Dissolved Salts, Drainage, Desalting, and Discharge

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Irrigated agriculture requires discharge of drainage water

Irrigation in arid or semi-arid regions always degrades water quality. Without proper management, the land becomes waterlogged and salinized. With or without good management, drainage water from irrigated lands carries salt that requires disposal.

All irrigation enterprises face problems of salinity management. All must consider the safe disposal of wastewater. Some have failed. Others have withstood the pressures for remarkably long periods of time.

Jan van Schilfgaarde in *Agricultural Salinity Assessment and Management*, 1990, p. 584-5.

Water diversion projects built without external discharge

- **Imperial Valley & the Salton Sea, CA**
  - Salton Sea restoration studies underway
- **Wellton-Mohawk, AZ**
  - Built bypass canal to Santa Clara Wetlands next to Gulf of California
  - Built Yuma Desalting Plant
- **San Joaquin Valley & Kesterson Reservoir, CA**
  - External discharge authorized but not built
  - Bulldozed Kesterson Reservoir & created on-farm ponds
  - Evaluation of brackish water disposal continues
- **Central Arizona Project, AZ**
  - External discharge authorized but not built
  - Started Central Arizona Salinity Study in 2001

Questions

What are the annual water costs to irrigate and discharge drainage from an acre of land?

1. How do dissolved salts affect the irrigation requirement?
2. How do dissolved salts affect the drainage flow?
3. Where does the drainage water go?
    - a. When will brackish groundwater surface?
    - b. When the aquifer fills up with drainage water, where can we discharge it?
4. What are some possible discharge solutions and who is evaluating them?

Water cost equations

What are the water costs to irrigate and discharge drainage from an acre of land?

Water cost equations

1. Annual water cost per acre without desalting

$$= Cost_{supply} \times Q_{supply} + Cost_{discharge} \times Q_{discharge}$$

2. Annual water cost per acre with desalting

$$= Cost_{supply} \times Q_{supply}$$
$$+ (Cost_{desalting} - Value_{desalting}) \times Q_{desalting}$$
$$+ Cost_{discharge} \times Q_{discharge}$$

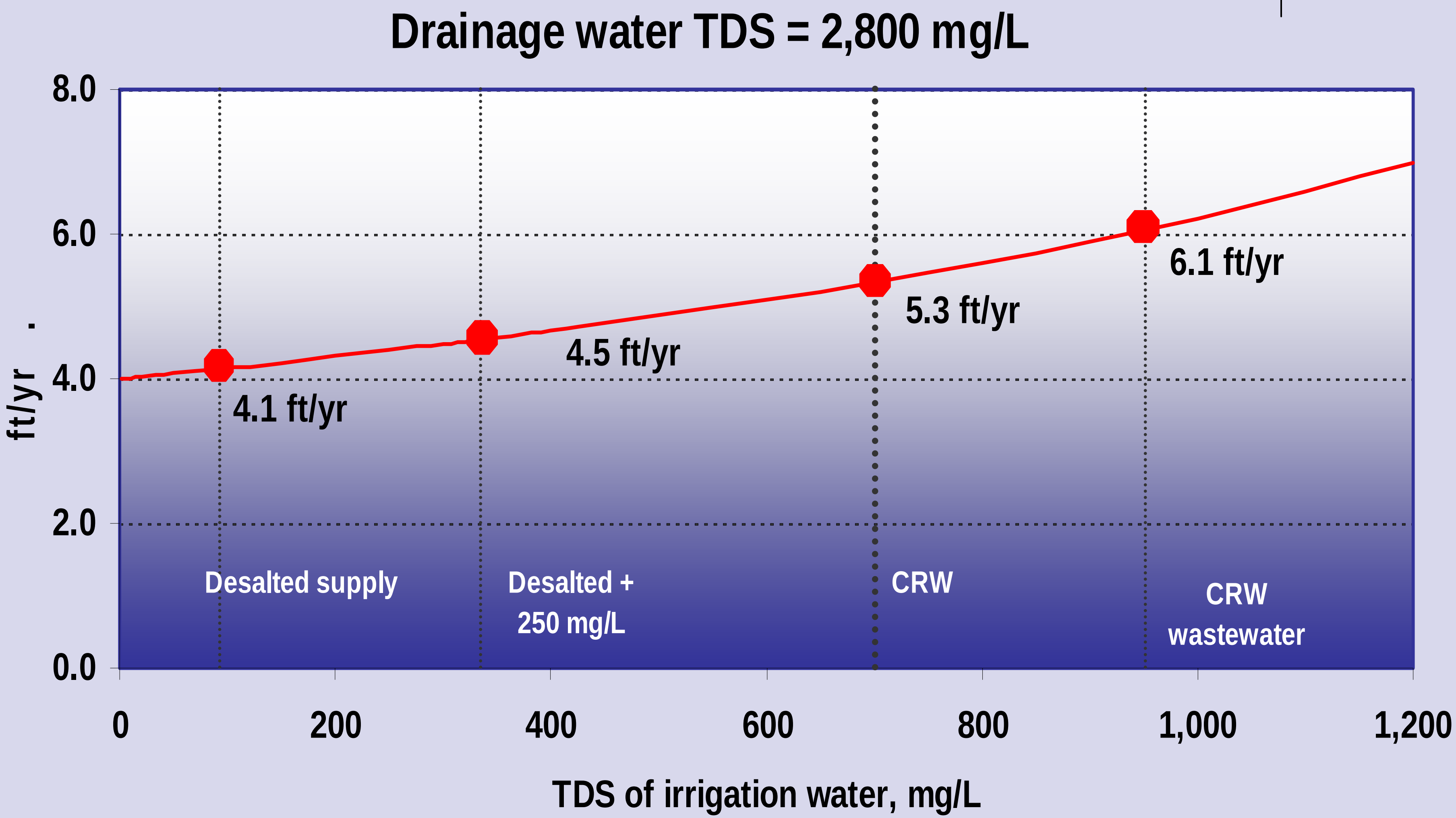
Detrimental effects of dissolved salts (TDS) on irrigation

