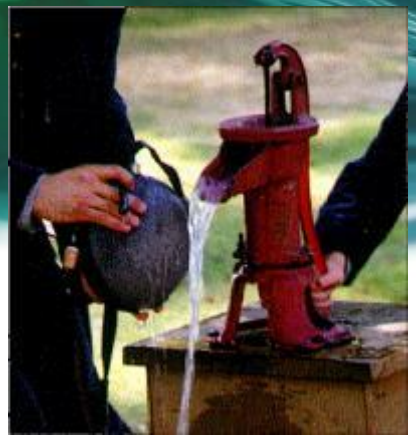
WATER EDUCATION FOUNDATION

Groundwater Tour:

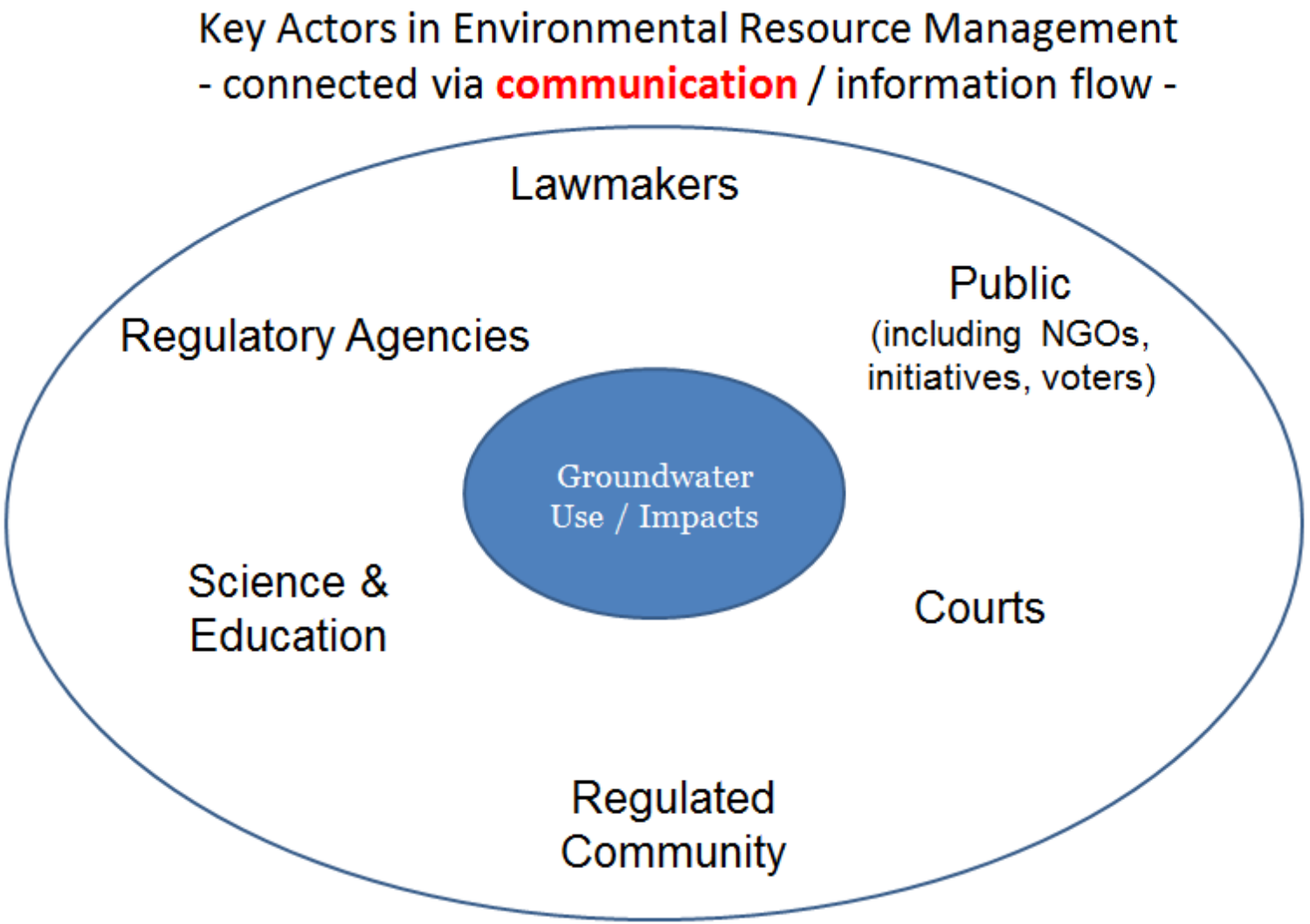
Groundwater Quality & Contaminants



Thomas Harter,
University of California, Davis

ThHarter@ucdavis.edu
http://groundwater.ucdavis.edu

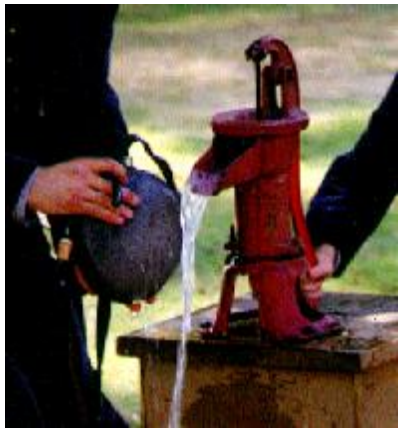
Why you are on this groundwater tour!



Groundwater Quality and Transport - Overview

- What is and what makes groundwater quality?
- What are key groundwater quality parameters?
- What is "natural" groundwater quality?
- What are key groundwater contaminants of interest and what are their sources?
- What is the contaminant transport and fate in groundwater?
- How do we measure groundwater quality in the field?
- How do we regulate groundwater quality?

What is Groundwater Quality?



Water Quality = Composition of Water

PHYSICAL
CHEMICAL
BIOLOGICAL
RADIOLOGICAL

What Makes Groundwater Quality?

SOIL / STREAMBED

↓

SEEPAGE

http://ngm.typepad.com/photos/uncategorized/2008/01/02/0103_08.jpg

↓

GROUNDWATER QUALITY

↑

ROCK / SEDIMENT

What Makes Groundwater Quality?

POLLUTION

SOIL / STREAMBED

SEEPAGE

POLLUTION

http://ngm.typepad.com/photos/uncategorized/2008/01/02/0103_os.jpg

GROUNDWATER QUALITY

ROCK / SEDIMENT

Key Reasons to be Concerned about Water Quality

- Health risks
- Ecological impacts / ecosystem services (hypoxia)
- Industrial uses
- Aesthetics
- Agricultural uses (irrigation: salinity, boron, sodium, ….)
- Operation of water system
- Impact on aquifer properties (and land subsidence/land rise)

How do we characterize groundwater quality?

- PHYSICAL
  - temperature, turbidity (suspended sediments), color, taste, oder
- CHEMICAL
  - Inorganic constituents (salts, nutrients, trace elements including metals)
  - Organic constituents (TCE, PCE, benzene, pesticides, organic carbon,….)
- BIOLOGICAL
  - Pathogen indicator organisms (Coliform, *E. coli*, *Enterococcus*)
  - Pathogens
    - Protozoa (*Cryptosporidium parvum, Giardia lamblia*)
    - Bacteria (E*. coli O157*, *Salmonella, Campylobacter*)
    - Viruses
- RADIOLOGICAL
  - Radioactivity, e.g., gross alpha radiation

Natural Chemical Constituents of Groundwater

Major Constituents (1.0 - 1000 mg/l)	Secondary Constituents (0.01 - 10 mg/l)	Trace Constituents (0.0001 - 0.1 mg/l>	Trace Constituents (< 0.001 mg/l)
cations:		antimony	beryllium
		aluminum	bismuth
		arsenic	cerium
sodium	potassium	barium	cesium
calcium	iron	bromide	gallium
magnesium	strontium	cadmium	gold
		chromium	indium
anions:		cobalt	lanthanum
		copper	niobium
bicarbonate	carbonate	germanium	platinum
sulfate	nitrate	iodide	radium
chloride	fluoride	lead	ruthenium
silica	boron	lithium	scandium
		manganese	silver
		molybdenum	thallium
		nickel	thorium
		phosphate	tin
		rubidium	tungsten
		selenium	ytterbium
		titanium	yttrium
		uranium	zirconium
		vanadium	
		zinc	

Sum = TDS

(total dissolved solids concentration)

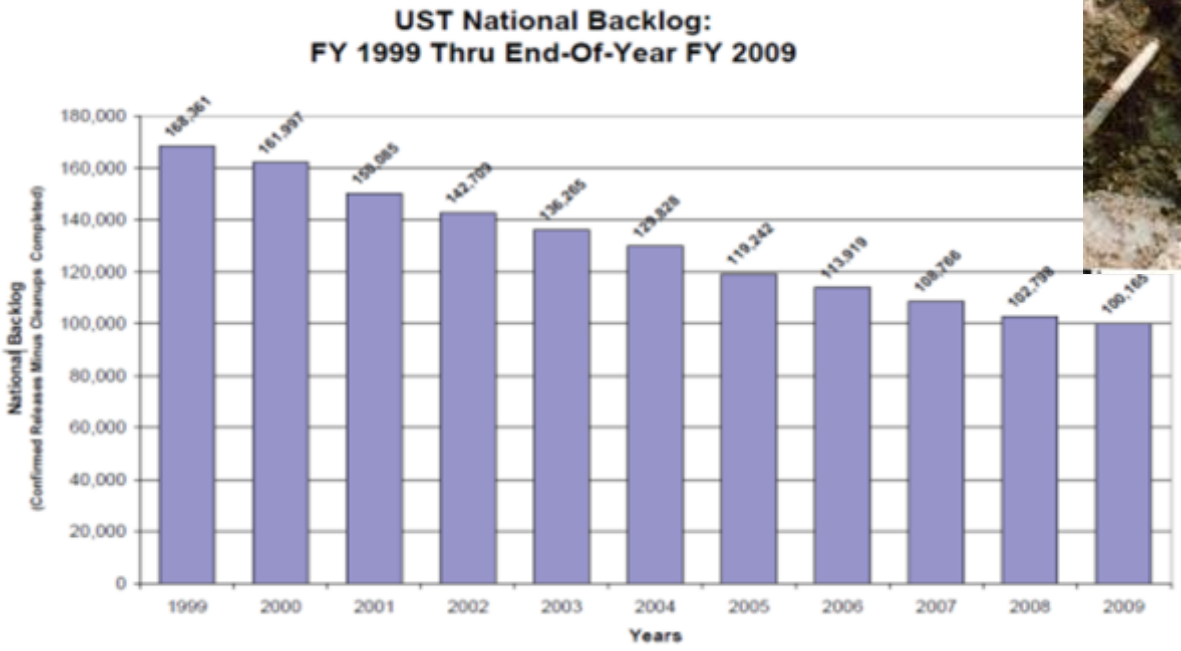
Groundwater Contamination – Common Sources

