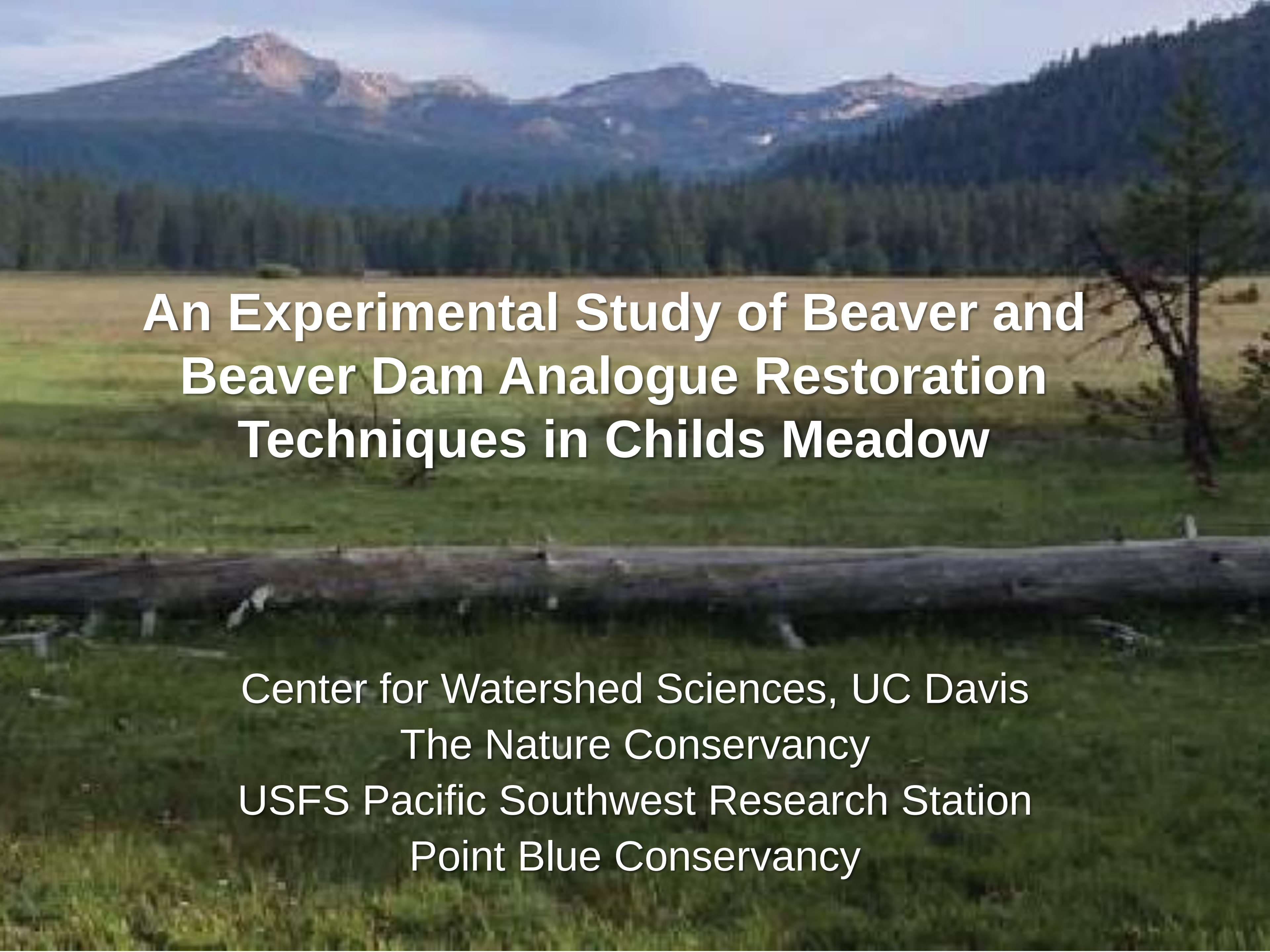
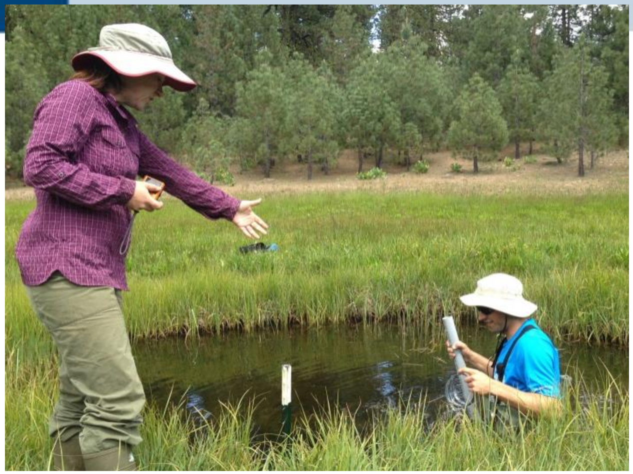


An Experimental Study of Beaver and Beaver Dam Analogue Restoration Techniques in Childs Meadow

Center for Watershed Sciences, UC Davis
The Nature Conservancy
USFS Pacific Southwest Research Station
Point Blue Conservancy

Childs Meadow Project Partners



UC Davis - Sarah Yarnell
(hydrology, geomorphology, restoration)

The Nature Conservancy – Kristen Willson, Rodd Kelsey, Andrea Craig,
(restoration and grazing management, geomorphology)

UC Davis – Evan Wolf
(carbon, restoration)

Point Blue –Ryan Burnett
(birds, restoration)

USFS PSW – Karen Pope
(amphibians, restoration)

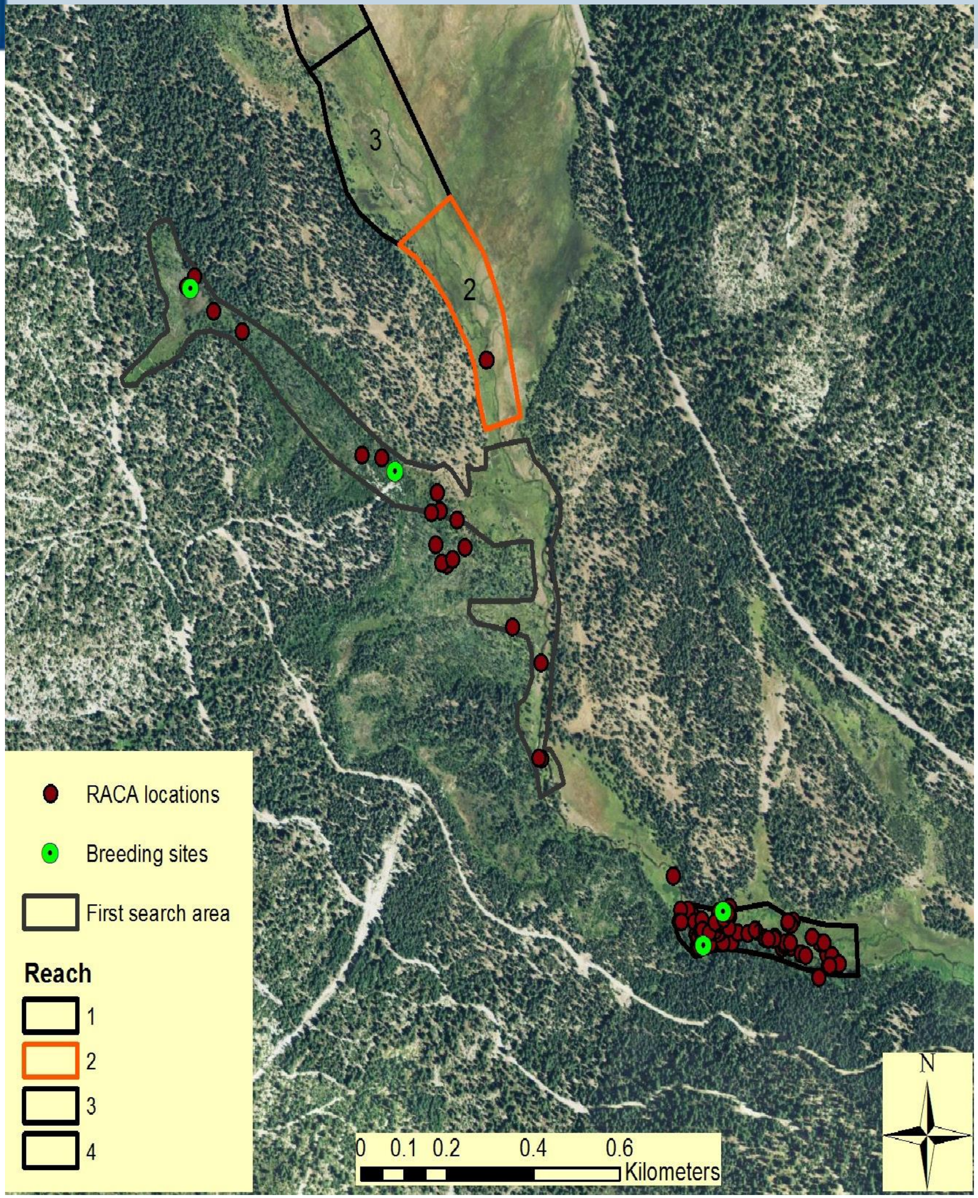
Childs Meadow Project Partners

U.S. Fish & Wildlife Service, Partnership Program - Jacob Byers and Sheli Wingo

Plumas Corporation
Leslie Mink
(Permitting)

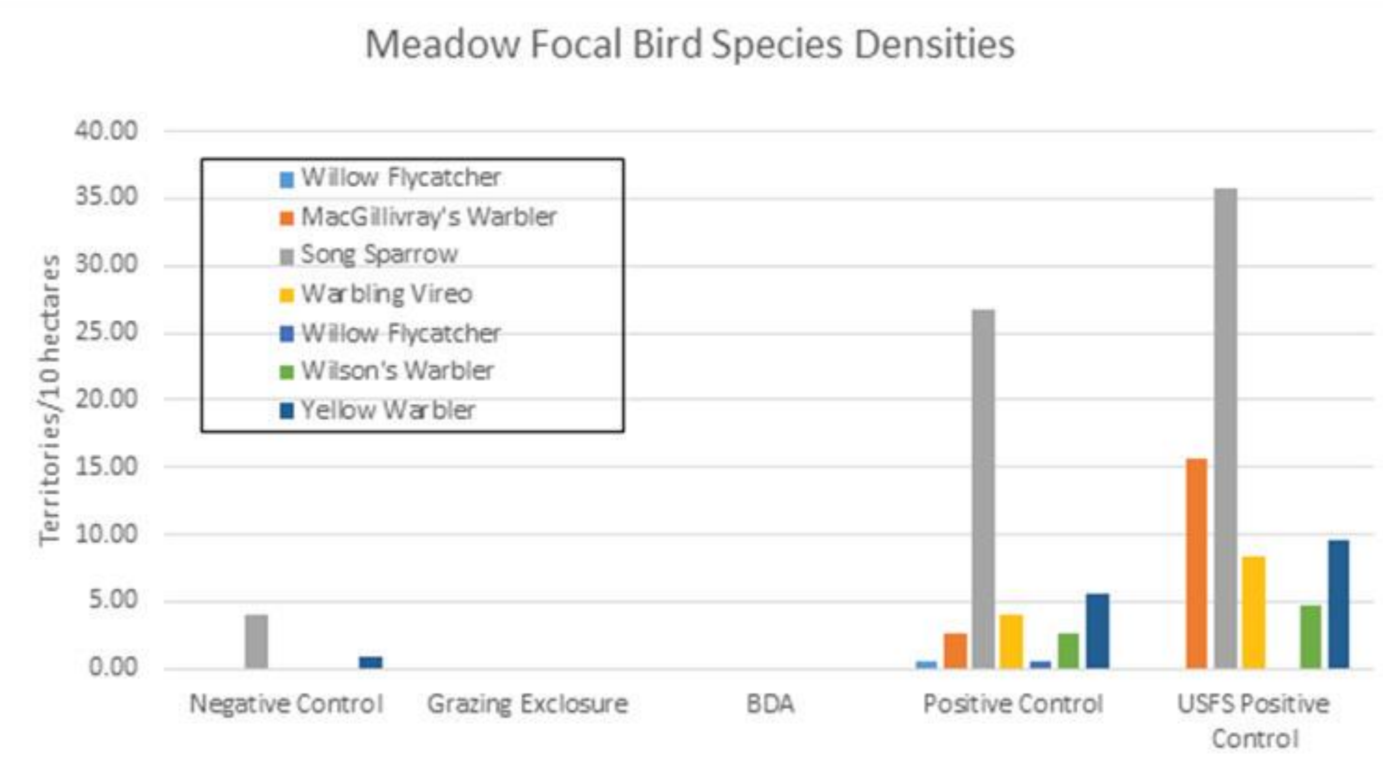
Scott River Watershed Council
Charna, Leslie, Peter
(BDA Construction)

Pre-restoration Meadow Conditions



Critical species:
Cascades frog
(Karen Pope's research)

Pre-restoration Meadow Conditions



Critical species: Willow flycatcher (Ryan Burnett's research)

Pre-restoration Meadow Conditions

Pre-treatment Reaches

Natural Beaver Reach

Images flown same day, Oct. 2014

- 100+ years of grazing
- Removal of timber from 1941-1974
- Ditching on edges of meadow by 1974
- Channel incised on average 1.6 ft, lacks woody vegetation
- Historic removal of beaver?

BDA Installation – Oct 2016


PELICAN

May 2017 – Wet Spring Conditions

BDAs withstood high winter flows

May 2017 – Wet Spring Conditions

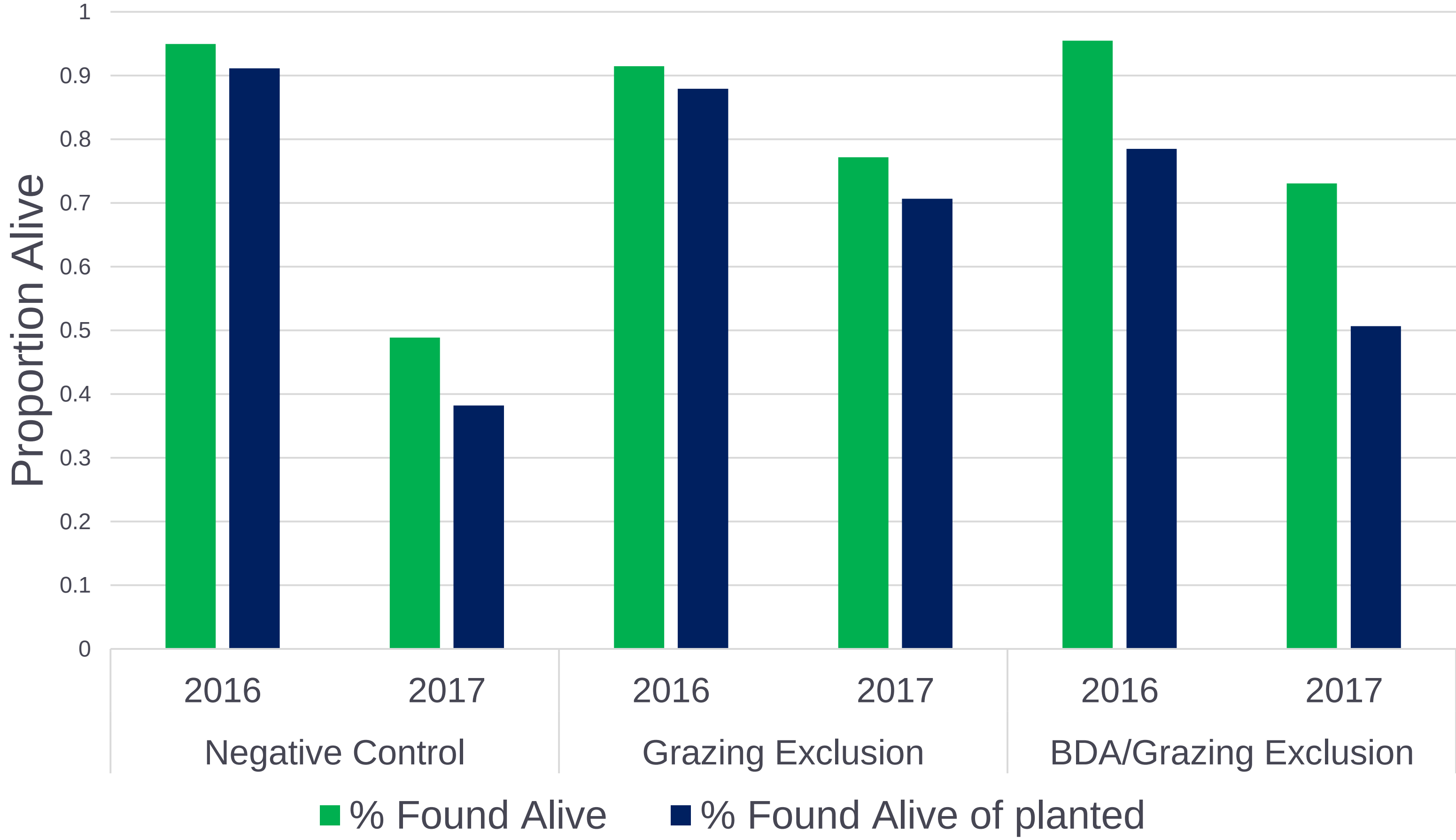
Natural beaver dams did not withstand high flows

Planted 750 more willows!