1. May reduce crop yield
2. May limit use of sprinkler irrigation
3. May require more frequent irrigation
4. May require change of crops
5. Increases irrigation equipment capital and maintenance costs
6. **Requires more irrigation water (Q_{supply})**
7. **Produces more brackish water drainage ($Q_{drainage} = Q_{discharge}$ in eq. 1)**

Water cost equations: Q_{supply}

1. How do dissolved salts affect the irrigation requirement?

Dissolved salts require more irrigation water (Q_{supply})



Estimating irrigation requirement from TDS levels

Irrigation requirement, Q_{supply}

$$= \frac{Q_{evap} \times TDS_{drainage}}{(TDS_{drainage} - TDS_{supply})}$$

Example with 700 mg/L TDS water supply,

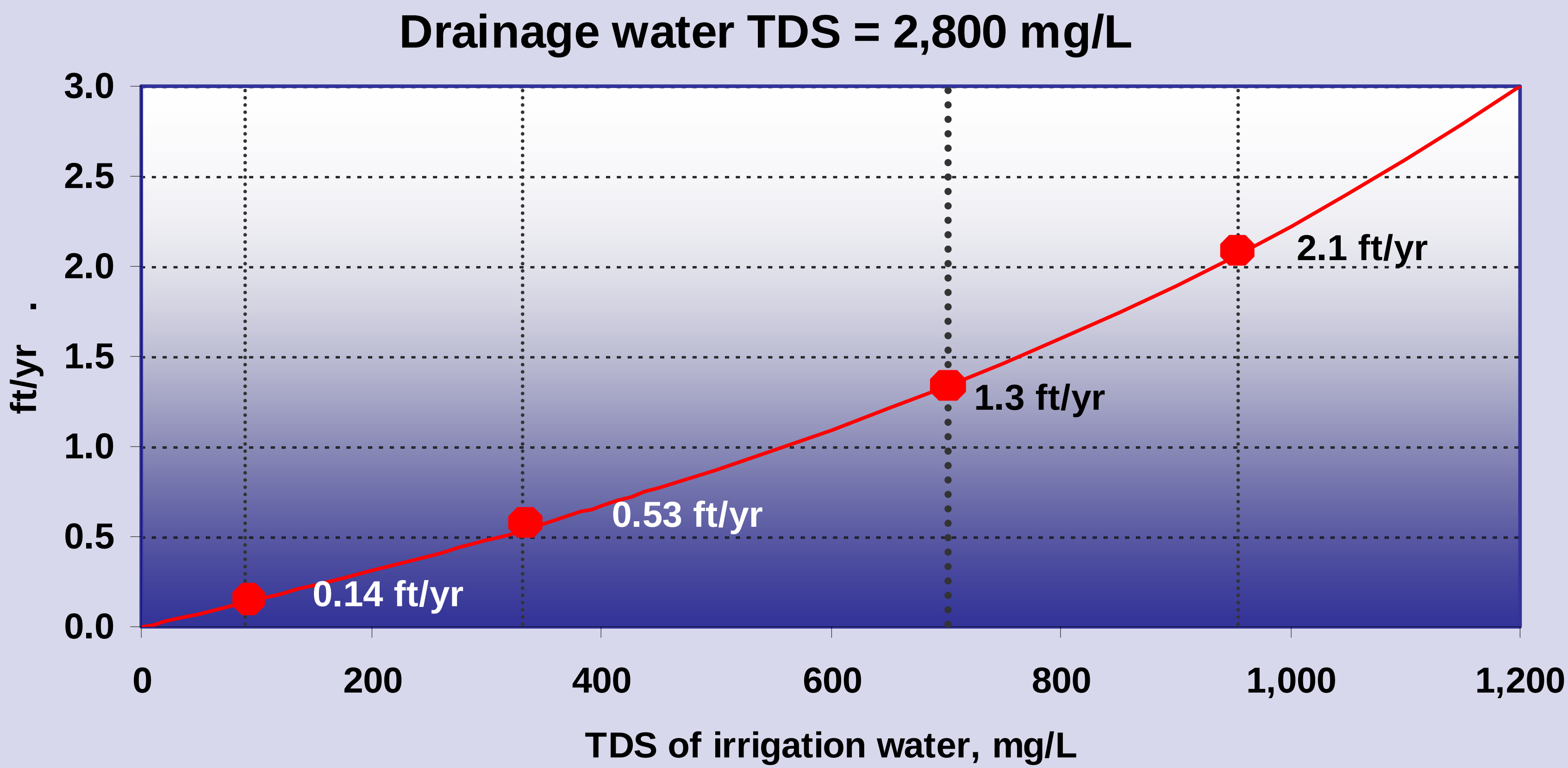
$$= \frac{4 \text{ ft/yr} \times 2{,}800 \text{ mg/L}}{(2{,}800 \text{ mg/L} - 700 \text{ mg/L})}$$

