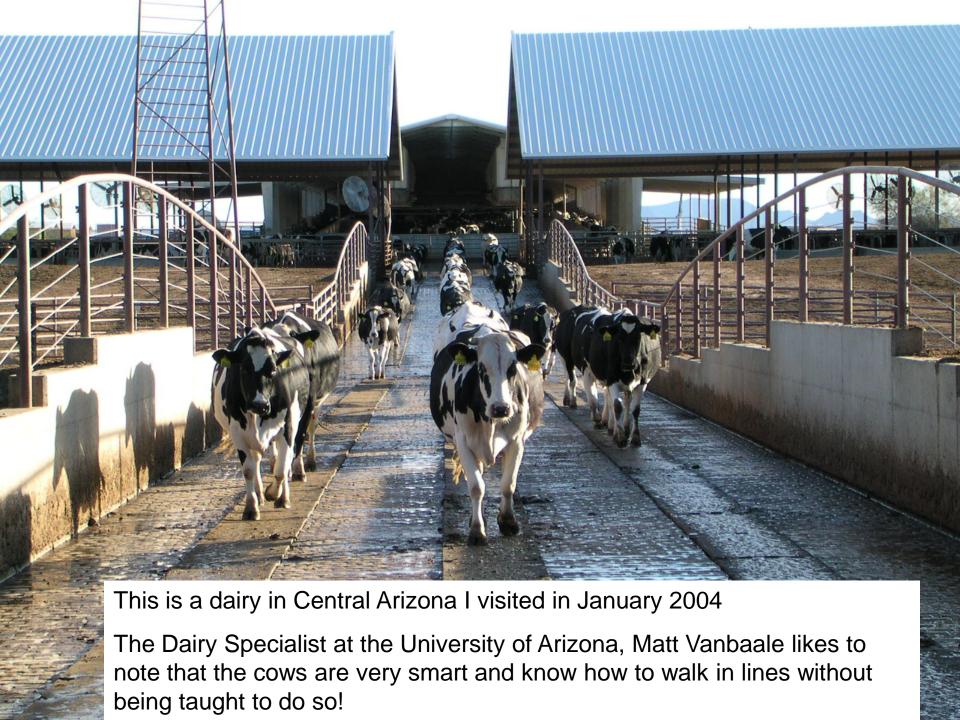


## 2002 First Half Milk Production Per Cow Ranking Top Ten States Highlighted



More recent data show Arizona at number 2 in the United States









You can see how this dairy is located in the middle of desert land

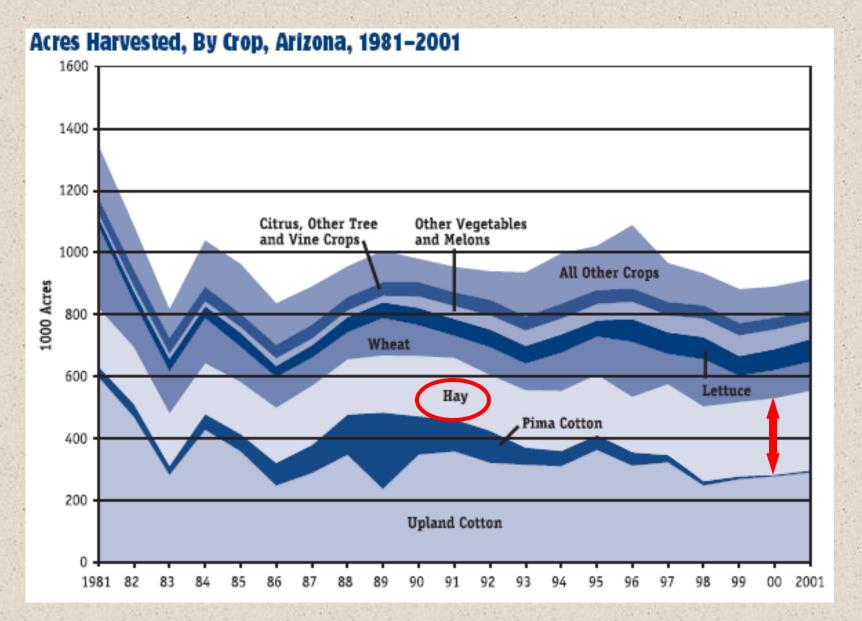


The increase in dairy operations in Arizona has led to an increase in hay and alfalfa production in the state.





