Sustainable groundwater management and groundwater dependent ecosystems

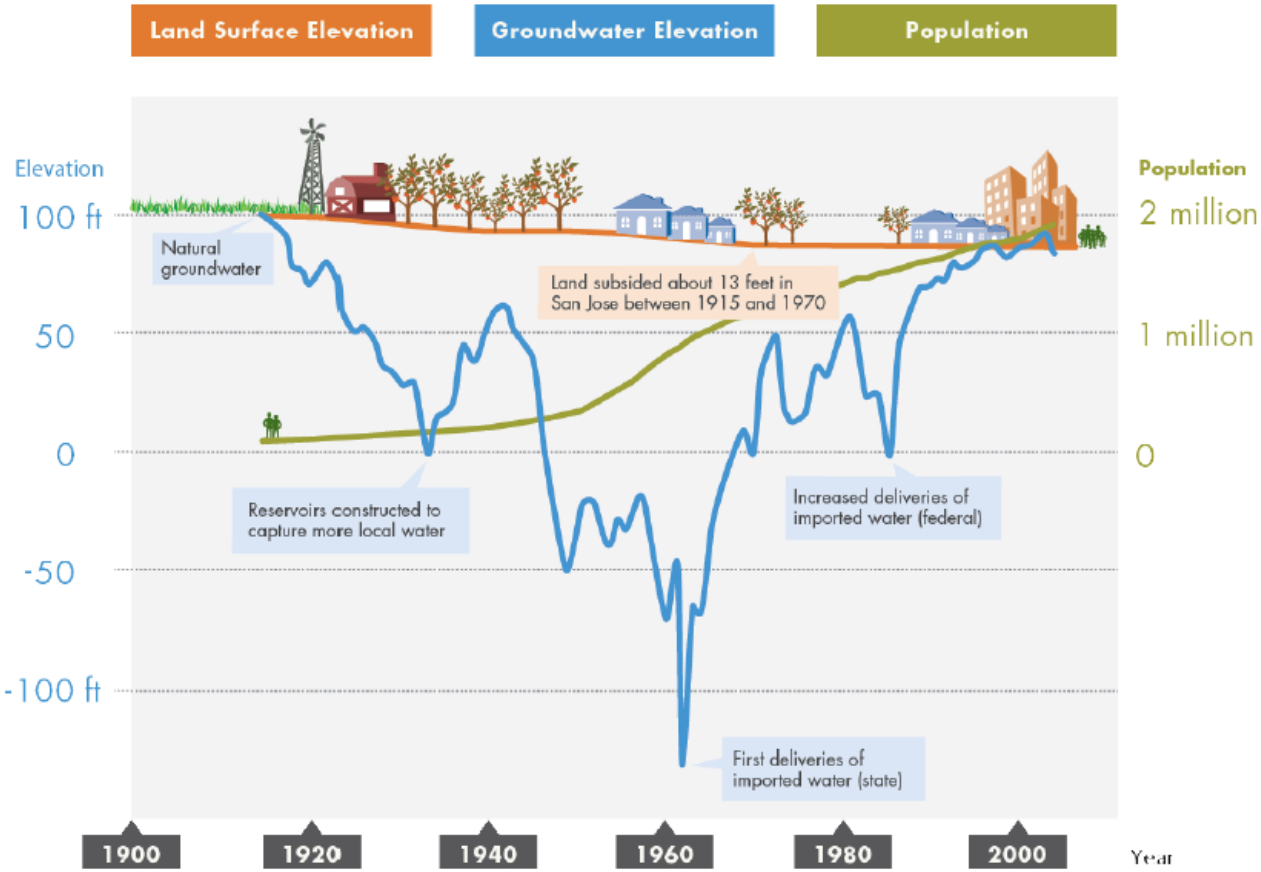
Jeanette Howard

Groundwater Data Workshop

January 28, 2016

The Nature Conservancy

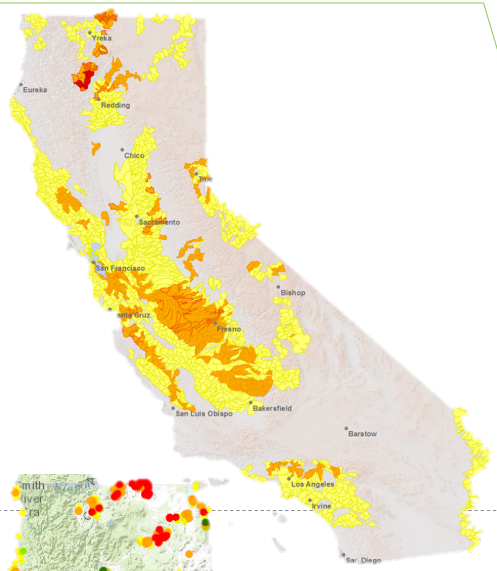
Groundwater is a key resource, impacting freshwater ecosystems, land, population ...



… and providing vital support to ecosystems

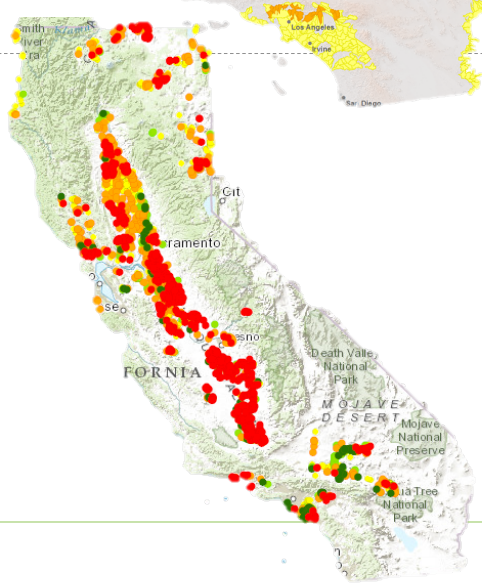
Native fish extirpations in CA, EU settlement - 2013, by HUC

- 0 extirpations
- 1 extirpation
- 2 extirpations
- 3 extirpations
- 4 extirpations
- 5 extirpations



Change in groundwater levels in CA, 2003 - 2013, by DWR

- Increase > 10 feet
- Increase 10 to 2.5 feet
- Change +/- 2.5 feet
- Decrease 2.5-10 feet
- Decrease > 10 feet



- **Ecosystems losses and drop in groundwater levels are correlated**
- **Groundwater levels maintain groundwater dependent ecosystems and baseflows to our rivers and streams**

Road Map

- How are GDEs protected under SGMA?
- What and where are GDEs?
- Thoughts on managing for interconnected surface water and GDEs

Road Map

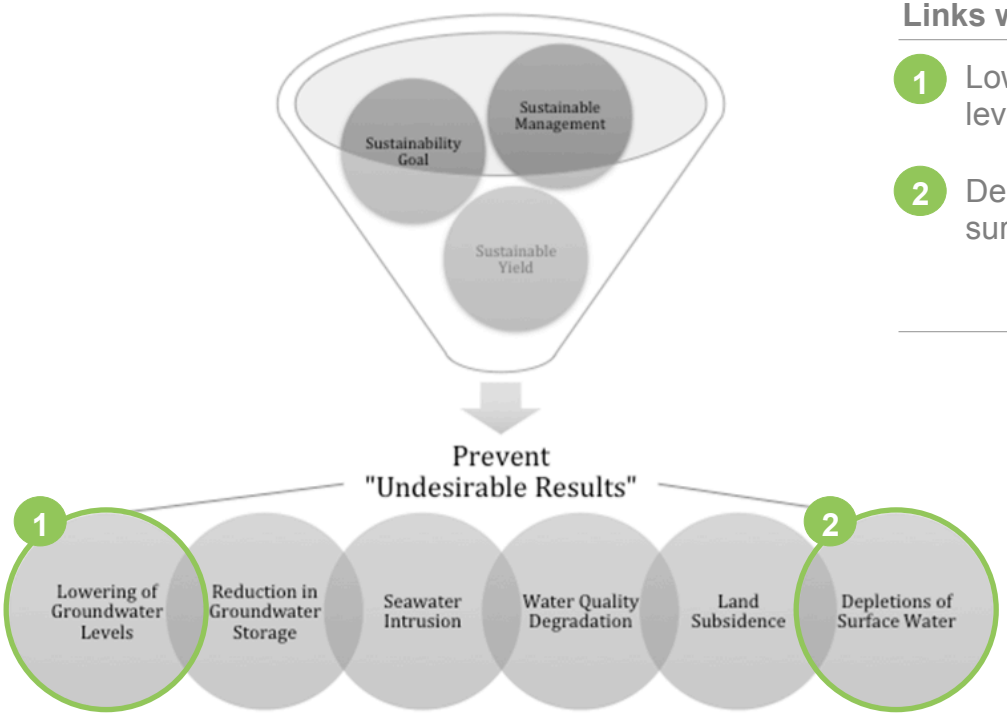
- **How are GDEs protected under SGMA?**
- What and where are GDEs?
- Thoughts on managing for interconnected surface water and GDEs

SGMA: STATE POLICY OF SUSTAINABLE, LOCAL GROUNDWATER MANAGEMENT

"It is the policy of the state that groundwater resources be managed sustainably for long-term reliability and multiple economic, social, and ***environmental benefits*** for current and future beneficial uses. Sustainable groundwater management is best achieved locally through the development, implementation, and updating of plans and programs based on the best available science." (Water Code Section 113)

SGMA's Ecosystem Protection Requirements

SGMA definition of sustainability



Links with ECOSYSTEMS benefits

1. Lowering of groundwater levels
2. Depletion of interconnected surface water

Source: Union of Concerned Scientists 2015

SGMA: GROUNDWATER SUSTAINABILITY PLANS

10727.4. ADDITIONAL PLAN ELEMENTS include:

(i) Impacts on groundwater dependent ecosystems.

