CENTRAL ARIZONA SALINITY STUDY --- PHASE I

Technical Appendix R

Evaluation of fertilizer use and associated salt contributions to Central Arizona Project Area

The following paper was prepared to provide rough estimates of fertilizer use in the Phoenix Metro area as well as to narratively discuss other possible salinity inputs to the Central Arizona area that should be considered in long-term salt balance projections.

Cropping Pattern

Table 1 lists the cropping pattern for the Phoenix Metro area.

Crop Type	Phoenix Agriculture	GRIC Agriculture
Cotton	69,900	3,443
Barley	11,200	406
Alfalfa (Hay)	55,280	2,975
Wheat	8,420	1,703
Corn	600	
Broccoli	4,000	
Cantaloupe	9,600	
Watermelon	3,900	408
Potatoes	6,500	
Head Lettuce		
Grapefruit	2,400	250
Oranges	4,600	700
Lemons	1,400	
Tangerine	3,200	
Onions	900	233
Olives		600
Cauliflower	300	
Carrots	1,800	
Honeydews	2,700	
Grapes	2,000	
Totals (acres)	**188,700**	**10,718**

Table 1. Phoenix Area cropping pattern

Fertilizer characteristics and properties

Although technically most fertilizers are nearly 100 percent salts, plants use most of the applied nutrient salts. These nutrient salts are removed by the crop or recycled in the soil. The salt index values of fertilizers are an effort by the fertilizer industry to rate the different fertilizers in relation to one another based on the amount of residual soluble salts contributed to the soils in addition to the primary nutrient salt used by plants. The salt index is based on the osmotic potential relative to Sodium Nitrate (salt index of 100). This data was developed by measuring the osmotic potential of the added fertilizer in planting beds. The main salinity hazard of the high salinity fertilizers is their use in bands near the seed row. Once the plants emerge and begin extending roots into the soil the salinity hazard from fertilizer is greatly reduced. From Table 3 it appears that a 500-pound application of ammonium sulfate (100 pounds of actual N) would contribute about 290 pounds of salt to the soil, while an application of anhydrous ammonia of about 123 pounds (also equal to 100 pounds of N) would only contribute about 48 pounds of soluble salt to the soil. These values are insignificant when compared to the salts applied in irrigation water. For example a four-foot annual application of 1000 mg/L salinity irrigation water would contain 10,880 pounds of salt. Eg: (1000ppm) (2.72 million pds/AF) (4AF) = 10,880 pds. Based on nutrient removal rates of crops listed in Table 4 compared to the fertilizer application rates listed in Table 4, it would appear that nutrient removal by crops would generally exceed and offset any salts applied in fertilizers. Removal of salts by crop plants probably ranges from about 200 - 600 pounds per acre, or about 3 percent of the harvested dry crop weight[3] removed from the field. Large portions of these salts are macronutrients that are added in fertilizers. Aside from the direct salinity inputs of fertilizer materials, there is a secondary influence on soil salinity, especially in soils containing residual carbonates such as the soils in the CAP area. Most fertilizer materials are acid forming. These acid forming constituents dissolve and combine with the residual calcium carbonate in the soil to form soluble salts. This is generally beneficial for exchangeable sodium reduction and the improvement of soil physical properties. However the soluble calcium salts do add to the salinity of the soil and groundwater. The acid forming potential of some common fertilizer materials is listed in Table 2.

Fertilizer	**Pds of CaCo3 dissolved in Neutralization process (100 pds bulk)**
Ammonium sulfate	110
Ammonium nitrate	62
Anhydrous ammonia	147
Uran	57
Super phosphate	0
Ammonium phosphate sulfate	88
Mono ammonium phosphate	58

Table 2 Acid forming potential of fertilizer components

The most common fertilizers used in the western states and their respective salt index values are presented on Table 3. Mixed fertilizers were evaluated based on the salt index of ammonium phosphate and of potassium chloride. A salt content value of 2.1 pounds of salt per pound of nitrogen and 0.1 pd per pound of phosphorous (P_20_5) and 0.77 pounds per pound of K_20 was used for mixed fertilizers.

		Pounds of salt per	
Fertilizer	**Salt Index**	**100 pds bulk fertilizer**	**pd of Nutrient**
Anhydrous ammonia 82-0-0	47.1	39.6	0.48
Ammonium nitrate 34-0-0	104.7	87.9	2.59
Ammonium phosphate 11-48-0	26.9	22.6	0.38
Ammonium sulfate 21-0-0	69.0	58.0	2.76
Calcium Nitrate 15.5-0-0	52.5	44.1	2.85
Ammonium, phos. Sulfate 16-20-0	48.0	30.7	0.85
Diammonium phosphate 16-48-0	29.9	25.1	0.39
Super phosphate 0–16-0	7.8	6.5	0.41
Super phosphate 0-48-0	10.1	8.5	0.18
Manure salts 20%	112.7	94.1	4.70
Sodium nitrate 16-0-0	100.0	84	5.25
Urea 46-0-0	75.4	63.3	1.38
Urea- am. nitrate sol. 32-0-0 (1)	66.4	42.4	1.32
Potassium chloride 0-0-60	116.3	46.5	0.77