Students and Teachers Restoring A Watershed (STRAW)

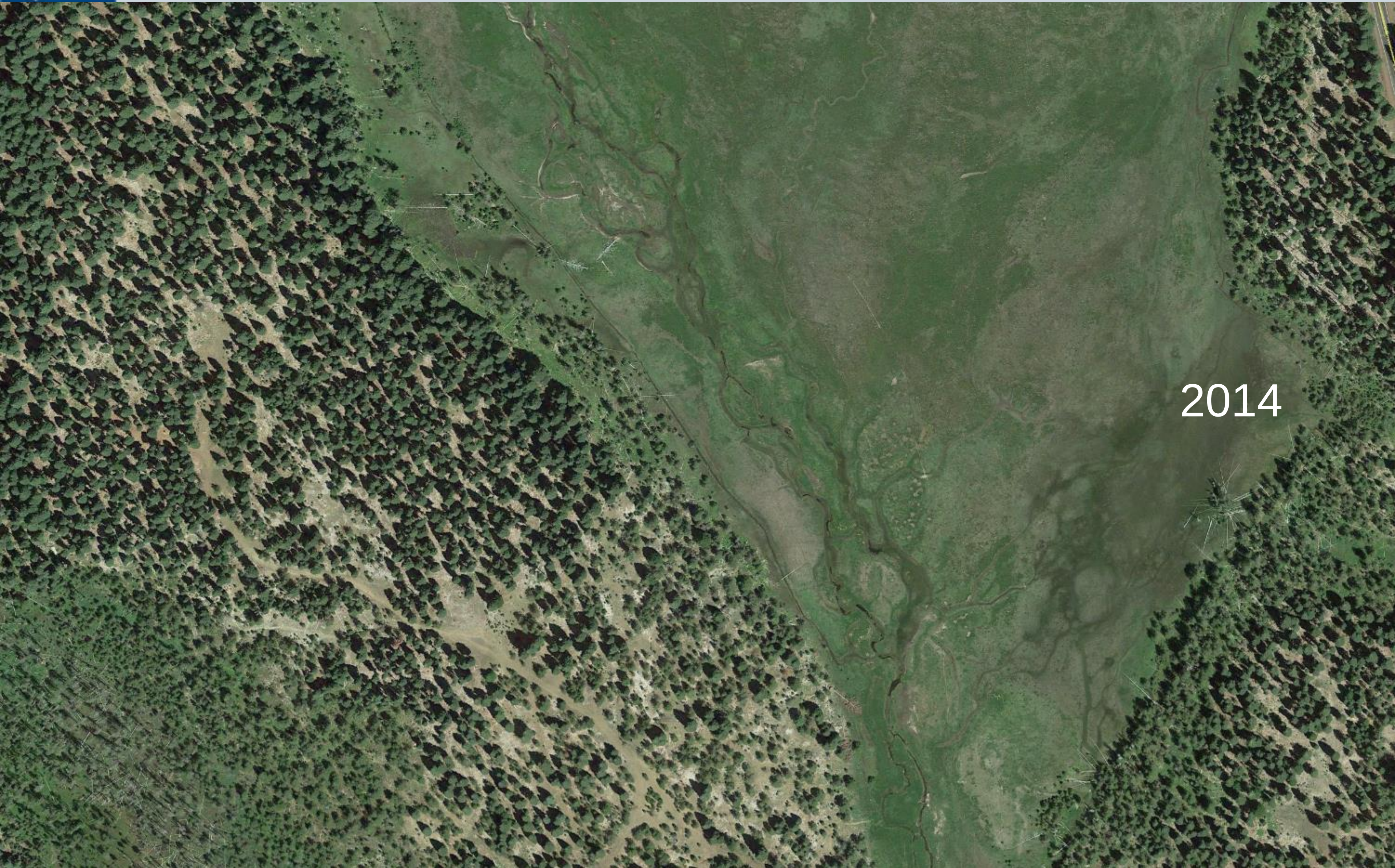
Point Blue

Childs Meadow willow survival

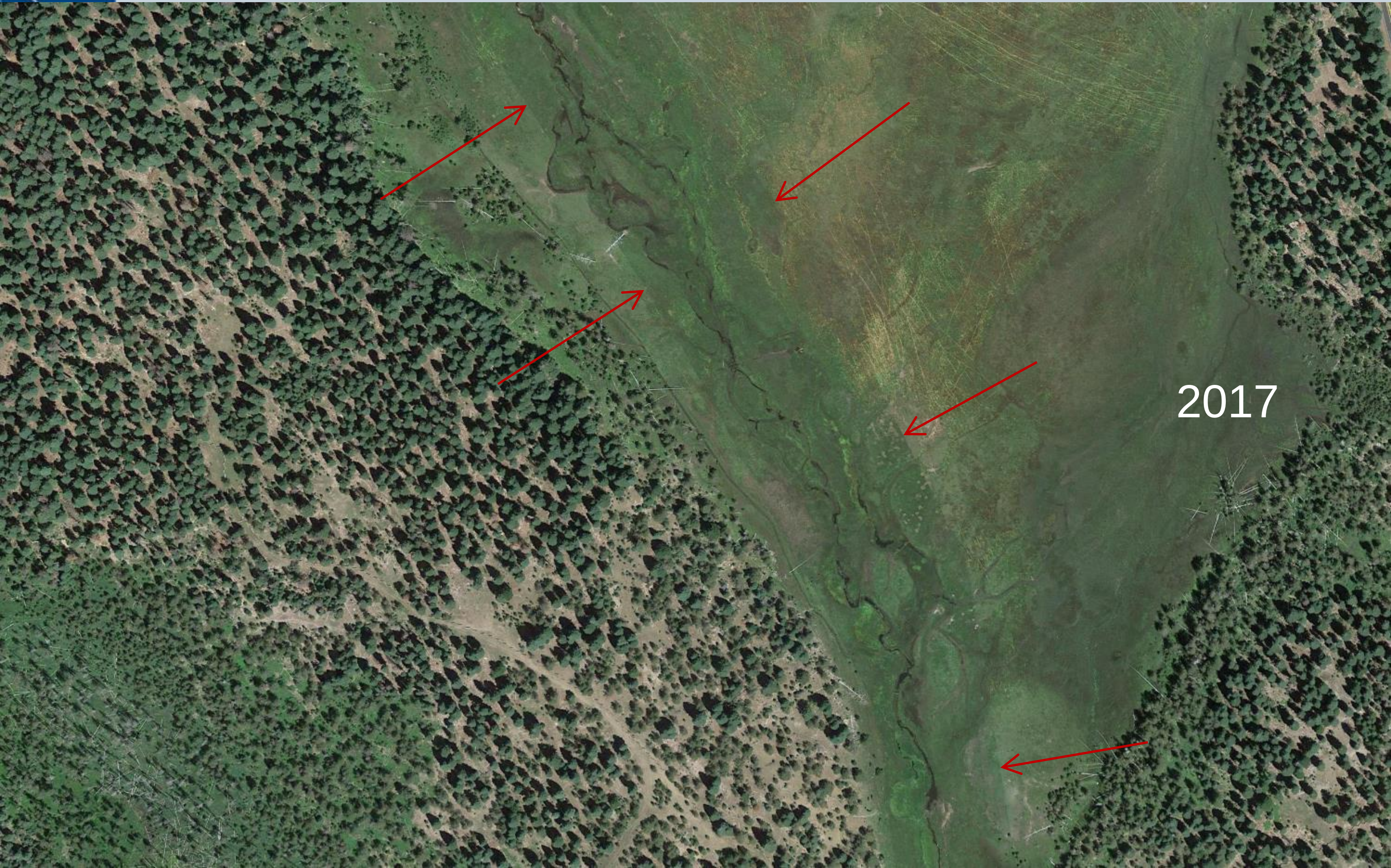


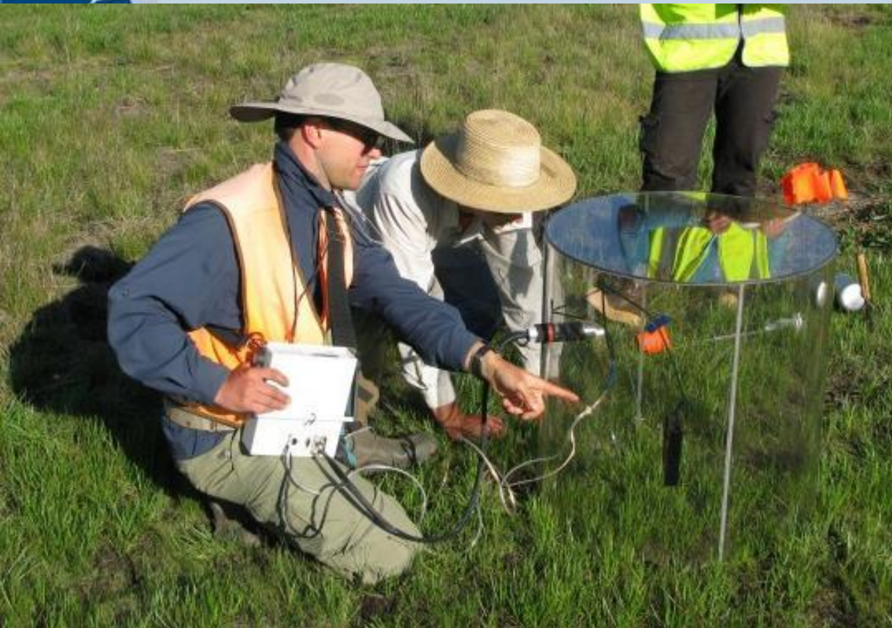
Point Blue

Carbon Sequestration – Effect of fencing



Carbon Sequestration – Effect of fencing





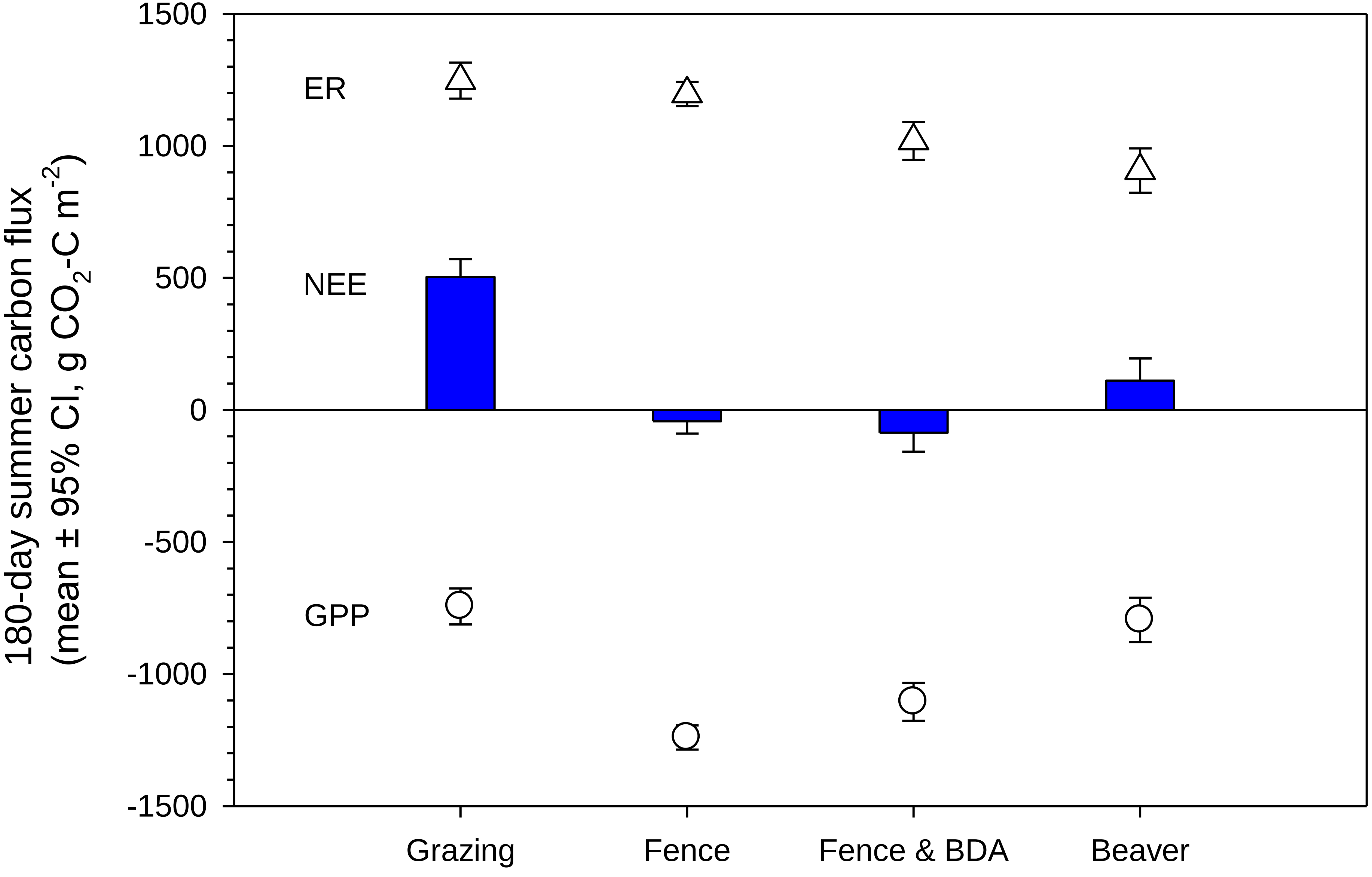
CO_2

- Photosynthetic uptake
- Ecosystem respiration

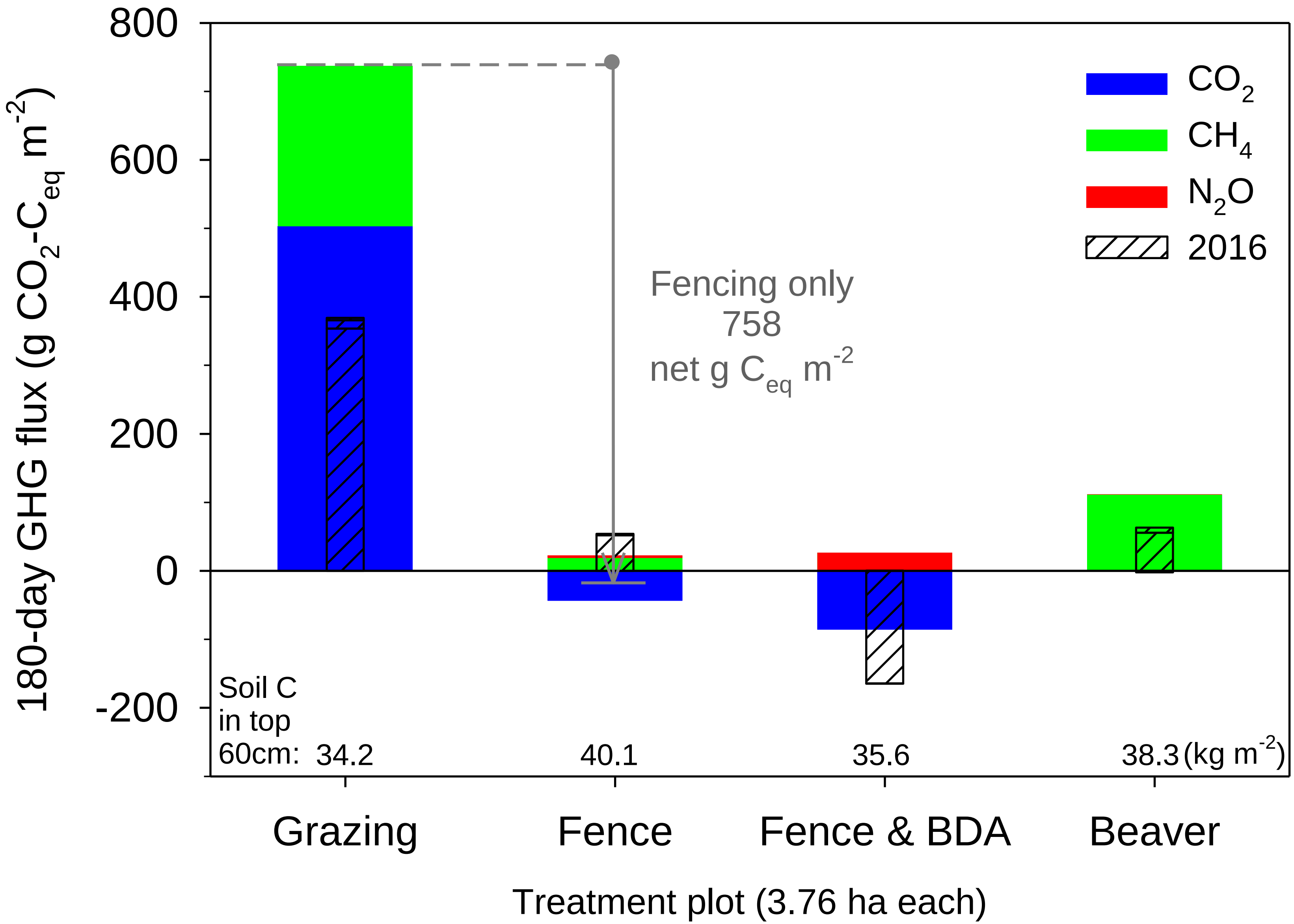
CH_4

N_2O

Carbon Sequestration – Effect of fencing



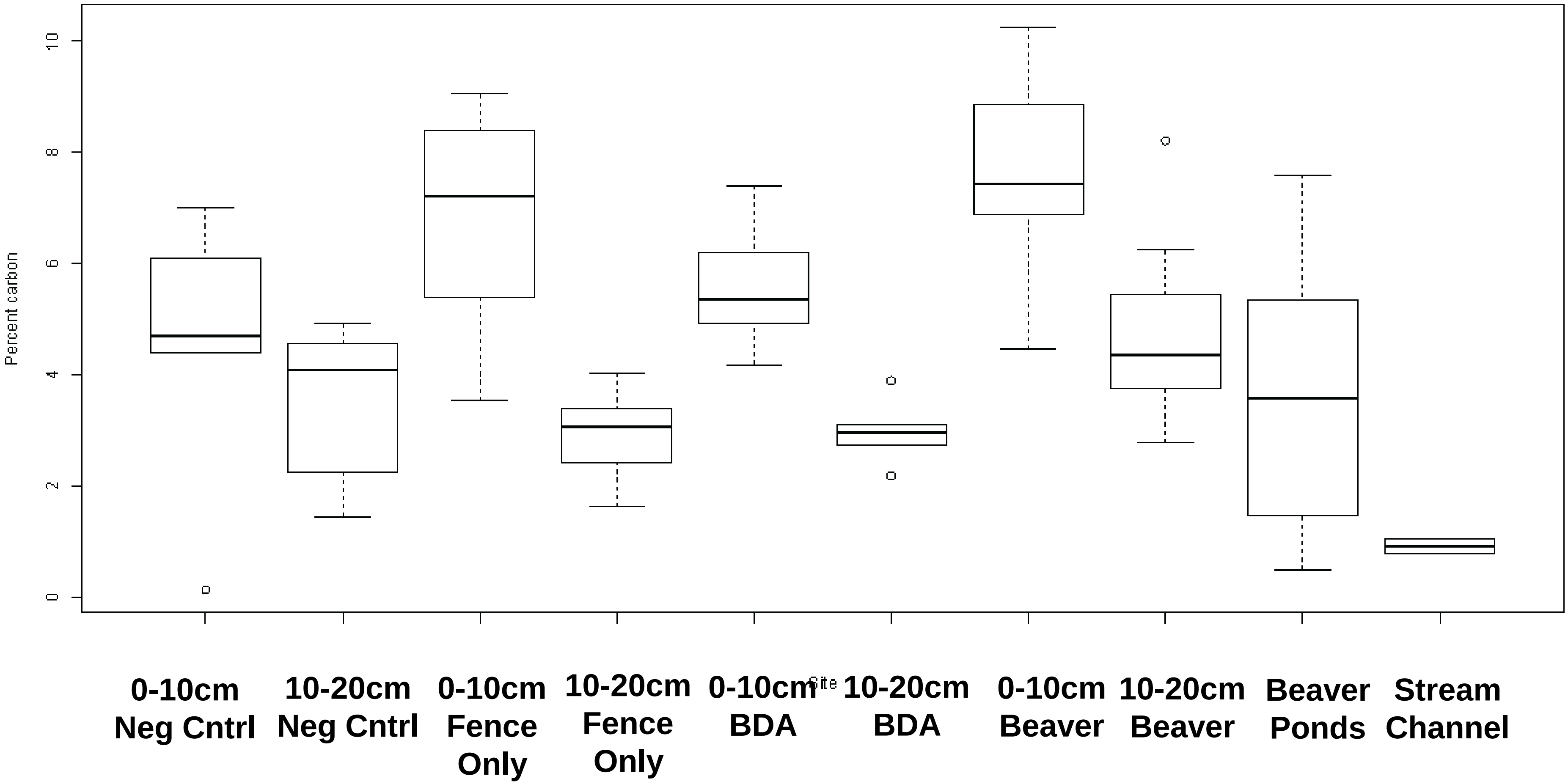
Carbon Sequestration – Effect of fencing

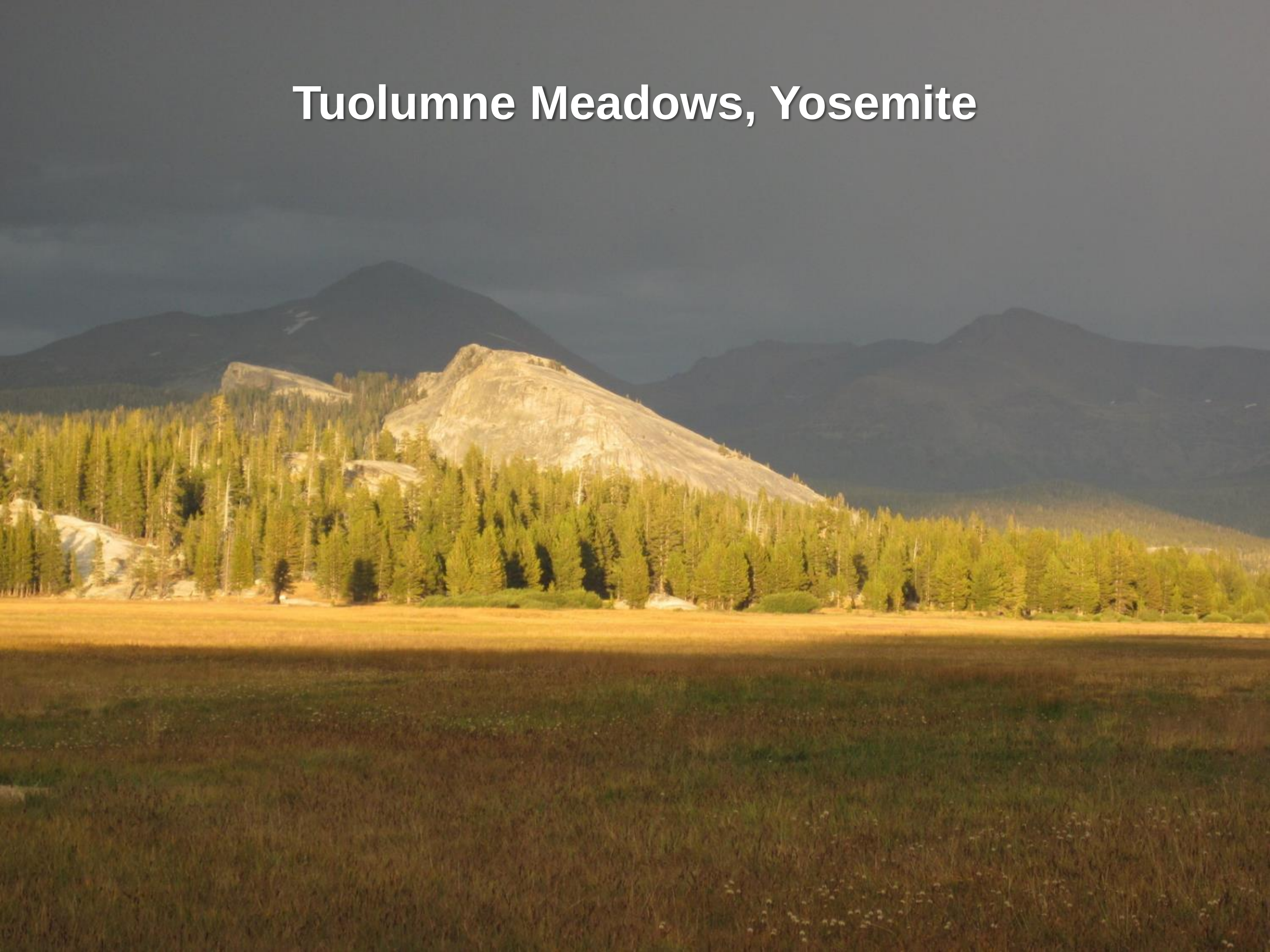


Carbon Sequestration – Soil and ponds

Carbon Sequestration – Soil and ponds

2016 Soil Core Data




Tuolumne Meadows, Yosemite

Wetland soil

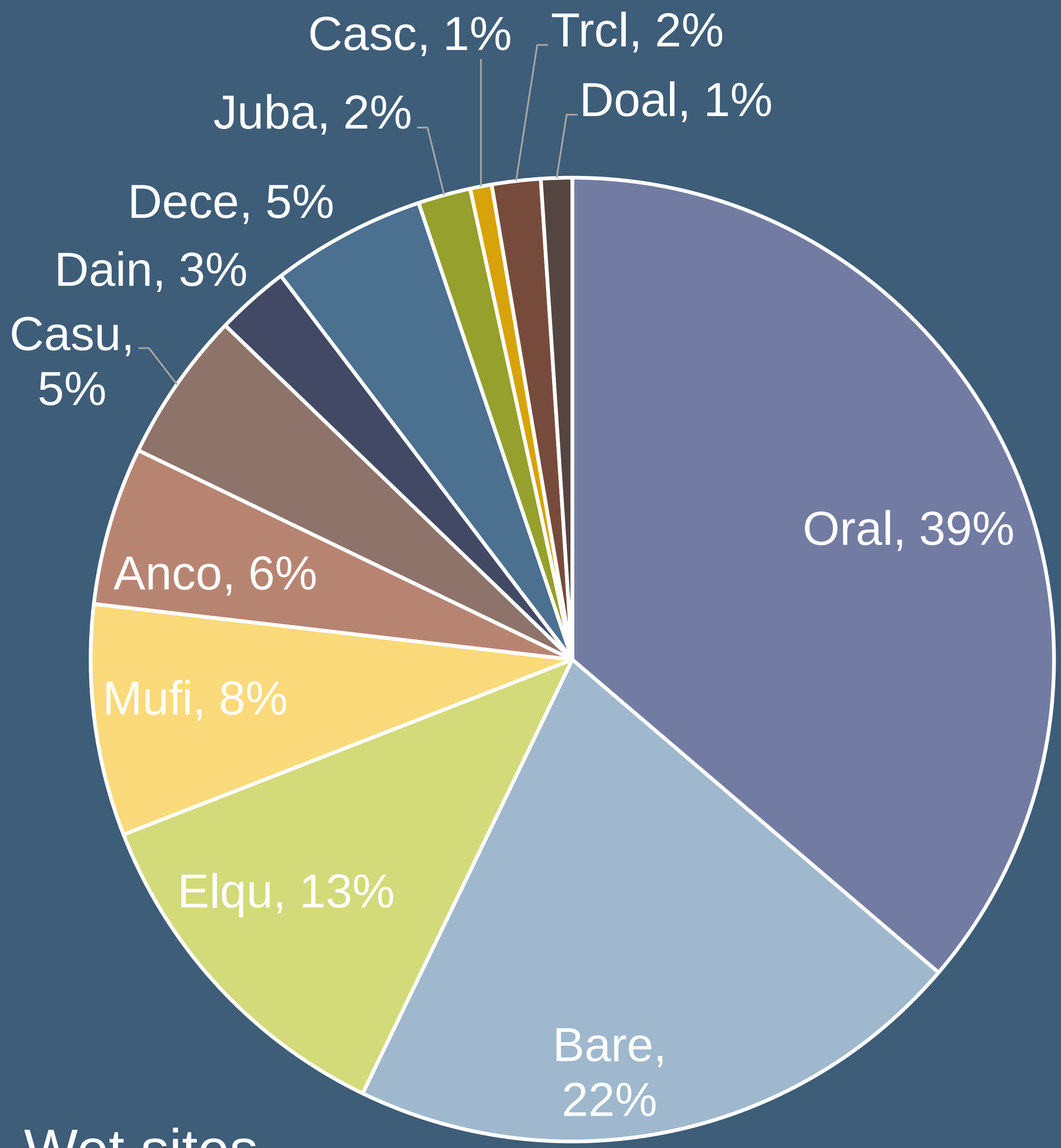
80 cm (2.6 ft) thick.