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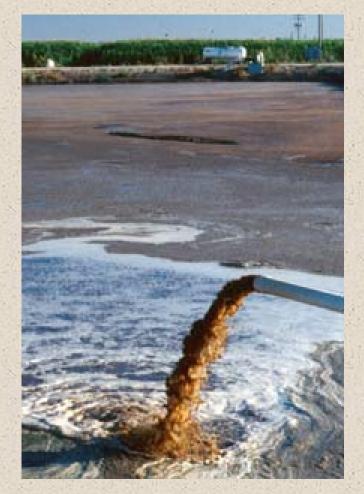
Source, Arizona Review, Spring 2003 Data: Arizona Agriculture Statistics Service



# Problems Facing AZ Dairy Producers

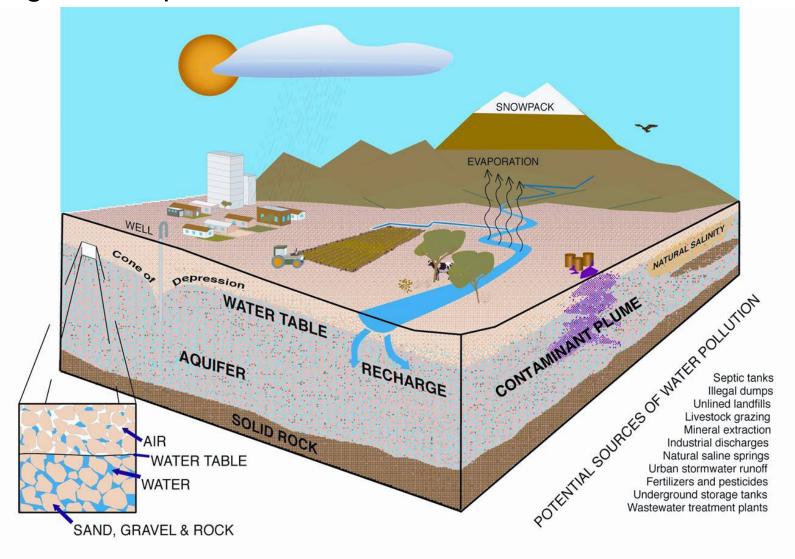
- Nutrient management
- Lagoon management
- Heat stress
- Employee management
- Water usage

This brings us back to our discussion of water management in Arizona





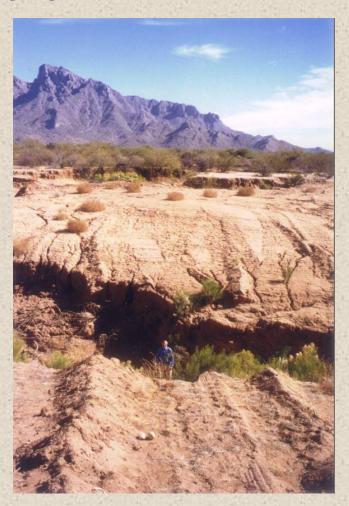
No new water is created. The water cycle, water use, and groundwater recharge determine how much water is in underground aquifers.





## Overdraft of groundwater has been a problem in Central Arizona

- Rapid growth and reliance on groundwater have led to declining water tables, resulting in higher costs of pumping groundwater. Water quality problems can also result.
- Fissuring and land subsidence, as shown in the photo to the right, can also result.





