Economics 134 L14. Conservation

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Logistics

- Last problem set posted; due Wednesday (11/26) before lecture
- Lecture next Monday is in-person; lecture next Wednesday (day before Thanksgiving) lecture is on **Zoom**, link on course website
- Office hours next week moved to **Monday** (11/24), at the usual 5–6.15pm
- Two more lectures after break (12/1, 12/3)
- Final exam: Saturday, 6 December. Comprehensive, cumulative; same format as midterms (but three hours)
  - can have **three** pages of notes (8.5" $\times$11", double-sided)
  - can bring, though should not need, calculator

Natural resources

Economics of natural resources:

- oil, cartels (L13)
- conservation (today)
- water (L15)
- forests, wildfires (L16)

Conservation

Raises critical issues with long-run economic analysis

Cannot value conservation without taking a stance on

1. how **important** the future is
   - decisions vary based on discounting, irreversibility
2. the **substitutability** between current and future resources
   - this raises empirical questions (how will new species evolve and change) as well as questions of values (individual, societal utility)

Optimal conservation
- Short-run utility maximization
- Problems with infinity
- Efficient outcome
- Policy solutions

Empirical application: historical California groundwater pricing

Conservation

Suppose that we have a natural reservoir, W_t.

Society obtains value from the reservoir in proportion to its size,

$$v \cdot W_t,$$

where $v > 0$ is some parameter.

Example, cont'd

Each year t, we can divert D_t units of water from the reservoir.

Our value from using water in year t is

$$u(D_t) = pD_t - \frac{c}{2}D_t^2$$

and we discount utility by a factor of $\beta = \frac{1}{1+\rho}$ per year.

Water evolves from this year to the next as

$$W_{t+1} = W_t - D_t.$$

Question: how should we conserve water?

Example, cont'd

I. Short-run utility maximization. Suppose that today is t and we only care about utility today. Then we will solve

$$\max_{D_t} \left[u(D_t) + v \cdot W_t \right].$$

The solution, D_t^*, satisfies the first-order condition

$$0 = \frac{\partial u}{\partial D_t} + v \frac{\partial W_t}{\partial D_t} = p - cD_t^* + 0$$

implying that

$$D_t^* = \frac{p}{c}$$

for all t. Note that the solution

- does **not** depend on W (or v)
- does **not** depend on β.

Example, cont'd

I. Short-run utility maximization, cont'd.

What are the payoffs? We obtain

$$u_t^* = u(D_t^*) + v W_t$$

each period, with $W_t = W_{t-1} - D_{t-1}^*$.

What are the environmental outcomes? Starting from $t = 0$, we have

$$W_1 = W_0 - D_0^*$$

and $W_2 = W_0 - D_0^* - D_1^*$, and so on, so that $W_T = W_0 - \sum_{t=0}^{T-1} D_t^*$.

Today's diversion affects **all future levels** of the conserved resource.

Example, cont'd

I. Short-run utility maximization, cont'd.

When $D_t^* = D^*$ doesn't depend on t, as in this case, then

$$W_T = W_0 - TD^*.$$

This implies

$$u_T^* = u(D^*) + vW_0 - vTD^*$$

which, as T becomes large, eventually goes to $-\infty$.

Discussion

When there are long-run conservation objectives (through v), then short-run utility maximization can lead to **serious** problems.

However, even if $\lim_{T\to\infty} u_T^* = -\infty$,

- it is not necessarily the case that our discounted utility becomes unbounded
- this is because $\lim_{T\to\infty} \beta^T = 0$.

What matters is whether

$$\lim_{T\to\infty} \beta^T u_T^*$$

goes to infinity.

Mathematical detour

Recall that, for $|x| < 1$, the infinite sum

$$\sum_{t=1}^{\infty} x^t = \frac{x}{1-x}.$$

So, in particular, if we obtain some value y in every period from $t = \{1, 2, \ldots, \infty\}$, then our discounted value of this arrangement at time zero is

$$\frac{\beta}{1-\beta} \cdot y.$$

Example, cont'd

II. First-best outcome. Suppose, instead, that we aim to maximize long-run utility,

$$\sum_{t=0}^{\infty} \beta^t \left(u(D_t) + v W_t \right). \qquad (\star)$$

Then, what should D_0 be?

Note that D_0 will

- only affect $\sum_{t=0}^{\infty} \beta^t u(D_t)$ at $t = 0$
- not affect W_0 at all
- affect W_t at all future dates $t > 0$.