High organic content (20%).
Formed over the past ~2,000 years.

Groundwater wetland hydrology

45 days/season high water + 35 days from OM
Little variation b/t wet and drought years.

Vegetation?

Soil and hydrology indicate productive wetland plant community.
What do we see?



Wet sites

Carex scop./ Oreo. alp.

Species	Ave cover
Casc	53%
Oral	26%
Mipr	24%
Bibi	17%
Mufi	16%
Elqu	9%
Pepa	8%
Bare	1%

Community composition @ 10 other Sierra Nevada subalpine meadows (Potter 2006)

Natural field-collected *Oreostemma alpigenum*

Nursery-grown, planted, field-collected *Carex scopulorum* washed in the lab

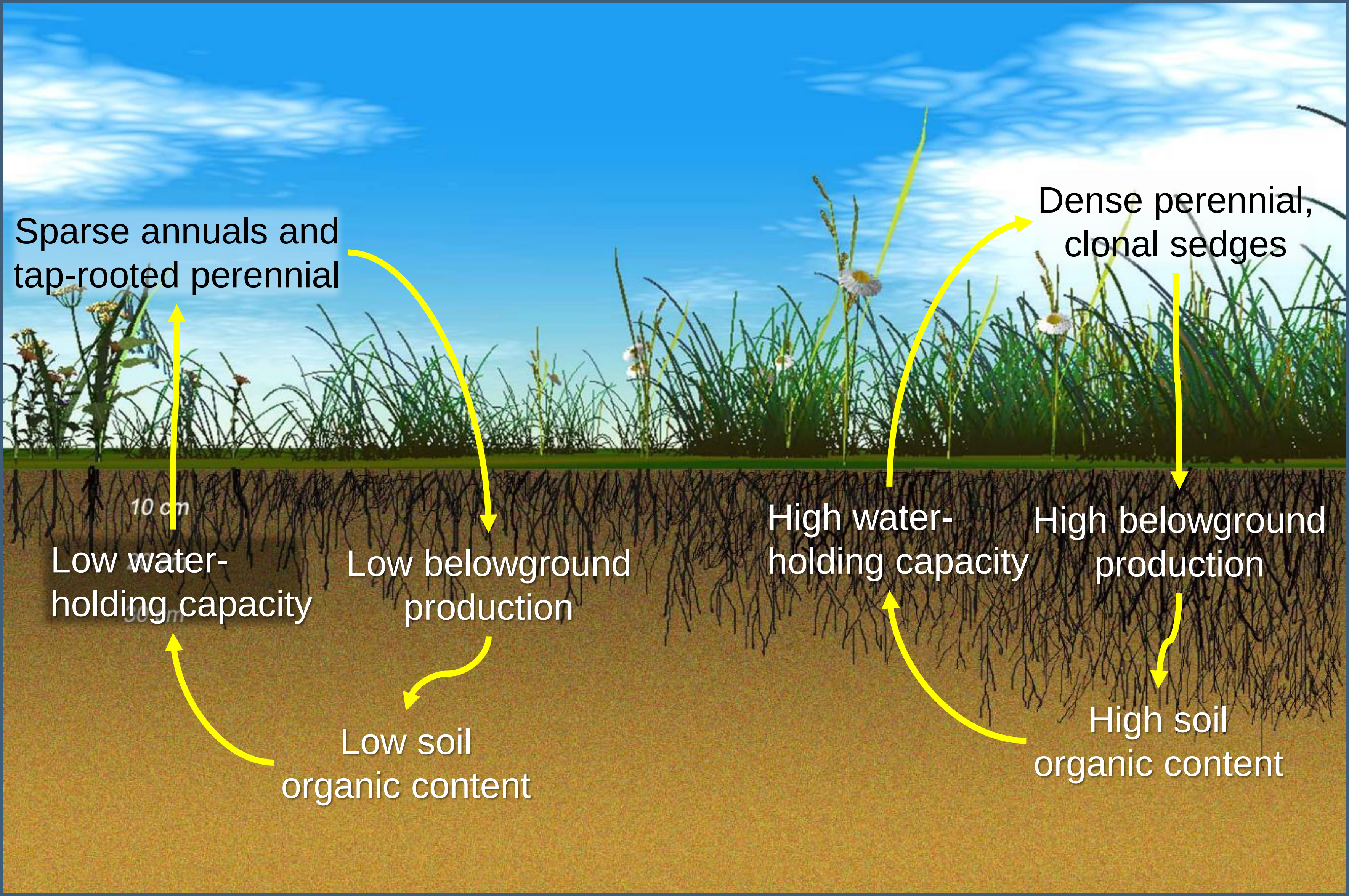

Natural field-collected *Carex subnigricans*

Primary research question 2011-14:

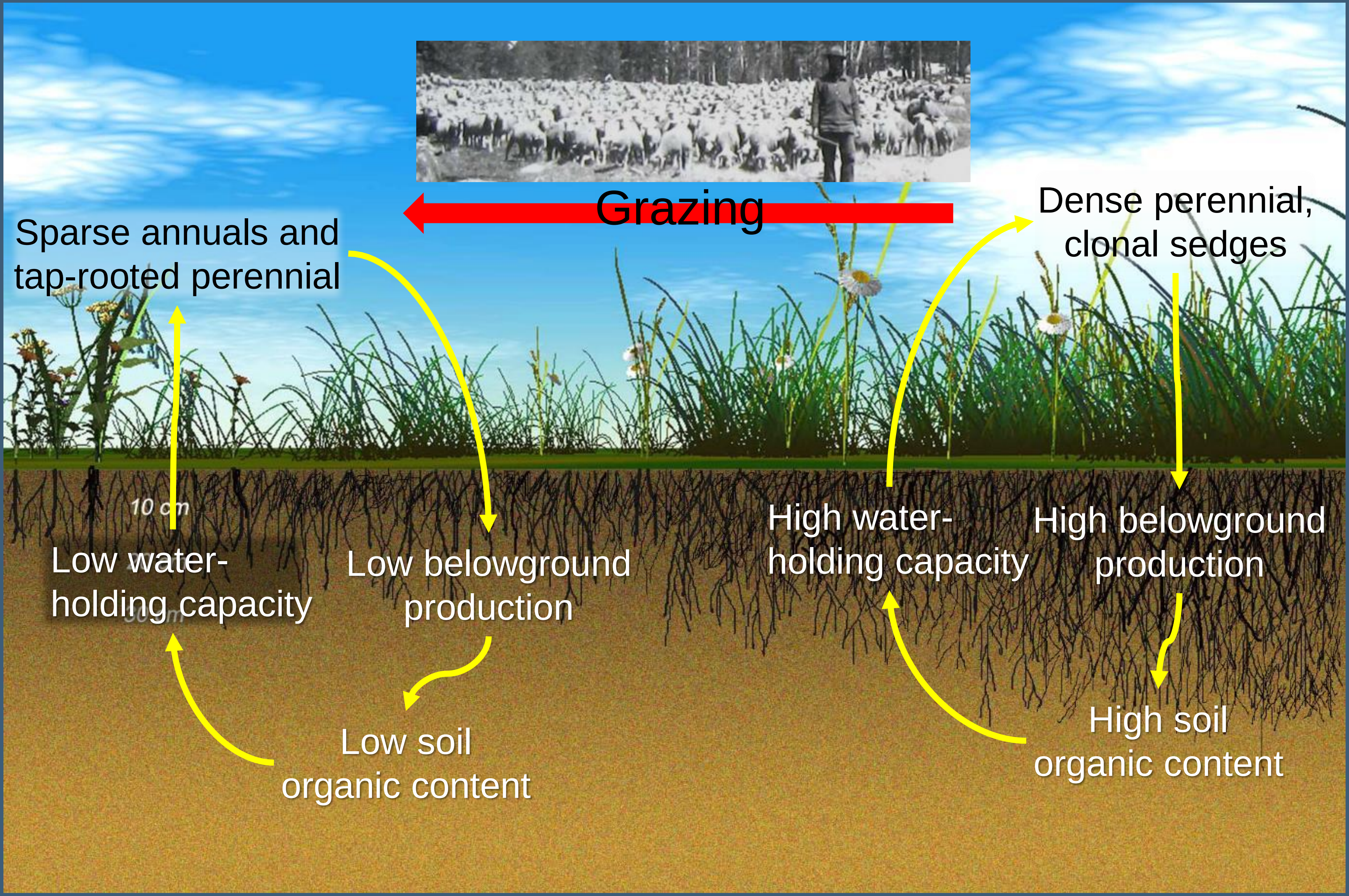
Is current (native) herbivory suppressing vegetation and altering ecosystem processes?