- Naturally occurring contamination
  - Cr^{6+} (hexavalent chromium)
  - As (arsenic)
  - Seawater intrusion
- Point Sources
  - Leaking underground storage tanks (gas stations)
  - Industrial spills
  - Landfills
  - Septic systems and leach fields
  - Sewer lines
  - Animal feedlots and manure lagoons
- Nonpoint Sources
  - Urban runoff
  - Agricultural activities

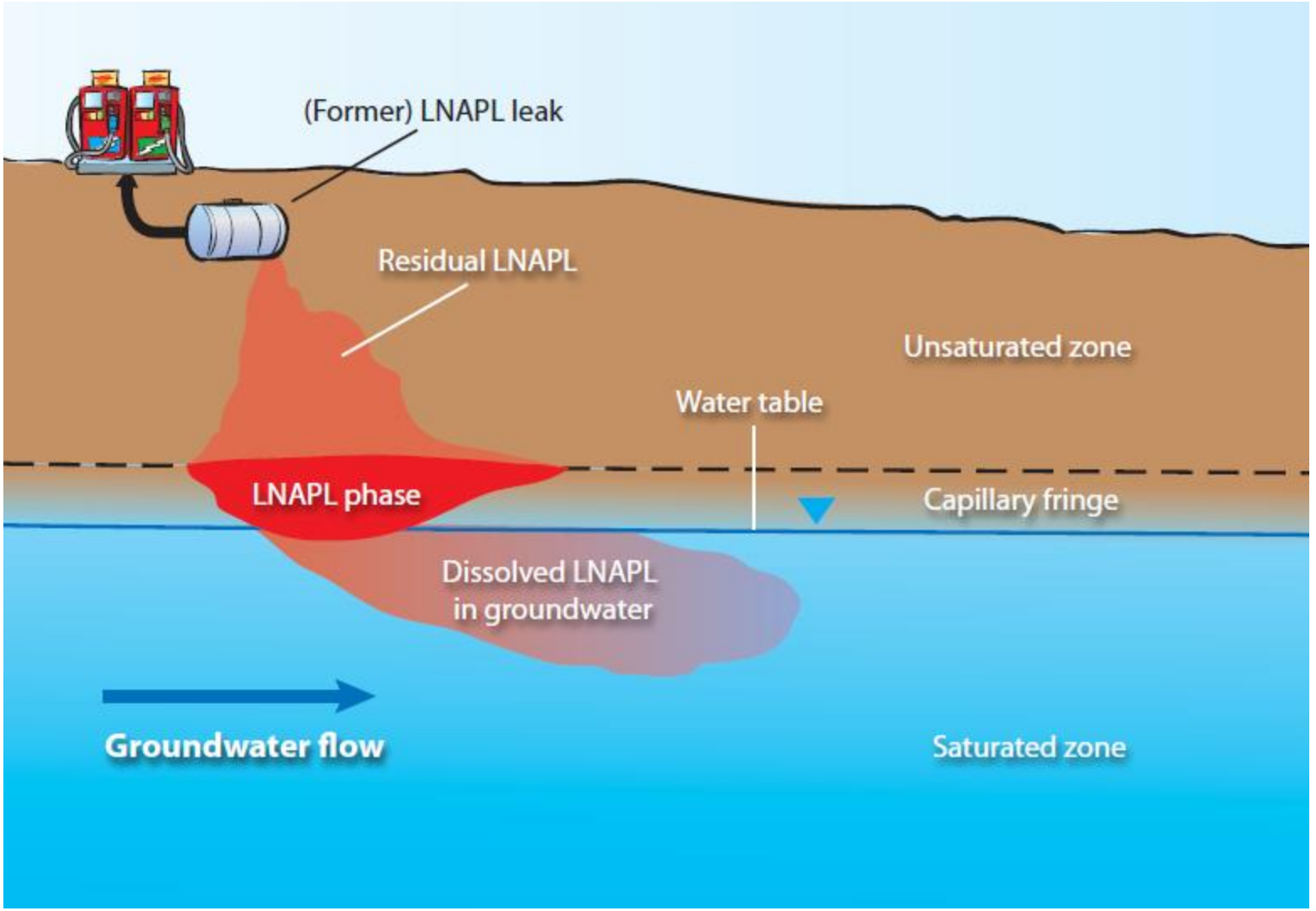
Leaking Underground Storage Tanks

non-aqueous phase liquids (NAPLs)

- Key pollutants: BTEX, MTBE
  - benzene, toluene, ethylbenzene, xylene
  - methyl tertiary buthyl ether

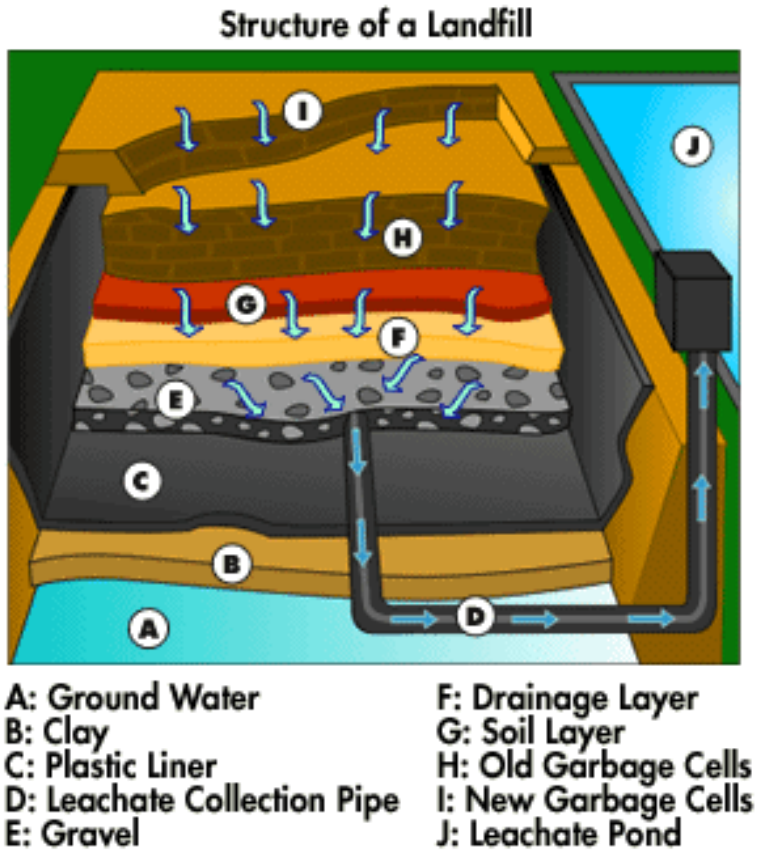


Organic Contaminants: LNAPLs (light NAPLs)



Landfills

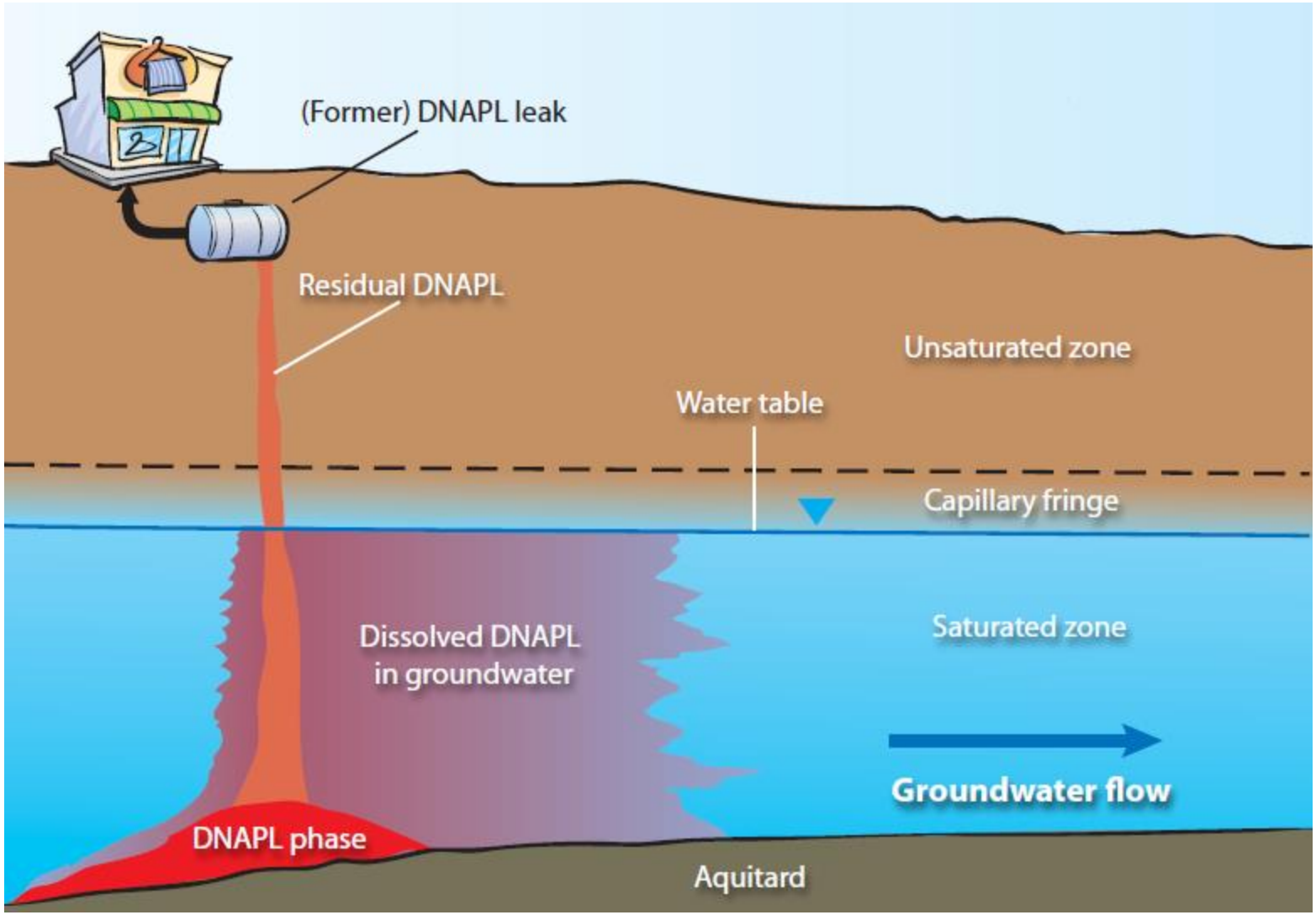
- Extensive regulatory control
  - Liners
  - Leachate collection system
- Contaminants include:
- Heavy metal
- Nitrate
- Organic compounds