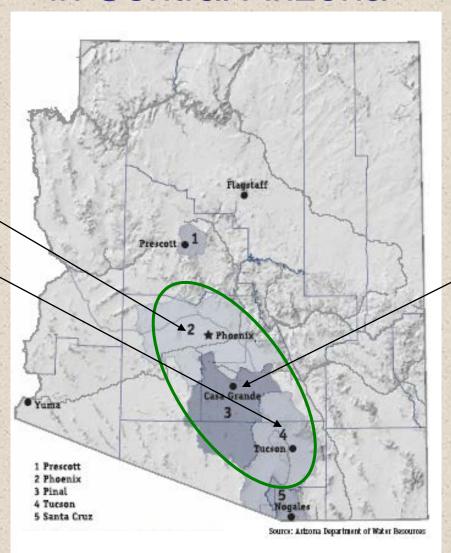
## Key Elements of the 1980 State of Arizona Groundwater Management Act (GMA)

- Established areas where groundwater management was required – Active Management Areas, each with a statutory management goal
- GMA required the adoption of Assured Water Supply Rules, which require municipal growth to depend on renewable supplies.
- Conservation programs for each water using sector and management plans are developed by the Arizona Department of Water Resources every 10 years.
- No expansion of agricultural land beyond what was irrigated during the late 1970s.



## There are three Active Management Areas in Central Arizona

Management goal is safe yield in the Phoenix and Tucson Active Management Areas



Management goal has been called "planned depletion" in the Pinal Active Management Area, where most water use is agricultural

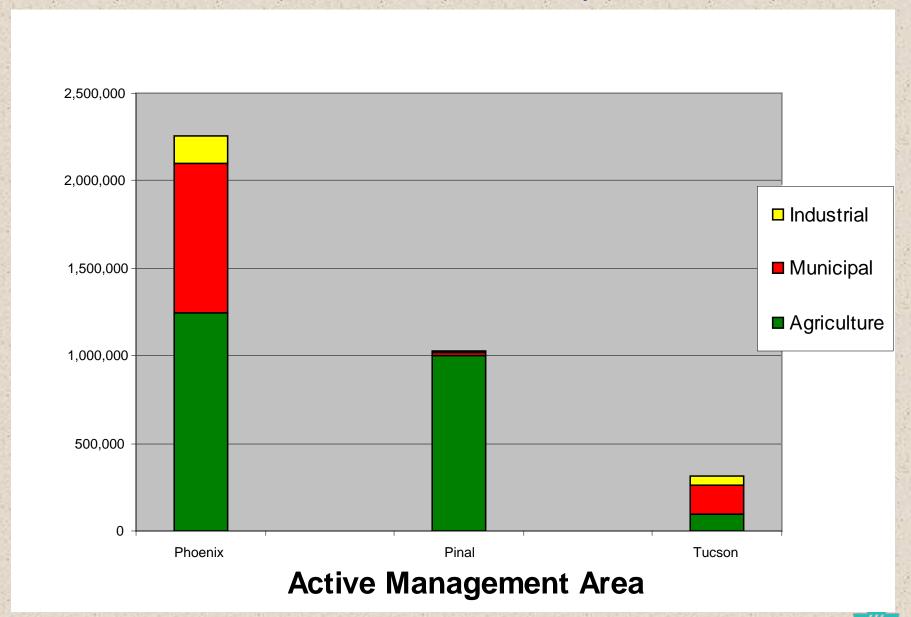


## Active Management Area Water Use by Sector in Acre Feet: 1998

AMA	Agriculture	Municipal	Industrial	Total
Phoenix	1,244,777	850,483	163,641	2,258,901
Dinal	1 000 211	10.770	0.202	4 000 202
Pinal	1,000,311	19,779	8,292	<u>1,028,382</u>
Tucson	94,909	163,198	57,544	<u>315,651</u>



### 1998 Water Use in Acre Feet by Sector



## Management Goal for Phoenix and Tucson Active Management Areas: Statutory Language

- The management goal of the Tucson and Phoenix Active Management Areas is safe-yield by January 1, 2025.
- "Safe-yield" means a groundwater management goal which attempts to achieve and thereafter maintain a long-term balance between the annual amount of groundwater withdrawn in an active management area and the annual amount of natural and artificial recharge in the active management area.