1869: John Muir in Tuolumne with 2,050 “hooved locusts”
1898: 214,050 sheep ejected from Yosemite by cavalry
Gold Rush, ~1850-1900. Era of unregulated grazing

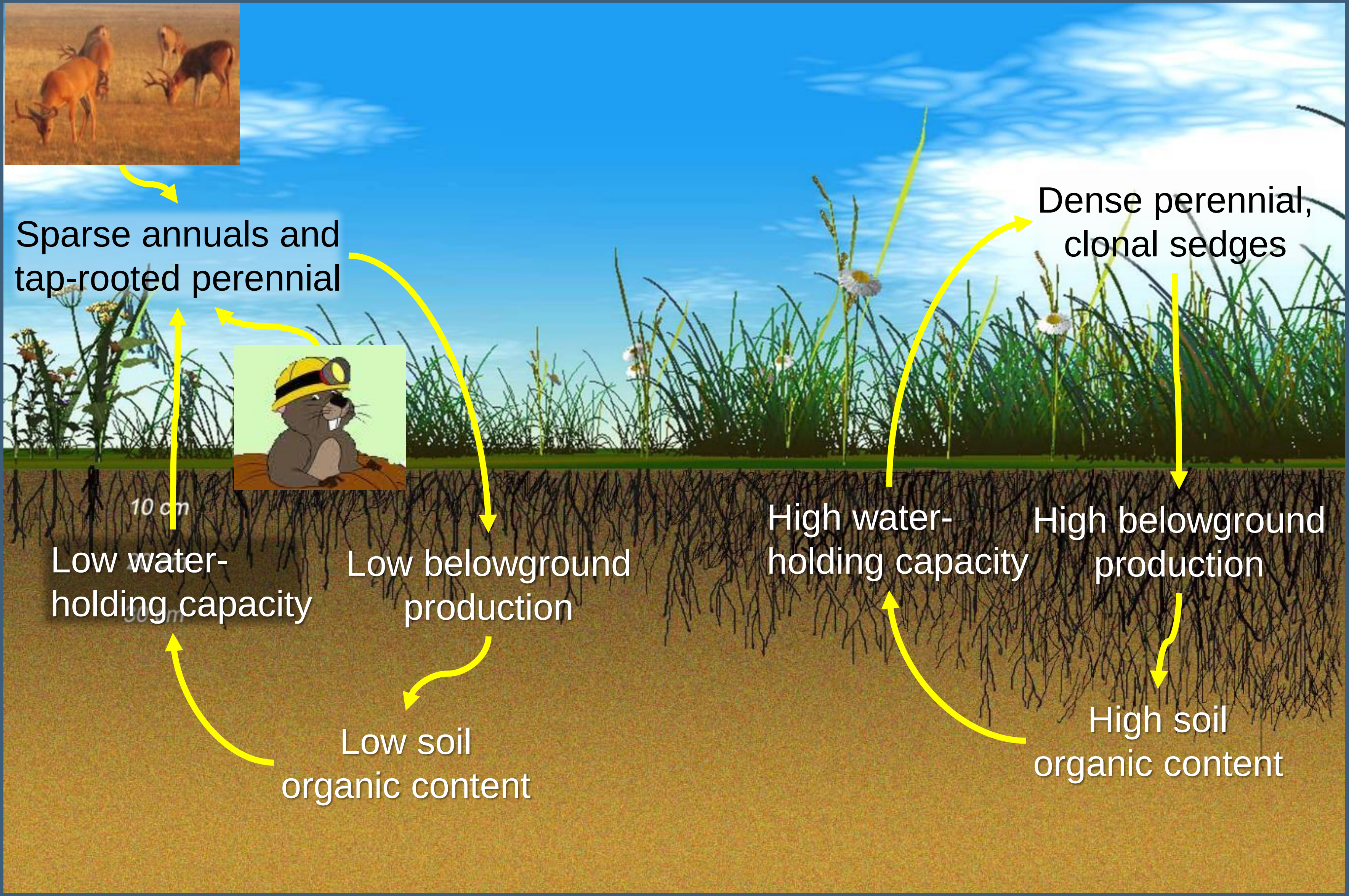
Soil + water + plants



Soil + water + plants

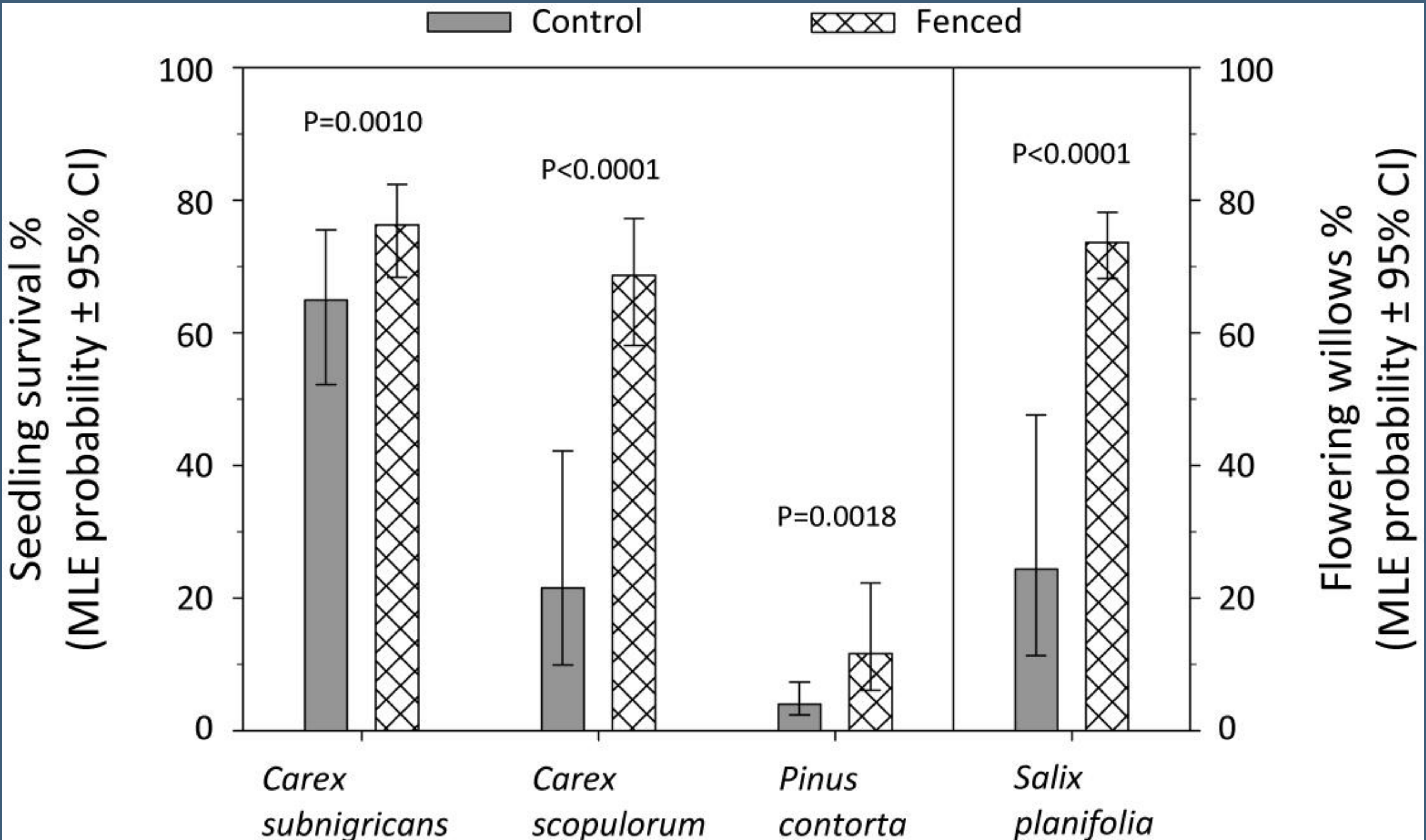


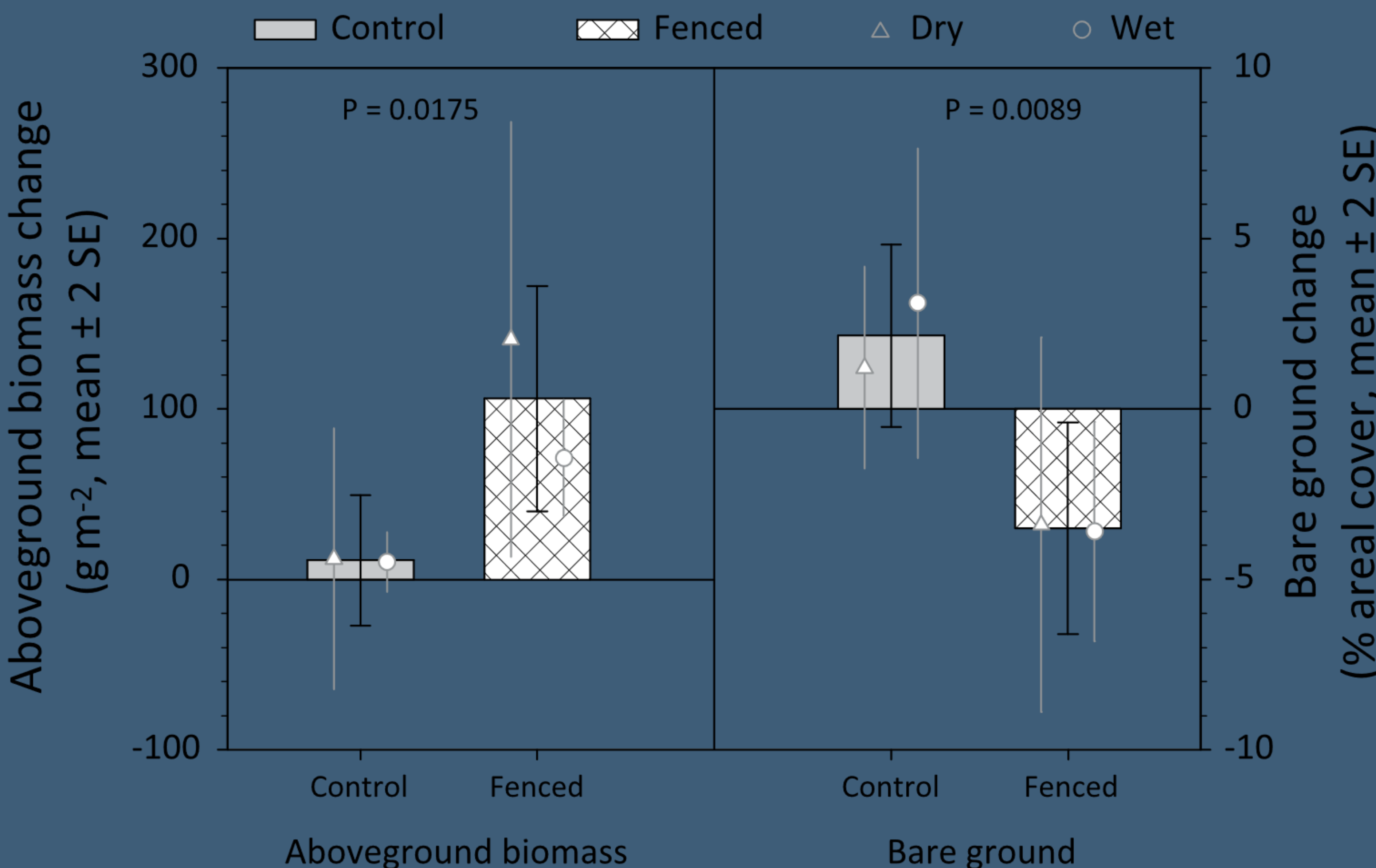
Soil + water + plants



Exclosed patches of meadow vegetation from herbivores

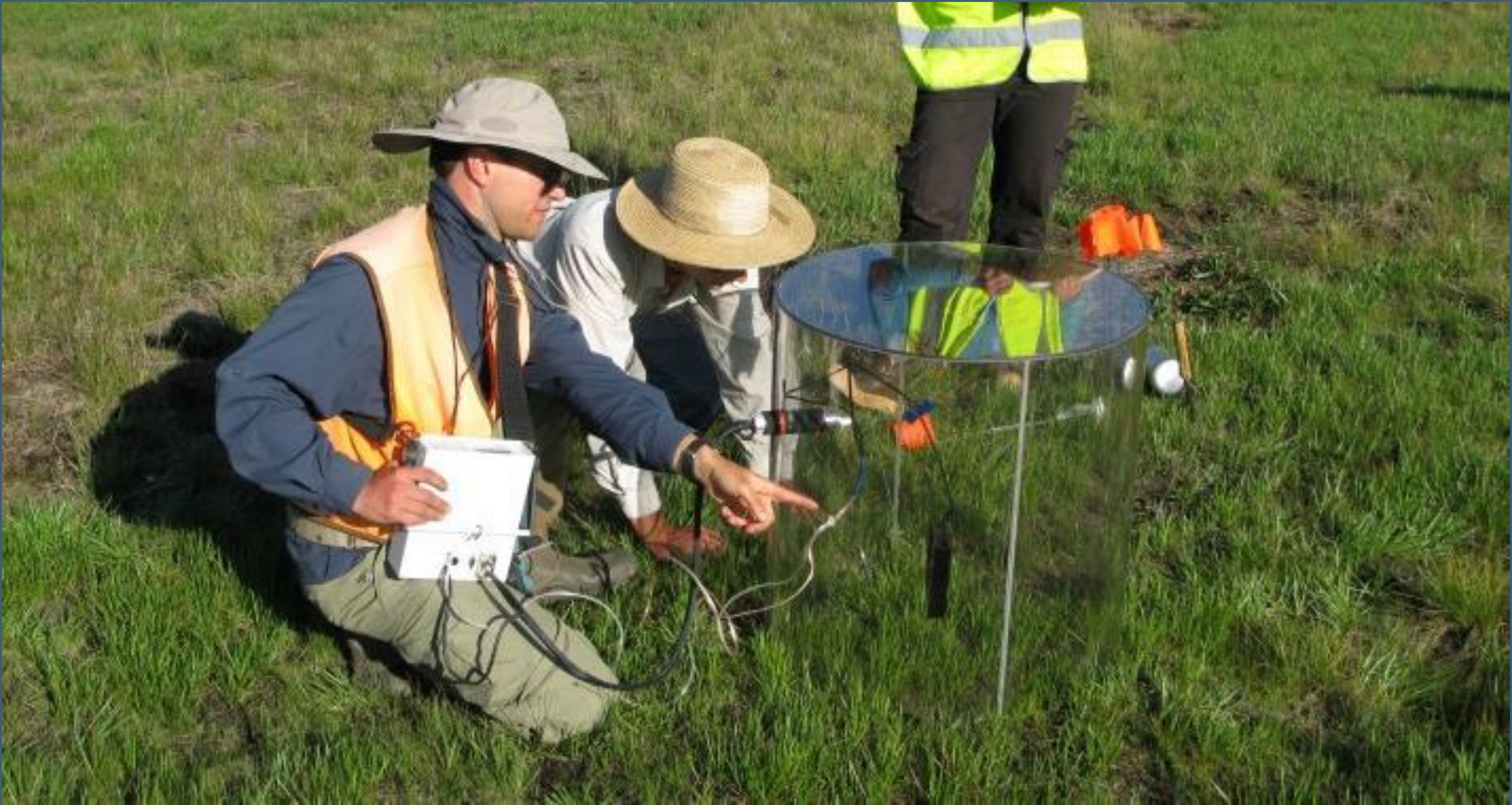
Outplanted clonal sedges, *Carex scopulorum* and *Carex subnigricans,* into herbivore exclosures and controls.