Dry Cleaners

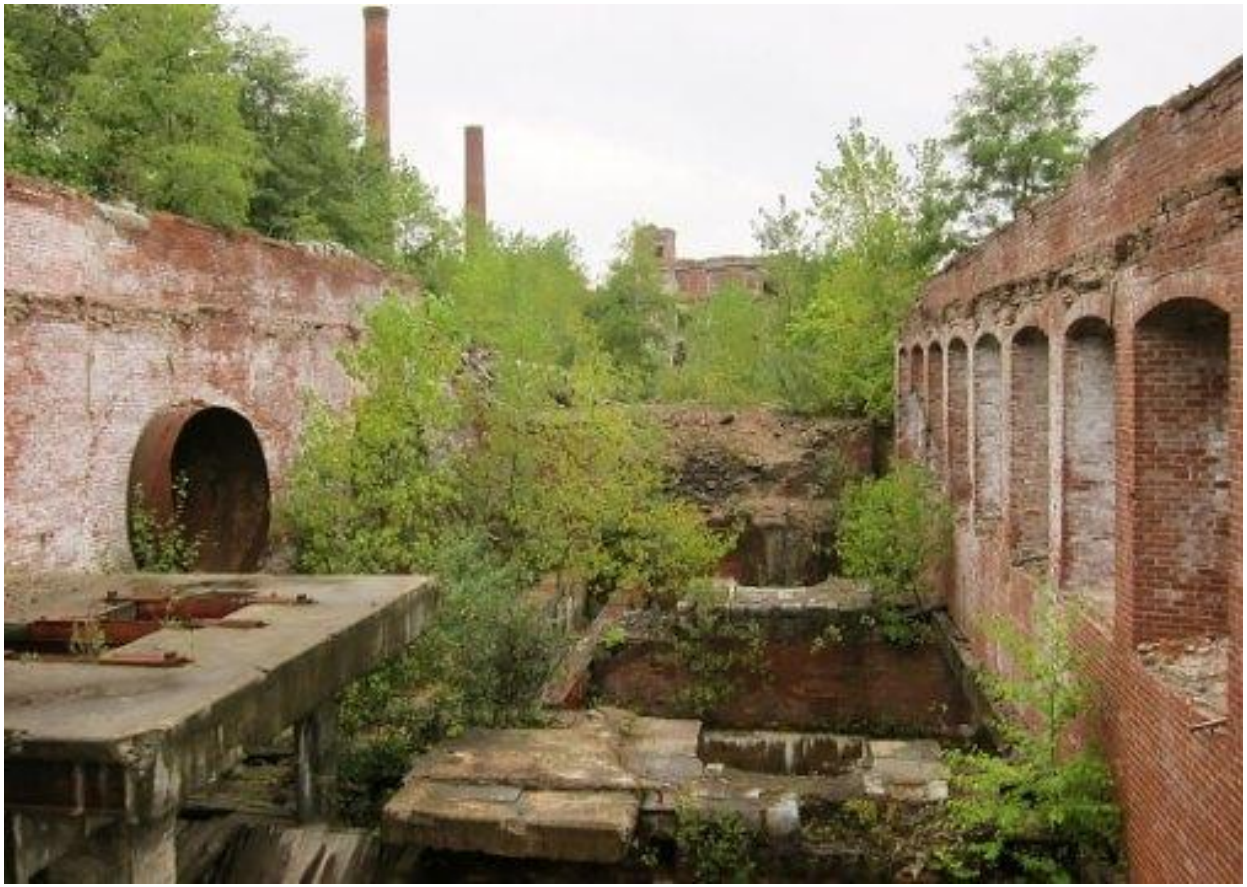
- Solvents (PCE => TCE => VC)

Organic Contaminants: DNAPLs (dense NAPLs)



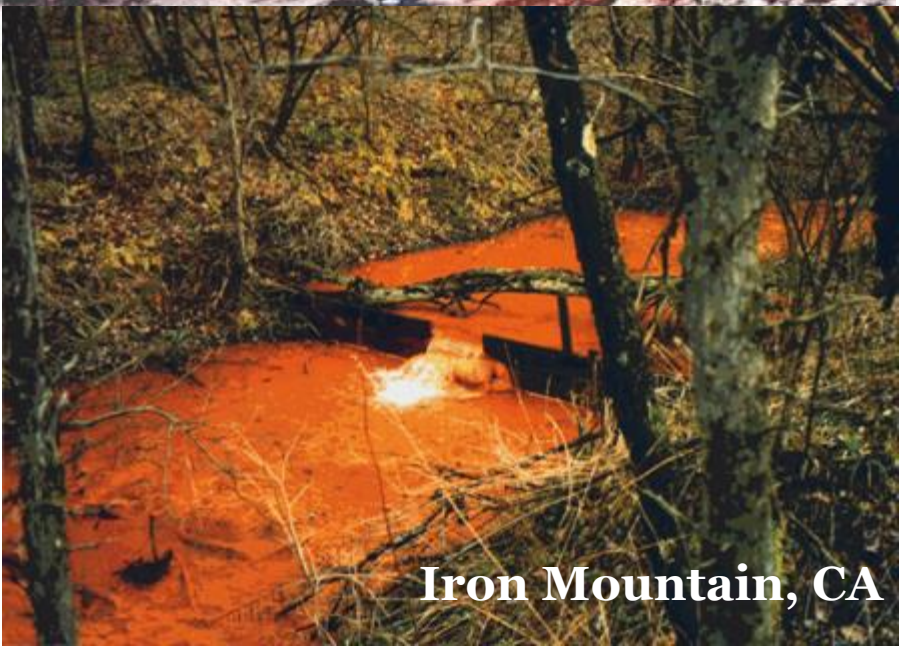
Urban Brownfield Sites

- Solvents
- Mercury
- Asbestos
- PCBs
- Lead, chromium, other heavy metals
- Decades to two centuries of industrial activities



http://www.westhartfordnews.com/articles/2012/09/17/news/doc50575a1c13343944922200.txt

Acid Mine Drainage

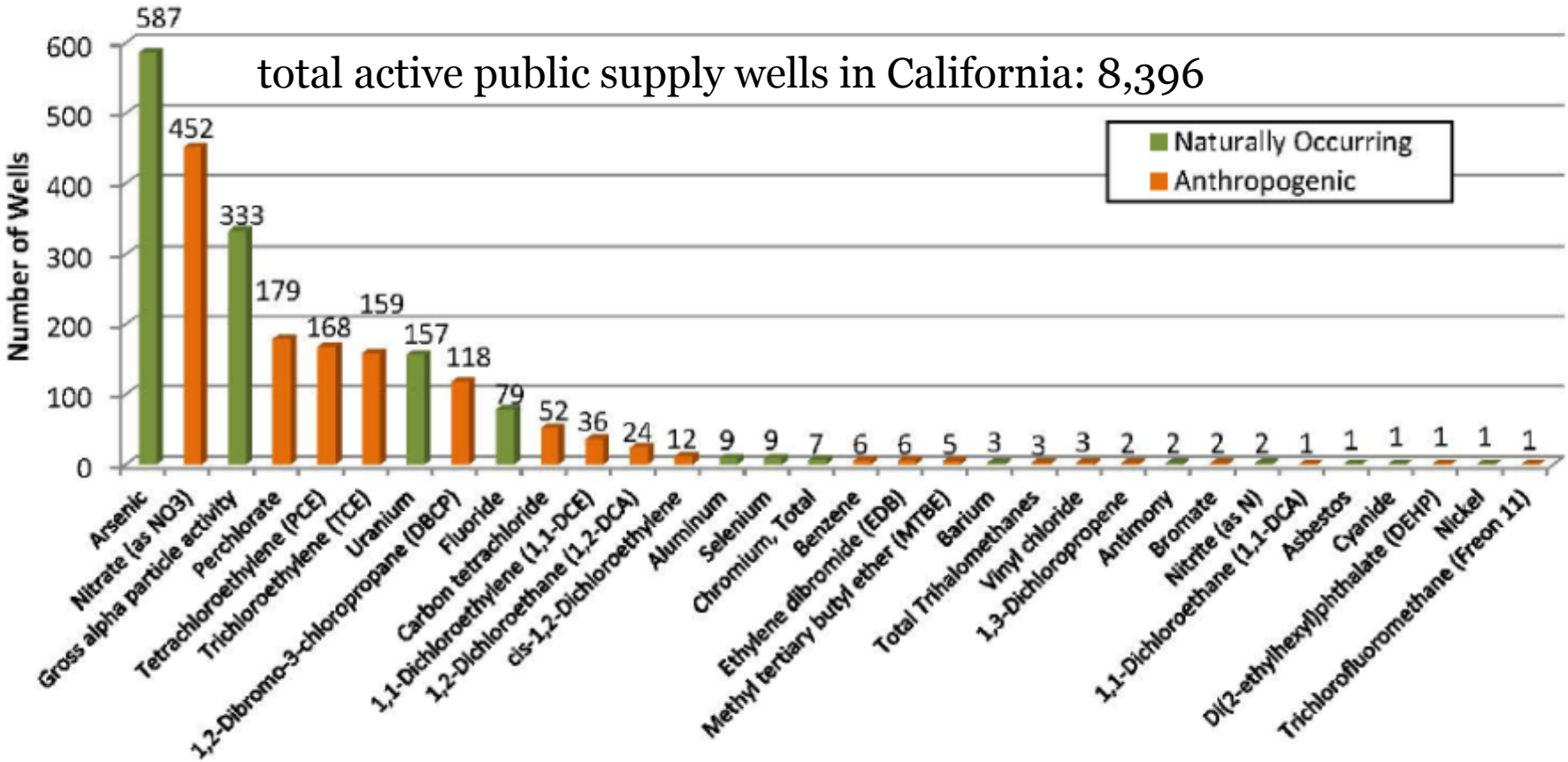


pH	-2.4
Fe (mg/L)	141,000
SO_4 (mg/L)	650,000
Cu (mg/L)	3,180
As (mg/L)	222
Zn (mg/L)	20,000

California has ~ 2,500 inactive and abandoned mine sites

Principal Contaminant Detections

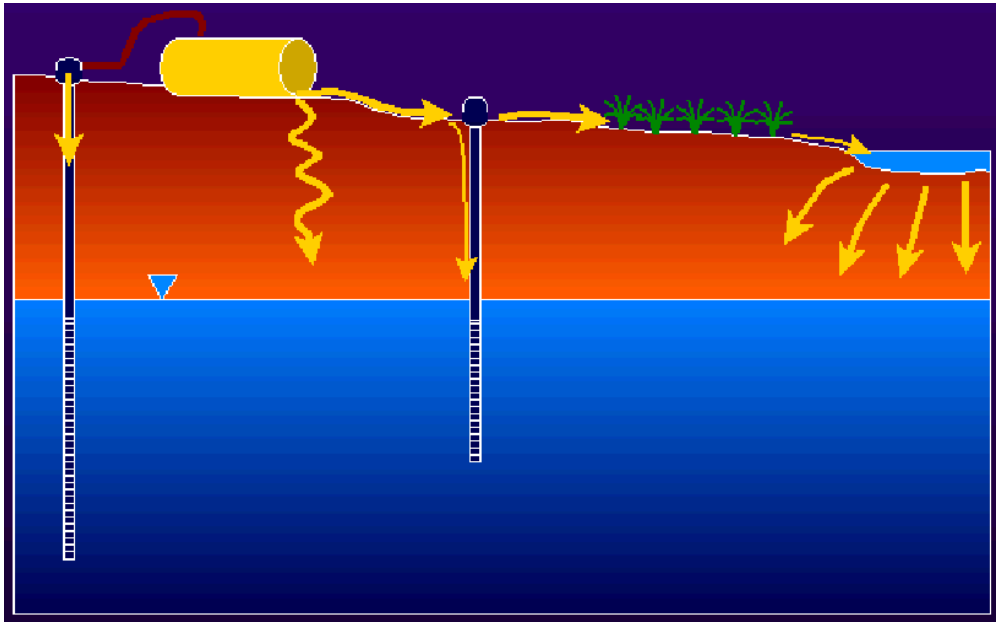
Two or More Detections Above the MCL
in Currently Active Wells
2002-2010