= 5.33 ft/yr

Water cost equations: $Q_{drainage}$

2. How do dissolved salts affect the drainage flow?

Salts in water produce more drainage water ($Q_{drainage}$)



Estimating drainage flow from TDS levels

Drainage flow, $Q_{drainage}$

$$= \frac{Q_{evap} \times TDS_{supply}}{(TDS_{drainage} - TDS_{supply})}$$

Example with 700 mg/L water supply,

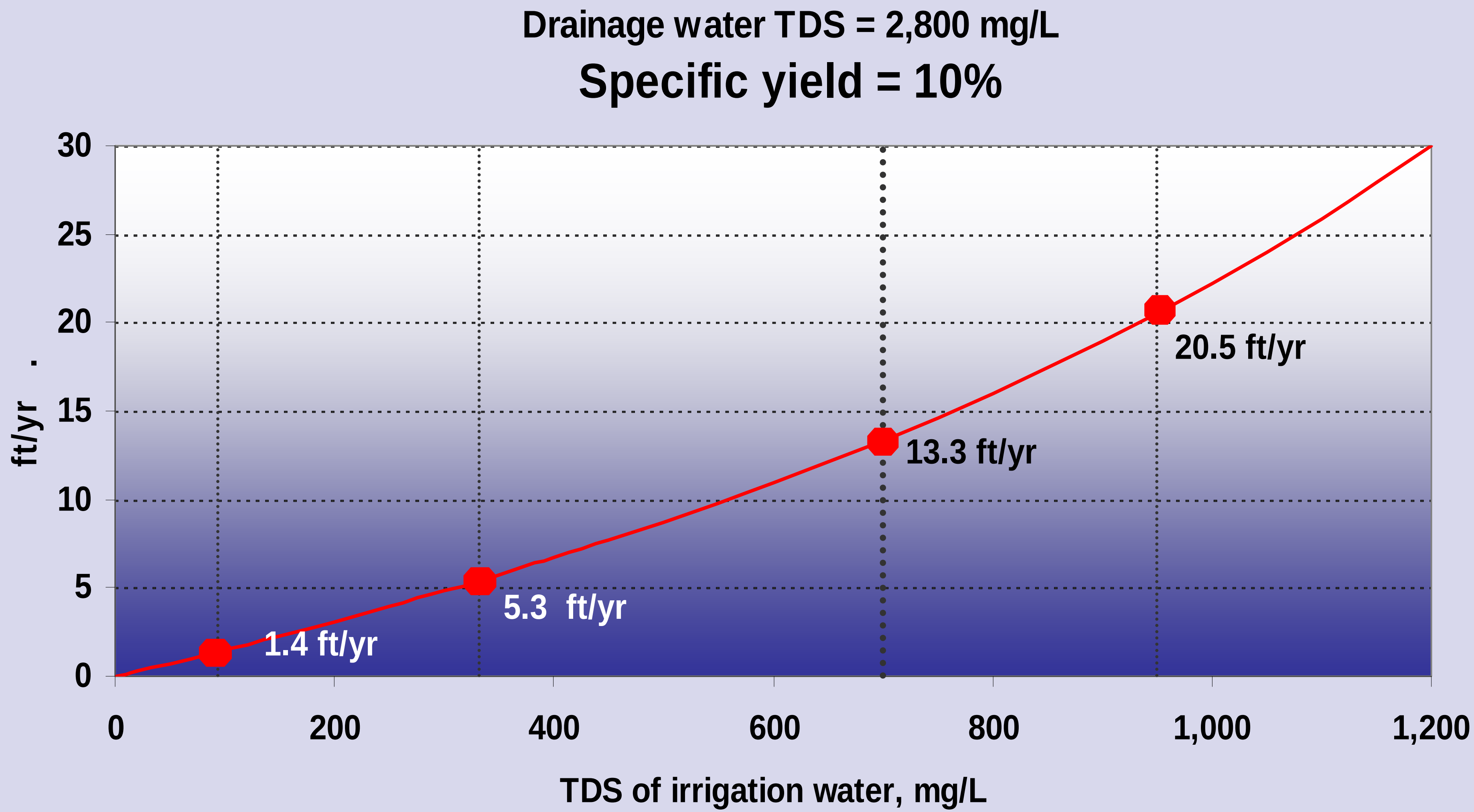
$$= \frac{4 \text{ ft/yr} \times 700 \text{ mg/L}}{(2{,}800 \text{ mg/L} - 700 \text{ mg/L})}$$