## Management Goal for Pinal AMA: Statutory Language

 The management goal of the Pinal active management area is to allow development of non-irrigation uses as provided in this chapter and to preserve existing agricultural economies in the active management area for as long as feasible, consistent with the necessity to preserve future water supplies for non-irrigation uses.

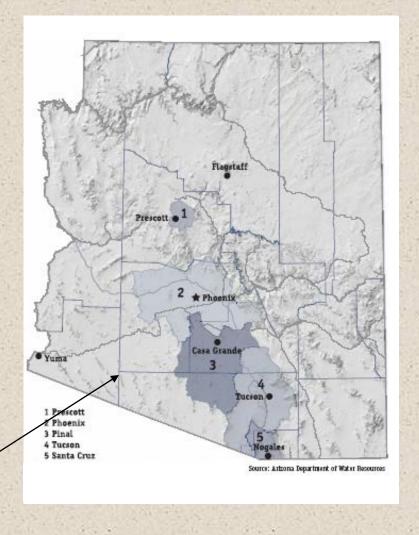


### Further explanation of Pinal AMA Management Goal (for reference use):

- In the past the water management goal of the Pinal AMA was referred to as "planned depletion." However, this characterization has recently been identified as encompassing only one aspect of the management goal.
- Preserving future water supplies for nonirrigation users is also an important part of the Pinal AMA management goal.
- Because agriculture can use mined groundwater supplies in the Pinal AMA until they are no longer affordable, and sufficient groundwater appears to be available based on projected needs, the goal of preserving the agricultural economies for as long as feasible is achievable well beyond 2025.
- With regard to achieving the goal for non-irrigation uses and accommodating projected population increases, strategies must be identified and implemented to lower overall water use, specifically the non-residential component, and/or secure additional renewable supplies.



 The Active Management Area water management goal is for the entire AMA. The boundaries for the AMAs are largely based on hydrologic basin boundaries rather than political jurisdiction boundaries. Inside each are cities, towns and parts of counties. Arizona's 15 counties are outlined on map.





## Management Plans are required by the GMA and include conservation targets.

- •The Arizona Department of Water Resources adopts

  Management Plans for each AMA every 10 years.

  These plans include conservation targets for each water using sector. The Third Management Plans are in effect.
- •The Management Plans have separate conservation targets for the municipal, industrial and agricultural water sectors.
  - -The water used for growing crops, such as the feed for dairy cows, is considered agricultural water use.
  - -The water used for operating the dairy is considered industrial water use. Limits on water per dairy cow are imposed on dairy operations.

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### Pinal AMA Third Management Plan

### Excerpts from Industrial Chapter Section on Dairy Operations

Available www.water.az.gov

#### 6.8 DAIRY OPERATIONS

#### 6.8.1 Introduction

DETAILED TEXT NOT TO BE READ AT CONFERENCE

The Department regulates dairy operations that annually house a monthly average of 100 or more lactating cows per day.

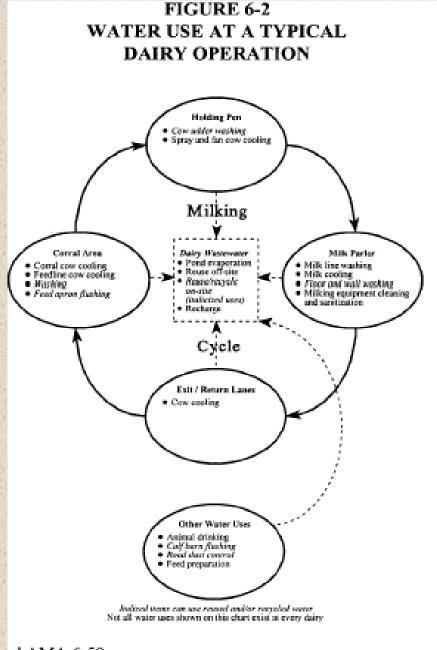
#### 6.8.2 Water Use by Dairy Operations

