ECOL 206
Aerial View of Tucson
(an exploration of the Tucson basin)

Laboratory Goals:
1. To observe the physical features, land use, and ecology of the Tucson basin from above
2. To time-travel by describing the historical changes that have occurred in the Tucson basin and the role humans played
3. To measure variables of the physical environment (e.g. temperature and humidity)
4. To obtain data for our next lab session

1. A description of the Tucson basin

A. General information

1. Mountains: North = Santa Catalina Mtns (USFS); Mt. Lemmon 9,157 ft (2793m)
   South = Santa Rita Mtns (USFS; Mt. Wrightson 9,453 ft (2864m)
   East = Rincon Mtns (NPS); Mica Mt. 8,666 ft (2626m)
   West = Tucson Mtns (NPS/Pima Co); Wasson Pk. 4,687 ft (1420m)
   Campus = 2,400 ft (727m)
2. Tucson:

Area = 99 sq.mi. Population (2000) = 486,699 (city); ≈ 700,00 (metro area); expected by 2010 = 595,000. Population density: 4,645 persons/sq.mi. Tucson is one of the five fastest growing cities in the U.S. For the U.S. standard of living, 2.6 acres of agricultural land are required to feed 1 person during one year. If the Tucson area was all farmed, it would produce enough food for only 5% (≈ 25,000) of its population. We are not a self-sufficient community!

3. Water (see water budget)

The southwestern U.S. accounts for 31% of water usage in the country, but has only 6% of the water supply!

a. Santa Cruz River: historically, it ran year-round for most of its course, forming several swampy areas. Tucson's early residents relied on river water and nearby springs. By the 1940's, the river stopped flowing due to groundwater pumping.
b. Groundwater: most entered the aquifer more than 10,000 yrs ago when the climate was wetter. Today, almost all of Tucson's potable water comes from the aquifers in the Tucson basin and Avra Valley. As groundwater is removed, the ground becomes compacted and the surface begins to sink (subsidence). Large crevices have developed near Picacho since the 50's when irrigation wells started to affect the water table; as a result, I-10 requires frequent repairs. Parts of central Tucson are sinking 0.8 in/yr, and some areas could drop 12 ft by 2025.
c. CAP: We have access to water from the Central Arizona Project (CAP), which is transported from the Colorado River 335 miles away. Tucson can receive up to 215,000 acre-ft/yr from CAP. CAP water is more expensive and of lower quality than groundwater, so few people use it directly. Recently, Tucson started to mix CAP water with groundwater for residential use.

4. Transportation

According to a telephone poll (biased by economics of access), 82% of those who commute to work in Pima Co. travel alone in a car. Only 18% bike, walk, car-pool, or use the bus.

B. Geology

1. Volcanic activity: Around 25 million yrs ago (same time first anthropoid primates appeared), the earth's crust in the Tucson area began to be stretched as the eastern edge of the Pacific plate pulled the western edge of the North American plate to the northwest. As the crust cracked, magma rose and created violent explosive volcanic eruptions throughout southeastern Arizona. In some places where the pressure was intense, melted rock collected under the surface, which eventually pushed the overlaying crust into a dome shape, cooled, and became granite. Thus, the Santa Catalina, Santa Rita, and Rincon Mtns formed.
2. Basin and range processes: Starting around 12 million yrs ago, basin and range processes began to occur as the stretching of the crust continued. As the crust stretched, faults formed and large areas of land slid downward, creating basins we see b/w mountain ranges (including Tucson basin). The mountains are part of the land that did not drop. These processes slowed down about 8 million yrs ago, and since then the mountains have been eroding and the sediments from the mountains have been washing into the basins, producing sediment layers up to 2 miles deep!

3. Fault lines: A fault line marks the separation between two sections of the earth's crust that are moving in opposite directions. Rivers often flow in the cracks along fault lines. A fault line associated with the Santa Cruz River runs under downtown Tucson! Earthquakes also occur along faults; do you think that an earthquake can occur here?