$$= 1.33 \text{ ft/yr}$$

Water cost equations: $Q_{drainage}$

3. Where does the drainage water go?

Drainage causes the groundwater table to rise



Estimating groundwater rise rate (v)

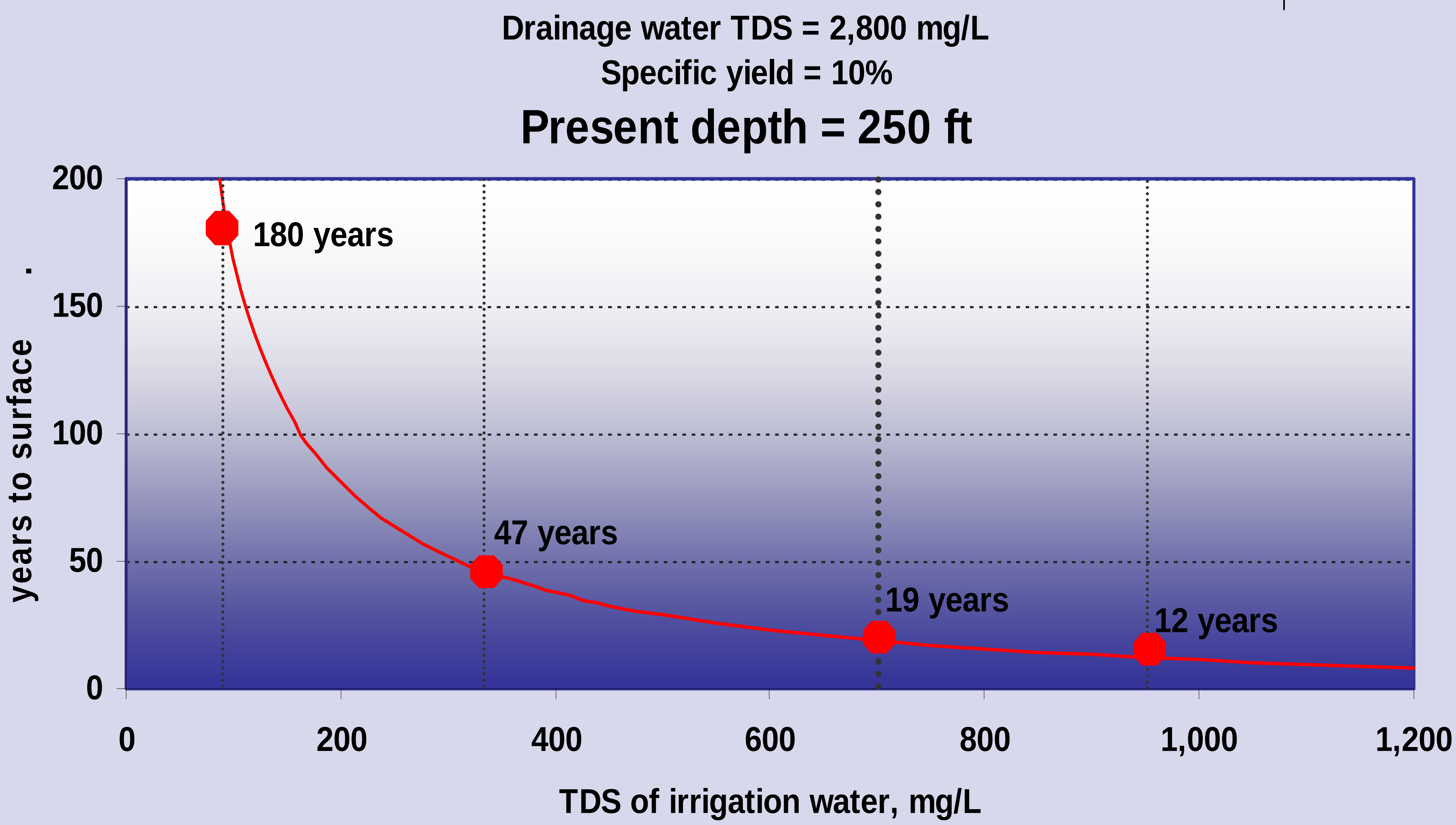
$v = Q_{drainage}$ / specific yield

Example with 700 mg/L TDS water supply,

v = 1.33 ft/yr / 0.10

= 13.3 ft/yr

When will brackish groundwater surface?



Groundwater rises to the the soil surface

Without drainage or pumping, time for groundwater to rise to the surface can be estimated by:

$t = \text{depth} / v$

Example with 700 mg/L TDS water supply,

$t = 250 \text{ ft} / 13.3 \text{ ft/yr}$

$= 19 \text{ years}$

Salts in irrigation water cause groundwater to surface sooner

$$t = \frac{\text{depth} \times \text{specific yield} \times (TDS_{drainage} - TDS_{supply})}{Q_{evap} \times TDS_{supply}}$$

Example with 700 mg/L TDS water supply,

$$t = \frac{250 \text{ ft} \times 0.10 \times (2{,}800 \text{ mg/L} - 700 \text{ mg/L})}{4 \text{ ft/yr} \times 700 \text{ mg/L}}$$

= 19 years

Surfacing groundwater: problems and solutions

Problem 1: Rising "salty" water degrades existing shallow drinking water wells

- Solution: Drill deeper wells, drill new wells, purchase bottled water, or connect to city water supply