There are currently nine dairy operations in the Pinal AMA. These facilities hold Type 1 and Type 2 grandfathered rights and groundwater withdrawal permits totaling more than 2,100 acre-feet. Water use by dairies in 1995 was nearly 1,000 acre-feet, or just less than 48 percent of their total annual allotments. Dairy water use has been steadily increasing since 1989, and the Department projects this trend will continue through the year 2025. Dairy operations are a small, but growing industrial water user in the AMA. Many of Arizona's large, established dairies are currently located in the Chandler/Gilbert area of the Phoenix AMA. However, this area is rapidly being urbanized and many of the dairies are relocating. It is anticipated that a number of these dairies will relocate to the Pinal AMA.



The Section is 10 pages long and there are appendix pages.

There is an "allotment based water conservation target" or a "best management practices" program.



al AMA 6-59



This text is being provided for illustrative purposes only. Consult the Management Plans for the Phoenix and Pinal AMAs for more detailed information.

#### **ALLOTMENT PROGRAM**

#### 6.8.4 Dairy Operations Conservation Program

#### 6.8.4.1 Allotment Based Requirements

The amount of water required by a dairy depends upon the number of cows and non-lactating animals housed at the dairy, herd composition, and dairy management practices. Table 6-2 summarizes daily water needs for each dairy process assuming use of appropriate water conservation technology and practices. The water needs listed are based upon two assumptions: (1) milking is done three times per day per lactating animal, and (2) cooling is done during the milking cycle for at least a portion of the herd.

The assumptions of Table 6-2 are the basis for the maximum annual water allotment for dairy operations. When calculating the annual allotment, lactating cows are allotted 105 gallons per animal per day (GAD) and non-lactating animals are allotted 20 GAD. The allotment is calculated annually and will vary with the average daily number of lactating cows and non-lactating animals present at the dairy each year.

Upon application, the Department may approve an additional allocation of water for a dairy operation above its annual allotments if the dairy operation demonstrates that one or more of the following conditions exist at the dairy:

- Milking is being done more than three times daily.
- Technologies that are designed to achieve industry health and sanitation objectives, such as the recommended pre-milking sanitation method, are being used.
- Animal cooling technologies designed to increase milk production are being used.

http://www.water.az.gov/adwr/Content/Publications/files/ThirdMgmtPlan/tmp\_final/default.htm



TABLE 6-2 WATER NEEDS AT A TYPICAL DAIRY

	Water Use Allocation (gallons per day)		
Operation	Lactating Cow	Non-Lactating Animal	
Drinking needs <sup>1</sup>	30	15	
Udder washing - based on 72 minutes/day at 8 gallons/minute; 16 cows per milking (two per group). (Varies with number of milkings per day. <sup>1</sup> )	35	0	
Barn cleanup and sanitizing. (Varies with number of milkings per day. <sup>1</sup> )	20	0	
Animal cooling management option (site-specific)	10	0	
Calf barn cleanup	0	5	
Milk cooling tower (if present)	5	0	
Miscellaneous	5	0	
Total	105	20	

Assumes three milkings per day.

In consideration of wet weather, the Department has included a three-year averaging provision in the maximum annual water allotment for the third management period. The water use of three consecutive years can be averaged and used to determine compliance with the annual allotment.



#### **BEST MANAGEMENT PRACTICES PROGRAM**

#### 6.8.4.2 Best Management Practices Requirements

As an alternative to the annual allotment requirement, a dairy operation may submit an application to the director under the Best Management Practices Program (BMP Program). This program requires implementation of conservation and management practices to maximize efficiency in the following water use categories:

- Delivery of drinking water for dairy animals;
- Udder washing and milk parlor cleaning;
- Corral maintenance and design;
- Cleaning and sanitizing milking equipment;
- Dust control, calf housing cleaning, and feed apron flushing;
- Dairy animal cooling; and
- Feed preparation.