In particular, the last comment implies that

$$\frac{\partial \left(\sum_{t=0}^{\infty} \beta^t v W_t \right)}{\partial D_0} = v \sum_{t=0}^{\infty} \beta^t \frac{\partial W_t}{\partial D_0} = -\sum_{t=1}^{\infty} \beta^t v$$

which, from our previous slide, equals $-\frac{\beta v}{1-\beta}$.

Example, cont'd

II. First-best outcome, cont'd. So, what is the first-best D_0?

Differentiating ($\star$) with respect to D_0, we obtain

$$p - cD_0^{\mathrm{FB}} - \frac{\beta v}{1-\beta} = 0,$$

so that

$$D_0^{\mathrm{FB}} = \frac{p - \frac{\beta v}{1-\beta}}{c}$$

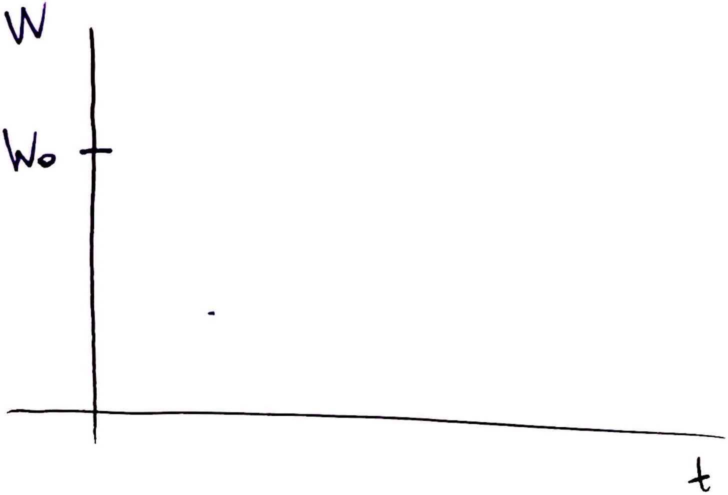
if $p > \beta v/(1-\beta)$, and

$$D_0^{\mathrm{FB}} = 0$$

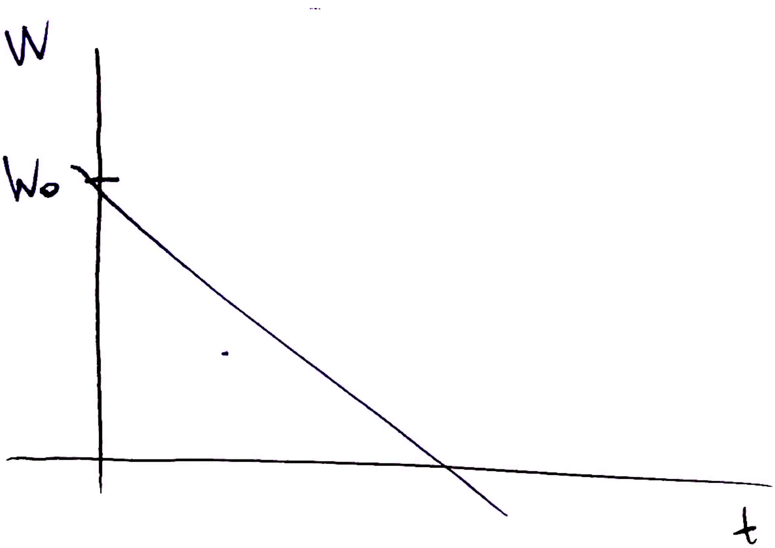
otherwise.

Note that, as the future becomes equally important as the past ($\beta \to 1$), we will never divert water!