C. **Climate**
   1. Aridity: Tucson is arid due to: a) a high pressure system that repeatedly forms off the Pacific Coast near our latitude, b) cold ocean currents off the Pacific Coast that cause rain to fall offshore, and c) rain shadow from mountains.
   2. Bimodal rainfall pattern: Part of the reason the Sonoran Desert has a high level of biological diversity is due to rainfall patterns. Most of our rain comes in the summer during the monsoon months (July-Sept). The monsoons are the result of a high-pressure system (heat!) that sits over our area drawing moist air from the Gulf of Mexico. We also get rains in the winter when the high pressure system of the Pacific Coast weakens or moves north/south and slow-moving clouds bring moisture our way from the pacific.

2. Time travel: effects of human activities on the physical, biological, and social environment

Native Americans first reached AZ around 12,000 yrs ago as they spread south from Alaska. When they arrived there were camels, mammoths, horses, lions, and giant ground sloths. By 11,000 yrs ago about 2/3 of the large animals of N.America had become extinct, probably as a result of human hunting. Around 3,000 yrs ago Native Americans started to use the Santa Cruz River near Tucson to irrigate crops (corn, squash, beans) and to catch fish and other aquatic animals.

Europeans began settling the area in the late 1600's, wiping out most (possibly up to 95%) of the Native Americans with introduced diseases (measles and smallpox). Europeans also brought cattle, which changed the vegetation and other aspects of the local ecology. Tucson was initially Native American village. Following periods as a Spanish and later a Mexican outpost, it became a U.S. town in 1877.

The area around Tucson used to be more of a grassland with some forests following river channels. A combination of overgrazing the drought around 1900 led to the dominance of mesquite trees, choyas, and other cacti. Over the last 50 yrs Tucson's population has dramatically increased from 45,500 in 1950 to 455,000 in 1997, while population density has actually *decreased* from 5,200 people/sq.mi. to 2,400 people/sq.mi. (sprawl!)

3. Measuring variables of the physical environment

Temperature and heat: Tucson is at 32N latitude. Its geographical position and altitude make it *hot*. The heat can be transferred by 4 processes:

a. radiation: energy transfer of electromagnetic form. The surface of a body determines the intensity and wavelength of the radiation it can produce. Depending on an object's color (dark/light) and surface (rough/smooth), it can absorb, reflect (albedo: fraction of light energy reflected), or transmit (light through a glass window) radiated energy.
b. Conduction: heat transfer in direct contact (from warmer surface to cooler one).
c. Convection: heat transfer in moving or circulating fluids (air or water currents). Like conduction, convection is driven by temperature and pressure differences.
d. Evaporation: net loss of molecules from a liquid (water); driven by difference in vapor pressure between wet surface and surrounding air. Heat lost from wet surface when water molecule changes into gas.

Assignment

Take notes on everything and use the information on this handout to write a 300-500 word summary and analysis of the physical and biological (including humans) environment of Tucson and its basin. Please **type** your assignment and turn it in separately from your field notebook.

Please address the following questions in your assignment:

1. Where are the major drainages and which way do they flow?
2. How do you describe today's weather? Where did it originate?
3. What effects do the surrounding mountains have on Tucson?
4. What are Tucson's most serious problems or potential problems?
5. How much can the population increase in the metropolitan area? What will ultimately limit this population?
6. What might the climate be like in a city located at 32 S latitude? Why?

Data Sheet

Name: TA:
Group Members:

Variable	**Method**	**Time 1 =**	**Time 2 =**	**Time 3 =**	**Ground**
Air Temp	Dry Bulb Thermometer				
Relative Humidity	Slide Rule, need dry and wet bulb temps				
Absolute Humidity	Table on back of sheet				
Sky Temp	IR gun				
Ground Temp	IR gun, only on ground				
Temp: E facing wall	IR gun, wall of building on rooftop				
Temp: S facing wall	Same				
Temp: W facing wall	Same				
Temp: N facing wall	Same				
Wind speed / direction	Beaufort scale				
Cloud Cover	Estimate %				