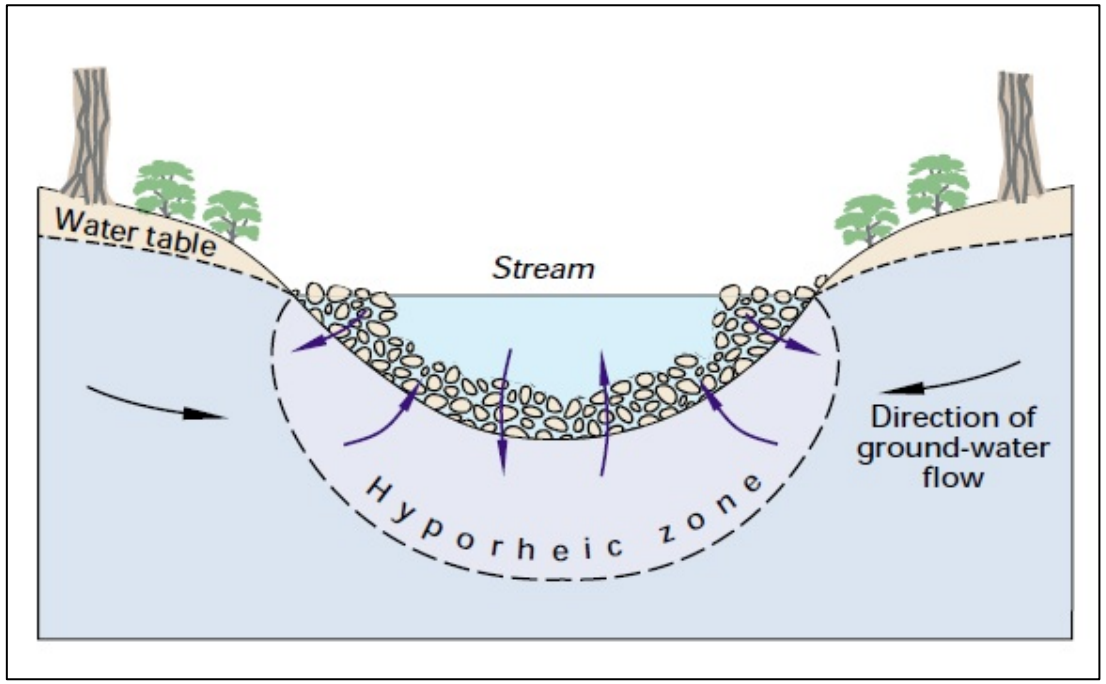
Road Map

- How are GDEs protected under SGMA?
- **What and where are GDEs?**
- Thoughts on managing for interconnected surface water and GDEs

GDE types and classification

SUBSURFACE ECOSYSTEMS

- Karst and caves
- Subsurface phreatic aquifer ecosystems
- **Baseflow (hyporheic)**



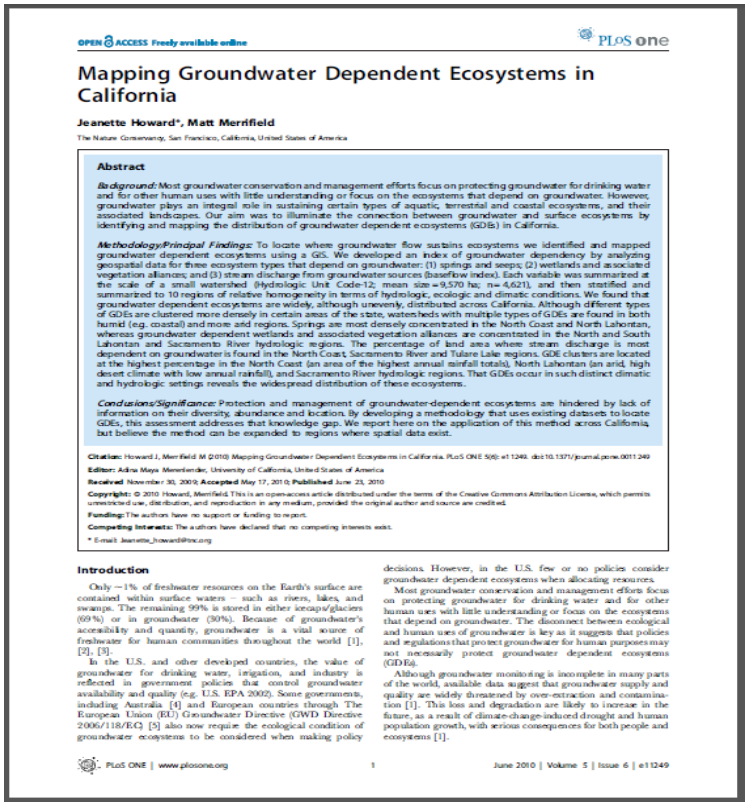
GDE types and classification

SURFACE ECOSYSTEMS

- Groundwater dependent wetlands and vegetation alliances
- **Baseflow (streams)**
- Phreatophytes
- Seeps and springs
- Estuarine and near shore marine ecosystems

Building the case for nature: Mapping GDEs Statewide

UPDATING DATA AND DEVELOPING ONLINE TOOL



OPEN ACCESS Freely available online PLoS one

Mapping Groundwater Dependent Ecosystems in California

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The Nature Conservancy, San Francisco, California, United States of America

Abstract

Background: Most groundwater conservation and management efforts focus on protecting groundwater for drinking water and for other human uses with little understanding or focus on the ecosystems that depend on groundwater. However, groundwater plays an integral role in sustaining certain types of aquatic, terrestrial and coastal ecosystems, and their associated landscapes. Our aim was to illuminate the connection between groundwater and surface ecosystems by identifying and mapping the distribution of groundwater dependent ecosystems (GDEs) in California.

Methodology/Principal Findings: To locate where groundwater flow sustains ecosystems we identified and mapped groundwater dependent ecosystems using a GIS. We developed an index of groundwater dependency by analyzing geospatial data for three ecosystem types that depend on groundwater: (1) springs and seeps; (2) wetlands and associated vegetation alliances; and (3) stream discharge from groundwater sources (baseflow index). Each variable was summarized at the scale of a small watershed (Hydrologic Unit Code-12; mean size = 9,570 ha; n= 4,621), and then stratified and summarized to 10 regions of relative homogeneity in terms of hydrologic, ecologic and climatic conditions. We found that groundwater dependent ecosystems are widely, although unevenly, distributed across California. Although different types of GDEs are clustered more densely in certain areas of the state, watersheds with multiple types of GDEs are found in both humid (e.g. coastal) and more arid regions. Springs are most densely concentrated in the North Coast and North Lahontan, whereas groundwater dependent wetlands and associated vegetation alliances are concentrated in the North and South Lahontan and Sacramento River hydrologic regions. The percentage of land area where stream discharge is most dependent on groundwater is found in the North Coast, Sacramento River and Tulare Lake regions. GDE clusters are located at the highest percentage in the North Coast (an area of the highest annual rainfall totals), North Lahontan (an arid, high desert climate with low annual rainfall), and Sacramento River hydrologic regions. That GDEs occur in such distinct climatic and hydrologic settings reveals the widespread distribution of these ecosystems.

Conclusions/Significance: Protection and management of groundwater-dependent ecosystems are hindered by lack of information on their diversity, abundance and location. By developing a methodology that uses existing datasets to locate GDEs, this assessment addresses that knowledge gap. We report here on the application of this method across California, but believe the method can be expanded to regions where spatial data exist.