Water stock over time



Short-run utility maximization



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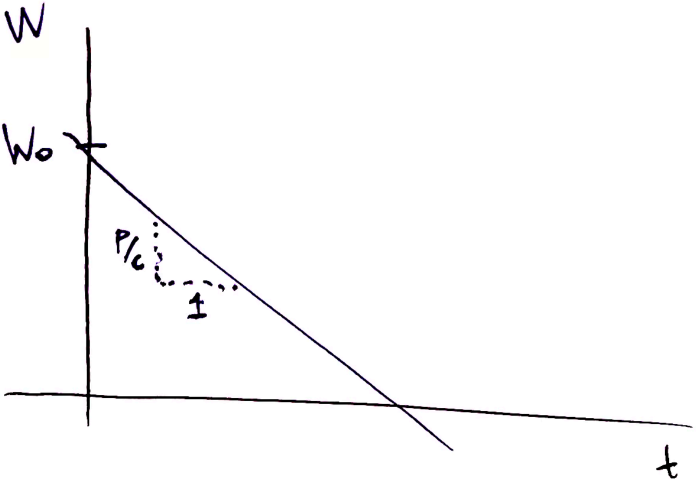
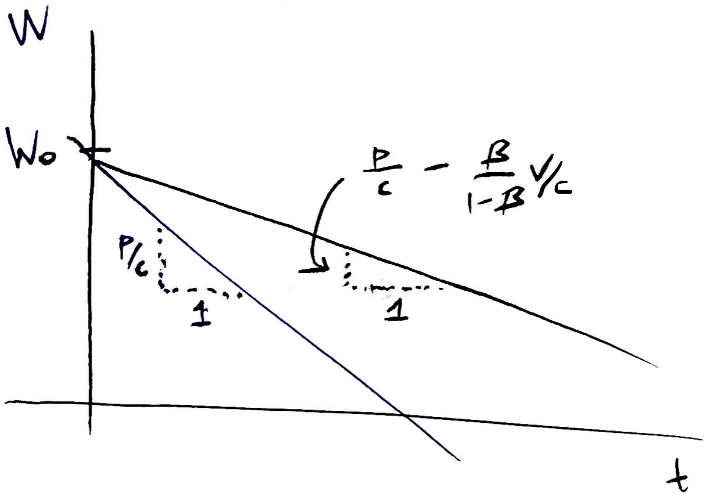
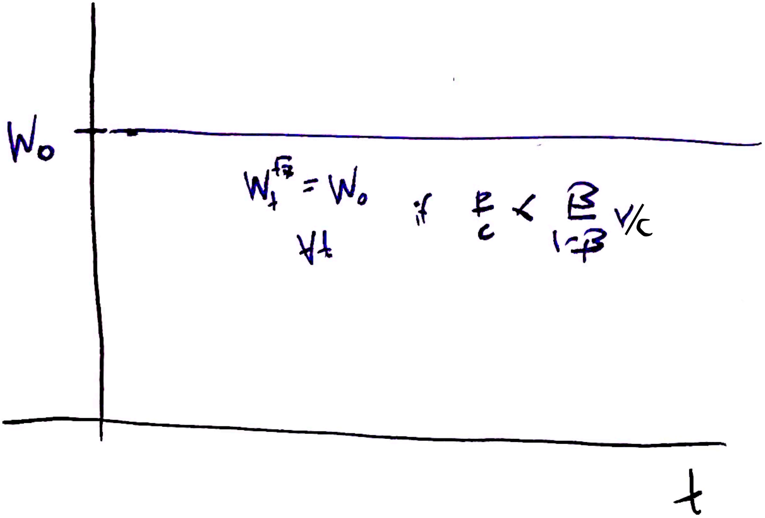


Efficient use, case #1



Efficient use, case #2



Optimal conservation policy

Major inefficiency when conservation choices are made by short-term decision-makers.

Structure of the problem: current choices create externalities for (all) future periods.

Our previous work suggests policy solutions:

- **conservation mandate**: conserve $\frac{\beta}{1-\beta}\frac{v}{c}$ every period
  - prohibit using the resource if $p < \frac{\beta}{1-\beta}v$.
- **tax**: pay $\frac{\beta}{1-\beta}v$ per unit of water diverted

Optimal conservation
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- Problems with infinity
- Efficient outcome
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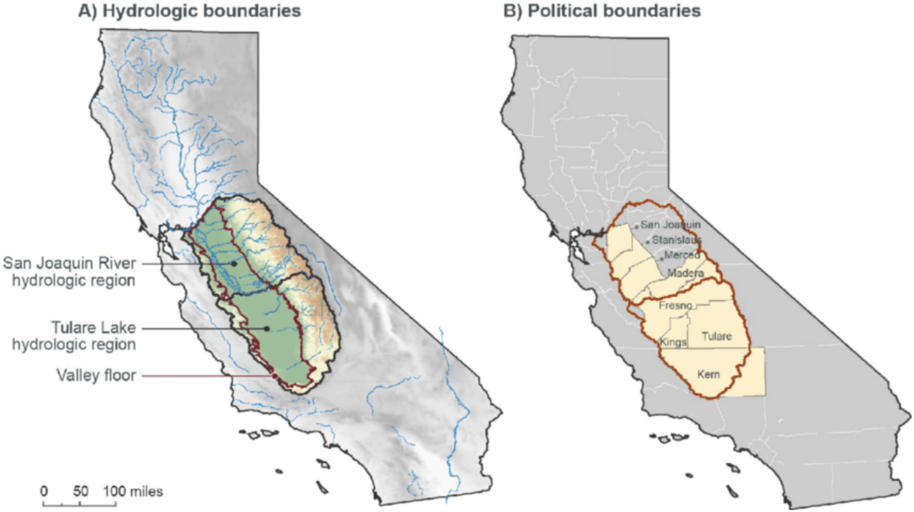
Empirical application: historical California groundwater pricing