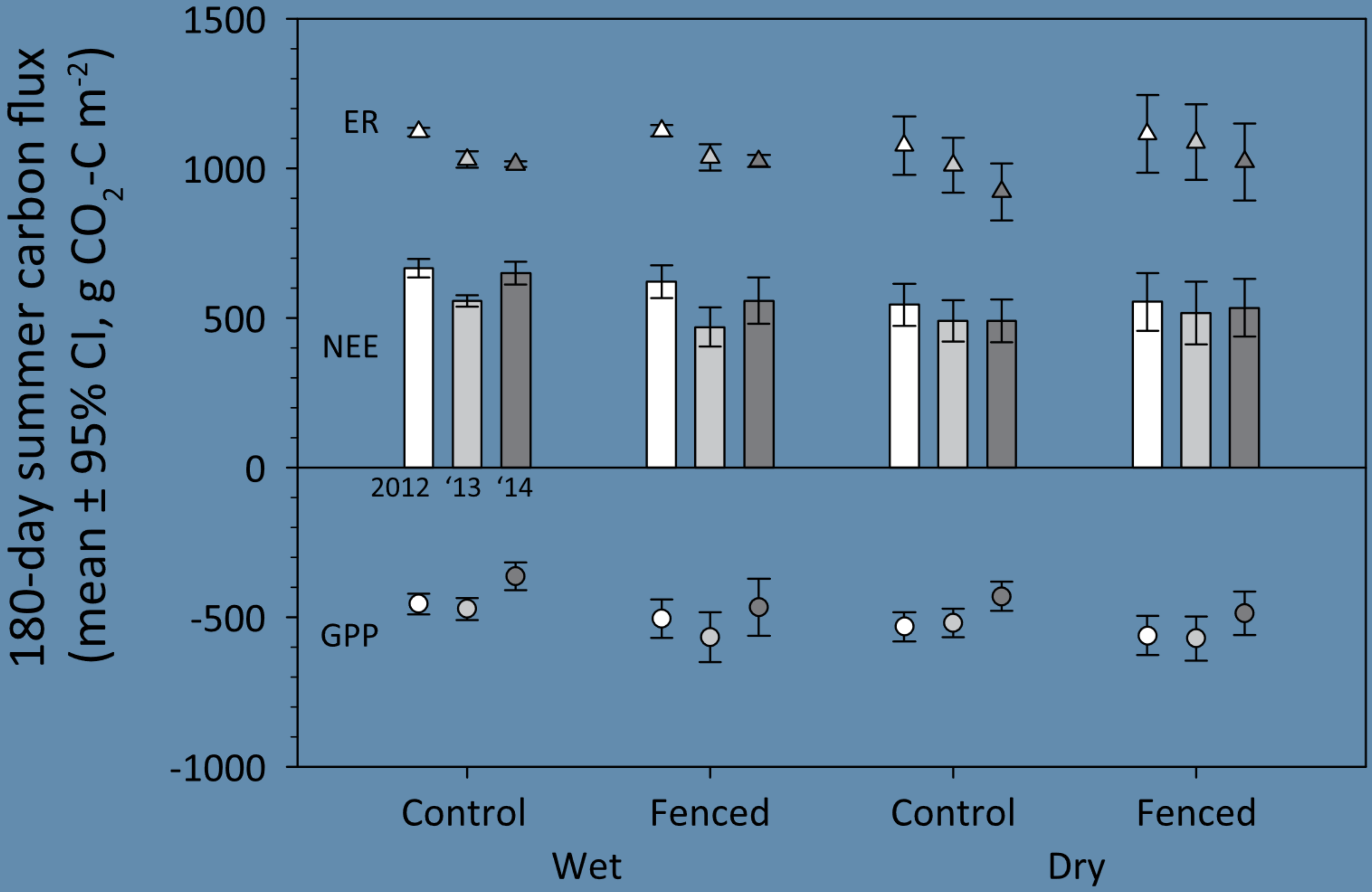

Control
Fenced
Seedling survival %
(MLE probability ± 95% CI)
Flowering willows %
(MLE probability ± 95% CI)
100
80
60
40
20
0
P=0.0010
P<0.0001
P=0.0018
P<0.0001
Carex subnigricans
Carex scopulorum
Pinus contorta
Salix planifolia



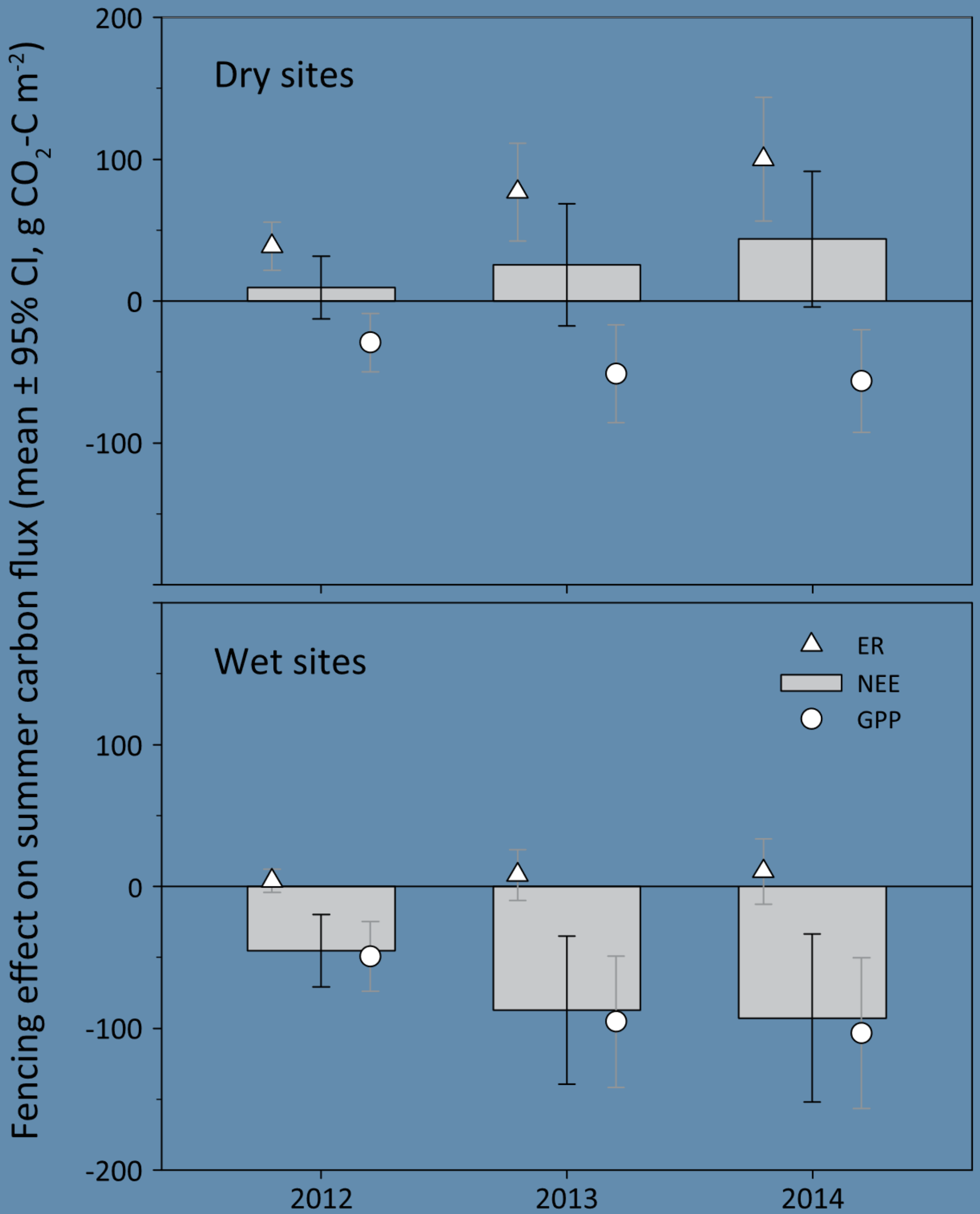
Control
Fenced
Dry
Wet
P = 0.0175
P = 0.0089
Aboveground biomass change
(g m-2, mean ± 2 SE)
Bare ground change
(% areal cover, mean ± 2 SE)
300
200
100
0
-100
10
5
0
-5
-10
Control
Fenced
Control
Fenced
Aboveground biomass
Bare ground

Carbon flux: ER + (-)GPP = NEE



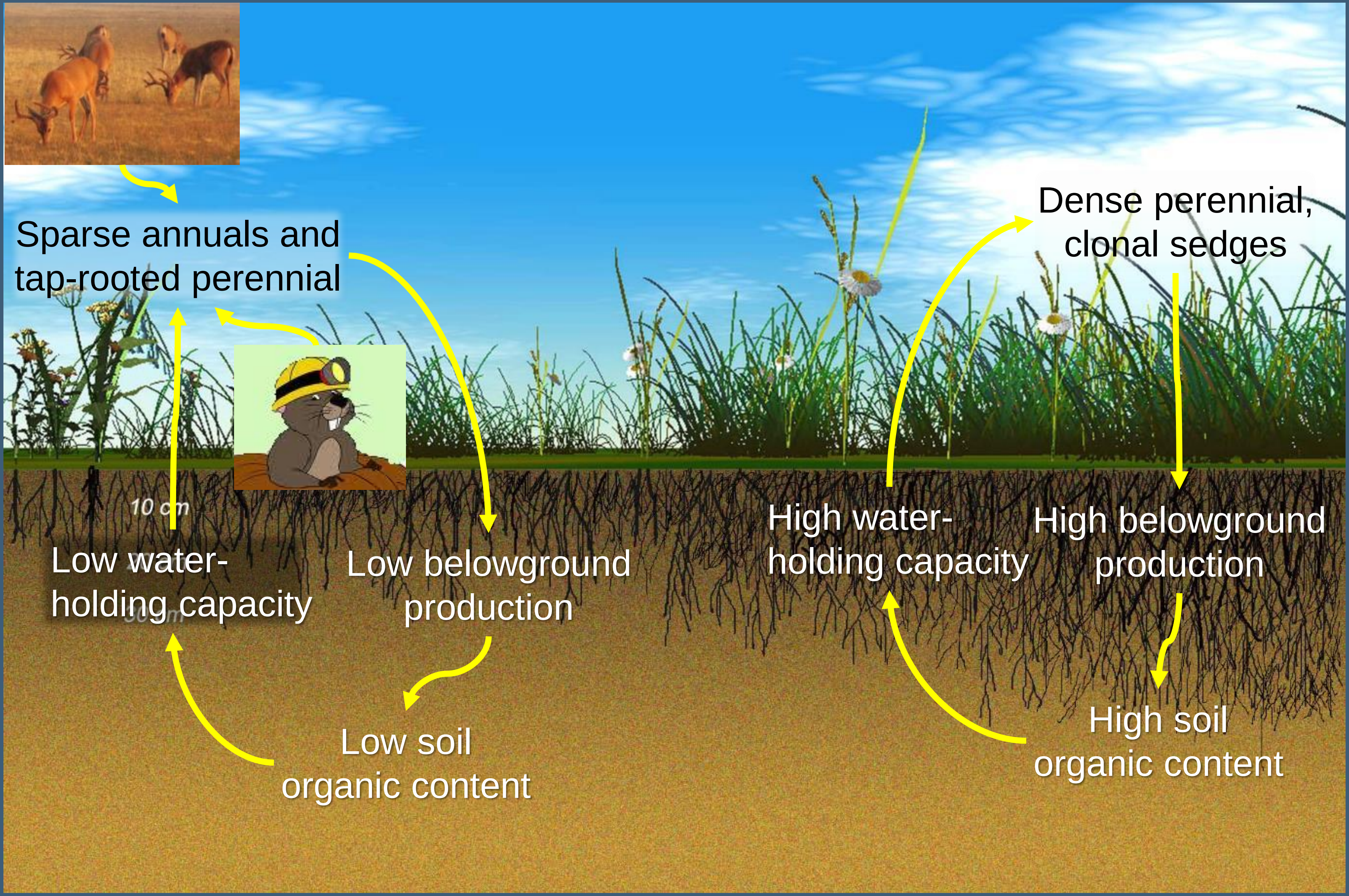


180-day summer carbon flux
(mean ± 95% CI, g CO_2-C m^{-2})
1500
1000
500
0
-500
-1000
ER
NEE
GPP
2012
'13
'14
Control
Fenced
Control
Fenced
Wet
Dry

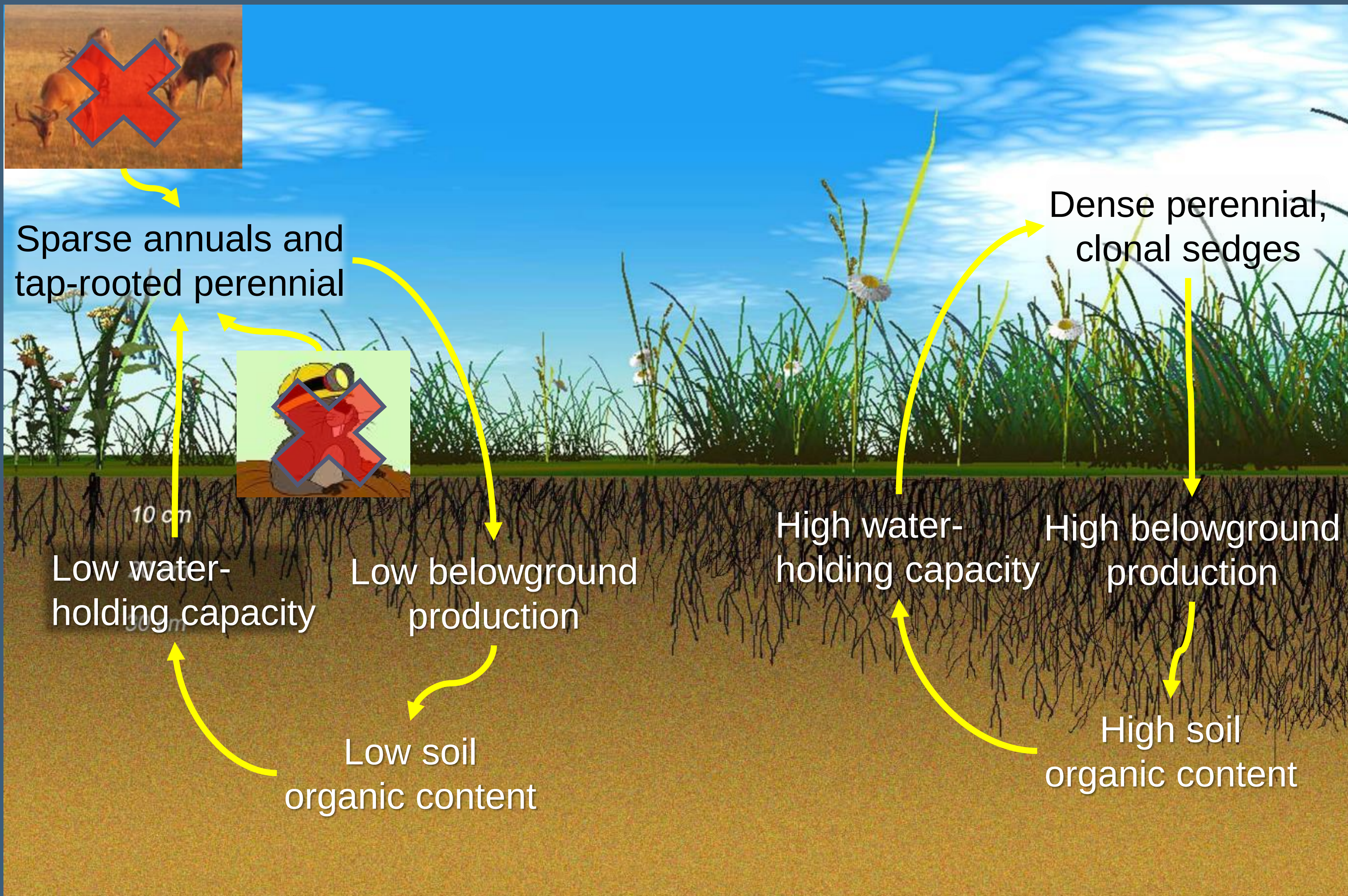


Fencing effect on summer carbon flux (mean ± 95% CI, g CO$_2$-C m^{-2})
Dry sites
Wet sites
200
100
0
-100
-200
ER
NEE
GPP
2012
2013
2014