DENSITY OF PURE WATER VAPOR AT SATURATION OVER WATER

→ RH value

mult by humidity

- to calc. absolute humidity

Dry bulb temp = air temp

Temperature °C	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
	$g. m.^{-3}$	$g. m.^{-3}$	$g. m.^{-3}$	$g. m.^{-3}$	$g. m.^{-3}$	$g. m.^{-3}$	$g. m.^{-3}$	$g. m.^{-3}$	$g. m.^{-3}$	$g. m.^{-3}$
−0	4.847	4.814	4.781	4.748	4.715	4.683	4.650	4.618	4.586	4.554
0	4.847	4.881	4.915	4.948	4.983	5.017	5.052	5.087	5.122	5.157
1	5.192	5.228	5.264	5.300	5.336	5.373	5.409	5.446	5.483	5.521
2	5.559	5.597	5.635	5.673	5.711	5.750	5.789	5.828	5.868	5.907
3	5.947	5.987	6.028	6.068	6.109	6.150	6.192	6.233	6.275	6.317
4	6.360	6.402	6.445	6.488	6.531	6.575	6.619	6.663	6.707	6.752
5	6.797	6.842	6.887	6.933	6.979	7.025	7.071	7.118	7.165	7.212
6	7.260	7.307	7.355	7.404	7.452	7.501	7.550	7.600	7.649	7.699
7	7.750	7.801	7.851	7.902	7.954	8.006	8.058	8.110	8.163	8.216
8	8.270	8.324	8.377	8.431	8.485	8.540	8.595	8.650	8.706	8.762
9	8.819	8.875	8.932	8.989	9.046	9.104	9.163	9.221	9.280	9.339
10	9.399	9.459	9.519	9.579	9.641	9.702	9.763	9.825	9.887	9.949
11	10.01	10.08	10.14	10.20	10.27	10.33	10.40	10.46	10.53	10.59
12	10.66	10.73	10.79	10.86	10.93	11.00	11.07	11.14	11.21	11.27
13	11.35	11.42	11.49	11.56	11.63	11.70	11.77	11.85	11.92	11.99
14	12.07	12.14	12.22	12.29	12.37	12.44	12.52	12.60	12.67	12.75
15	12.83	12.91	12.99	13.07	13.14	13.23	13.31	13.39	13.47	13.55
16	13.63	13.72	13.80	13.88	13.97	14.05	14.14	14.22	14.31	14.39
17	14.48	14.57	14.65	14.74	14.83	14.92	15.01	15.10	15.19	15.28
18	15.37	15.46	15.55	15.65	15.74	15.83	15.93	16.02	16.12	16.21
19	16.31	16.41	16.50	16.60	16.70	16.80	16.90	17.00	17.10	17.20
20	17.30	17.40	17.50	17.60	17.71	17.81	17.91	18.02	18.12	18.23
21	18.34	18.44	18.55	18.66	18.77	18.88	18.99	19.10	19.21	19.32
22	19.43	19.54	19.65	19.77	19.88	20.00	20.11	20.23	20.34	20.46
23	20.58	20.70	20.81	20.93	21.05	21.17	21.29	21.42	21.54	21.66
24	21.78	21.91	22.03	22.16	22.28	22.41	22.54	22.66	22.79	22.92
25	23.05	23.18	23.31	23.44	23.58	23.71	23.84	23.97	24.11	24.24
26	24.38	24.52	24.66	24.79	24.93	25.07	25.21	25.35	25.49	25.63
27	25.78	25.92	26.06	26.21	26.35	26.50	26.65	26.79	26.94	27.09
28	27.24	27.39	27.54	27.69	27.85	28.00	28.15	28.31	28.46	28.62
29	28.78	28.93	29.09	29.25	29.41	29.57	29.73	29.89	30.05	30.22
30	30.38	30.55	30.71	30.88	31.05	31.22	31.38	31.55	31.72	31.89
31	32.07	32.24	32.41	32.59	32.76	32.94	33.11	33.29	33.47	33.65
32	33.83	34.01	34.19	34.38	34.56	34.74	34.93	35.11	35.30	35.49
33	35.68	35.87	36.06	36.25	36.44	36.63	36.83	37.02	37.22	37.41
34	37.61	37.81	38.01	38.21	38.41	38.61	38.81	39.01	39.22	39.42
35	39.63	39.84	40.05	40.26	40.47	40.68	40.89	41.10	41.31	41.53
36	41.75	41.96	42.18	42.40	42.62	42.84	43.06	43.28	43.50	43.73
37	43.96	44.18	44.41	44.64	44.87	45.09	45.33	45.56	45.79	46.02
38	46.26	46.50	46.74	46.97	47.21	47.45	47.69	47.94	48.18	48.42
39	48.67	48.92	49.17	49.42	49.66	49.92	50.17	50.42	50.67	50.93
40	51.19	51.45	51.70	51.96	52.22	52.49	52.75	53.01	53.28	53.54
41	53.82	54.09	54.36	54.63	54.90	55.17	55.44	55.72	56.00	56.27
42	56.56	56.84	57.12	57.40	57.68	57.97	58.25	58.54	58.83	59.12
43	59.41	59.70	60.00	60.29	60.59	60.88	61.18	61.48	61.78	62.08
44	62.39	62.70	63.00	63.31	63.62	63.92	64.23	64.55	64.86	65.17
45	65.50	65.81	66.13	66.45	66.77	67.10	67.42	67.74	68.07	68.40
46	68.73	69.06	69.39	69.73	70.06	70.40	70.73	71.07	71.41	71.75
47	72.10	72.45	72.79	73.13	73.49	73.84	74.18	74.53	74.89	75.25
48	75.61	75.96	76.33	76.69	77.05	77.41	77.77	78.14	78.51	78.88
49	79.25	79.63	80.01	80.38	80.76	81.14	81.52	81.90	82.28	82.67
50	83.06	83.45	83.84	84.23	84.62	85.01	85.41	85.81	86.20	86.60
51	87.01	87.41	87.82	88.22	88.63	89.04	89.45	89.86	90.27	90.69
52	91.12	91.54	91.96	92.38	92.80	93.23	93.66	94.09	94.52	94.95
53	95.39	95.83	96.27	96.71	97.14	97.59	98.03	98.47	98.92	99.37
54	99.83	100.3	100.7	101.2	101.7	102.1	102.6	103.0	103.5	104.0
55	104.4	104.9	105.4	105.9	106.3	106.8	107.3	107.8	108.2	108.7
56	109.2	109.7	110.2	110.7	111.2	111.7	112.2	112.7	113.2	113.7
57	114.2	114.7	115.2	115.7	116.2	116.8	117.3	117.8	118.3	118.8
58	119.4	119.9	120.4	121.0	121.5	122.0	122.6	123.1	123.6	124.2
59	124.7	125.3	125.8	126.4	126.9	127.5	128.0	128.6	129.1	129.7
60	130.3									