Citation: Howard J, Merrifield M (2010) Mapping Groundwater Dependent Ecosystems in California. PLoS ONE 5(6): e11249. doi:10.1371/journal.pone.0011249

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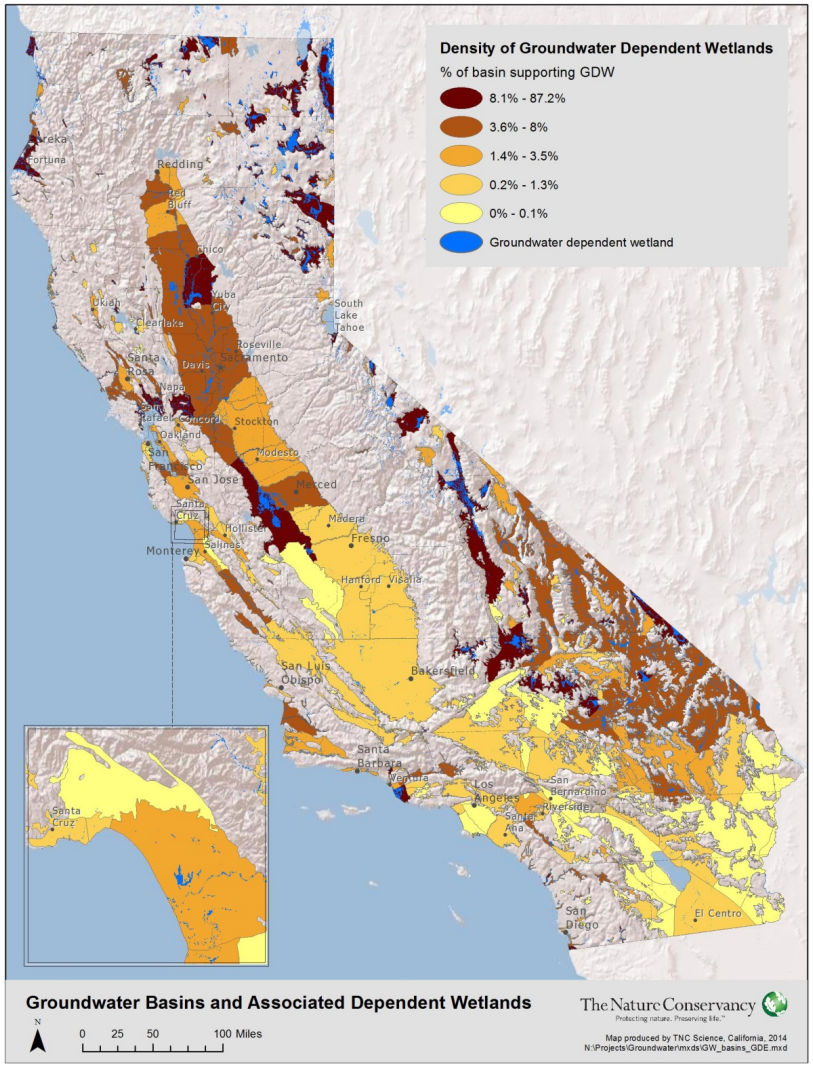
Introduction

Only ~1% of freshwater resources on the Earth's surface are contained within surface waters – such as rivers, lakes, and swamps. The remaining 99% is stored in either icecaps/glaciers (69%) or in groundwater (30%). Because of groundwater's accessibility and quantity, groundwater is a vital source of freshwater for human communities throughout the world [1], [2], [3].

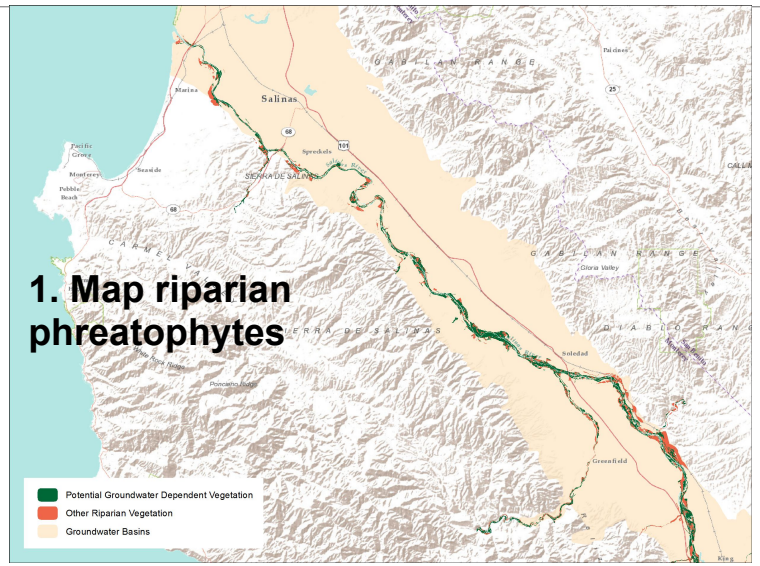
In the U.S. and other developed countries, the value of groundwater for drinking water, irrigation, and industry is reflected in government policies that control groundwater availability and quality (e.g. U.S. EPA 2002). Some governments, including Australia [4] and European countries through The European Union (EU) Groundwater Directive (GWD Directive 2006/118/EC) [5] also now require the ecological condition of groundwater ecosystems to be considered when making policy decisions. However, in the U.S. few or no policies consider groundwater dependent ecosystems when allocating resources.

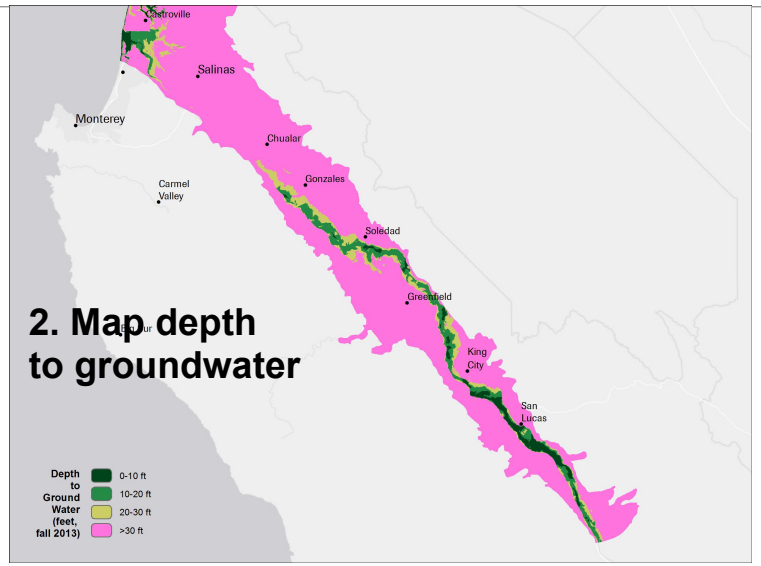
Most groundwater conservation and management efforts focus on protecting groundwater for drinking water and for other human uses with little understanding or focus on the ecosystems that depend on groundwater. The disconnect between ecological and human uses of groundwater is key as it suggests that policies and regulations that protect groundwater for human purposes may not necessarily protect groundwater dependent ecosystems (GDEs).

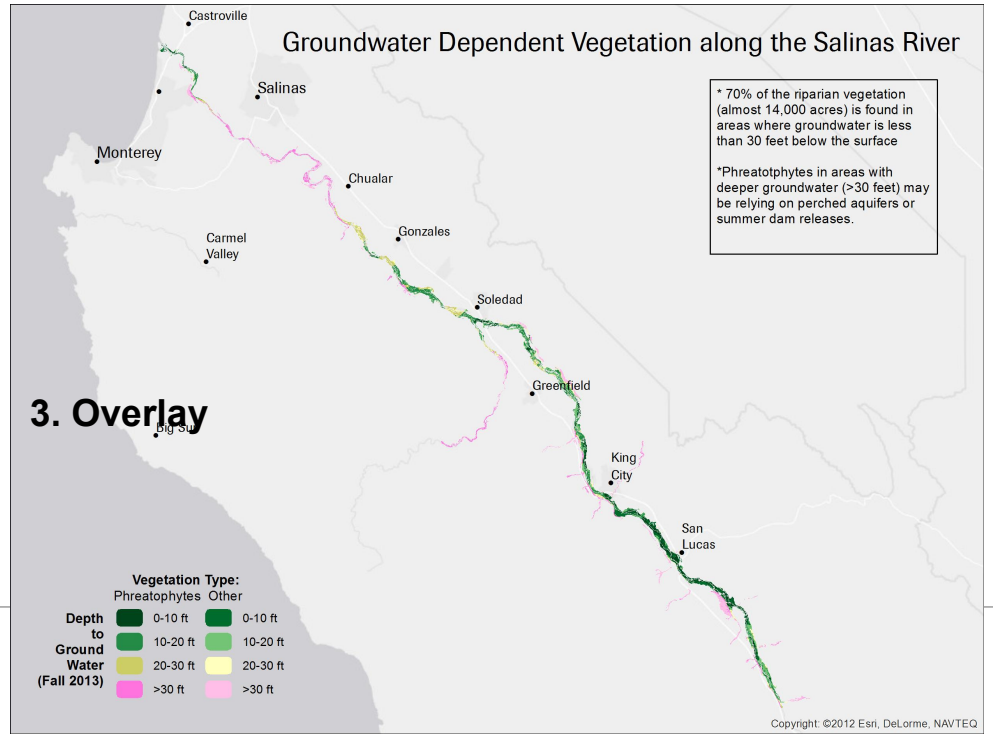
Although groundwater monitoring is incomplete in many parts of the world, available data suggest that groundwater supply and quality are widely threatened by over-extraction and contamination [1]. This loss and degradation are likely to increase in the future, as a result of climate-change-induced drought and human population growth, with serious consequences for both people and ecosystems [1].