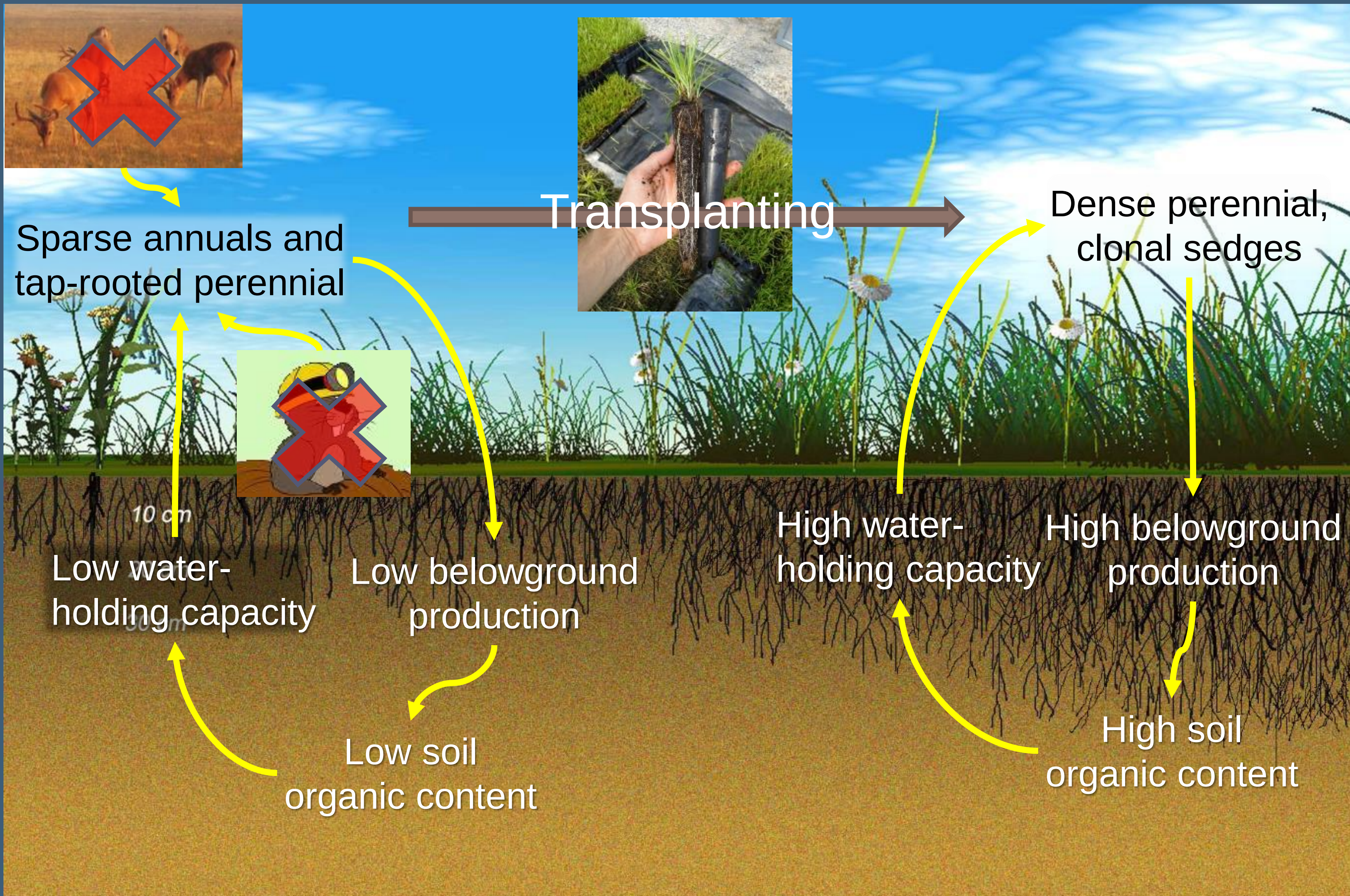
Soil + water + plants



Soil + water + plants

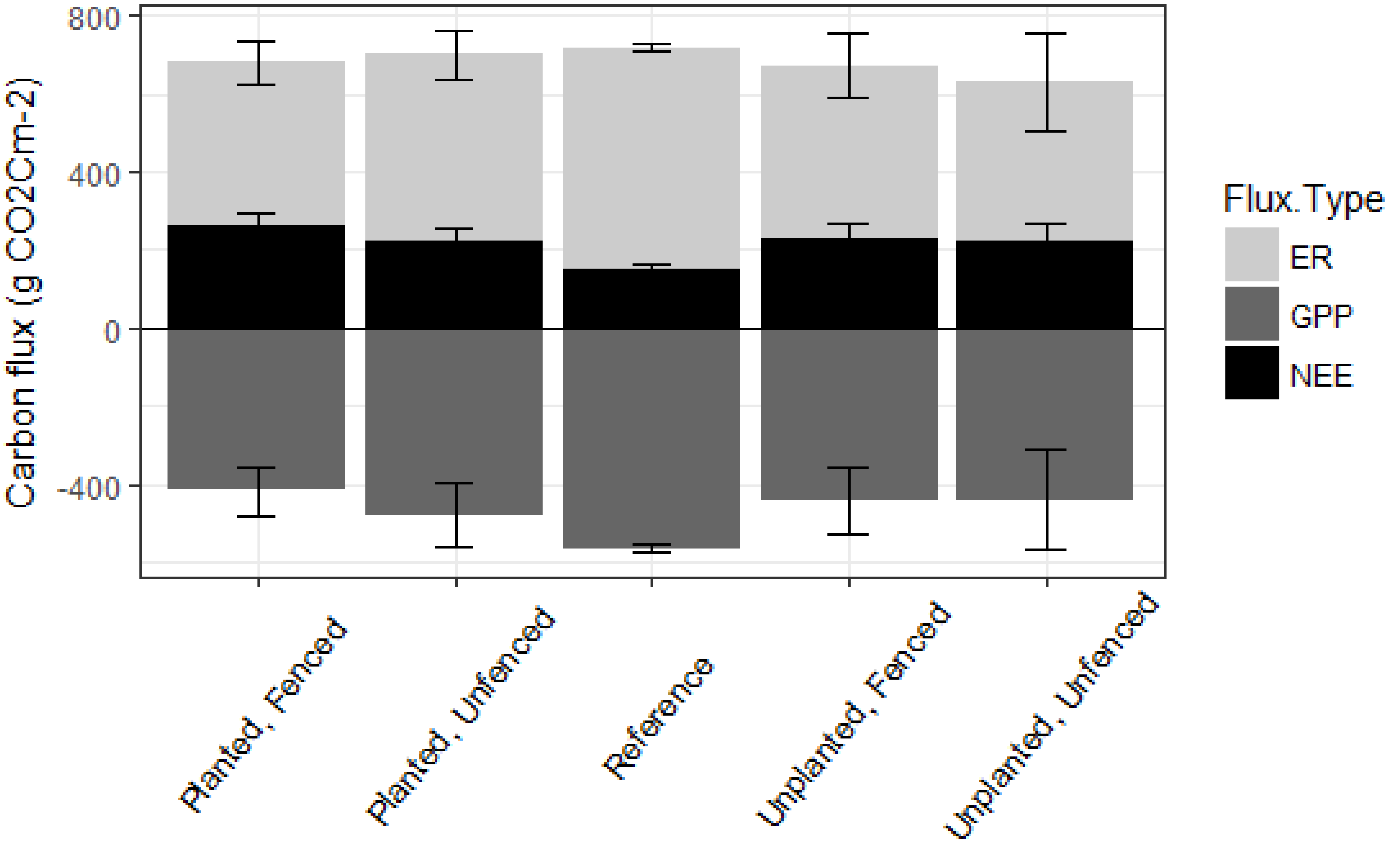


Soil + water + plants



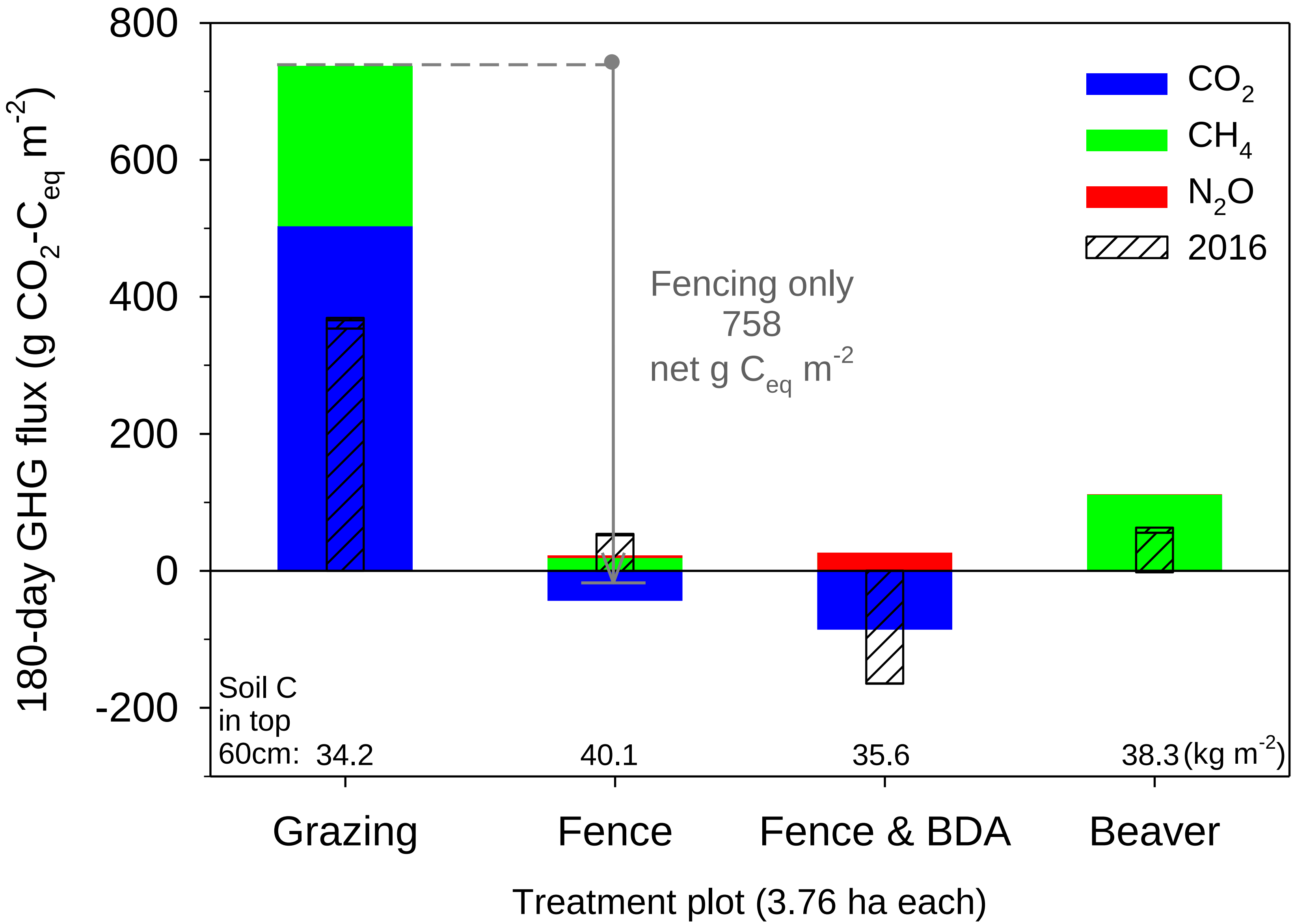
2017

Very wet, 177% of average



Baldwin 2018

Carbon Sequestration – Effect of fencing



Carbon Sequestration – Soil C loss

Carbon budget component	Wet	Dry	
Below-ground live plant biomass, control plot mean	177.47	206.68	$g\ m^{-2}$
Below-ground live biomass C content [a]	33.79	33.79	%
Below-ground live plant C, control plot mean	59.97	69.84	$g\ C\ m^{-2}$
Above-ground live plant biomass, control plot mean	128.11	200.09	$g\ m^{-2}$
Above-ground live biomass C content [b]	43.70	43.70	%
Above-ground live plant C, control plot mean	55.98	87.44	$g\ C\ m^{-2}$
Below-ground biomass : Above-ground biomass	1.39	1.03	ratio
Below-ground C : Above-ground C	1.07	0.80	ratio
Soil organic matter, by mass (in top 80 cm) [c]	17.13	10.96	%
Soil organic matter C content [d]	55.61	55.35	%
Soil bulk density [d]	0.50	0.63	$g\ cm^{-3}$
Soil C content (in top 80 cm)	38.10	30.57	$kg\ C\ m^{-2}$
Mean summer C loss (2012-14 control plot NEE)	0.62	0.51	$kg\ C\ m^{-2}$
Soil C pool lost per summer, control	1.64	1.66	%
Mean summer C loss in fenced plots	0.55	0.53	$kg\ C\ m^{-2}$
Soil C pool lost per summer, fenced	1.44	1.75	%

Carbon Sequestration – Other studies

Observed loss in grazed Childs and Tuolumne
~ **500** gC m^{-2} yr^{-1}

Observed accumulation in fenced Childs
~ **50-100** gC m^{-2} yr^{-1}

Est. long-term acc. in Tuolumne
~ **83** gC m^{-2} yr^{-1} (based on C14 dates, soil depth, and C content)

Carbon loss rates in degraded wetlands (ER dominant):
-- **1400** gC m^{-2} yr^{-1} Tropical peatland
-- **573** gC m^{-2} yr^{-1} Rockies

Carbon accumulation rates (NEE) in functional wetlands:
-- **75-100** gC m^{-2} yr^{-1} Sierra Nevada
-- **83** gC m^{-2} yr^{-1} Rockies
-- **37-134** gC m^{-2} yr^{-1} Andes

<u>Max. loss rate is 5-10x faster than max. accumulation</u>

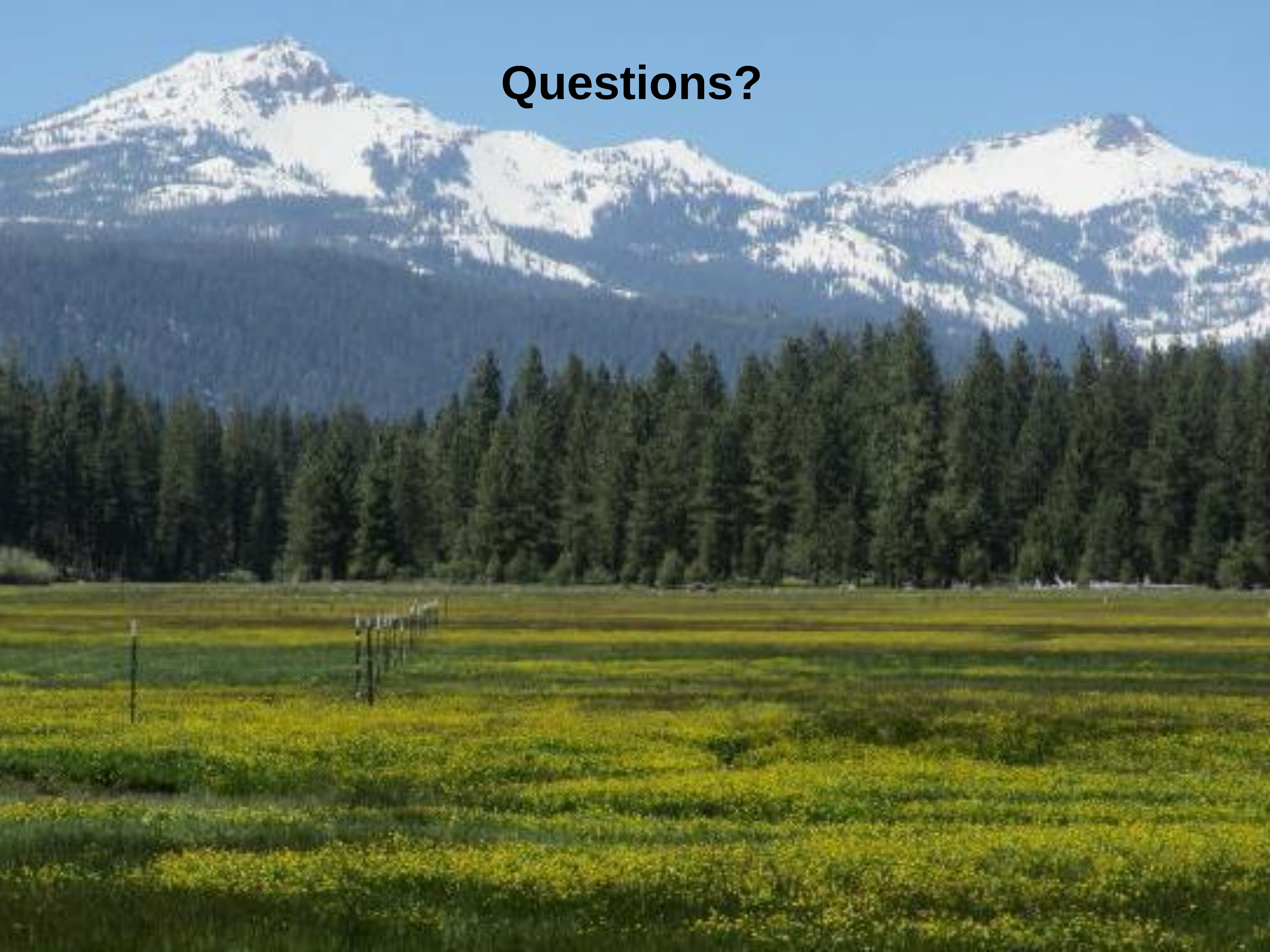
Carbon Sequestration – Projections

Observed loss in grazed Childs
~ **500** gC m^{-2} yr^{-1}
~1.3% of upper soil C stock lost per year (does not account for deeper C stocks)
At this rate, all will be gone in 80 years (does not account for slower rates as soil C declines).

Observed accumulation in restored Childs
~ **75** gC m^{-2} yr^{-1}

Stop-loss value
500 gC m^{-2} yr^{-1}
x 208.2 ha = 1,041 Mg C per year
x $16/Mg C = $16,600 per year
x 80 years = **$1.3M**

Ongoing accumulation value
75 gC m^{-2} yr^{-1}
x 208.2 ha = 156 Mg C per year
x $16/Mg C = **$2,500** per year
In perpetuity.


Questions?