Beaufort Wind Scale

Developed in 1805 by Sir Francis Beaufort of England

Force	Wind (Knots)	WMO Classification	Appearance of Wind Effects: On the Water	Appearance of Wind Effects: On Land
0	Less than 1	Calm	Sea surface smooth and mirror-like	Calm, smoke rises vertically
1	1-3	Light Air	Scaly ripples, no foam crests	Smoke drift indicates wind direction, still wind vanes
2	4-6	Light Breeze	Small wavelets, crests glassy, no breaking	Wind felt on face, leaves rustle, vanes begin to move
3	7-10	Gentle Breeze	Large wavelets, crests begin to break, scattered whitecaps	Leaves and small twigs constantly moving, light flags extended
4	11-16	Moderate Breeze	Small waves 1-4 ft. becoming longer, numerous whitecaps	Dust, leaves, and loose paper lifted, small tree branches move
5	17-21	Fresh Breeze	Moderate waves 4-8 ft taking longer form, many whitecaps, some spray	Small trees in leaf begin to sway
6	22-27	Strong Breeze	Larger waves 8-13 ft, whitecaps common, more spray	Larger tree branches moving, whistling in wires
7	28-33	Near Gale	Sea heaps up, waves 13-20 ft, white foam streaks off breakers	Whole trees moving, resistance felt walking against wind
8	34-40	Gale	Moderately high (13-20 ft) waves of greater length, edges of crests begin to break into spindrift, foam blown in streaks	Whole trees in motion, resistance felt walking against wind
9	41-47	Strong Gale	High waves (20 ft), sea begins to roll, dense streaks of foam, spray may reduce visibility	Slight structural damage occurs, slate blows off roofs
10	48-55	Storm	Very high waves (20-30 ft) with overhanging crests, sea white with densely blown	Seldom experienced on land, trees broken or uprooted, "considerable