Implementation of all the standard BMPs listed in Appendix 6B will have a specific measurable result. While most of the standard BMPs are applicable to all dairies, the water use activities associated with some of the standard BMPs may not exist at all dairies. If a dairy cannot implement a standard BMP, the dairy may apply to implement a substitute BMP with a specific measurable result that demonstrates a water savings equivalent to the water savings associated with the standard BMP. If a substitute BMP is not possible, the dairy may apply for a waiver of the standard BMP. The director may grant a waiver only for the following standard BMPs: (1) BMP 2.1.2 (Udder Wash System); (2) BMP 2.2.2 (Milking Parlor Floor and Wall Washing); (3) BMP 4.1.1 (Milk Cooling and Vacuum Pump); (4) all of the standard BMPs in Water Use Category No. 5 (Dust Control, Calf Housing Cleaning, and Feed Apron Flushing); (5) all of the

Pinal AMA 6-62



standard BMPs in Water Use Category No. 6 (Dairy Animal Cooling); and (6) all of the standard BMPs in Water Use Category No. 7 (Dairy Animal Feed Preparation).

Five years after a dairy operation is accepted for regulation under the BMP Program, the director will review the dairy's BMPs to determine if they are still appropriate. If the BMPs are no longer appropriate due to an expansion of the dairy or a change in management practices, the director will require a modification to the BMPs.

#### 6.8.5 Future Directions

Although newer dairies tend to use more water for cow cooling than older dairies by employing more cooling technologies and practices, thoughtful design will allow dairies to reuse and recycle more water than they have in the past. The latest "state of the art" dairies even effectively collect or use rainfall. Fourth management period conservation requirements may need to be adjusted to reflect the increased presence of these changes. Any changes to the allotment, however, will need to be based on verifiable data.

The Arizona Department of Water Resources is responsible for development of and enforcing compliance with these conservation programs.



# How are the Active Management Areas in Central Arizona able to make measurable progress in achieving their respective management goals?

- Conservation is one way
- Use of alternative water supplies is another, critically important way.
- The two primary alternative water supplies are surface water, particularly Colorado River Water brought in through the Central Arizona Project (CAP) Canal, and effluent.

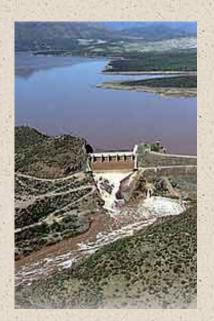


The Salt River Project (SRP) is one of the first major water reclamation systems in the western United States. Its water is important to many in the Phoenix area. Seven dams are part of the system.



Roosevelt Dam

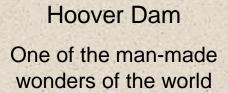
Horseshoe Dam







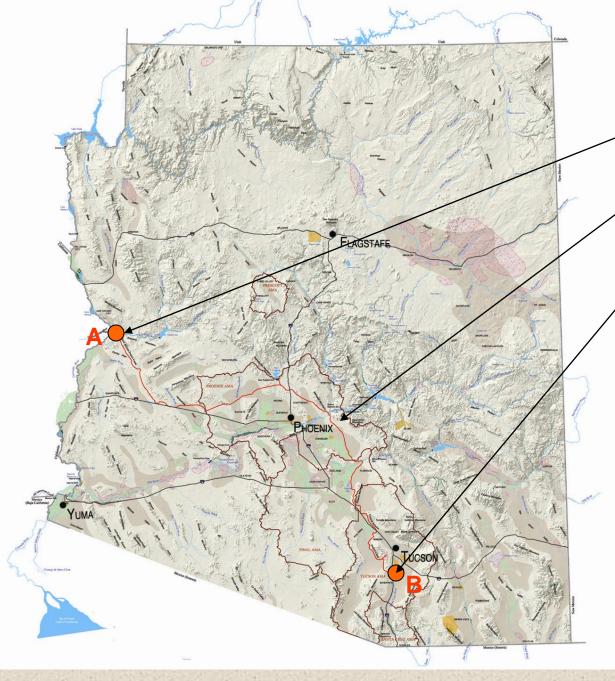






The construction of the Central Arizona **Project (CAP)** enabled the transport of Colorado River Water into Central Arizona. The CAP has provided a key source of water for agricultural, industrial, and municipal water users in Central Arizona to substitute for groundwater.