Groundwater in California

We'll now discuss a historical analysis of groundwater conservation in the San Joaquin Valley:

- Timmins, Christopher (2002). "Measuring the dynamic efficiency costs of regulators' preferences: Municipal water utilities in the Arid West," Econometrica, vol. 70, no. 2, pp. 603–629

San Joaquin Valley



Approach

Timmins takes data from thirteen cities in the San Joaquin Valley, 1970–1994

- water service charges and water prices
- groundwater pumping records and costs
- groundwater reservoirs ("lift-heights")

The value of conservation arises because lower levels of groundwater ($\uparrow$ lift-height) make pumping **more costly**.

Two main findings:

1. observed prices below short-run marginal costs
2. accounting for the value of **conservation** even more important
   - net benefits $2\frac{1}{2}\times$ the net benefits of pricing at short-run marginal cost

Nearly half of cities charged zero marginal price

TABLE II

DISTRIBUTION OF MARGINAL PRICE PER ACRE-FOOT, FULL DATA PANEL
($n = 195$, CONSTANT 1982–84 DOLLARS)

Percentile	0	48.2	50	60	70	80	90	95
Price	0.0	0.0	19.61	50.51	73.35	99.96	119.19	149.69

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Evidence of under-pricing

TABLE I

MARGINAL COSTS AND PRICES, AVERAGES BY CITY
(CONSTANT 1982–84 DOLLARS)

City	Obs	$MC_{i,t} - P_{i,t}$	$(MC_{i,t} - P_{i,t})/MC_{i,t}$
Clovis	16	19.67***	0.087
Delano	15	118.60*	0.818
Dinuba	15	97.69*	0.406
Exeter	22	47.74*	0.468
Firebaugh	14	174.40*	1.000
Fresno	19	124.99*	1.000
Hanford	21	65.15*	0.449
Kerman	6	109.44*	1.000
Madera	16	124.46*	1.000
Mendota	15	101.50*	0.446
Reedley	17	171.14*	1.000
Sanger	16	43.88*	0.410
Shafter	15	120.61*	1.000

Notes: *** indicates statistical significance at the 10% level, ** indicates significance at the 2.5% level, and * indicates significance at the 0.5% level. All figures are reported in constant 1982–84 dollars.