			foam, heavy rolling, lowered visibility	structural damage"
11	56-63	Violent Storm	Exceptionally high (30-45 ft) waves, foam patches cover sea, visibility more reduced	
12	64+	Hurricane	Air filled with foam, waves over 45 ft, sea completely white with driving spray, visibility greatly reduced	

Humidity Definitions – from USATODAY.COM

Why humidity can be less than 100% when it's raining

Humidity is a measure of the amount of water vapor in the air, not the total amount of vapor and liquid. For clouds to form, and rain to start, the air does have to reach 100% relative humidity, but only where the clouds are forming or where the rain is coming from. This normally happens when the air rises and cools. Often, rain will be falling from clouds where the humidity is 100% into air with a lower humidity. Some water from the rain evaporates into the air it's falling through, increasing the humidity, but usually not enough to bring the humidity up to 100%.

Definitions

Absolute humidity: The mass of water vapor in a given volume of air(i.e., density of water vapor in a given parcel, usually expressed in grams per cubic meter

Actual vapor pressure: The partial pressure exerted by the water vapor present in a parcel. Water in a gaseous state (i.e. water vapor) exerts a pressure just like the atmospheric air. Vapor pressure is also measured in millibars.

Condensation: The phase change of a gas to a liquid. In the atmosphere, the change of water vapor to liquid water.

Dewpoint: the temperature air would have to be cooled to in order for saturation to occur. The dewpoint temperature assumes there is no change in air pressure or moisture content of the air.

Dry bulb temperature: The actual air temperature. See **wet bulb temperature** below.

Freezing: The phase change of liquid water into ice.

Evaporation: The phase change of liquid water into water vapor.

Melting: The phase change of ice into liquid water.

Mixing ratio: The mass of water vapor in a parcel divided by the mass of the dry air in the parcel (not including water vapor)

Relative humidity: The amount of water vapor actually in the air divided by the amount of water vapor the air can hold. Relative humidity is expressed as a percentage and can be computed in a variety of ways. One way is to divide the actual vapor pressure by the saturation vapor pressure and then multiply by 100 to convert to a percent.

Saturation of air: The condition under which the amount of water vapor in the air is the maximum possible at the existing temperature and pressure. Condensation or sublimation will begin if the temperature falls or water vapor is added to the air.