Mapping GDEs at the Basin scale







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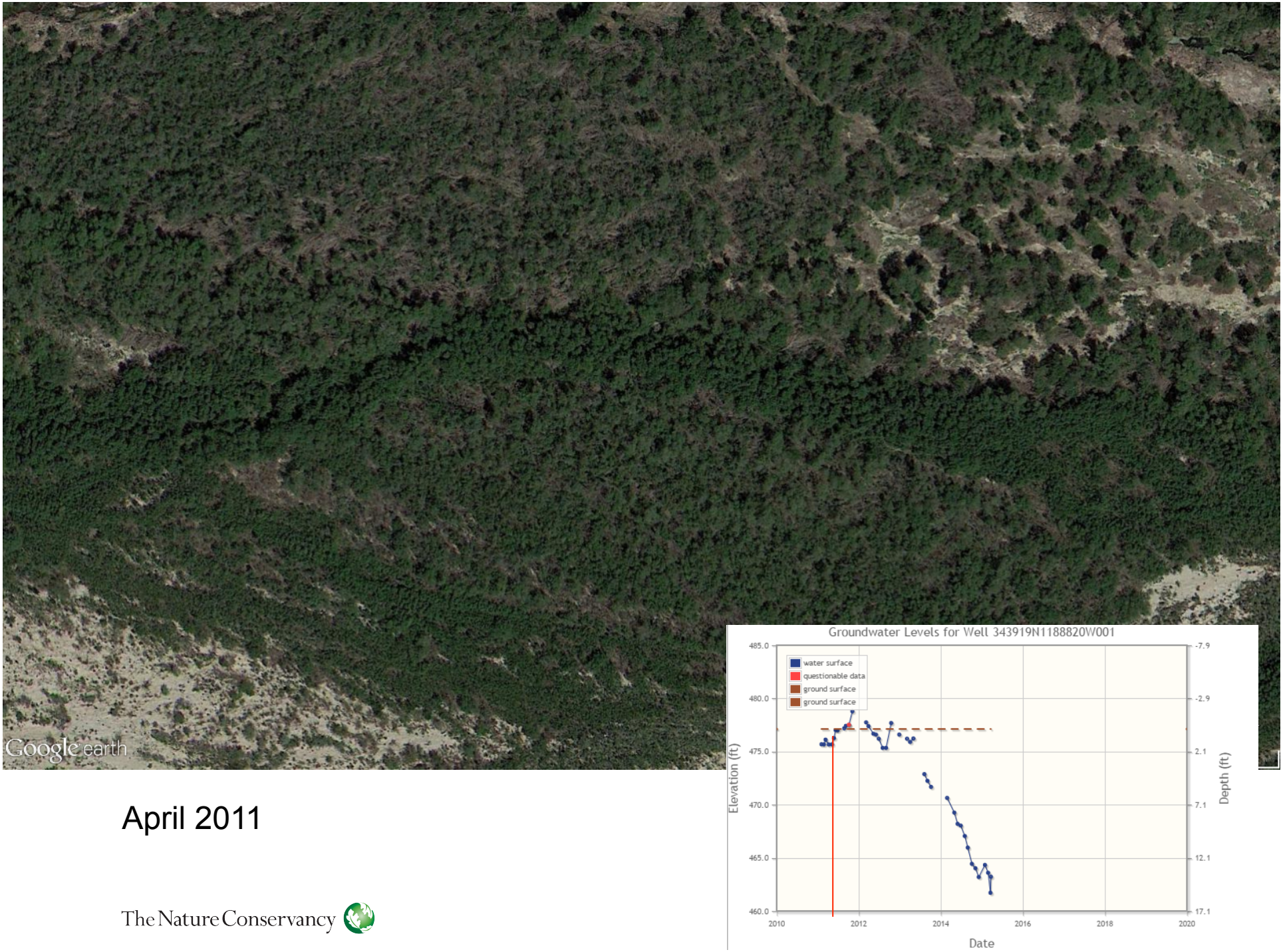
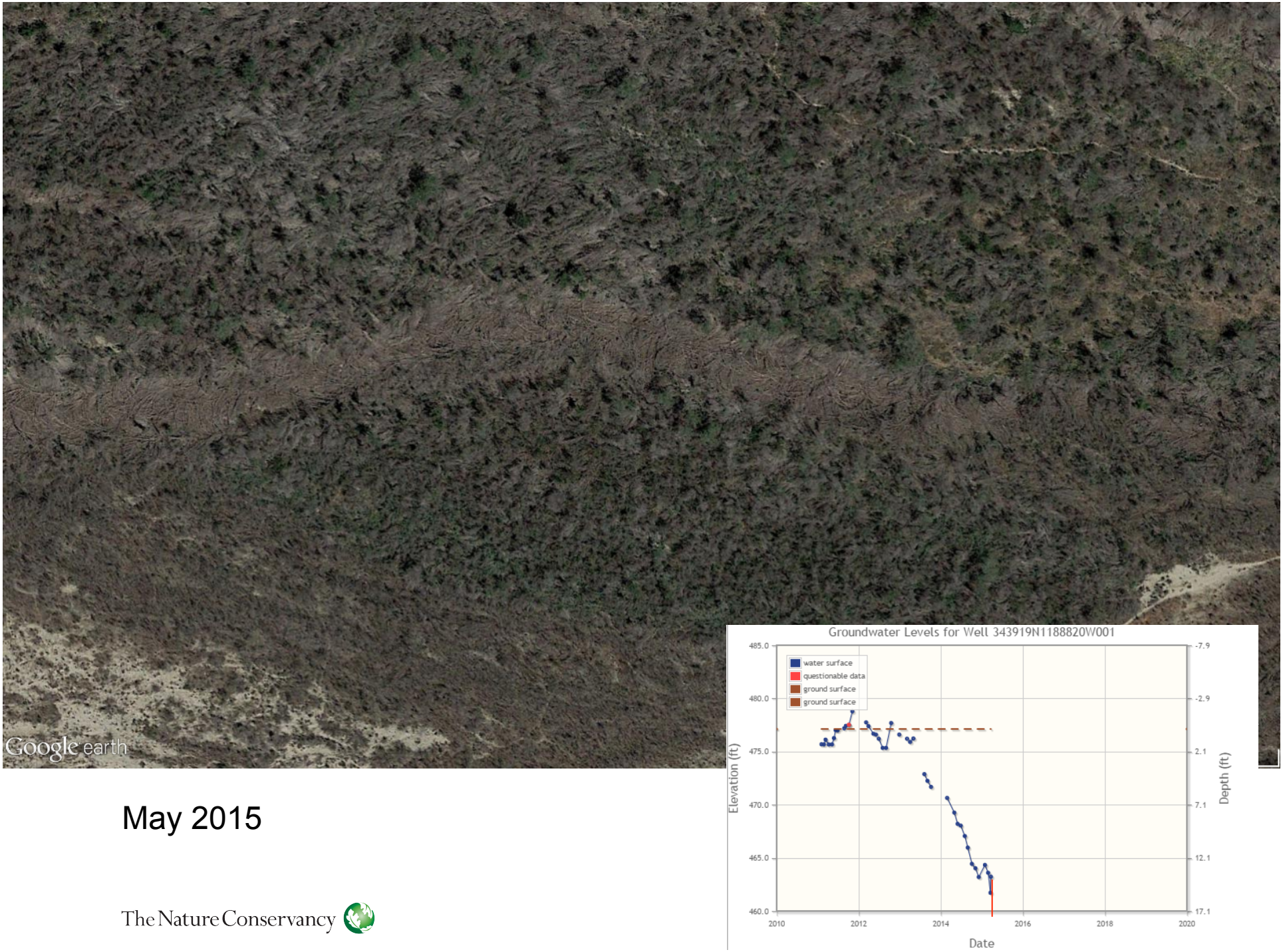