Timeline

May 2015-Today

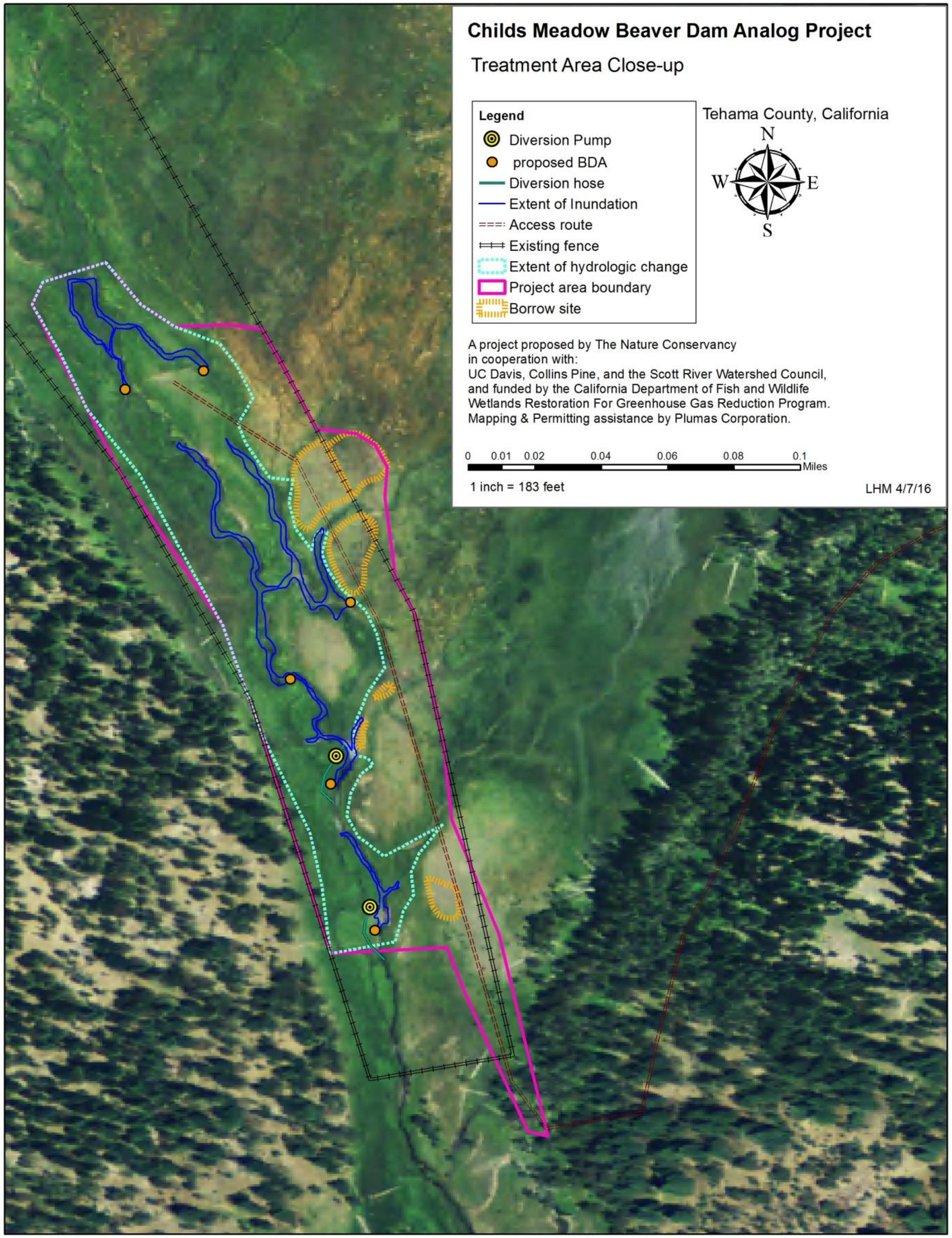
- Collect data

Fall 2015

- Cattle exclosure fence
- Planted willow stakes

Fall 2016

- Installed 6 BDAs



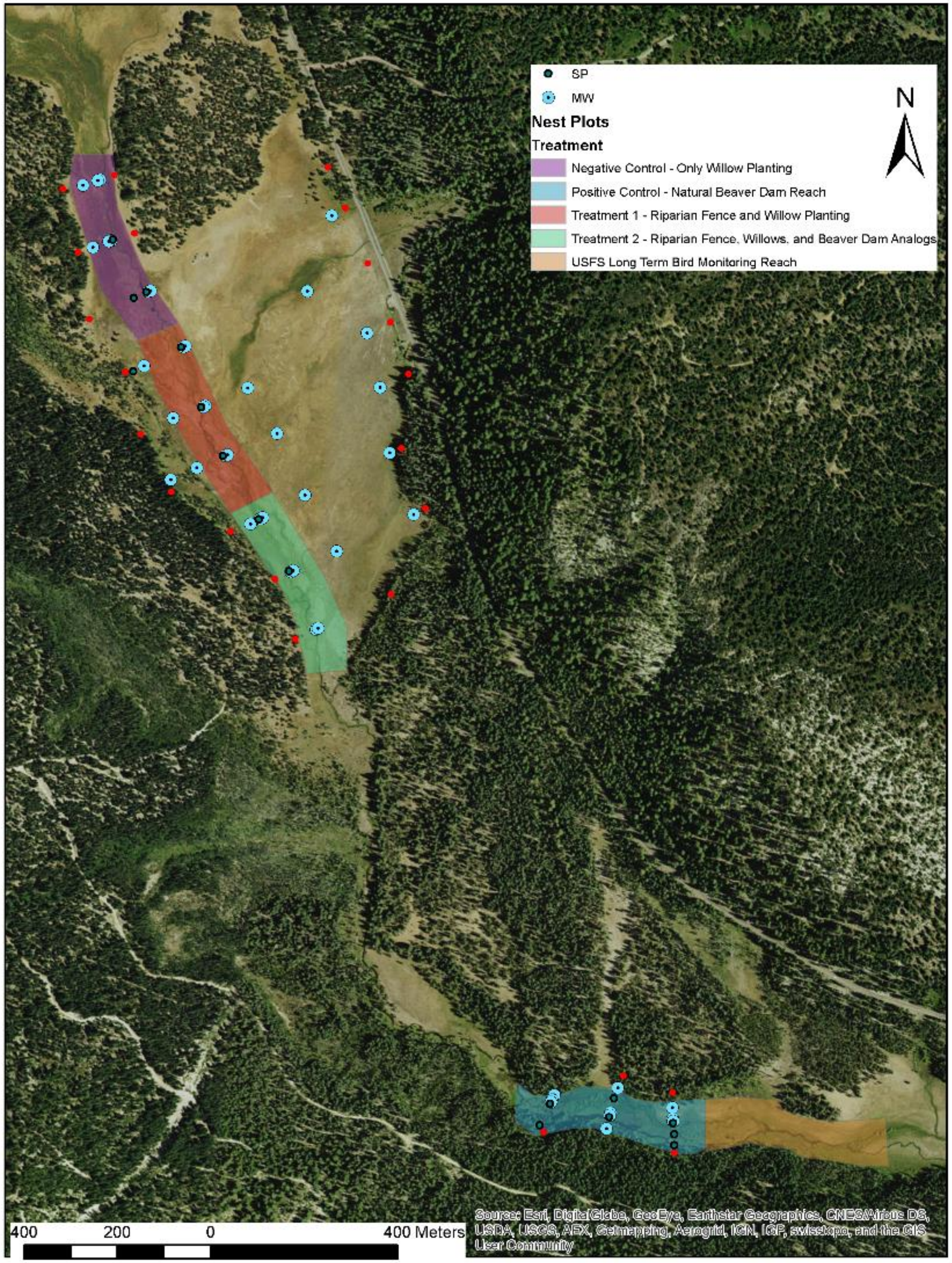
Study Design

BACI Design:

- 2 treatments
- 2 controls

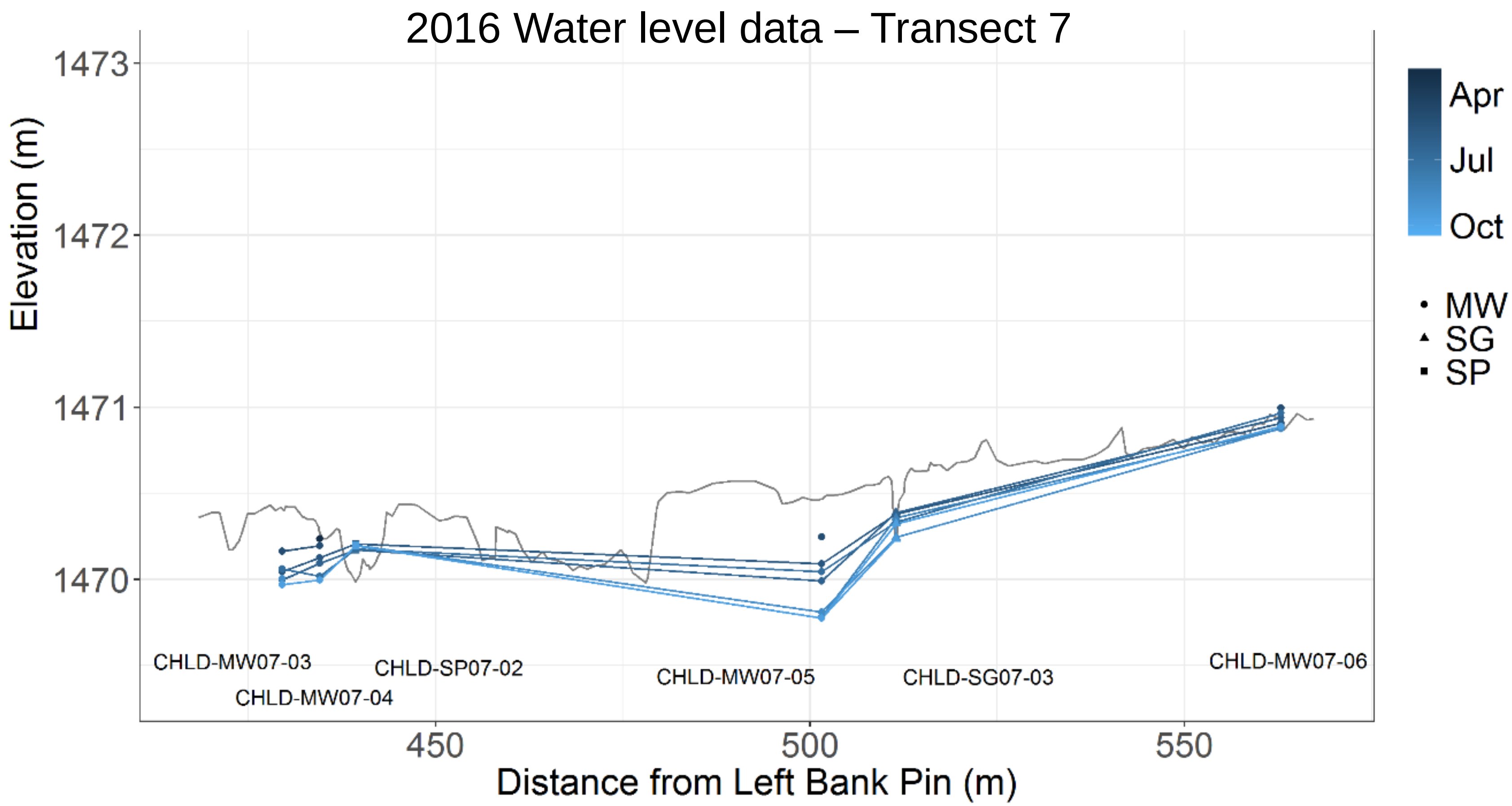
Monitoring:

- Above and below-ground carbon
- Hydrogeomorphic conditions
- Response of targeted wildlife species:
  - Willow flycatcher
  - Cascades frog



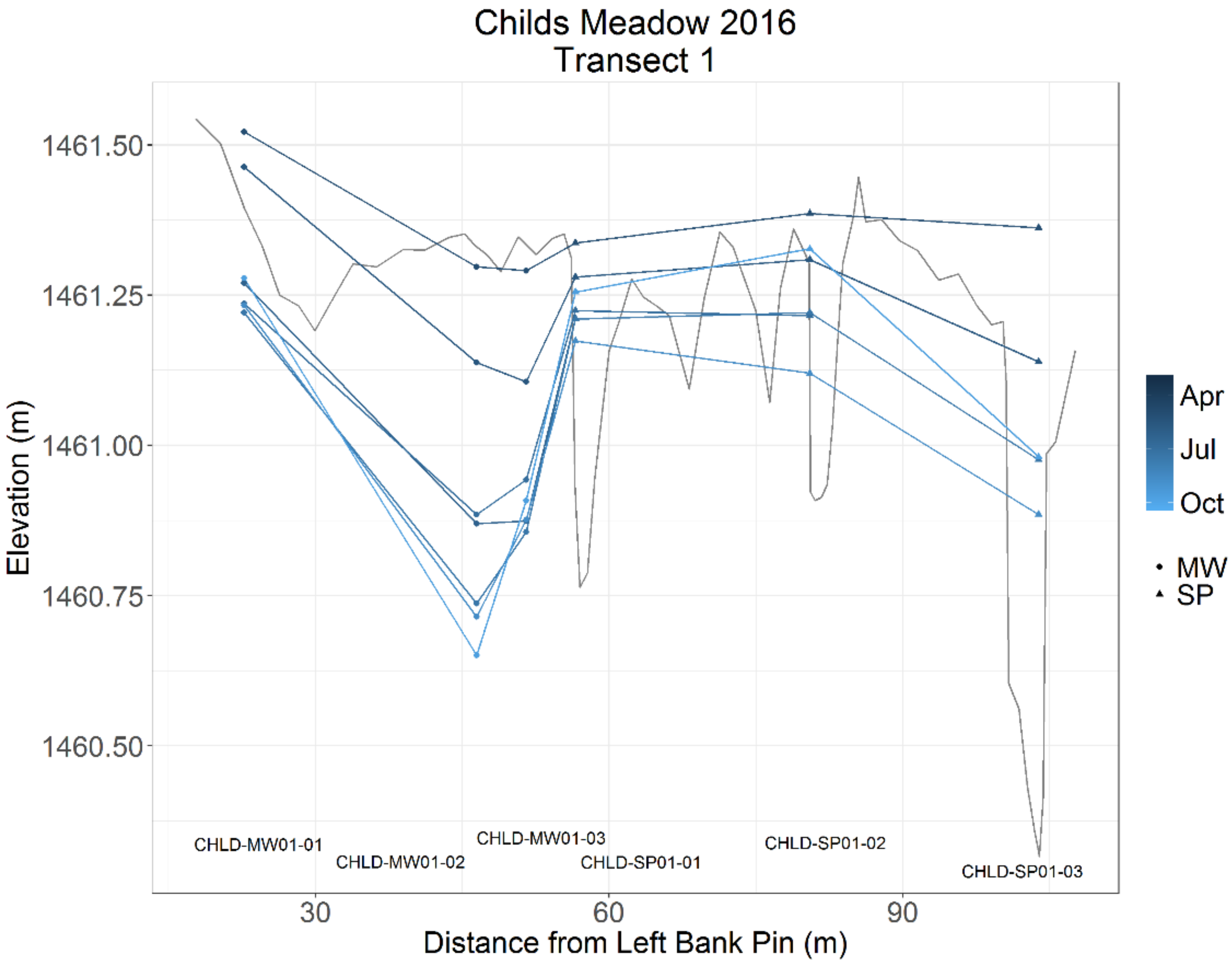
Pre-restoration Meadow Conditions

Pre-treatment Reaches – Cross-sectional profile



Pre-restoration Meadow Conditions

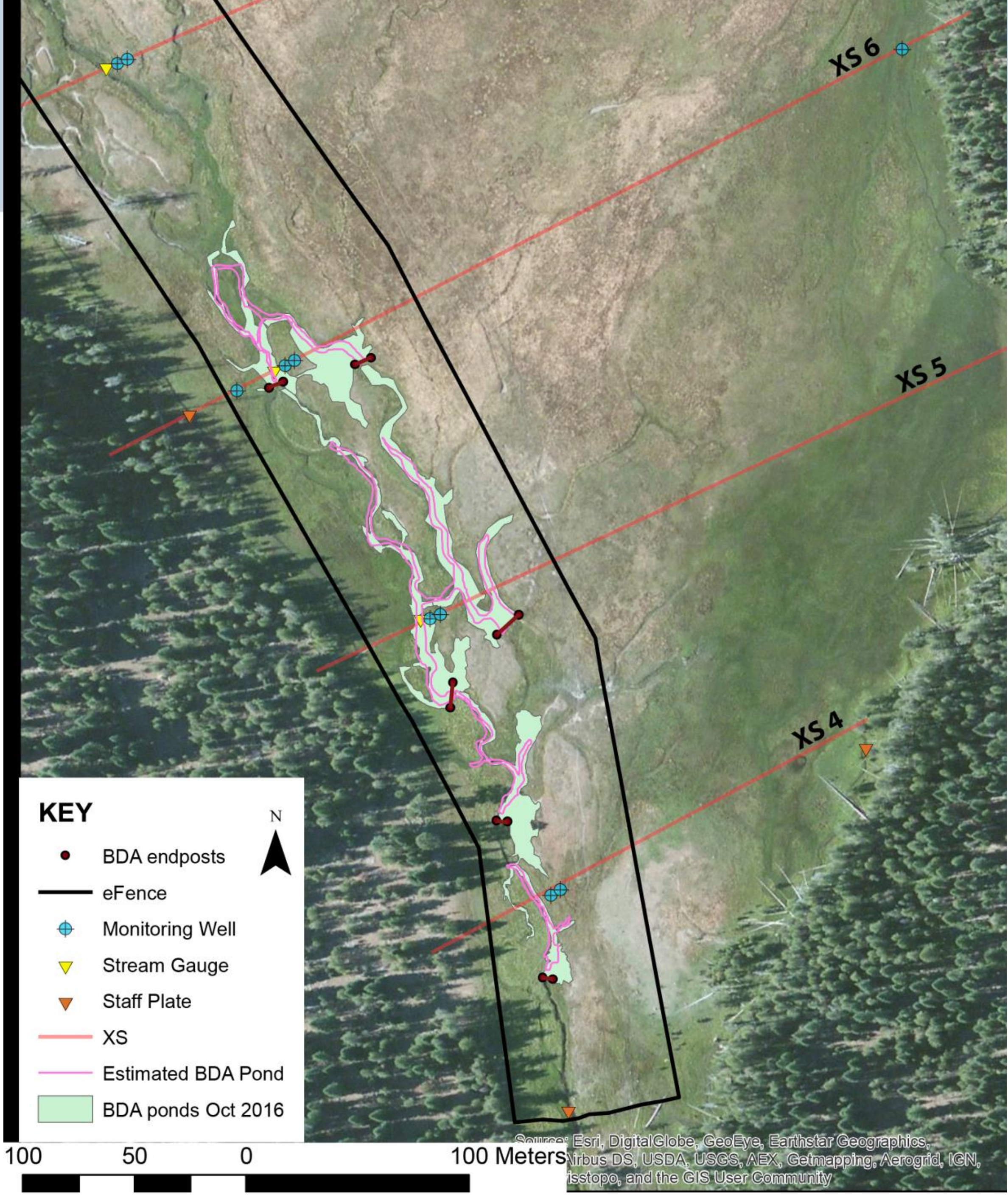
Natural Beaver Reach – Cross-section Profile