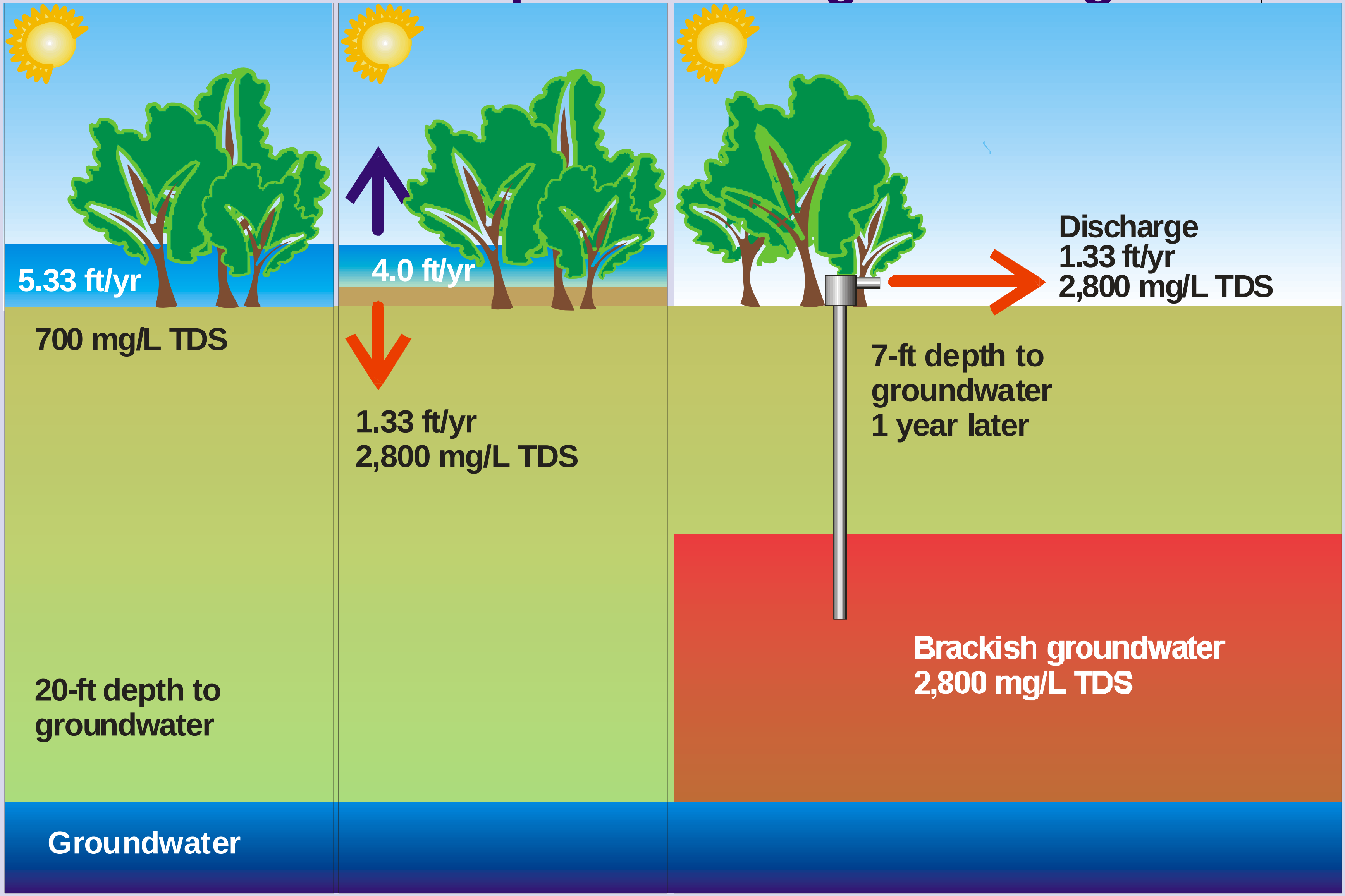
Problems 2 & 3: Soil waterlogs & evaporating water leaves behind solid salts on soil surface