April 2011

The Nature Conservancy

December 2013

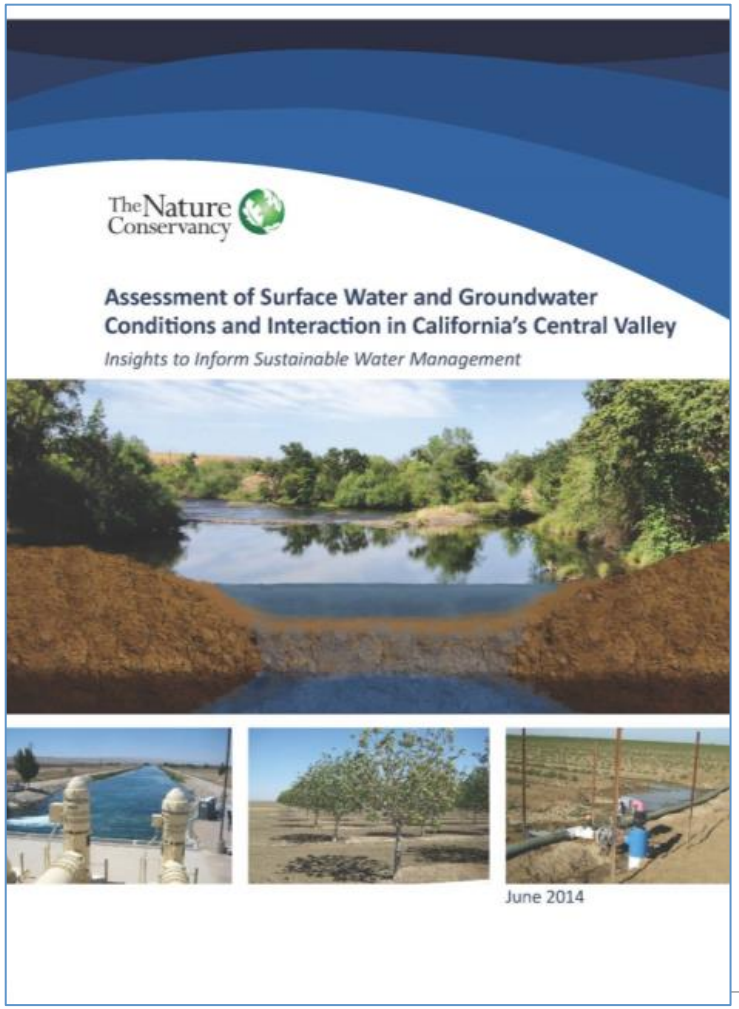
The Nature Conservancy

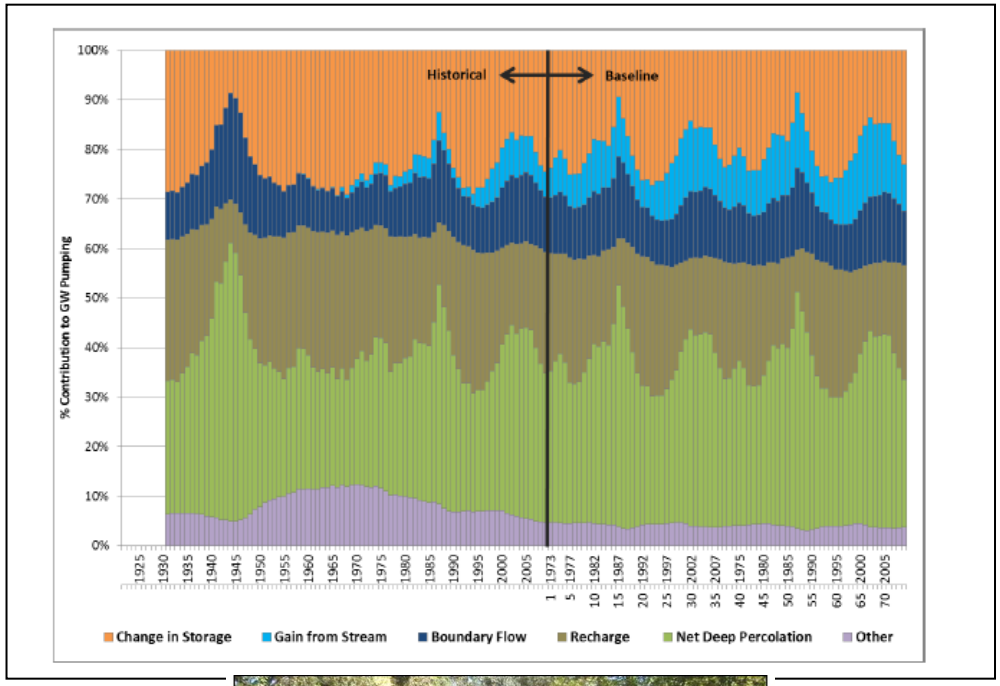


May 2015

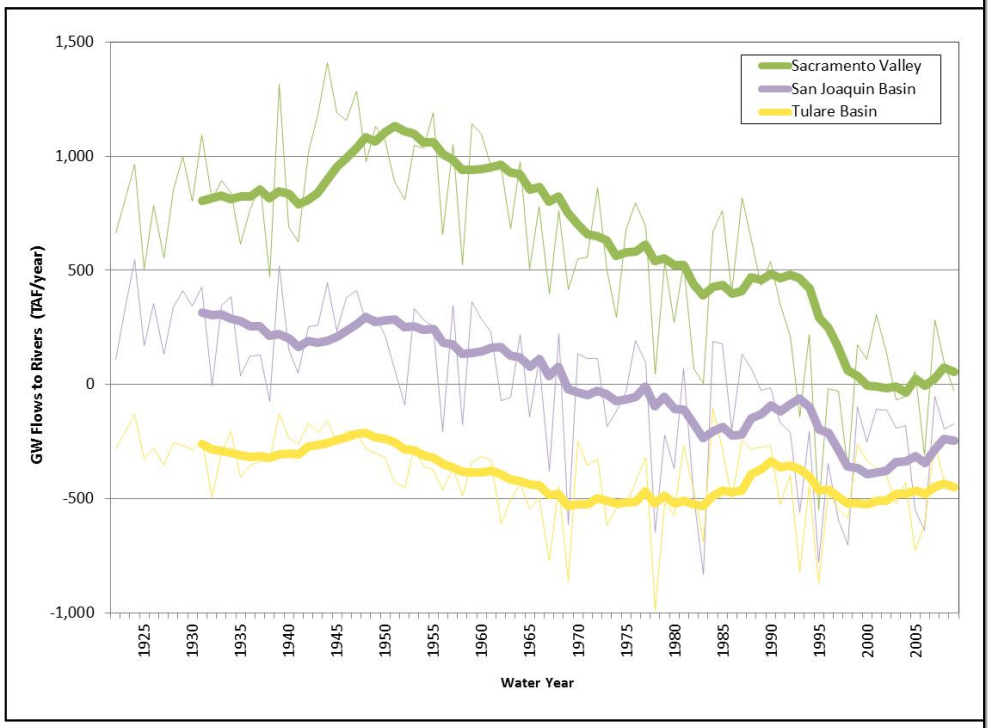
The Nature Conservancy

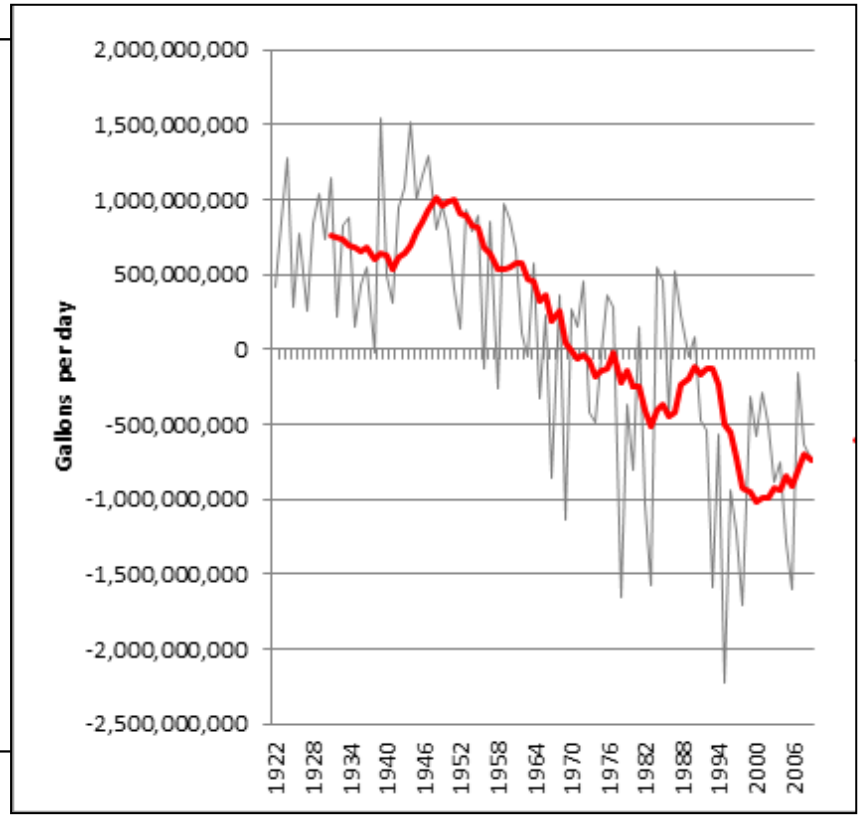
Building the case for nature:
Assess surface water-groundwater interaction