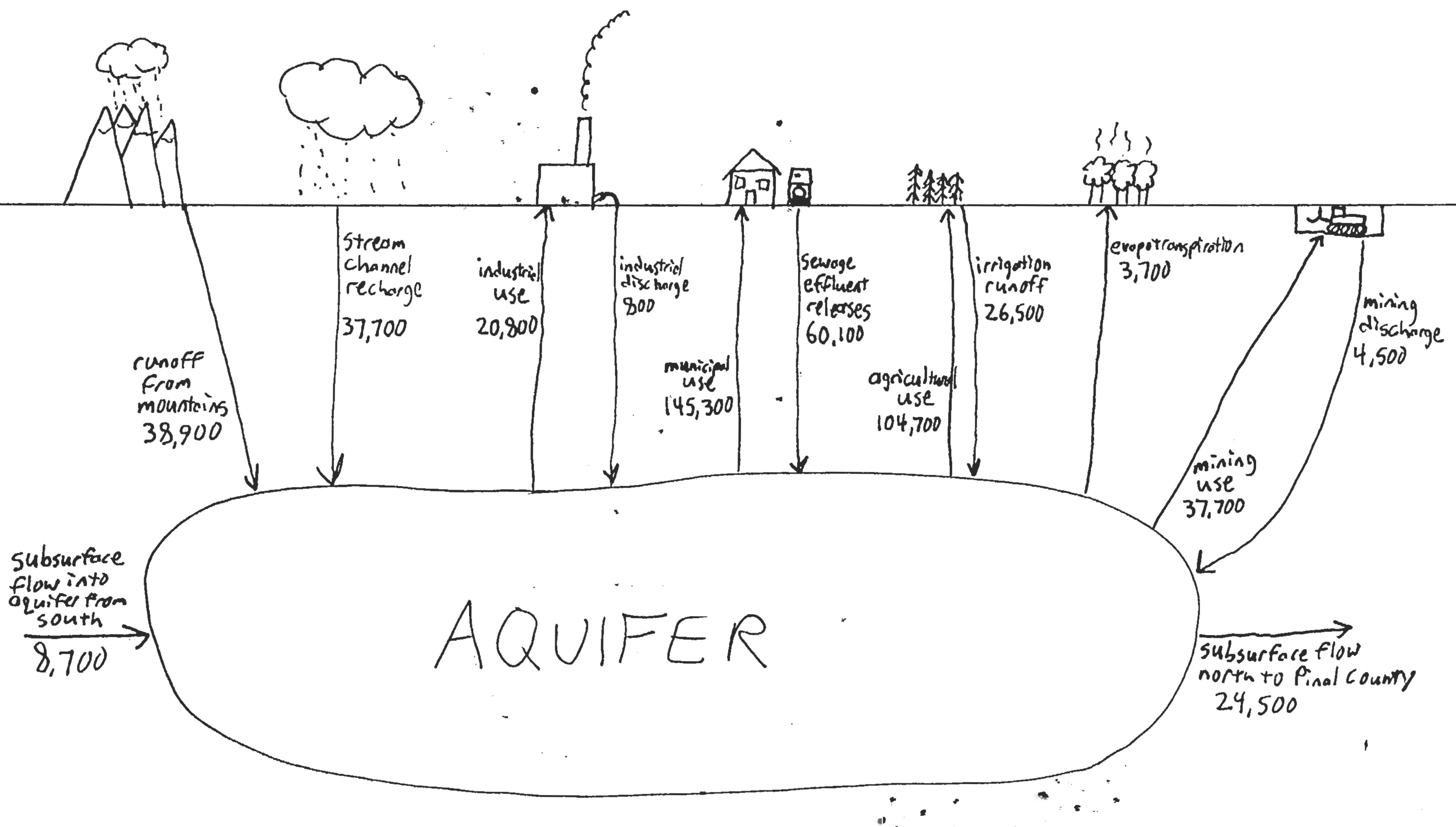
Saturation vapor pressure: The maximum partial pressure that water vapor molecules would exert if the air were saturated with vapor at a given temperature. Saturation vapor pressure is directly proportional to the temperature.

Specific humidity: The mass of water vapor in a parcel divided by the total mass of the air in the parcel (including water vapor)

Sublimation: In U.S. meteorology, the phase change of water vapor in the air directly into ice or the chance of ice directly into water vapor. Chemists, and sometimes meteorologists, refer to the vapor to solid phase change as "deposition."

Wet bulb temperature: The lowest temperature that can be obtained by evaporating water into the air at constant pressure. The name comes from the technique of putting a wet cloth over the bulb of a mercury thermometer and then blowing air over the cloth until the water evaporates. Since evaporation takes up heat, the thermometer will cool to a lower temperature than a thermometer with a dry bulb at the same time and place. Wet bulb temperatures can be used along with the dry bulb temperature to calculate dew point or relative humidity

TUCSON'S WATER BUDGET (in acre-feet per year)