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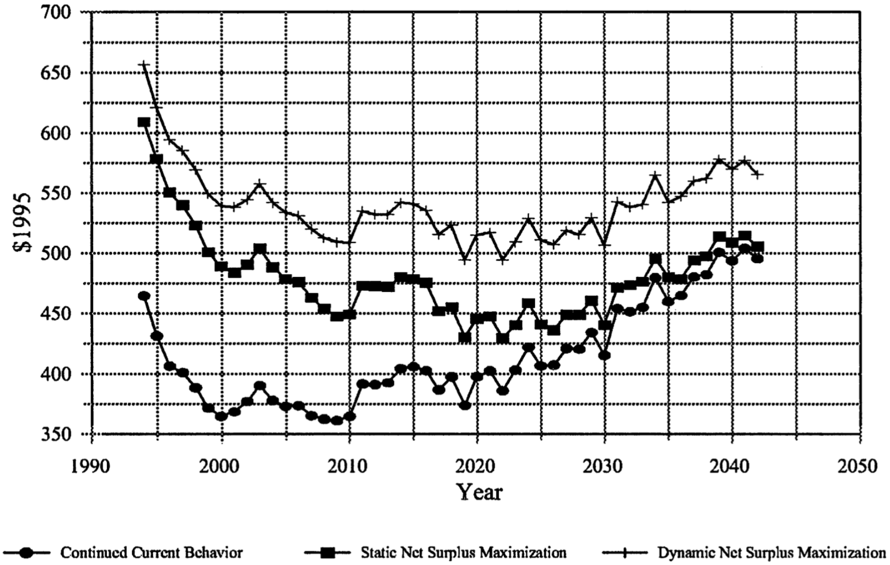
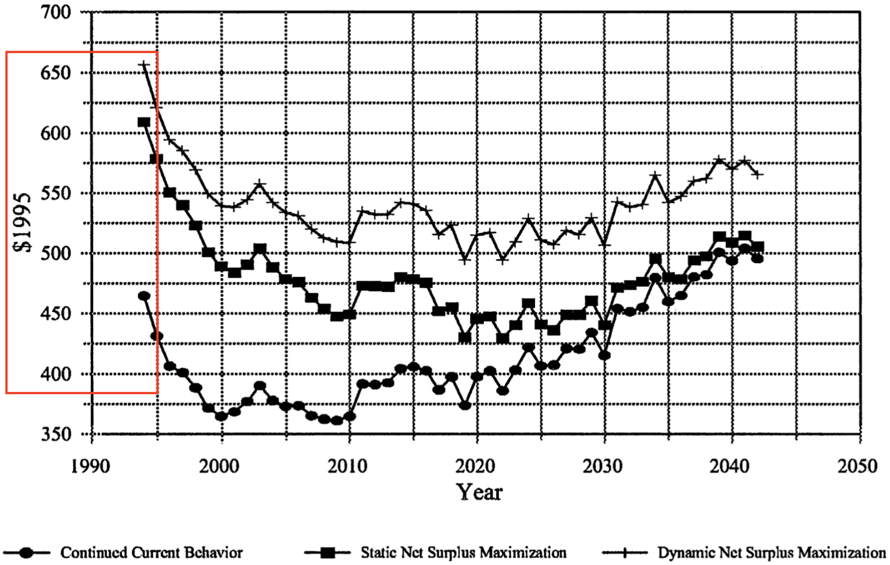
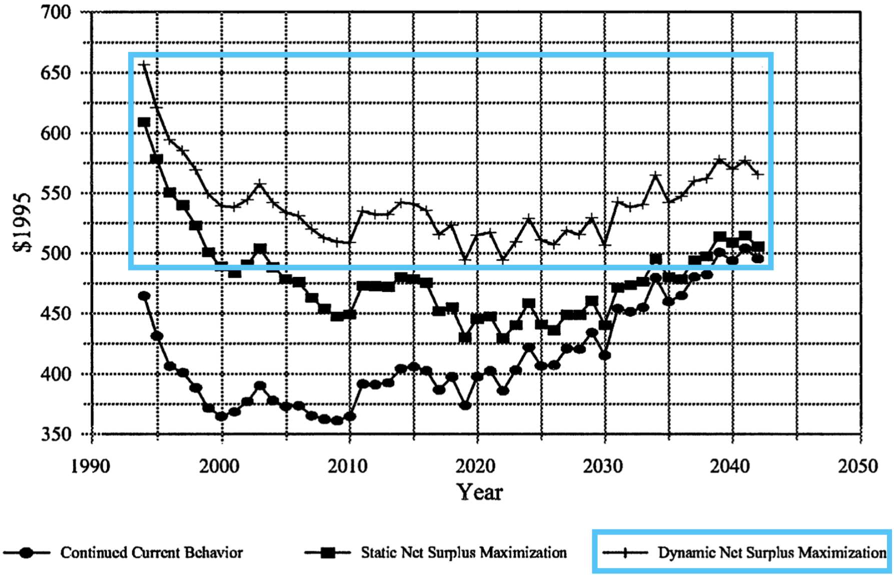
Actual v. short-run v. efficient water pricing