(1) Liquid solution 11.2 pounds per gallon 1.33 sp gravity

Table 3 Fertilizer salt index values

Salts in soil amendments

Large applications of gypsum, sewage sludge, and manure and other materials are sometimes applied to agricultural lands. Gypsum applications on newly irrigated sodic soils can sometimes exceed 10 tons per acre. Gypsum application rates on most newly developed lands using CAP water can be reduced because Colorado River water contains significant soluble calcium. Sulfuric acid is the current soil amendment of choice in CAP irrigated lands. Chemical reactions and cation exchange processes that occur following application of these amendments generally liberates large quantities of calcium and sodium salts. Calcium and sodium salts are probably imported with the water into the area. Each amendment listed below would result in ten tons of soluble salts. Probably less than 10 percent of the land in the basin will require these amendments, including some lands planned for development on the Gila River Reservation.

Soil amendments	Typical application rates required on newly developed lands
Gypsum	10 tons per acre
Sulfuric acid	6 tons acre
Sulfur	2 tons acre

Table 4 Application rates of Soil Amendments

Manure applications of 10 tons per acre are generally considered an agronomic rate that would supply a crop with most of its nutrient needs. Sewage sludge application rates vary depending on heavy metal and nutrient content, but probably average about 5 tons per acre. Although these materials contain significant salts, the salts probably originate and are recycled in the survey area and thus should not be considered in the long-term salt balance.

Amendment	**Typical application rate/ acre**
Steer manure	10 tons
Dairy manure	10 tons
Sewage sludge	5 tons

Table 5 Manure Application rates

Plant food utilization

Plant food utilization is typically higher than fertilizer applications since soils typically contain a reserve of nutrient elements. For example desert soils such as those in the survey area are sometimes well supplied with native phosphorous and potassium but are typically low in nitrogen. These soil reserves may become depleted after many years of continuous cropping and additional fertilizers will need to be added. For example, a crop of alfalfa uses over 1000 pounds of nutrient elements, nearly all of which is removed from the field in the crop. Because the alfalfa is able to fix nitrogen from the atmosphere, little nitrogen is needed for this crop. Data from the University of Arizona Extension Service indicates that typical soils irrigated with CAP water are well supplied with potassium (K) and phosphorous (P). Alfalfa does respond to phosphorous fertilization in many areas of the west and also requires a great deal of potassium. It is predicted that in future years additional P and K will be added in fertilizers as native reserves of these elements are depleted.

Crop	Yield	Pounds per Acre			
		N	P_2O_5	K_2O	Source
Barley	2.5 tons	175	65	175	1
Cotton	1500 pounds	210	90	150	1
Wheat	3.0 Tons	175	80	140	1
Alfalfa	8.0 tons	450	80	480	1
Corn	5 tons	240	100	230	1
Cantaloupes	30 tons	190	60	340	1
Potatoes	500 cwt	250	115	355	1
Broccoli	18000 lbs	80	30	75	1
Oranges	30 tons	120	40	175	1
Grapes	15 tons	105	45	125	1
Carrots	20 tons	92	28	84	2
Lettuce	21 tons	95	28	208	2
Cantaloupe	7.25 tons	30	12	62	2
Onions	12.5 tons	53	26	64	2
Potatoes	18 tons	120	30	200	2
Tomatoes	15 tons	93	24	130	2
Cauliflower	13 tons	72	24	50	2
Broccoli	6 tons	60	20	50	2
Cabbage	15 tons	100	25	100	2

1 Western Fertilizer handbook (1), total crop use.
2 Vegetables growers' handbook (2), Nutrients removed in harvested portion of crop.

Table 6 Plant food utilization by crop

The data listed in Table 7 are based on crop budgets from the University of Arizona Extension Service. Data for citrus is based mostly on oranges since that is the dominant citrus crop in the area.