#### **Arizona Water Map**

Central Arizona
Project shown in
orange

**541 kilometers** 

Cost over \$4 billion

Pumps water from
Point A, at sea level,
to Point B, to a
maximum elevation
near Tucson of about
850 meters

Built to transport 1.5 million acre feet of water annually



## CAP water some times is not where it is needed spatially or in time

- Solution: Storage (Recharge) and Recovery
  - Water stored at Underground Storage
     Facilities and Groundwater Savings Facilities
     for recovery later in time or elsewhere
  - Water banking by the Arizona Water Banking Authority



## Underground Storage Facilities (USF): Storage through infiltration Water delivered to basins or riverbeds







#### Tucson Water Central Avra Valley Storage and Recovery Facility

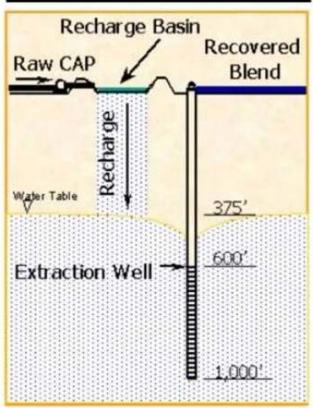
Basin-opening ceremony

**Recovery Wells** 









Credits are accrued for water stored at underground storage facilities. This graphic shows how the water infiltrates the ground and makes its way to the aquifer, where it mixes with ambient groundwater. A well recovers the water from the aquifer. In the early years of this recharge and recovery program, the chemical composition of the recovered water is similar to groundwater. Over time, more and more CAP water mixes with the groundwater, changing the chemical composition of the recovered water.

Graphic courtesy of
Tucson Water Water Resources Research Center – University of Arizona

#### Groundwater Savings Facilities (GSF): Instead of using groundwater, agriculture substitutes CAP water or effluent.





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- How much CAP water is used by agriculture depends in large part on the price of CAP water.
- The pricing of CAP water to agriculture varies according to sometimes complex pricing practices of the operators of the CAP. In addition to direct purchase of CAP water by agriculture, municipalities assist in the funding of water purchases in order to receive credits to pump groundwater due to the "groundwater savings" associated with replacing groundwater use with CAP water use.
- In addition, the Arizona Water Banking Authority has stored significant quantities of water, much of it at groundwater savings (agricultural) facilities.



#### Important Water Storage Agency: The Arizona Water Banking Authority

- Established in 1996
- Purposes
  - Assist state in making full utilization of Arizona's Colorado River Water
  - Storage for times of shortage or outages on the canal
  - Groundwater Management
  - Indian Settlements
- Very successful to date about 2 million acre feet of water has been stored



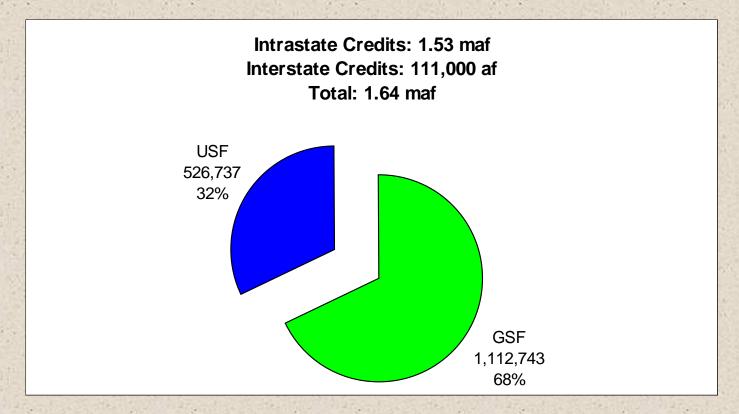
# The Arizona Water Banking Authority has stored water in the three Central Arizona AMAs that have been the focus of this presentation.