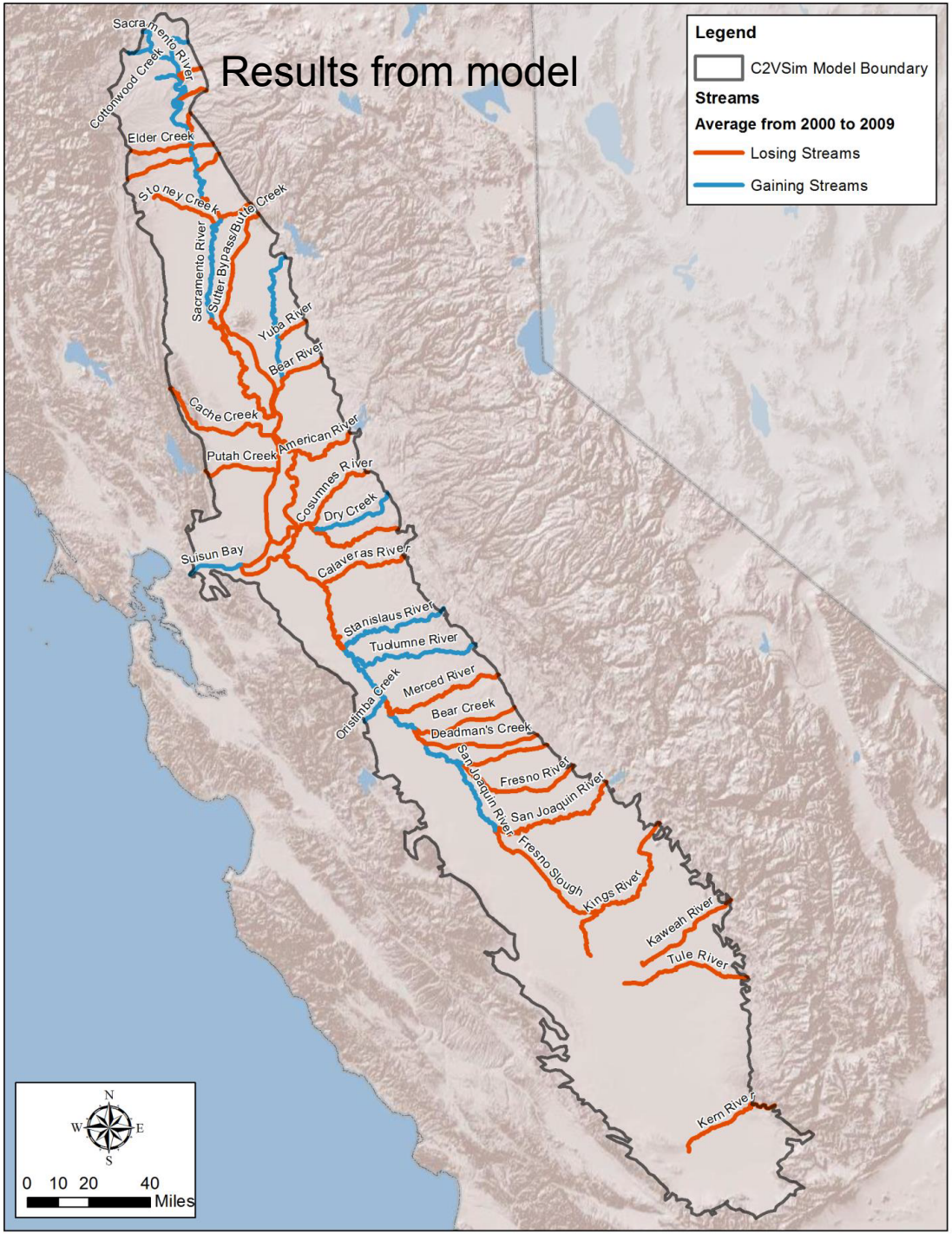


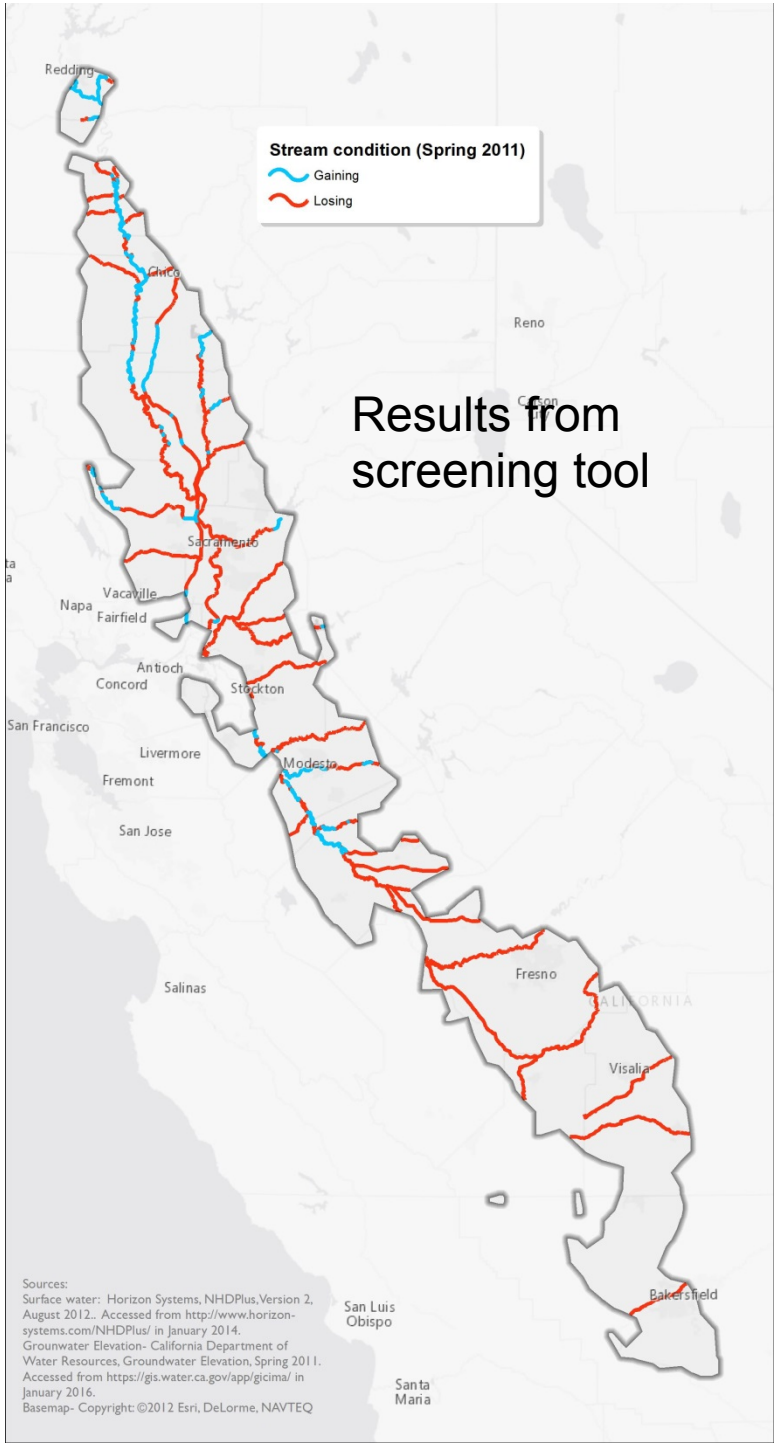


Groundwater contribution to rivers






Results from model
Legend
C2VSim Model Boundary
Streams
Average from 2000 to 2009
Losing Streams
Gaining Streams
Sacramento River
Cottonwood Creek
Elder Creek
Stoney Creek
Sutter Bypass/Butte Creek
Sacramento River
Yuba River
Bear River
Cache Creek
American River
Putah Creek
Cosumnes River
Dry Creek
Suisun Bay
Calaveras River
Stanislaus River
Tuolumne River
Merced River
Orestimba Creek
Bear Creek
Deadman's Creek
San Joaquin River
Fresno River
San Joaquin River
Fresno Slough
Kings River
Kaweah River
Tule River
Kern River
N
W
E
S
0 10 20 40
Miles