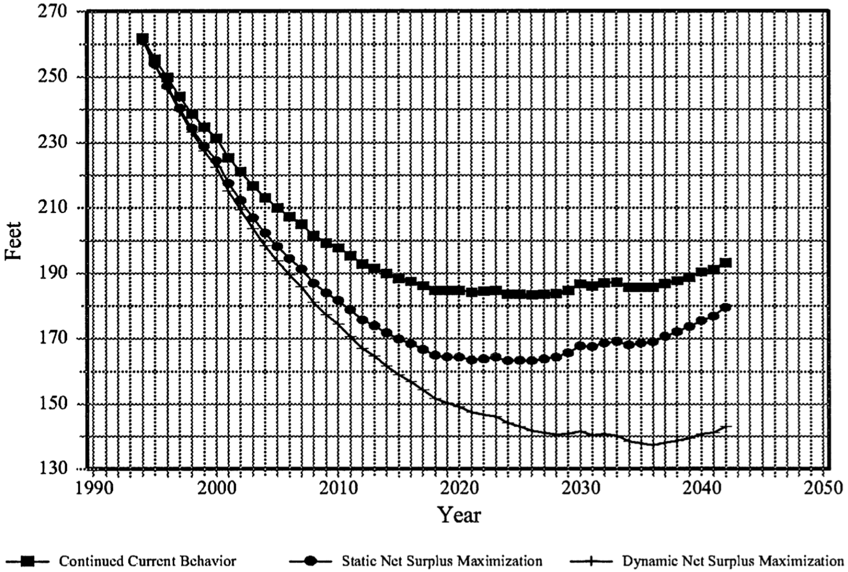
Historical prices too low



Optimal conservation keeps water prices higher



More efficient pricing leads to greater conservation



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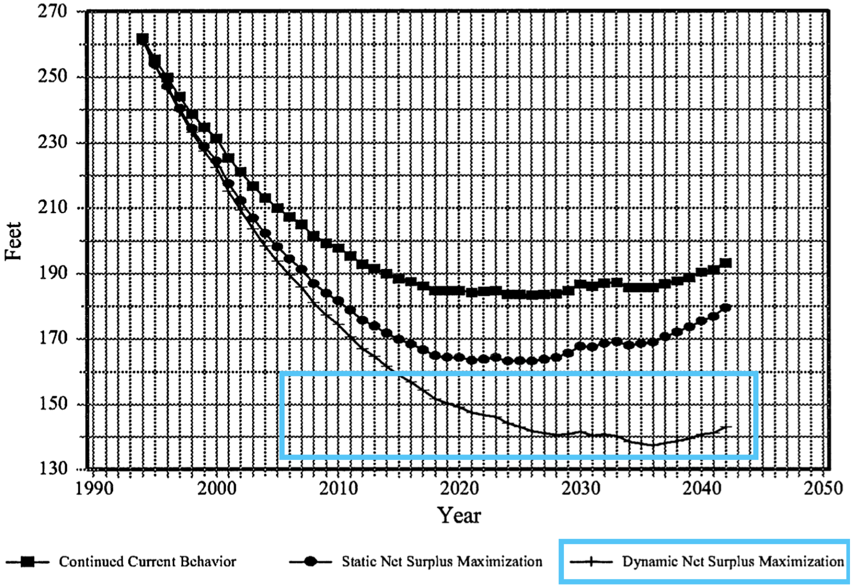
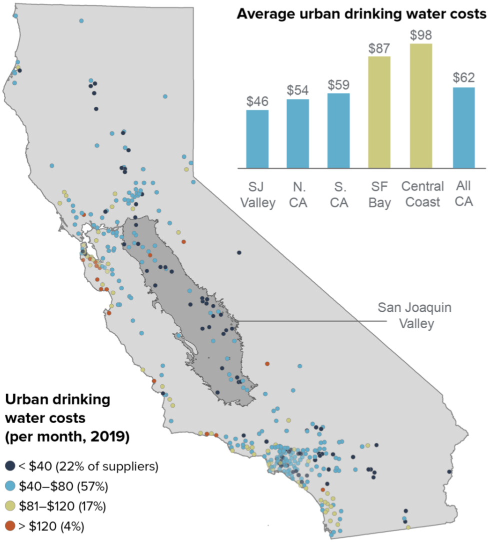
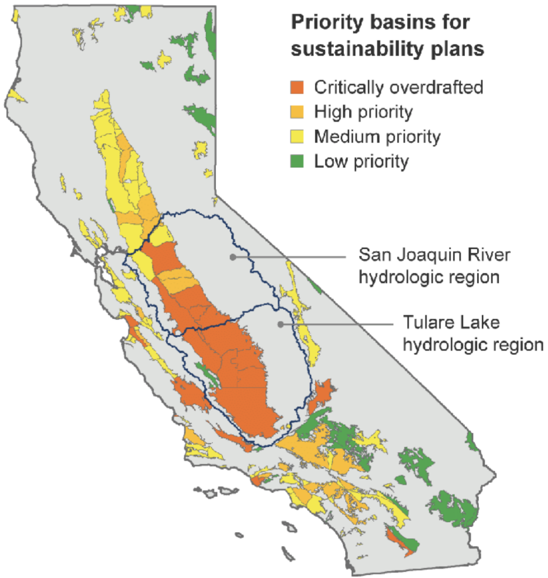


California water prices, 2019



California's Sustainable Groundwater Management Act

2014



Next time

Last lecture on natural resources (natural hazards; wildfires).