Total Long-term Storage Credits Accrued by AMA by the AWBA: 1996-2003

AMA	Total
Phoenix	952,912
Pinal	804,378
Tucson	228,172
	1,985,462



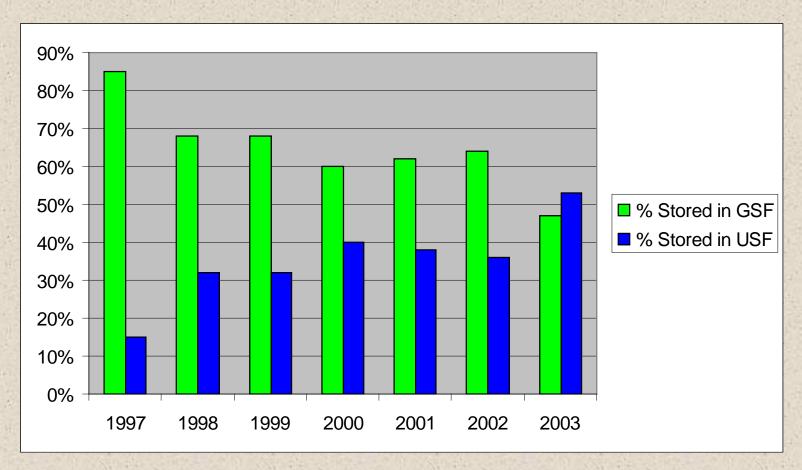
#### AWBA Water Credits (AF) through 2002: Underground Storage Facilities and Groundwater Storage Facilities % Distribution



The next chart shows that, for the first time in 2003, the AWBA stored more water at underground storage facilities than groundwater savings facilities.



## AWBA Long-term Water Credits Comparison of Percentage USF vs. GSF Credits.





### Another important water source for all of Arizona is treated wastewater

- It is a source of water that generally grows with the population of a region
- Effluent is treated wastewater
  - In Arizona it is used for some irrigation, for cooling water for power plants, and for some turf irrigation
- Reclaimed water is effluent treated to a higher quality.
  - It is widely used for turf irrigation because, according to state water quality regulations, irrigated areas do not have to be fenced.



Many urban golf courses are irrigated with reclaimed water.



Effluent or reclaimed water is also used to irrigate pastures near urban areas.





### Effluent discharges can have hydrologic and environmental benefits.

The Santa Cruz
River bed in Tucson
is dry above the
outfall for the
wastewater
treatment plant

Riparian growth downstream of the outfalls for two wastewater treatment facilities. There is a permit pending to grant recharge credits for a portion of the effluent recharging the stream bed.







## Many unresolved issues related to water management in Central Arizona. Some examples of issues being worked on:

- The hydrologic and water quality implications of long-term storage of surface water or effluent
- Use of effluent for potable water needs the next major new water source
- Recovery of stored water
- Water Transfers and Water Marketing
- Drought issues



#### Unresolved Issues (continued)

- What groundwater use regulations, if any, to impose outside of the Active Management Areas? There are rapidly growing areas where water supplies issues exist and there are no regulations in place.
- Water quality regulations
- Interstate and international Colorado River issues



### About the University of Arizona Water Resources Research Center

- The Arizona Water Resources Research Center (WRRC) was established in 1957.
- Its mission is to provide statewide outreach and education focused on critical water issues affecting Arizona and to provide expertise on state and regional water management and policy.
- See our web site <u>www.ag.arizona.edu/azwater/</u> for our publications and recent papers and presentations.
- April 28, 2004 conference on the Future of Agricultural Water Use in Arizona. For more information, visit our web site.



#### Closing Thoughts

 When the well's dry, we know the worth of water. – Benjamin Franklin, Poor Richard's Almanac, 1746

•The frog does not drink up the pond in which he lives. – *American Indian Proverb* 