Results from screening tool
Stream condition (Spring 2011)
Gaining
Losing
Redding
Chico
Reno
Carson
Sacramento
Napa
Vacaville
Fairfield
Antioch
Concord
Stockton
San Francisco
Livermore
Modesto
Fremont
San Jose
Salinas
Fresno
Visalia
Bakersfield
San Luis Obispo
Santa Maria
Sources:
Surface water: Horizon Systems, NHDPlus, Version 2, August 2012.. Accessed from http://www.horizon-systems.com/NHDPlus/ in January 2014.
Grounwater Elevation- California Department of Water Resources, Groundwater Elevation, Spring 2011. Accessed from https://gis.water.ca.gov/app/gicima/ in January 2016.
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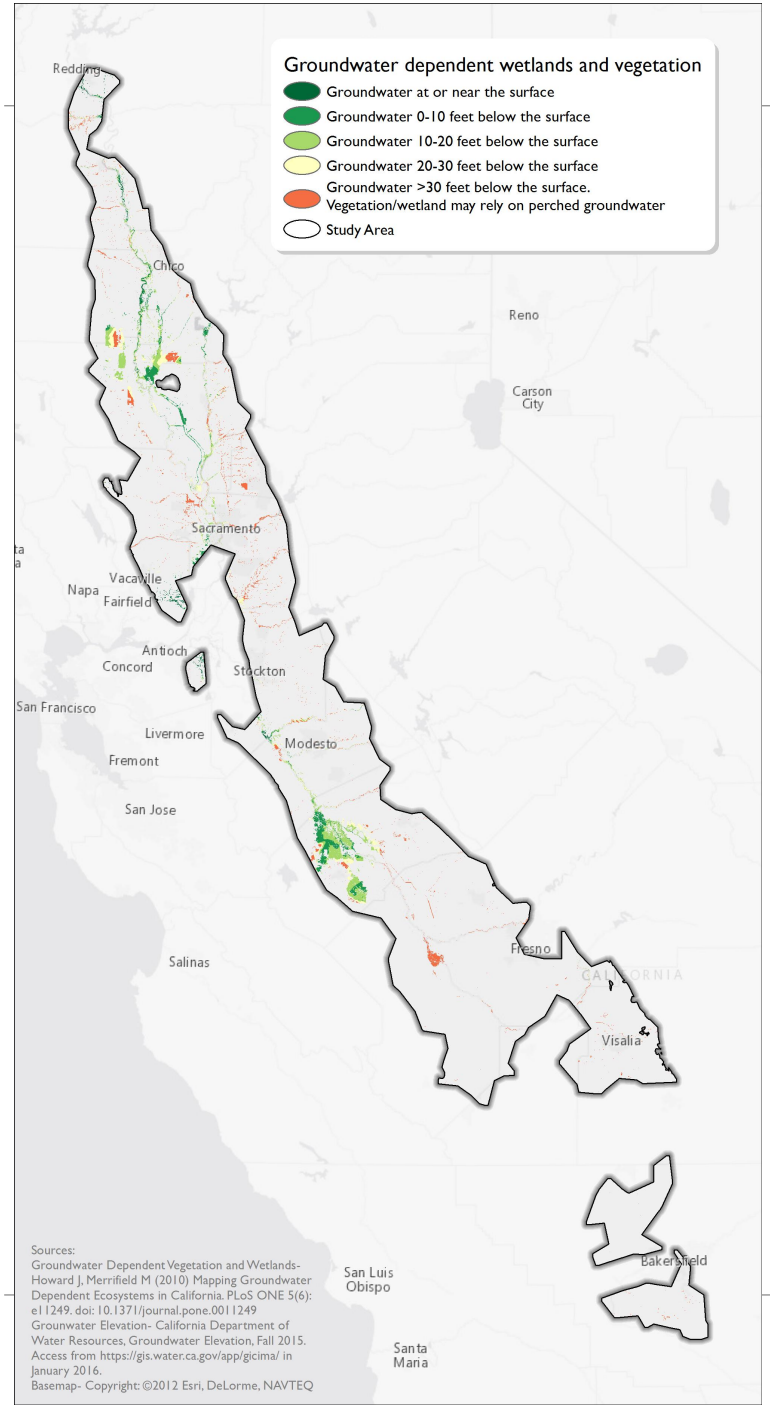
Groundwater dependent wetlands and vegetation
Groundwater at or near the surface
Groundwater 0-10 feet below the surface
Groundwater 10-20 feet below the surface
Groundwater 20-30 feet below the surface
Groundwater >30 feet below the surface.
Vegetation/wetland may rely on perched groundwater
Study Area
Redding
Chico
Reno
Carson City
Sacramento
Napa
Vacaville
Fairfield
Antioch
Concord
Stockton
San Francisco
Livermore
Modesto
Fremont
San Jose
Fresno
Salinas
Visalia
Bakersfield
San Luis Obispo
Santa Maria
Sources:
Groundwater Dependent Vegetation and Wetlands- Howard J, Merrifield M (2010) Mapping Groundwater Dependent Ecosystems in California. PLoS ONE 5(6): e11249. doi: 10.1371/journal.pone.0011249
Grounwater Elevation- California Department of Water Resources, Groundwater Elevation, Fall 2015. Access from https://gis.water.ca.gov/app/gicima/ in January 2016.
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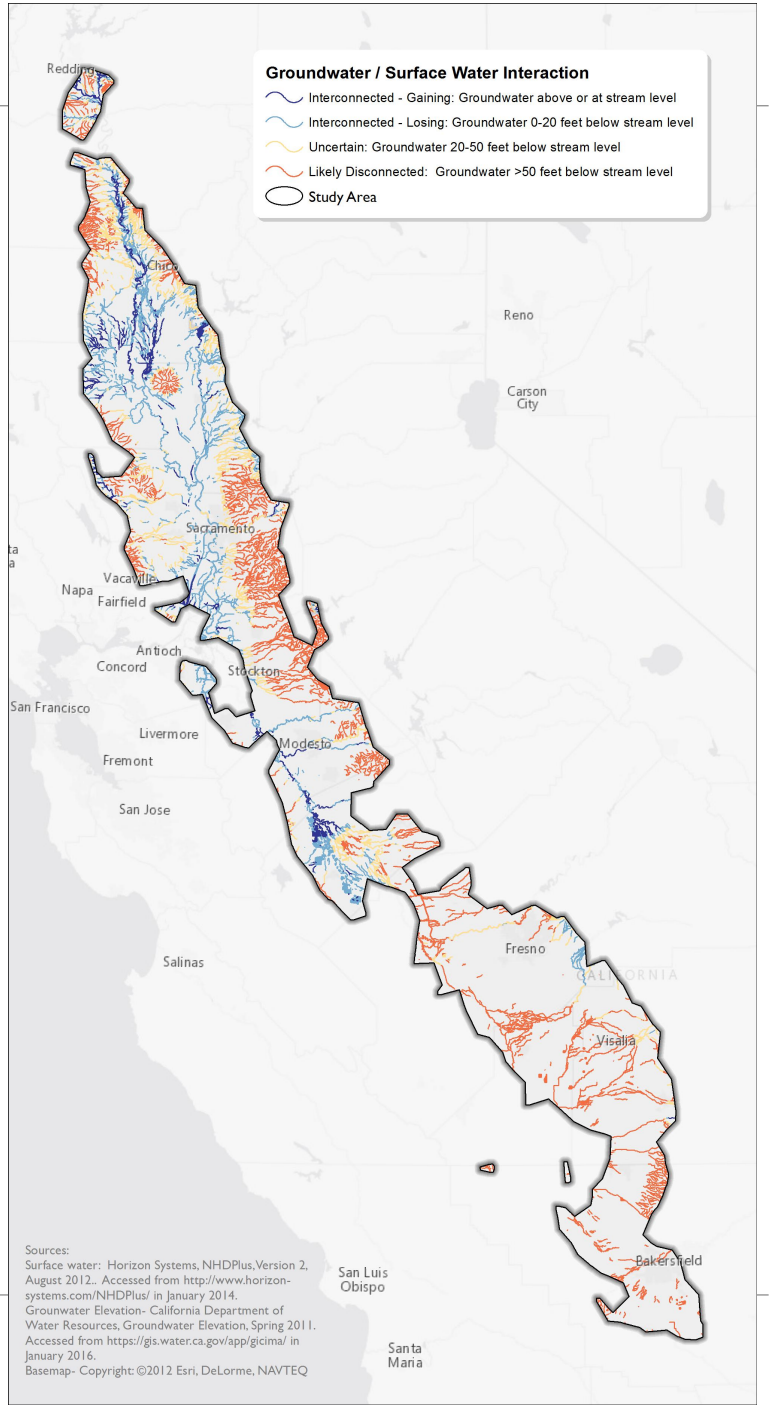
Groundwater / Surface Water Interaction
Interconnected - Gaining: Groundwater above or at stream level
Interconnected - Losing: Groundwater 0-20 feet below stream level
Uncertain: Groundwater 20-50 feet below stream level
Likely Disconnected: Groundwater >50 feet below stream level
Study Area
Redding
Chico
Reno
Carson City
Sacramento
Napa
Vacaville
Fairfield
Antioch
Concord
Stockton
San Francisco
Livermore
Modesto
Fremont
San Jose
Fresno
Salinas
Visalia
Bakersfield
San Luis Obispo
Santa Maria
Sources:
Surface water: Horizon Systems, NHDPlus,Version 2, August 2012.. Accessed from http://www.horizon-systems.com/NHDPlus/ in January 2014.
Grounwater Elevation- California Department of Water Resources, Groundwater Elevation, Spring 2011. Accessed from https://gis.water.ca.gov/app/gicima/ in January 2016.
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Road Map

- How are GDEs protected under SGMA?
- What and where are GDEs?
- **Thoughts on managing for interconnected surface water and GDEs**

INCLUDE DEFINITIONS IN REGULATIONS

Groundwater-Dependent Ecosystems: Ecosystems that require access to, replenishment or benefit from, or otherwise rely on subsurface stores of water to function or persist. Groundwater-Dependent Ecosystems are often supported by Interconnected Surface Water.