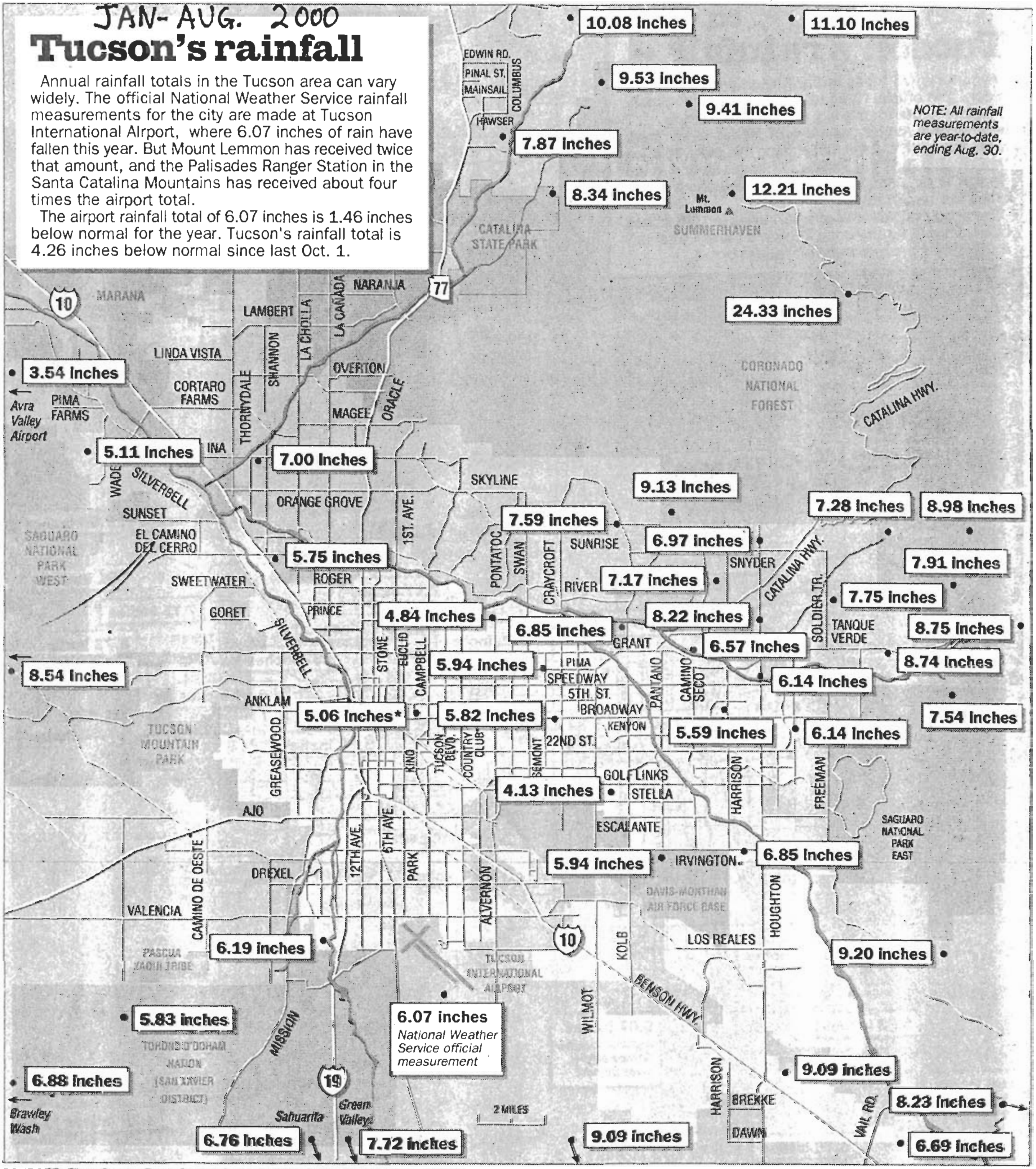
Arizona Daily Star, 3 Sept. 2000

JAN-AUG. 2000

Tucson's rainfall

Annual rainfall totals in the Tucson area can vary widely. The official National Weather Service rainfall measurements for the city are made at Tucson International Airport, where 6.07 inches of rain have fallen this year. But Mount Lemmon has received twice that amount, and the Palisades Ranger Station in the Santa Catalina Mountains has received about four times the airport total.

The airport rainfall total of 6.07 inches is 1.46 inches below normal for the year. Tucson's rainfall total is 4.26 inches below normal since last Oct. 1.



SOURCES: Pima County Flood Control District; National Weather Service, staff research by Johanna Eubank

*U.A. Coop Weather Station measurement

Warren Huskey / Staff