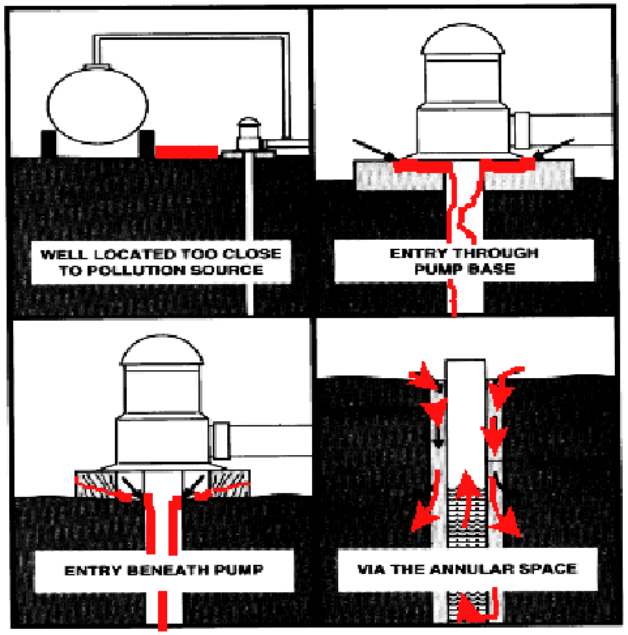
State Water Resources Control Board, AB2222 Report to Legislature, 2013

Pathways to Groundwater

- Runoff and overland flow to a retention area/basin and seepage
- Direct seepage through the unsaturated zone
- Seepage between groundwater and stream / lake
- Direct discharge
  - Through leaky /improperly constructed wells
  - Injection wells / accidental discharge into wells

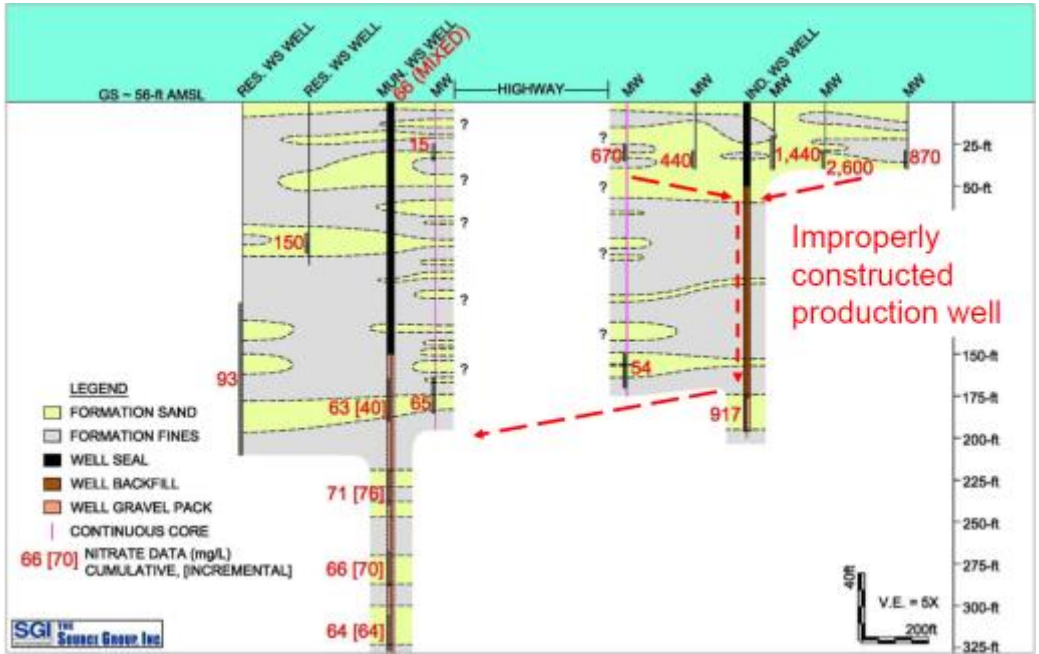


Contamination at the Well-Head



- Poorly sealed well annulus
- Back-siphoning of chemicals
- Illegal injection
- Well completion in multiple aquifers: cross-contamination
- Dry wells and abandoned wells

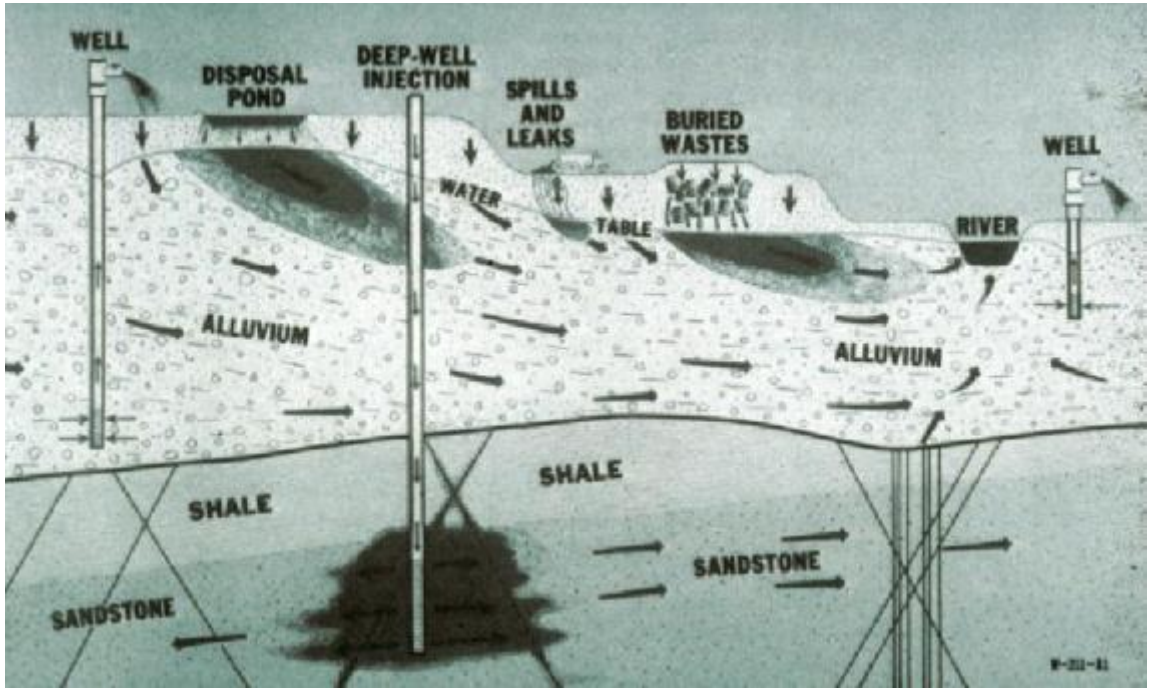
Courtesy: David VonAspern, Derek Jacks, Sac. County



Dry well for stormwater infiltration

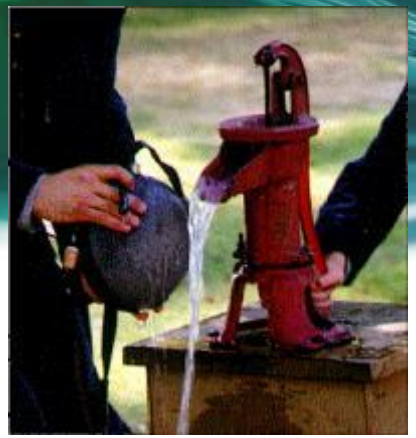
Fate and Transport of Contaminants in the Subsurface

- Advection
- Diffusion
- Dispersion
- Sorption
- Volatilization
- Chemical reactions
- Radioactive decay
- Facilitated transport
- Filtration



Groundwater and Watershed Hydrology Shortcourse:

Legal Control of Water Resources



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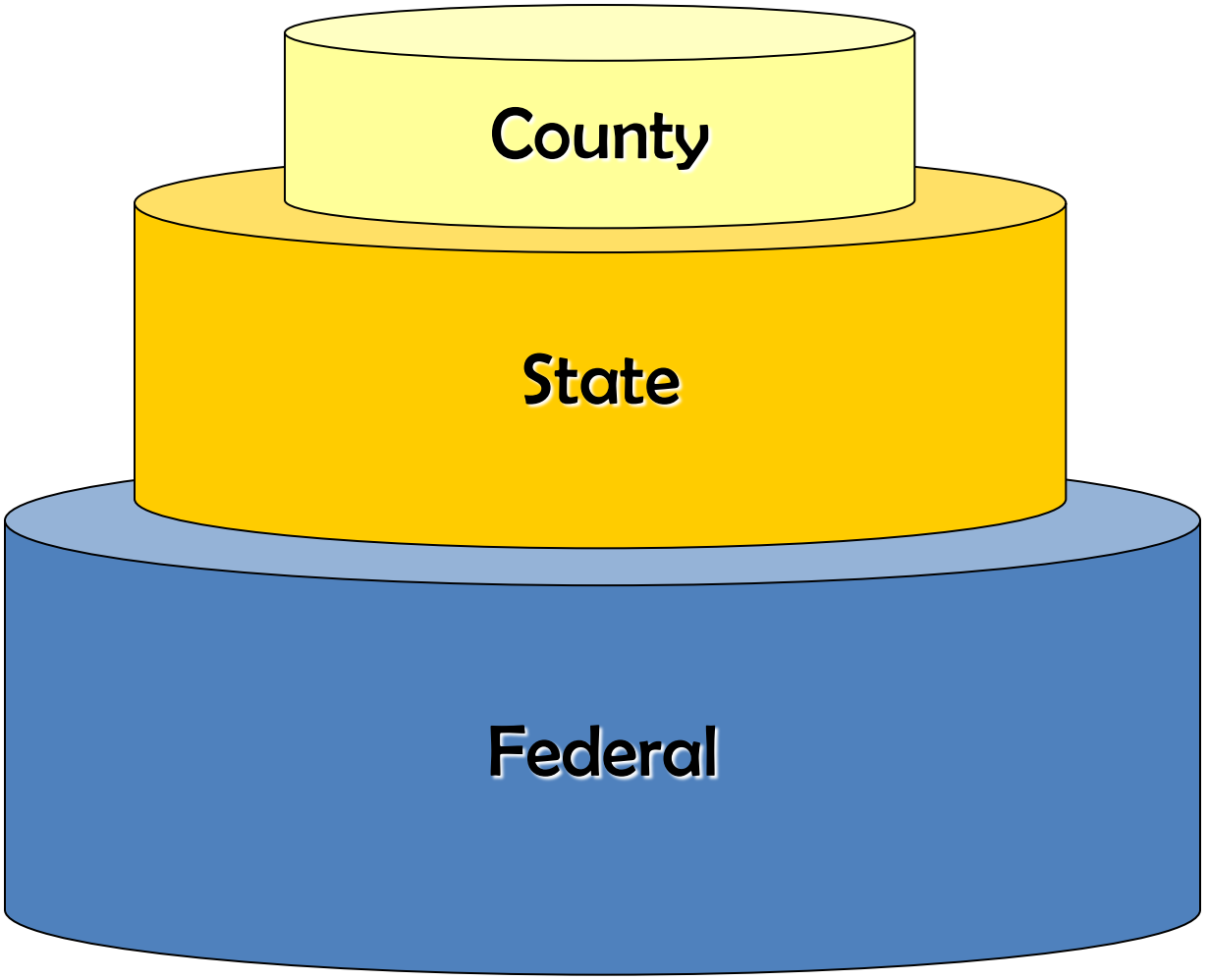
Legal Control of Water Resources