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Crop	Yield Per Acre	Nitrogen pds/acre	P_2O_5 pds/acre	K_2O pds/acre	Net Salt pds/ acre	Bulk Fert.
Cotton	1227 pounds	150	0	0	206	326
Barley	4600 pounds	167	50	0	291	653
Alfalfa	8 tons	0	0	0	0	0
Wheat	5600 pds/ acre	182	50	0	230	628
Corn	8400 pds/ acre	341	90	0	223	660
Broccoli	597 cwt	151	158	23	238	786
Cantaloupe	260 cwt	371	126	15	546	1500
Watermelon	16.3 tons	189	115	0	225	608
Potatoes	291 cwt	150	184	0	346	824
Head lettuce	212 cartons	192	156	0	281	804
Citrus	30 tons	160	40	0	231	600
Olives	10 tons	160	40	0	231	600
Onions	928 sacks	252	212	0	375	1072
Cauliflower	816 cwt	197	208	0	524	894
Carrots	1046 car	154	60	0	235	636
Honeydews	638 cart	158	126	15	265	854
Grapes	15 tons	140	40	0	204	557
Lawns	na	100	40	40	245	543

Data from the University of Arizona Extension Service

Table 7 Fertilizer application rates

<u>Lawn fertilization</u>

Lawn areas do not require much fertilizer if the grass clippings are returned to the soil. However, since homeowner lawn management varies greatly, the fertilizer requirements for lawn areas presented below are based on good management practices. The following fertilizer application is assumed based on recommended values from various sources.

Spring	Weed and feed	26-3-3
Summer	ammonium sulfate	21-0-0
Fall	balanced fertilizer	12-12-12
Winter	winterizer	16-4-8

Lawn areas per acre 100pds N 40 pds P_2O_5 40 pds K_2O

Salt values:
Non nutrient salinity 245 pounds/ acre
Total Weight of fertilizer 543 pounds/ acre

Other sources of salts

Irrigated agriculture can lead to three primary avenues of salt pick up from the calcareous arid soils in the survey area.

1. Native, nonirrigated soils such as those on the Gila River Indian Community farms sometimes contain a large quantity of residual salt. During the first few years of irrigation a large portion of this salt will be dissolved and leached into the substrata and vadose zone. Eventually these salts will reach the groundwater. The top 10 feet of soil in some of the more saline arable lands contain about 1 percent soluble salts, or about half a million pounds of salt per acre. Although these soils are reclaimable, at least 50 percent of these salts will be leached from the soil during the agricultural development period.

2. Many fertilizer materials are acid forming. In the arid climate of the study area nearly all soils are calcareous and contain large quantities of residual carbonates (lime). The addition of acid forming fertilizers can solublize these salts. While this may be beneficial for short-term sodic soil remediation, it does tend to add to the long-term salt problem in the basin. For example: A grower decides to use ammonium sulfate to supply his nitrogen needs, which are 100 pounds of actual nitrogen per acre. This would require 476 pounds of bulk fertilizer. Based on Table 3, he is adding about 276 pounds of salt directly. However, the acid forming component of the fertilizer will also dissolve the equivalent of about 524 pounds of calcium carbonate from the soil. Generally the reaction by-products would be carbon dioxide, and soluble calcium sulfate. Calcium sulfate is only sparingly soluble, but the dissolved calcium will exchange with other cations on the exchange complex and liberate other soluble cations into the soil solution.

3. Chemical weathering of soil minerals generally accelerates following irrigation. Carbonates and gypsum are the primary minerals, but weathering of silicates and other minerals can also occur. Generally, the greater the deep percolation volume the greater the weathering. When a leaching fraction of over 25 percent is considered there is a net increase of drainage water salts at the bottom of the soil root zone[(3)]. At leaching fractions of less than 25 percent there is generally a net loss of salts in the drainage water at the bottom of the root zone due to precipitation of salts from the soil solution[(3)].

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Summary Crop	Fertilizer net salt inputs million pounds	Total weight of fertilizer million pounds
Cotton	14.4	22.8
Barley	3.3	7.3
Alfalfa	0.0	0.0
Wheat	1.94	5.3
Corn	0.13	0.4
Broccoli	0.95	3.14
Cantaloupe	5.24	14.40
Watermelon	0.88	2.37
Potatoes	2.25	5.36
Citrus	2.70	6.96
Onions	0.34	0.96
Cauliflower	0.16	0.27
Carrots	0.42	1.14
Honeydews	0.72	2.31
Grapes	0.41	1.11
Totals	**33.84**	**73.82**

Gila River Indian Community (GRIC) Crop		
Cotton	0.71	1.12
Barley	0.12	0.27
Alfalfa	0	0
Wheat	0.39	1.07
Watermelon	0.09	0.25
Citrus	0.22	0.57
Onions	0.09	0.25
Olives	0.14	0.36
Total	**1.76**	**3.89**

Table 8 Salts added to crops via fertilizers in Phoenix Metro area and GRIC

Results

Based on data presented in this paper, my estimate of salt inputs into the Phoenix area is presented below:

Salts imported in fertilizers non-nutrients to crops	35.60 million pounds/ year
Lawns	245-pounds/acre/ year

References

(1) Western Fertilizer Handbook, California Fertilizer Association, 1973, copyright 1975.
(2) Handbook for Vegetable Growers, J. E. Knott, 1957, University of California, Davis.
(3) Agricultural Salinity Assessment and Management ASCE manuals and Reports on Engineering Practice No. 71, Kenneth K. Tanji, editor, 1990