- Solution: Install drainage with subsurface gravity drains or pumped wells

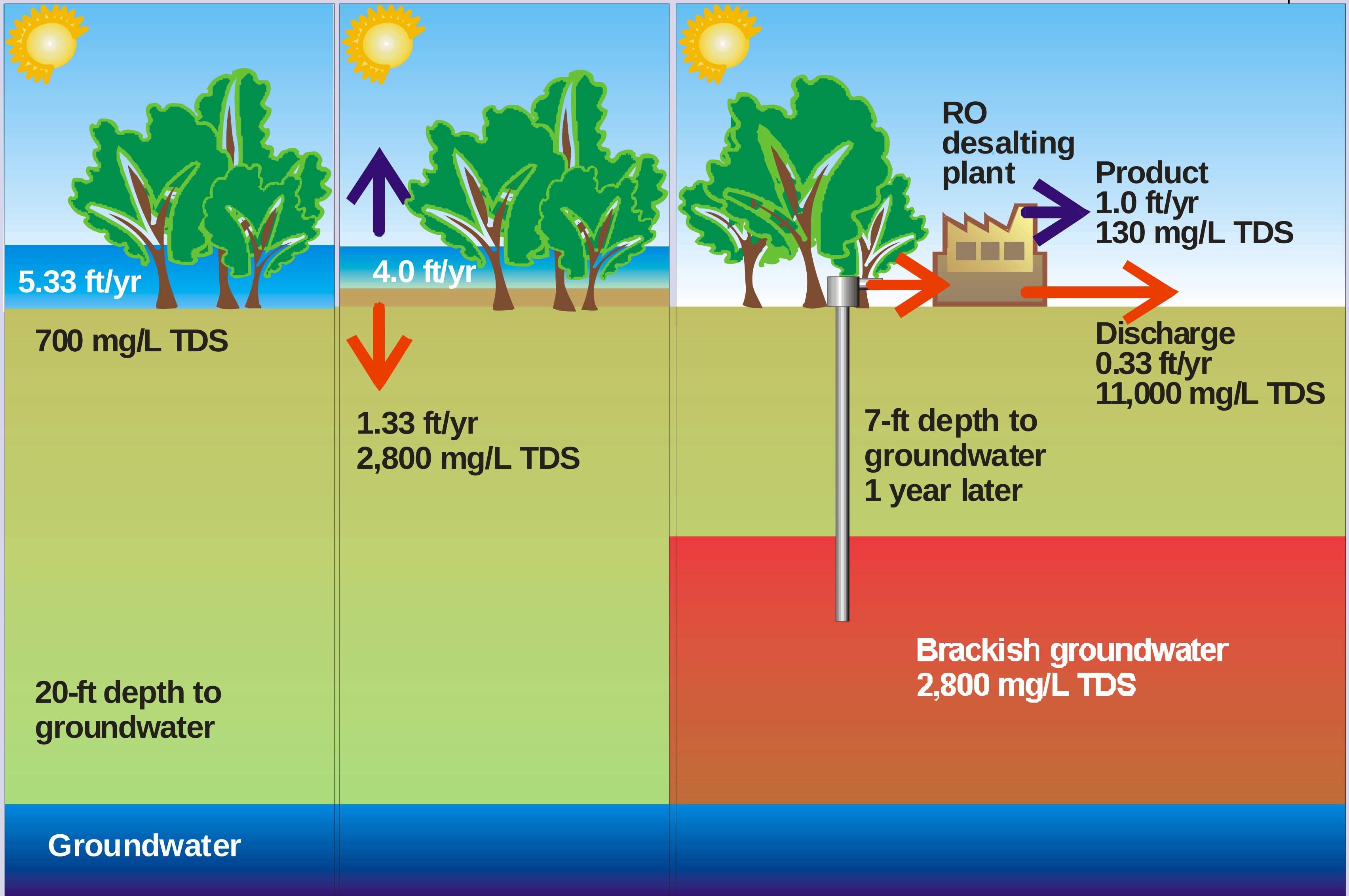
Central Arizona will soon have problems with high groundwater & costly discharge options

4. What are some possible discharge solutions and who is evaluating them?