- Water quality protection
  - Federal framework
  - California's implementation of the federal framework
- Who owns how much water?
  - Surface water rights
  - Groundwater rights

The Babylonic Tower of Water Quality Regulations



Federal Framework

- National Environmental Policy Act (NEPA, 1970)
- Clean Water Act (CWA, 1972)
- Marine Protection Research and Sanctuaries Act (MPRSA, 1972)
- Safe Drinking Water Act (SDWA, 1974)
- Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA, 1972)
- Toxic Substances Control Act (TSCA, 1976)
- Resource Conservation and Recovery Act (RCRA, 1974)
- Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, 1980) “Superfund Act”

The Federal Framework ....

...and the California

Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA, 1972)

* registration of pesticides
* use of pesticides

Dep. Pesticide Regulations

Water Well Standards

Dep. Water Resources

California Environmental Quality Act, CEQA;

Porter-Cologne Act

SWRCB / RWQCB / local

Safe Drinking Water Act, 1974

* drinking water standards
* wellhead protection program
* source water assessment
* source water protection
* annual reporting to customers

Dep. Health Services

Clean Water Act, 1972

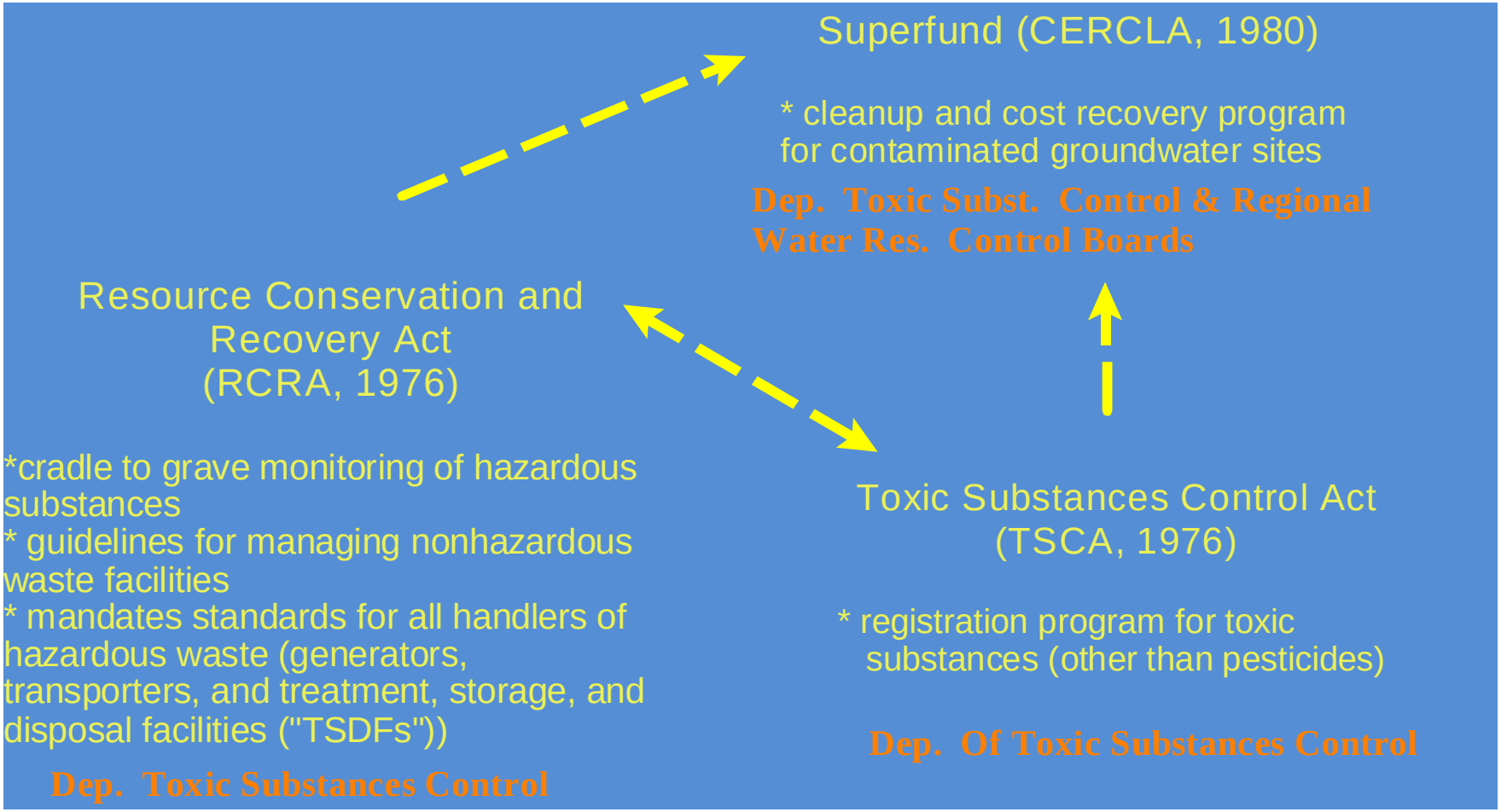
* point source (NPDES)
* nonpoint source regulation
* BMP mandate
* TMDL (total max. daily load)

State Water Resources Control Board
&
Regional Water Res. Control Boards

[Porter-Cologne Water Quality Control Act]

The Federal Framework ....

...and the California Framework



Major Water Quality Regulations related to Farming

USDA:
Comprehensive Nutrient Management Plans
(guideline only)
farm / field scale

EPA:
Permit Nutrient Plans
(under revised NPDES regulations)
farm / field scale

CWA:
Effluent limitation guidelines
(under revised NPDES regulations)
farm scale

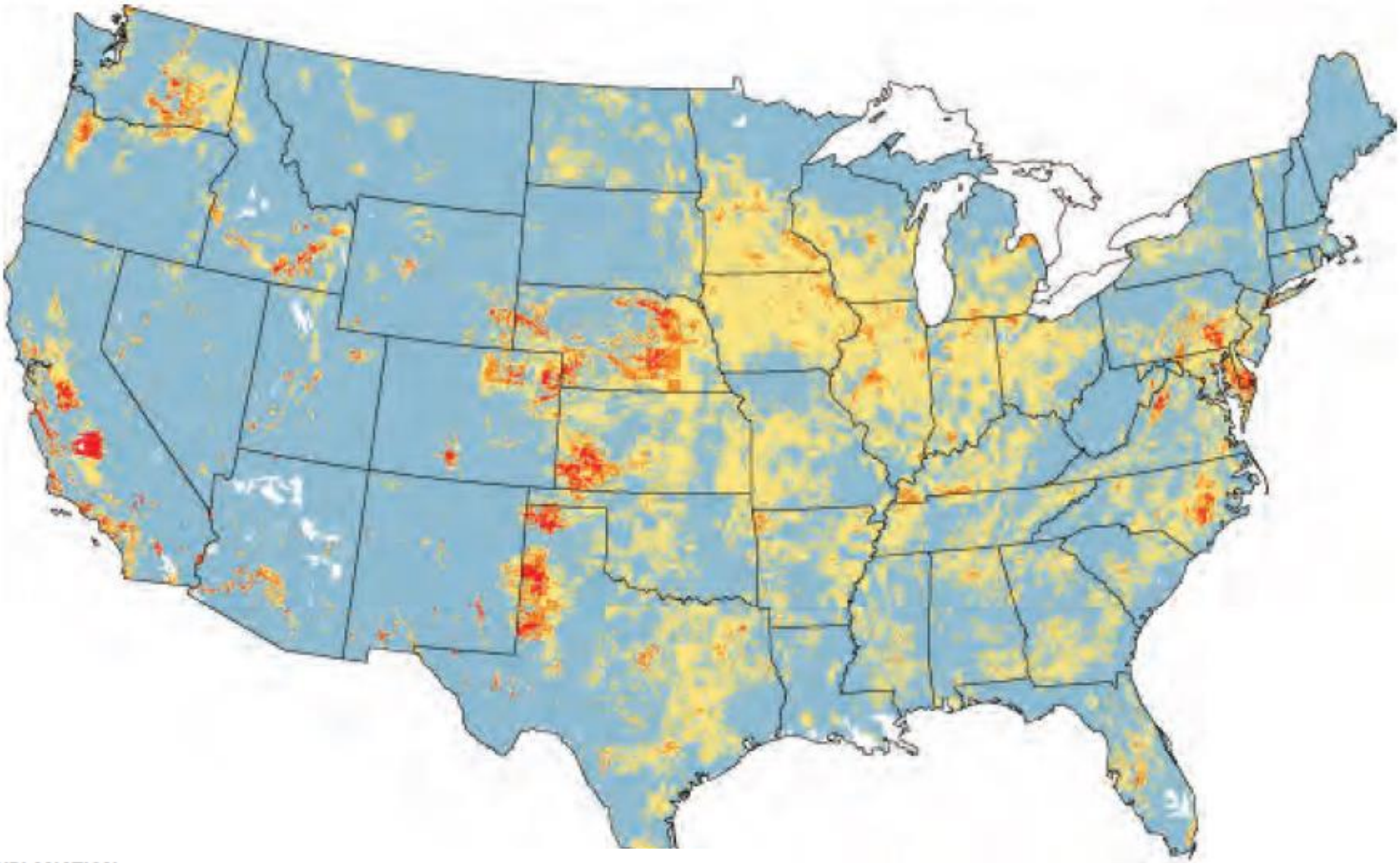
NEPA/CEQA:
EIR process for new permits
field / subfield scale

CWA: TMDLs
watershed scale

FIFRA:
pesticide use
farm / field scale

12/2002 sunset of 1982 CEQA ag effluent waiver (Porter-Cologne)
* waste dicharge requirements (e.g. dairy WDR)
* waiver of waste discharge (e.g. Irrigated Lands Conditional Waiver)
farm / field scale