INCLUDE DEFINITIONS IN REGULATIONS

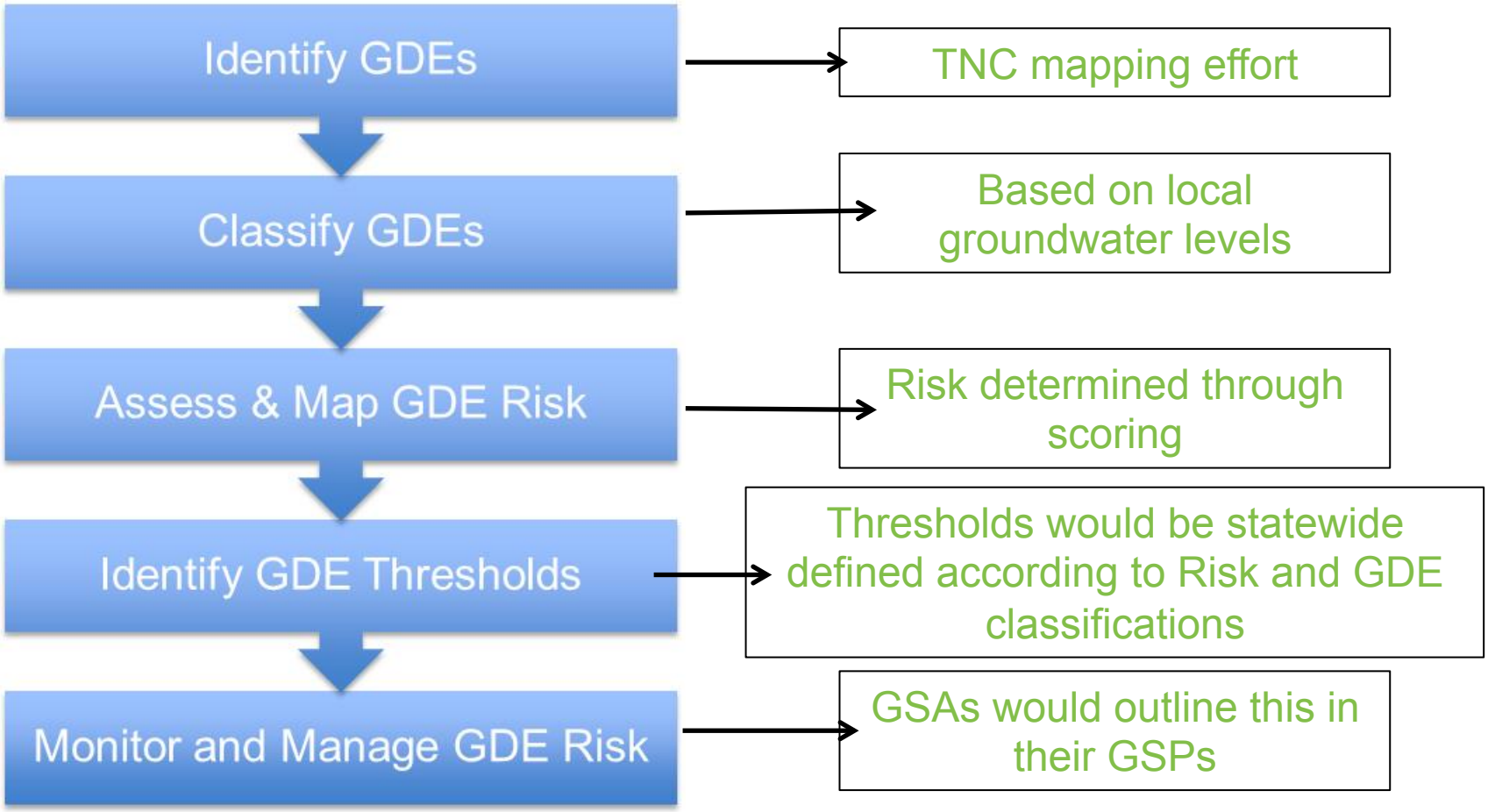
Disconnected Surface Water: surface waters that feature a *year-round, unsaturated zone of sediments between the lowest elevation of the surface water body and the top of the saturated groundwater zone* and that infiltrate water through the unsaturated zone into groundwater.

Interconnected Surface Water: *Surface waters, including streams, lakes, rivers, and wetlands that are not disconnected from groundwater*. This includes losing streams and water bodies where surface water is being lost but is still connected to groundwater by a saturated zone. Interconnected Surface Water often supports Groundwater-Dependent Ecosystems.

GSPs

- Map Interconnected Surface Water (ISW) and Groundwater-Dependent Ecosystems (GDEs)
- List of ecosystems rely on ISW and/or comprise GDEs
- A water budget that includes needs of native plants and animals in terms groundwater levels necessary to sustain them.
- Measurable ecological objectives for maintaining and enhancing ISW and GDE health. (e.g. *Measuring What Matters 2015)*
  - Objectives to maintain groundwater levels should include levels needed to sustain GDEs.
  - Objectives to maintain interconnected surface waters
  - Set ecological thresholds and triggers conservatively
- Monitor the size, volume and temporal availability of interconnected surface water bodies.
- Monitor extent and health of GDEs

Assessing and Managing Risk:
A Framework for Managing for GDEs (and ISWs)



Source: NSW Office of Water, 2012
Froend et al., 2004

Assessing Risk to GDEs: A Wetland example

SUSCEPTIBILITY SCORE = A + B + C

A

Conservation Value Category	Score
Ecosystem with international, national or regional conservation values (legislated) that has little evidence of alteration from surrounding land-use practices	1
Ecosystem with international, national, or regional conservation values (legislated) that has evidence of low to moderate impacts from surrounding land-use practices	2
Ecosystem that has not been assessed for conservation values or is poorly understood, and that has evidence of low to moderate impacts from surrounding land-use	3
Ecosystem with no recognized conservation values that has been moderately to severely degraded by surrounding land-use patterns	4

B Historic rate of gw level change

Wetland Category	No change or increase	Low	Moderate	High
Score	4	3	2	1
0-3 m	-	<0.25m	0.25-0.5m	>0.5m
3-6m	-	<0.75m	0.75-1m	>1m
6-10m	-	<1.25m	1.25-1.5m	>1.5m

C

Depth to groundwater Category	Score
>10m	4
6-10m	3
3-6m	2
0-3m	1

Susceptibility Score	Risk Classification
4-6	Severe
7-9	Significant
10-12	Moderate
13-15	Low

(Froend, et al., 2004)

Identifying Thresholds Based on Risk Classification

RISK OF IMPACT LEVEL AND MAGNITUDE OF CHANGE (M/YEAR)

Table 2: Risk of impact level and magnitude of permissible change (m) for phreatophtyic vegetation.

Phreatophytic category	Low	Moderate	High	Severe
0-3m (wetland)	0-0.25	0.25-0.5	0.5-0.75	>0.75
0-3m (terrestrial)	0-0.75	0.75-1.25	1.25-1.75	>1.75
3-6m	0-1.0	1.0-1.5	1.5-2.25	>2.25
6-10m	0-1.25	1.25-2.0	2.0-2.75	>2.75

Table 3: Risk of impact level and rate of permissible change (m/year) for phreatophytic vegetation.

Phreatophytic category	Low	Moderate	High	Severe
0-3m (wetland)	0-0.1	0.1-0.2	0.2-0.3	>0.3
0-3m (terrestrial)	0-0.1	0.1-0.25	0.25-0.5	>0.5
3-6m	0-0.1	0.1-0.25	0.25-0.5	>0.5
6-10m	0-0.1	0.1-0.25	0.25-0.5	>0.5

(Froend, et al., 2004)

Monitoring and Managing GDEs Based on Risk Classification

Phreatophytic Category	Low	Moderate	High	Severe
0-3m (wetland)	0-0.1	0.1-0.2	0.2-0.3	>0.3
0-3 m (terrestrial)	0-0.1	0.1-0.25	0.25-0.5	>0.5
3-6m	0-0.1	0.1-0.25	0.25-0.5	>0.5
6-10m	0-0.1	0.1-0.25	0.25-0.5	>0.5

Possible Management Options:

1. **Restrict groundwater pumping or impose groundwater management fees (as authorized under SGMA).**

2. **Construct groundwater recharge projects (in lieu or direct)**

FINAL THOUGHTS

- We can begin to develop tools and guidance to manage for GDEs today.
- Data will help reduce uncertainty – but we don’t need to wait for perfect data to take action.








The End