Solution 1. Pump & discharge drainage



Solution 2. Pump & desalt drainage water. Discharge desalting plant concentrate.



For solution 2, desalting costing about $230/acre-foot

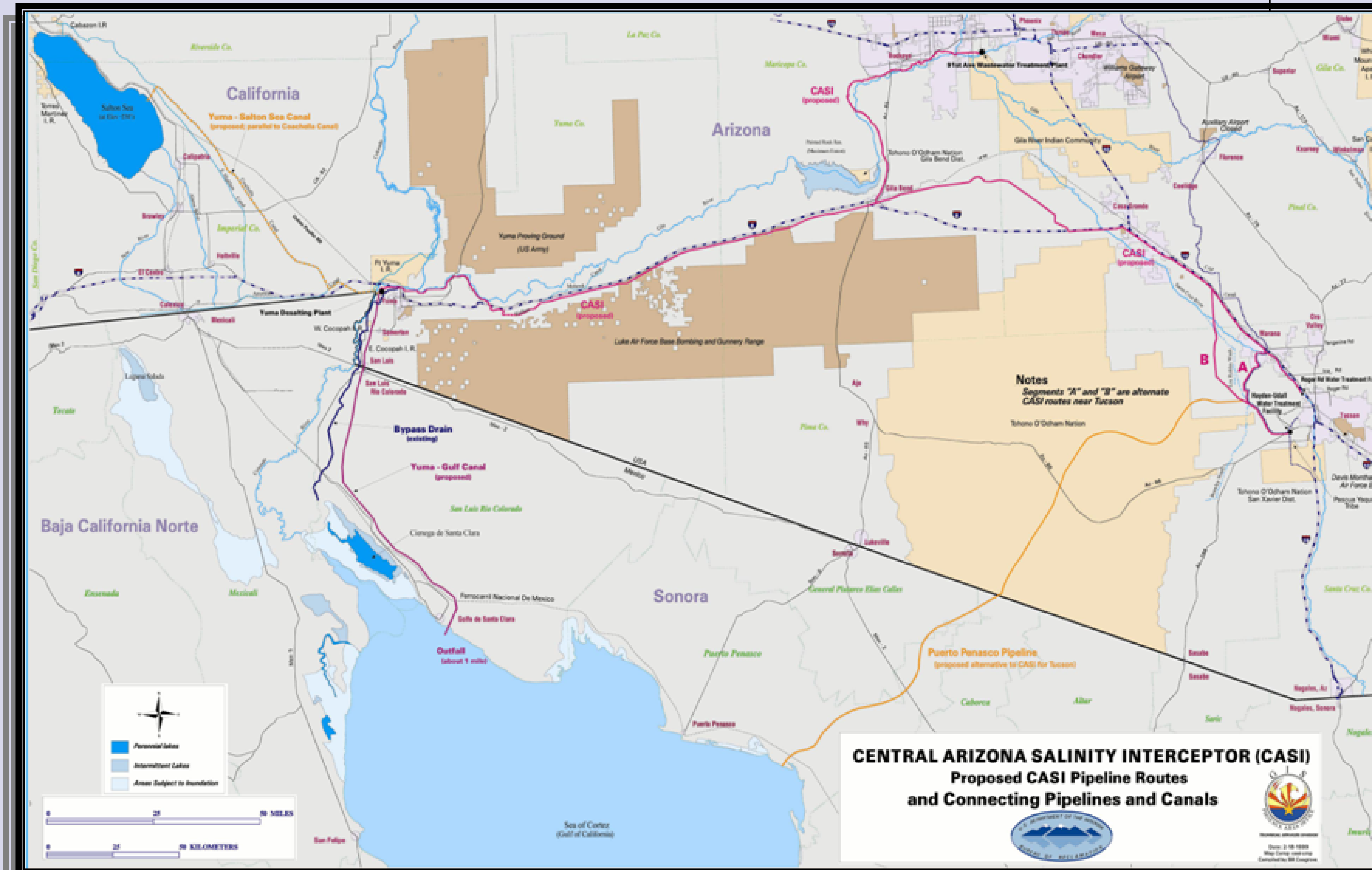
- Converts brackish water to fresh drinking water
- Reduces the discharge volume