Model for deep groundwater used as drinking water (50-m simulation depth)



EXPLANATION

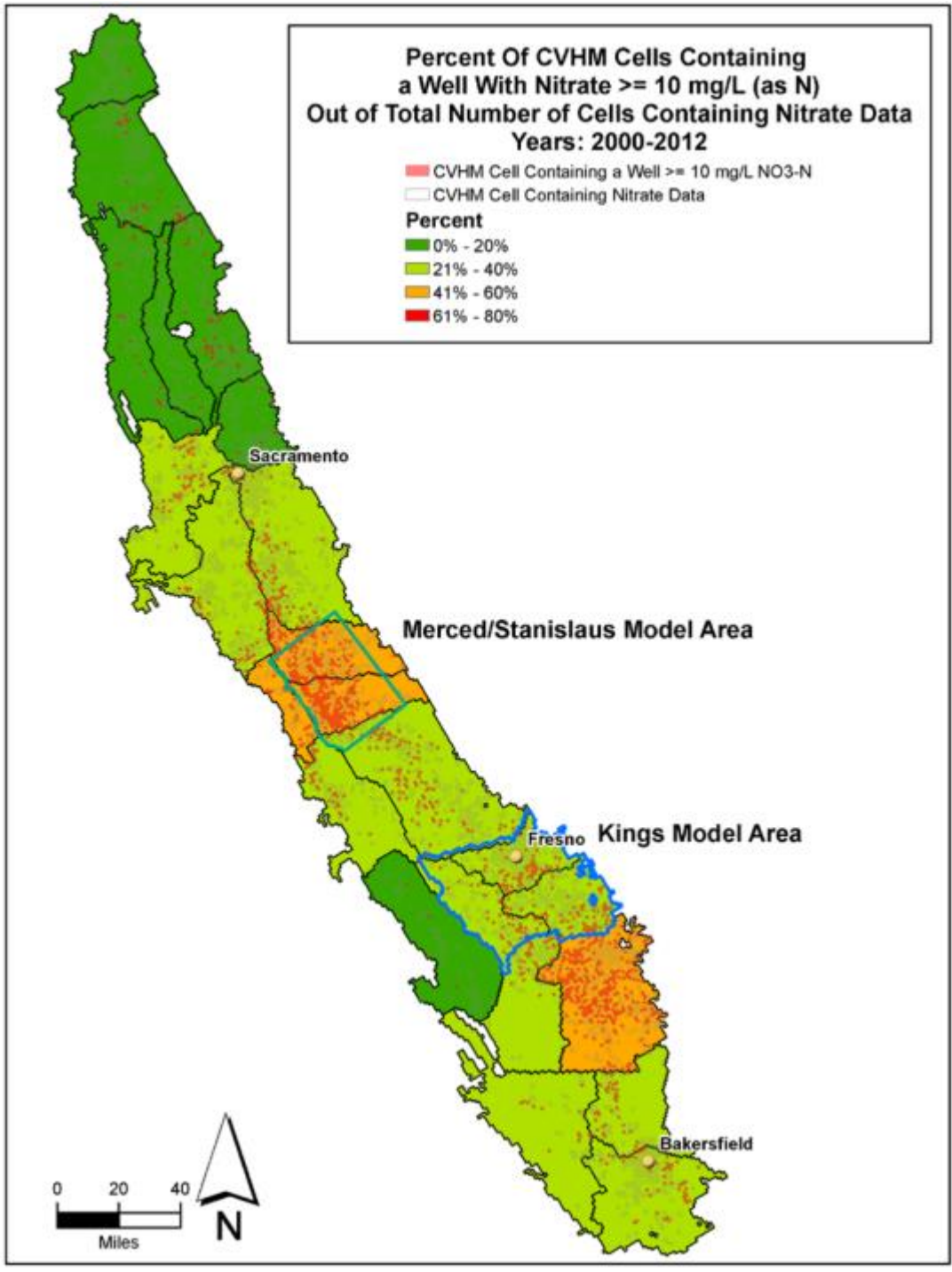
Predicted nitrate concentration, in milligrams per liter as N

≤1 | >1–5 | >5–10 | >10 | Missing data

Dubrovsky et al., USGS, 2010

Nitrate: Impacted regions within the Central Valley

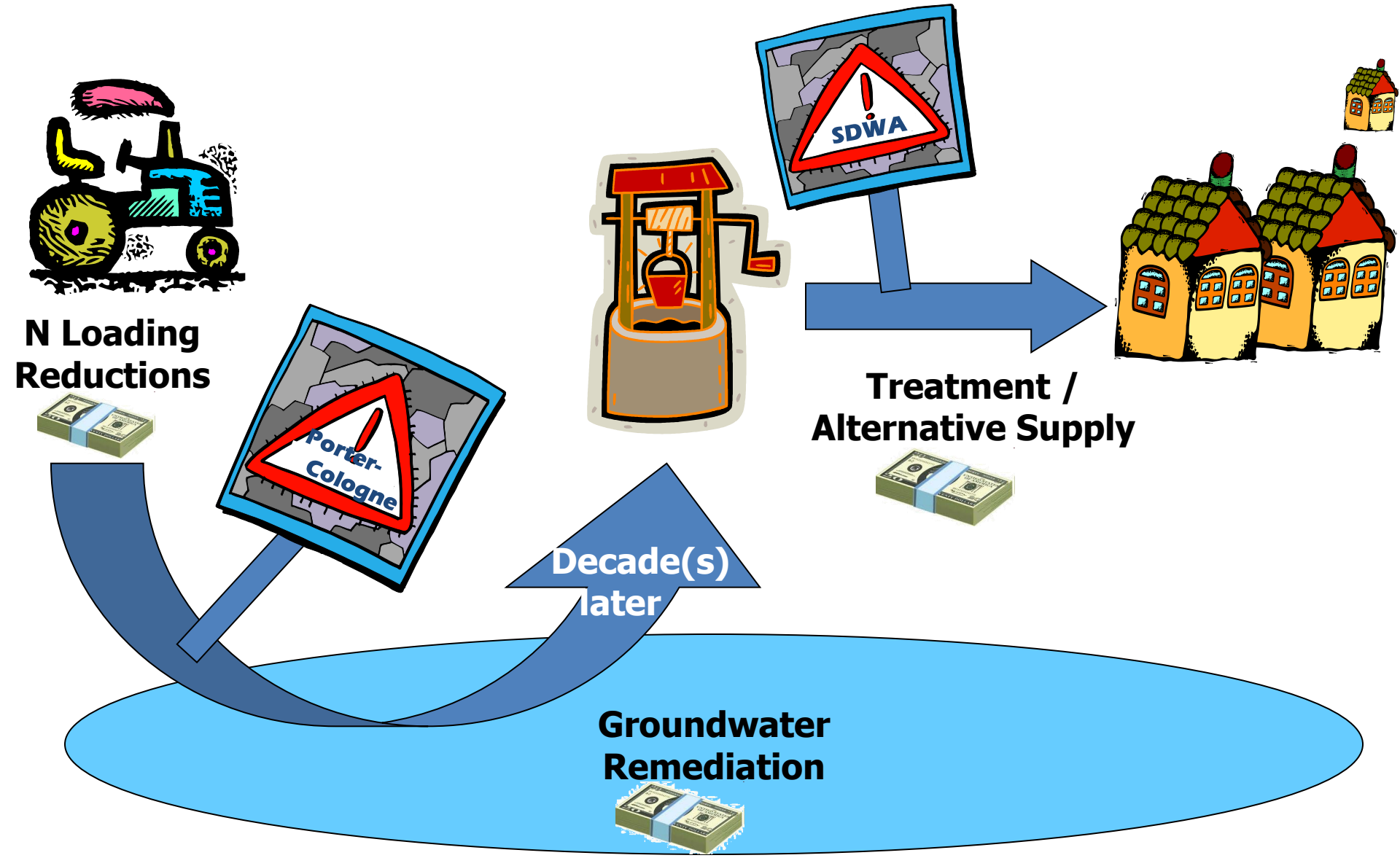
red dots: wells above MCL for nitrate



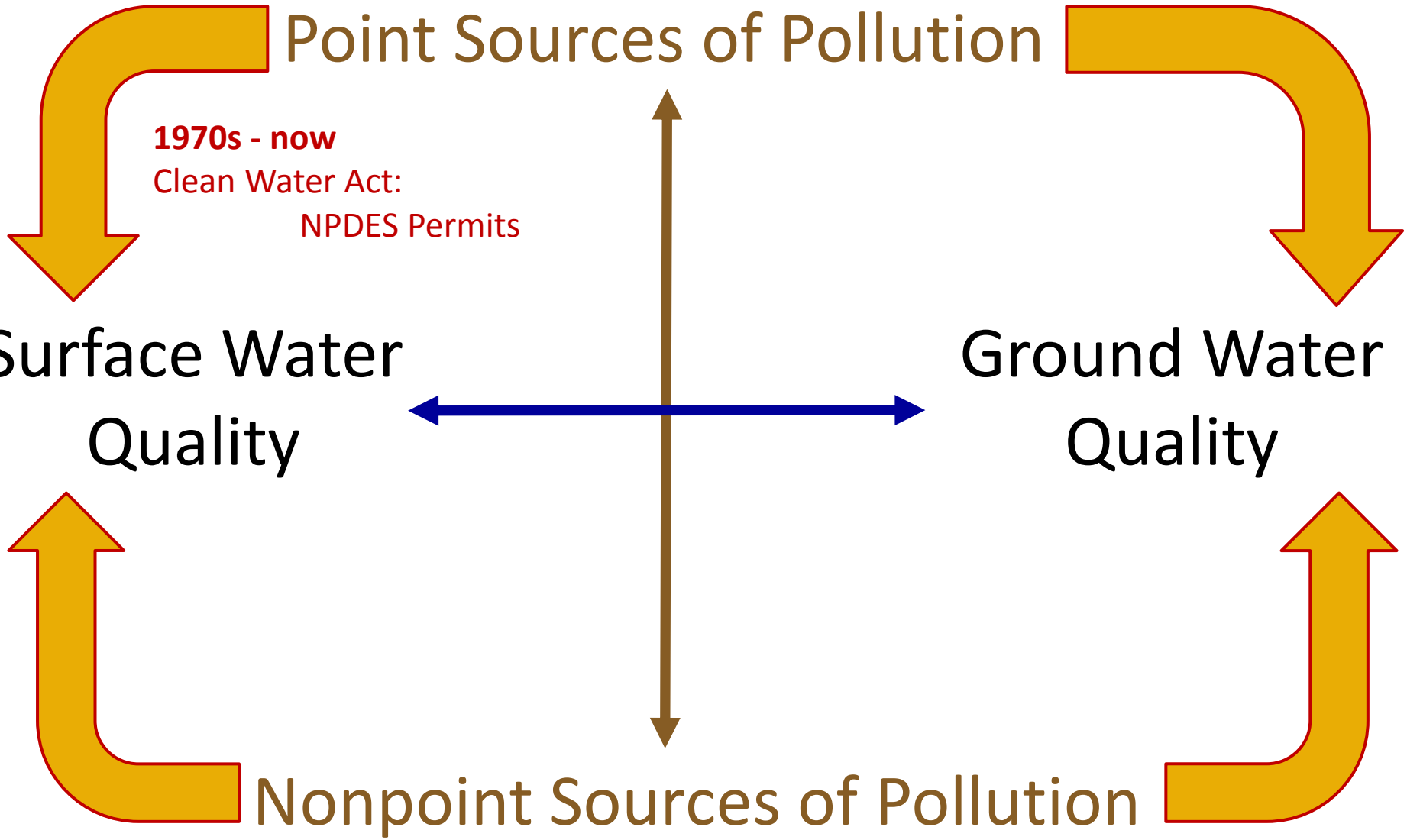
CVSALTS, Tasks 7 and 8 – Salt and Nitrate Analysis for the Central Valley Floor Final Report, December 2013

Figure 7-14

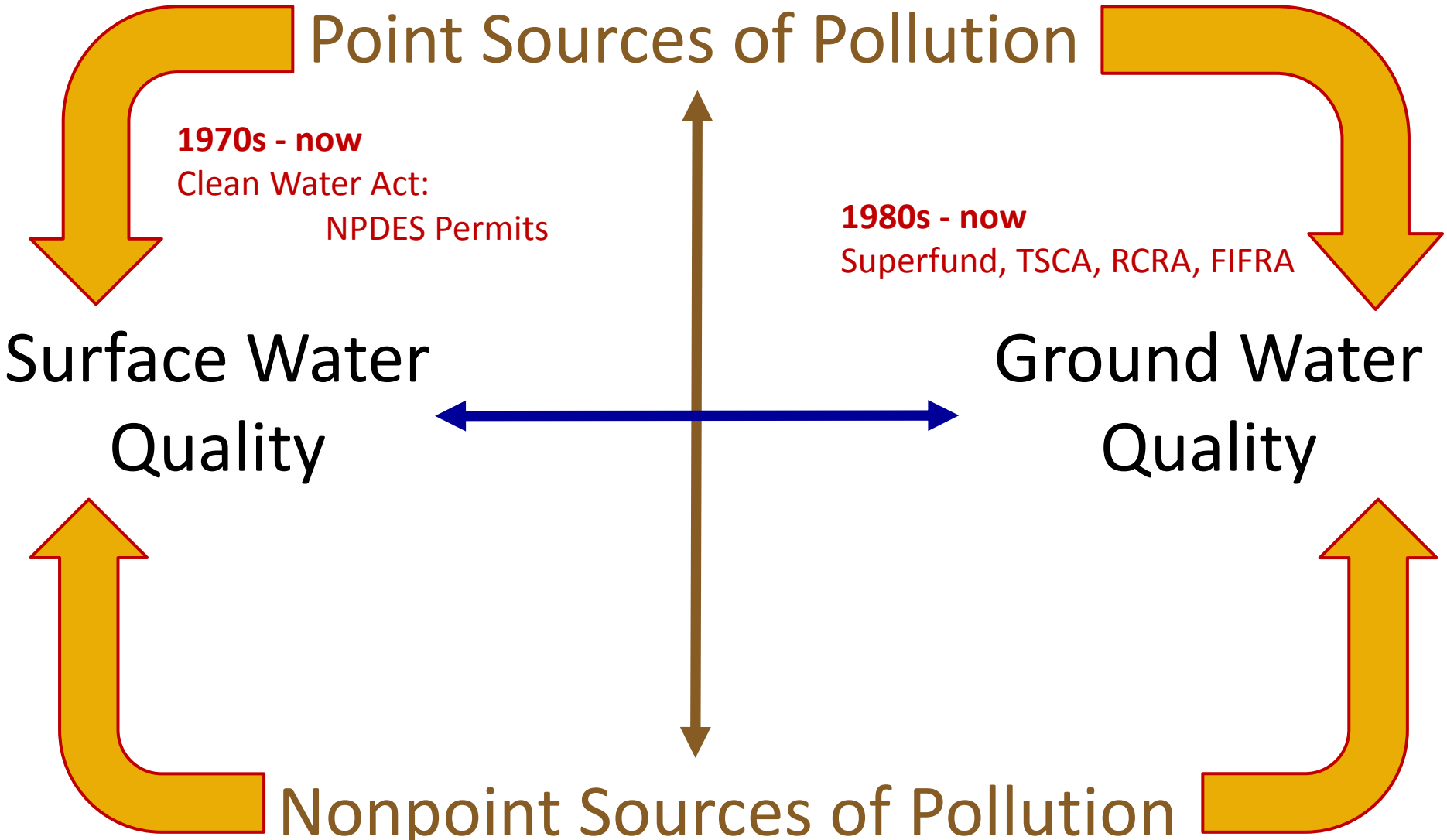
Nitrate: Funding and Regulatory Framework



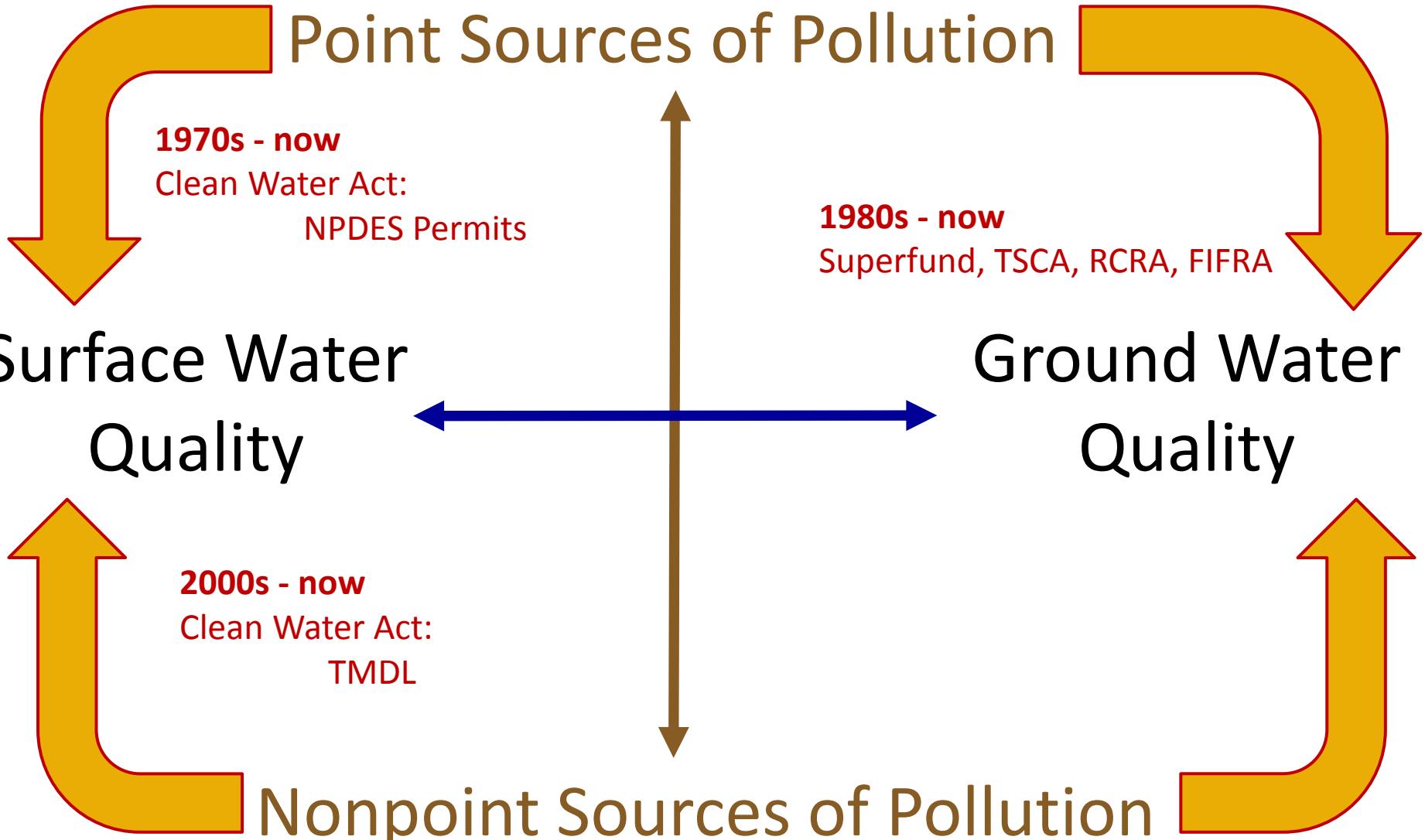
Regulating Water Pollution Sources



Regulating Water Pollution Sources



Regulating Water Pollution Sources



Focus: Enforcement Monitoring

Example of Working with a Regulation: Speed Limit

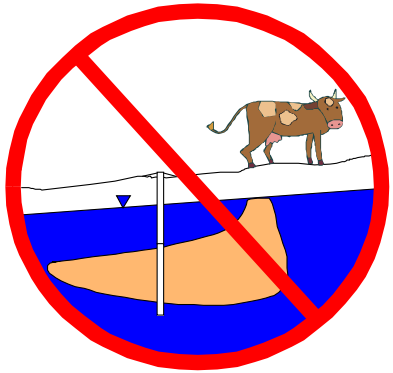
Responsible Party:
Driver

Feedback:
Speedometer

Management Tool:
Brakes

Enforcement:
Radar Controls

Why is Nonpoint Source Pollution Different from Point Source Pollution of Groundwater?