Because drainage water has been “soil-filtered,” little or no additional filtering is needed prior to desalting by reverse osmosis

For both solutions, where could we discharge?

- Evaporation ponds
- Halophyte irrigation (& discharge)
- Deep well injection
- Evaporator/crystallizers
- Saltwater wetlands or reservoir (& discharge)
- Pipeline to ocean

One discharge alternative: Pipeline to ocean



Who is evaluating desalting and discharge alternatives?

- Desalting studies
  - USBR and several Arizona & California water providers, both on-site & at the USBR Water Quality Improvement Center in Yuma AZ
- Central Arizona discharge alternatives
  - USBR & Cities of Phoenix, Tempe, Glendale, Mesa, and Scottsdale initiated the Central Arizona Salinity Study (CASS)

Solving the water cost equations

What are the annual water costs to irrigate and discharge drainage from an acre of land?

1. Cost equation without desalting

Annual water cost per acre

$$= Cost_{supply} \times Q_{supply} + Cost_{discharge} \times Q_{discharge}$$

Example with a low salinity supply TDS_{supply} = 0 mg/L

Cost = $36/af x 4 ft/yr + $0 for discharge

= $144/acre

Example with CAP water TDS_{supply} = 700 mg/L

Cost = $36/af x 5.33 af/yr + $240/af x 1.33 af/yr

= $192/yr + $320/yr

= $512/yr

2. Cost equation with desalting

Annual water cost per acre

$$= Cost_{supply} \times Q_{supply}$$
$$+ (Cost_{desalting} – Value_{desalting}) \times Q_{desalting}$$
$$+ Cost_{discharge} \times Q_{discharge}$$

Example with TDS_{supply} = 700 mg/L

Cost = \$36/af x 5.33 af/yr

+ [\$230/af – (\$109/af + \$190/af)] x 1.0 af/yr

+ \$240/af x 0.33 af/yr

= \$192/yr - \$69/yr + \$80/yr

= \$203/yr

For Central Arizona

- **What are the estimated annual water costs to irrigate and discharge drainage from an acre of land?**

With low-TDS supply …………… $144

With 700-mg/L TDS CAP water

Now……………………………….. $192

In about 20 years (in 2003 dollars)

Without desalting …………. $512 approx.

With desalting ……….......... $203 approx.

Present challenge for Central Arizona

Within about 20 years, we face the challenge of finding and implementing an effective and economical way to discharge brackish waters from agriculture, cities, and desalting plants.

The Central Arizona Salinity Study, initiated in 2001 by the Bureau of Reclamation and the Cities of Phoenix, Tempe, Glendale, Mesa, and Scottsdale will evaluate discharge alternatives.