- Scale
  - Millions of acres vs. 1-10 acres
- Intensity
  - Within ~1 order magnitude above MCL vs. many orders of magnitude above MCL
- Hydrologic Function
  - Recharge vs. non-leaky
- Frequency
  - Ongoing/seasonally repeated vs. incidental
- Heterogeneity & Adjacency

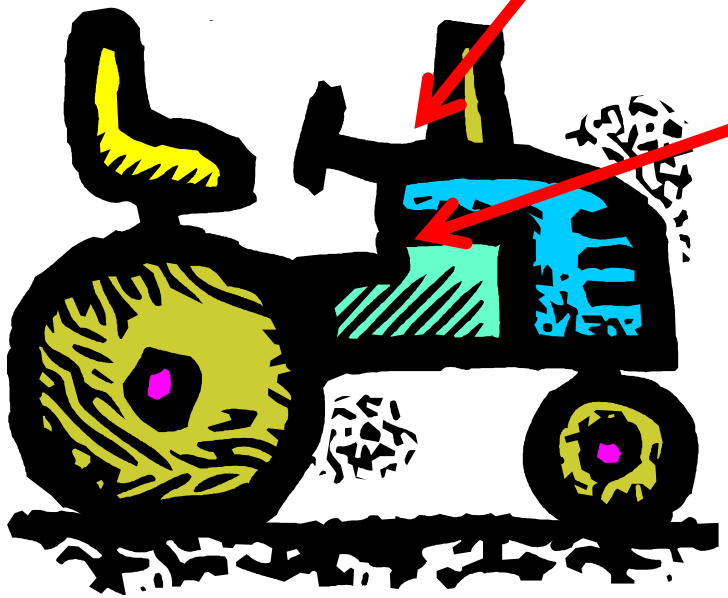
Focus: Enforcement Monitoring

Applying Point Source Approach to Nonpoint Source:

Responsible Party:
Landowner

Feedback:
missing

Management Tool:
$$$ "agronomic"



Enforcement:
Monitoring Wells

Focus: Enforcement Monitoring

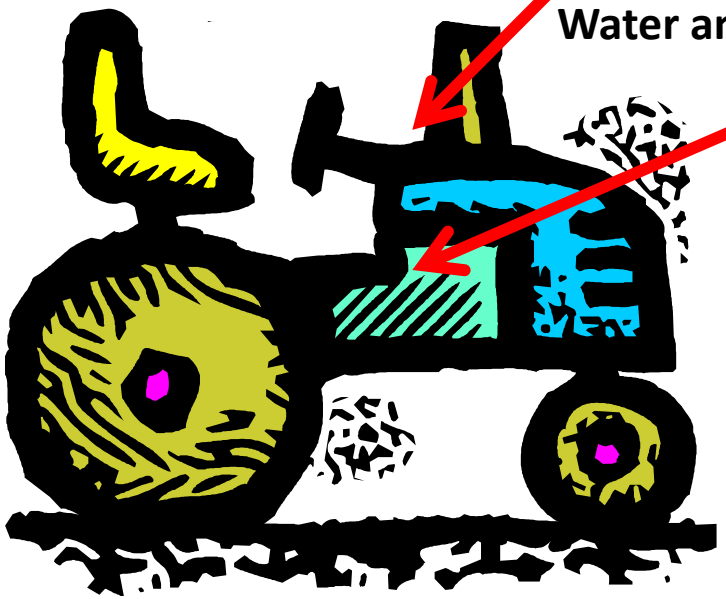
Alternative Monitoring Approach to Nonpoint Source:

Responsible Party:
Landowner

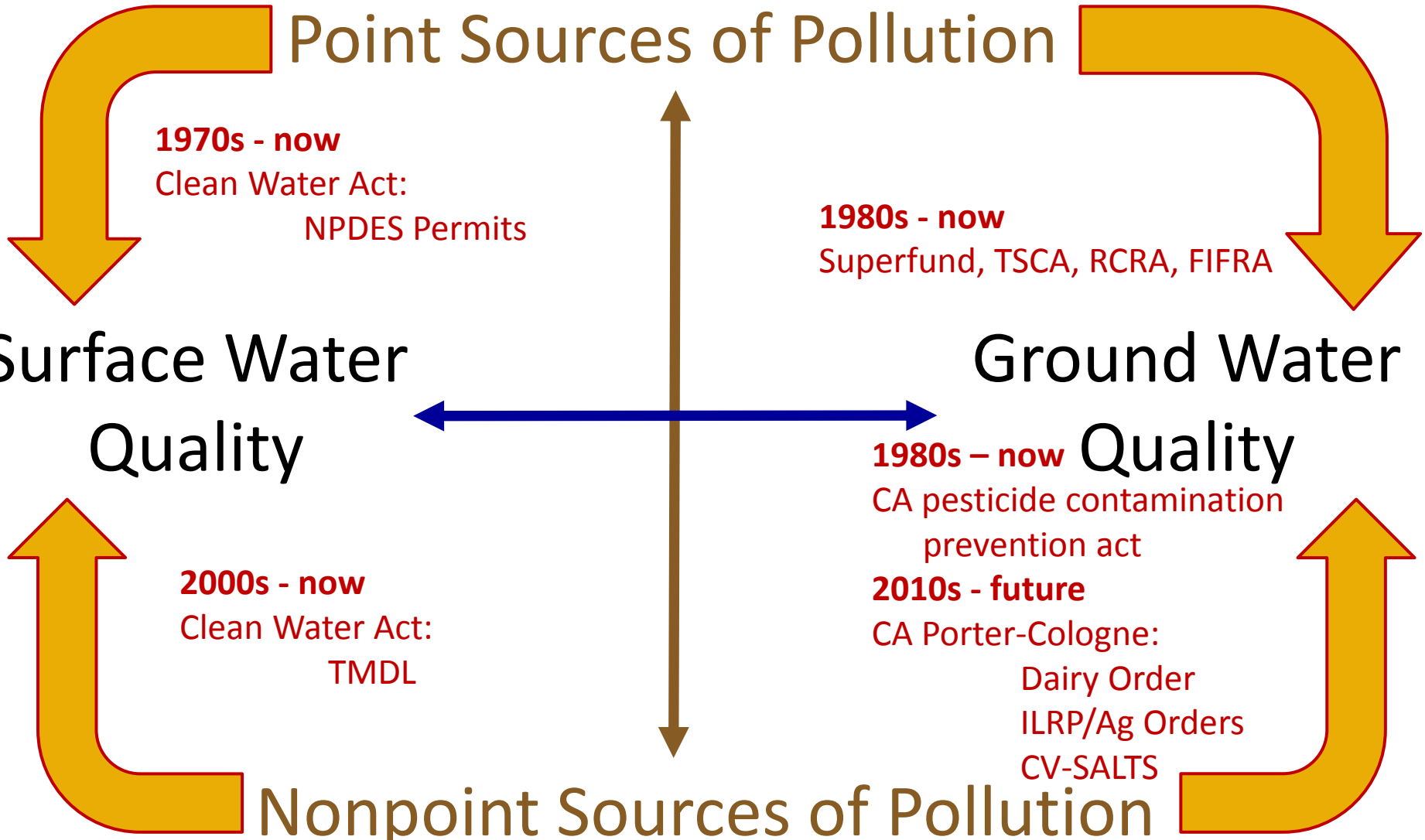
Feedback:
Nutrient/Water Monitoring & Assessment

Management Tool:
Water and Nutrient Management

Enforcement:
Annual Nitrogen Budget
+
Management Practice Assessment
+
Regional Trend Monitoring



Regulating Water Pollution Sources

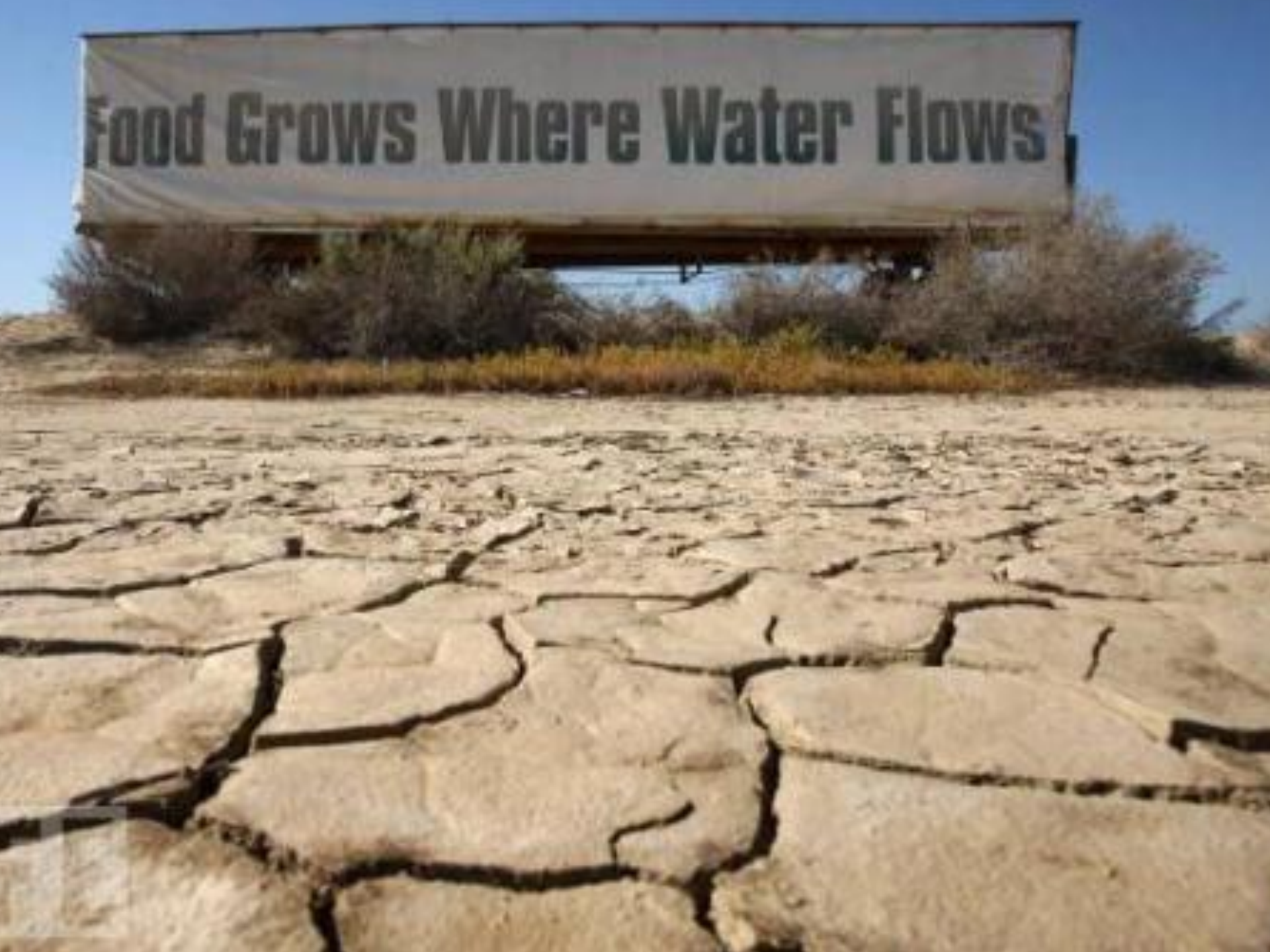


Future of Groundwater Management in Agricultural Regions:

Opportunity for creative solutions to **simultaneously** address

- groundwater supply enhancement
- groundwater quality improvement
- drinking water protection
- economic viability of agriculture

High irrigation efficiency + High nutrient use efficiency + CLEAN groundwater recharge


Food Grows Where Water Flows


13
15
20
18
18

Online Resources

- http://groundwater.ucdavis.edu/sgma
- http://groundwater.ucdavis.edu/calendar
- http://www.water.ca.gov/groundwater/casgem/ (California DWR groundwater level monitoring program
- http://www.water.ca.gov/waterconditions/drought/# (California DWR drought information)
- http://www.waterboards.ca.gov/gama/geotracker_gama.shtml (California groundwater quality information)
- http://groundwater.ucdavis.edu/links_California/ (miscellaneous groundwater information sources)
- Contact Dr. Thomas Harter at ThHarter@ucdavis.edu


THE
END