BDA installation – Oct 2016

BDA Inundation

- Full inundation in less than 24 hours
- Mapped surface water extent from aerial drone flight approximately 2 weeks after install = roughly 3-4x predicted extent



Post-Treatment Monitoring

- 3 seasons: 2017-2019
- Continued hydrogeomorphology, GHG monitoring, and amphibian and avian ecology
- BDA maintenance as needed

Dec 15 2016 Flood

Aug 31 2017 – Summer Conditions

Leaky dams - BDA maintenance required

September 2017 – Summer Conditions

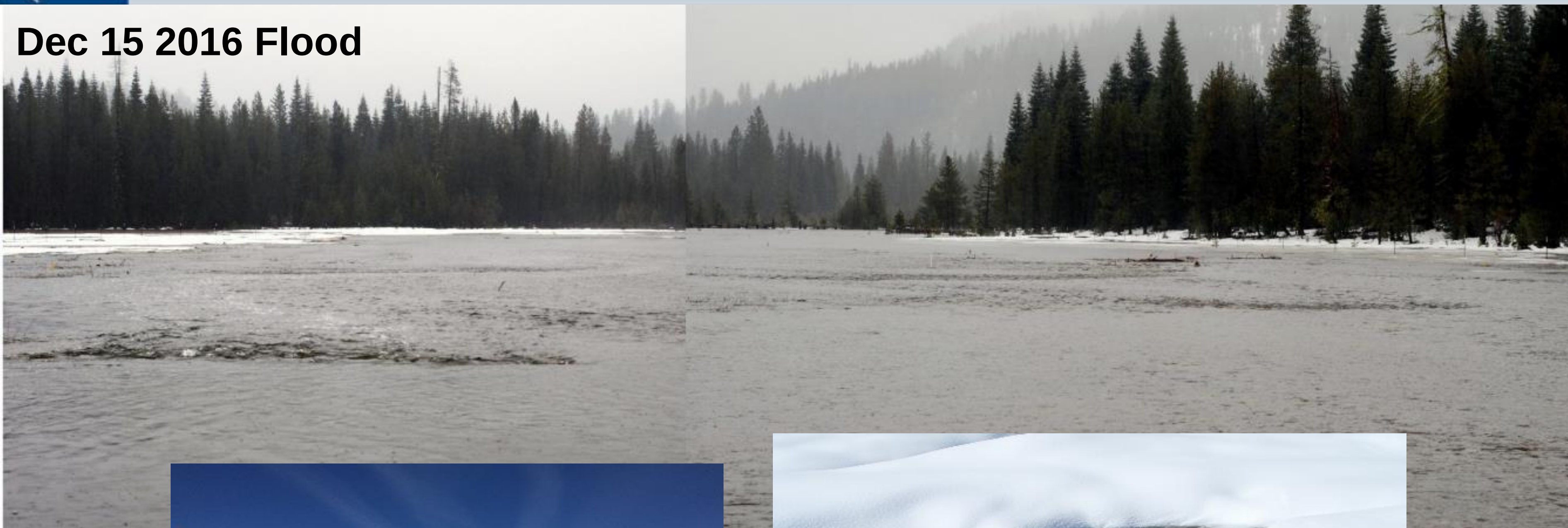
BDA maintenance - repacked dams from meadow materials

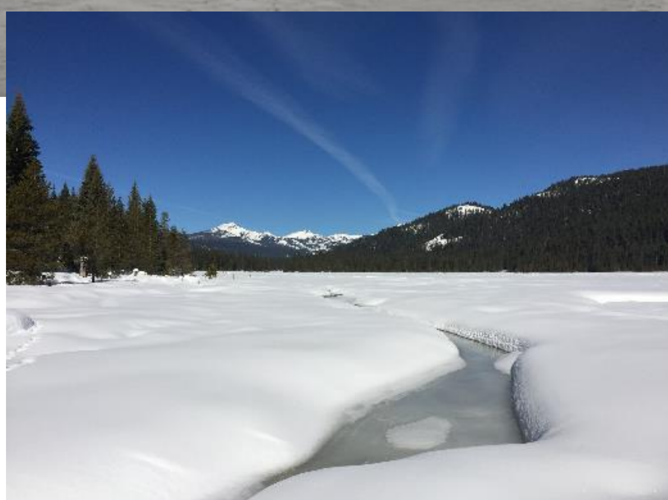
October 10 2017 – Fall Conditions

BDAs at full capacity following maintenance

WY 2017 - Wettest Winter on Record

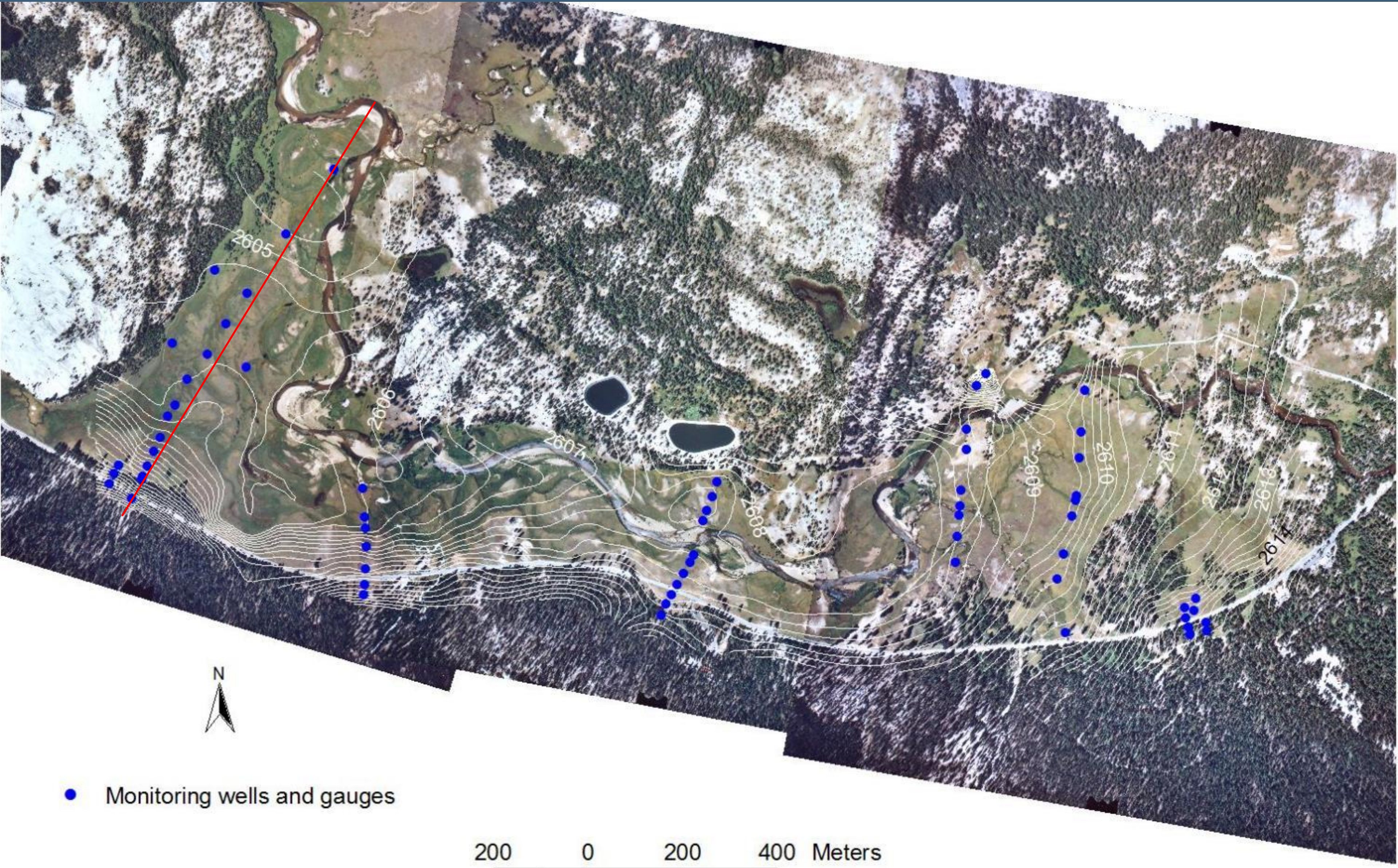
Dec 15 2016 Flood





Jan 30 2017 Snow and Ice on BDAs

Tuolumne Meadows

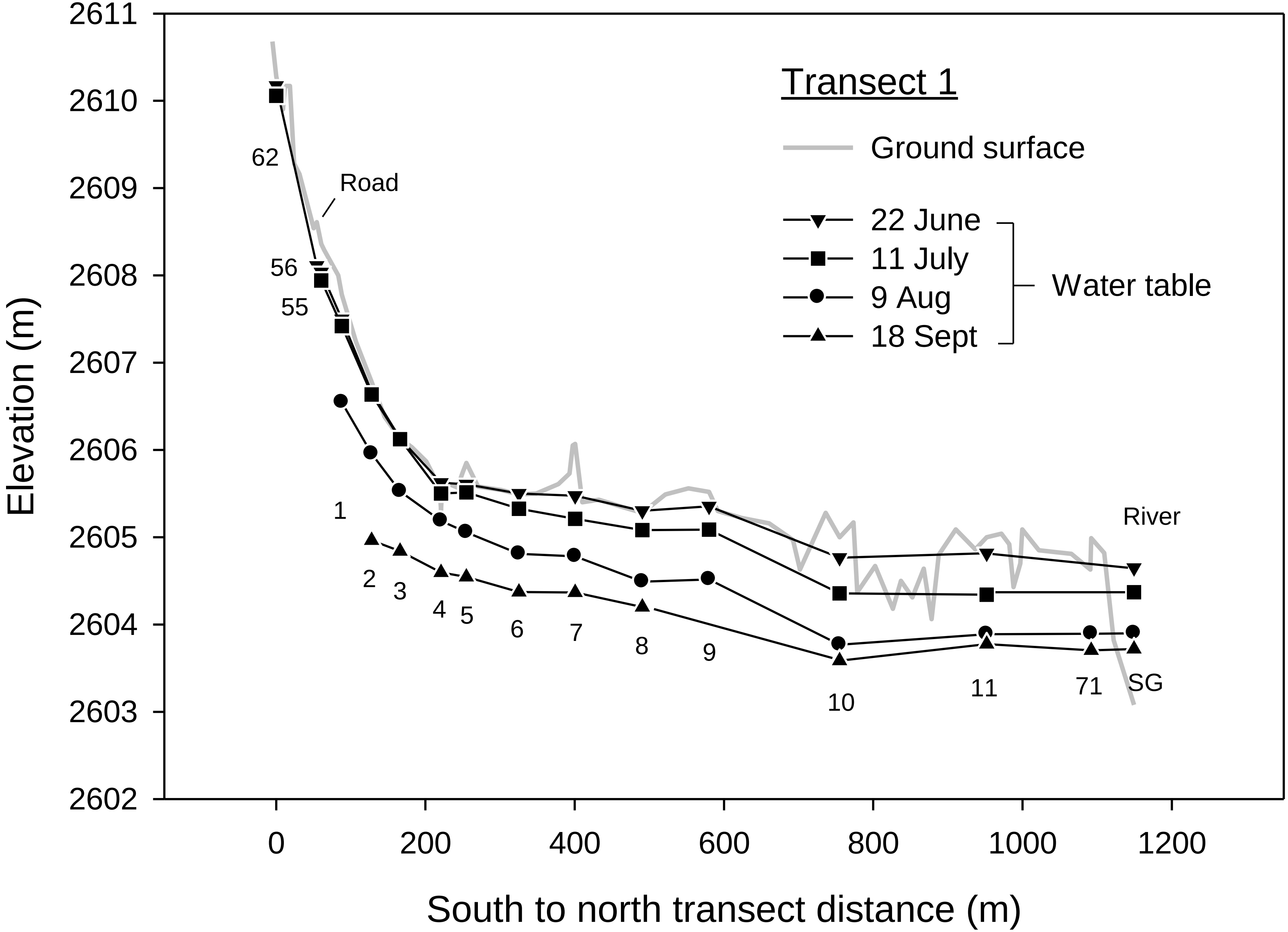


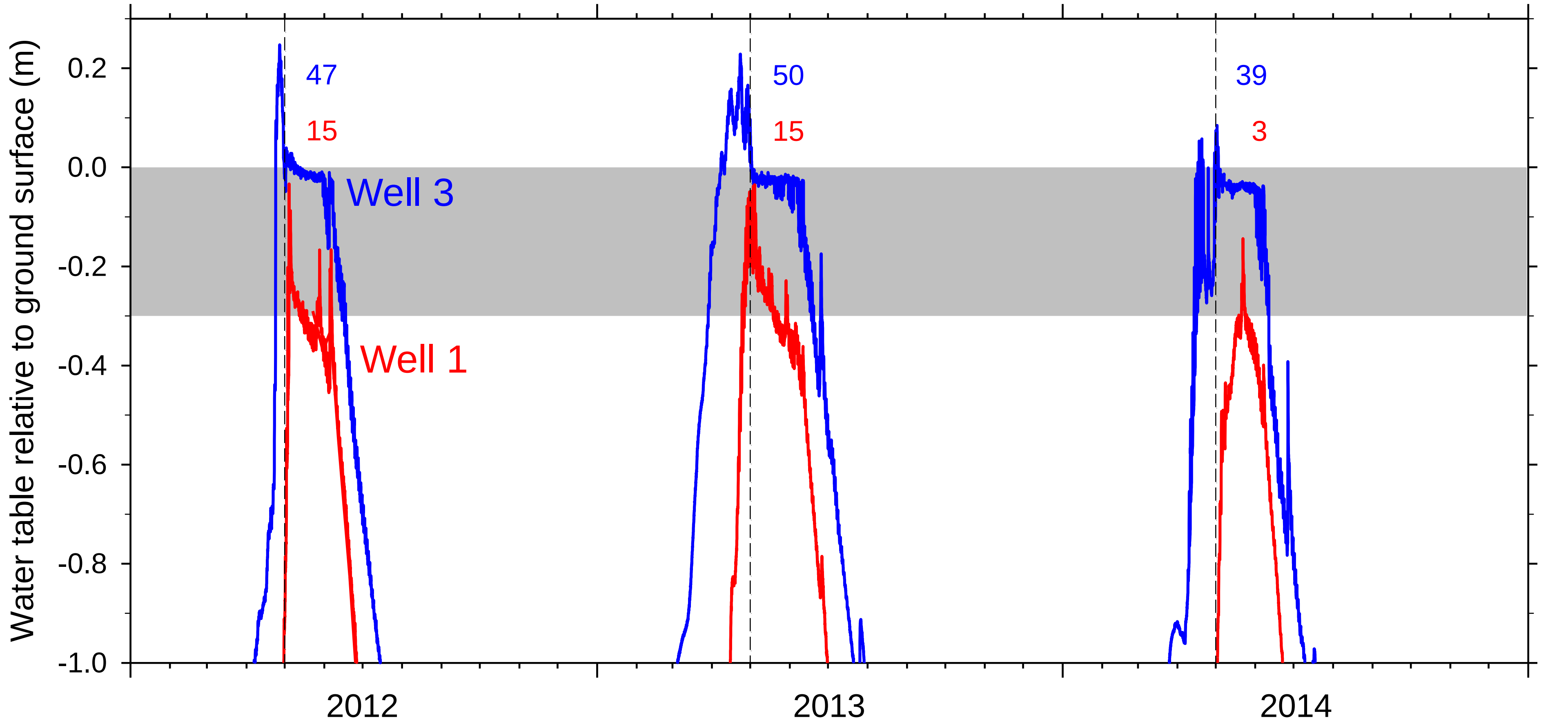
Monitoring wells and gauges

200 0 200 400 Meters

25 cm water table elevation contours

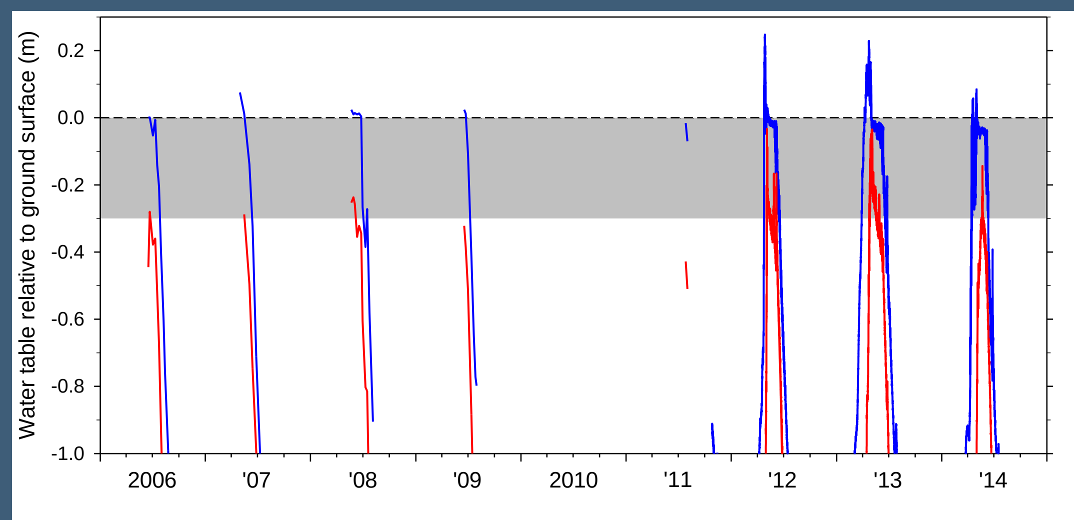
Combination ground- and surface-water

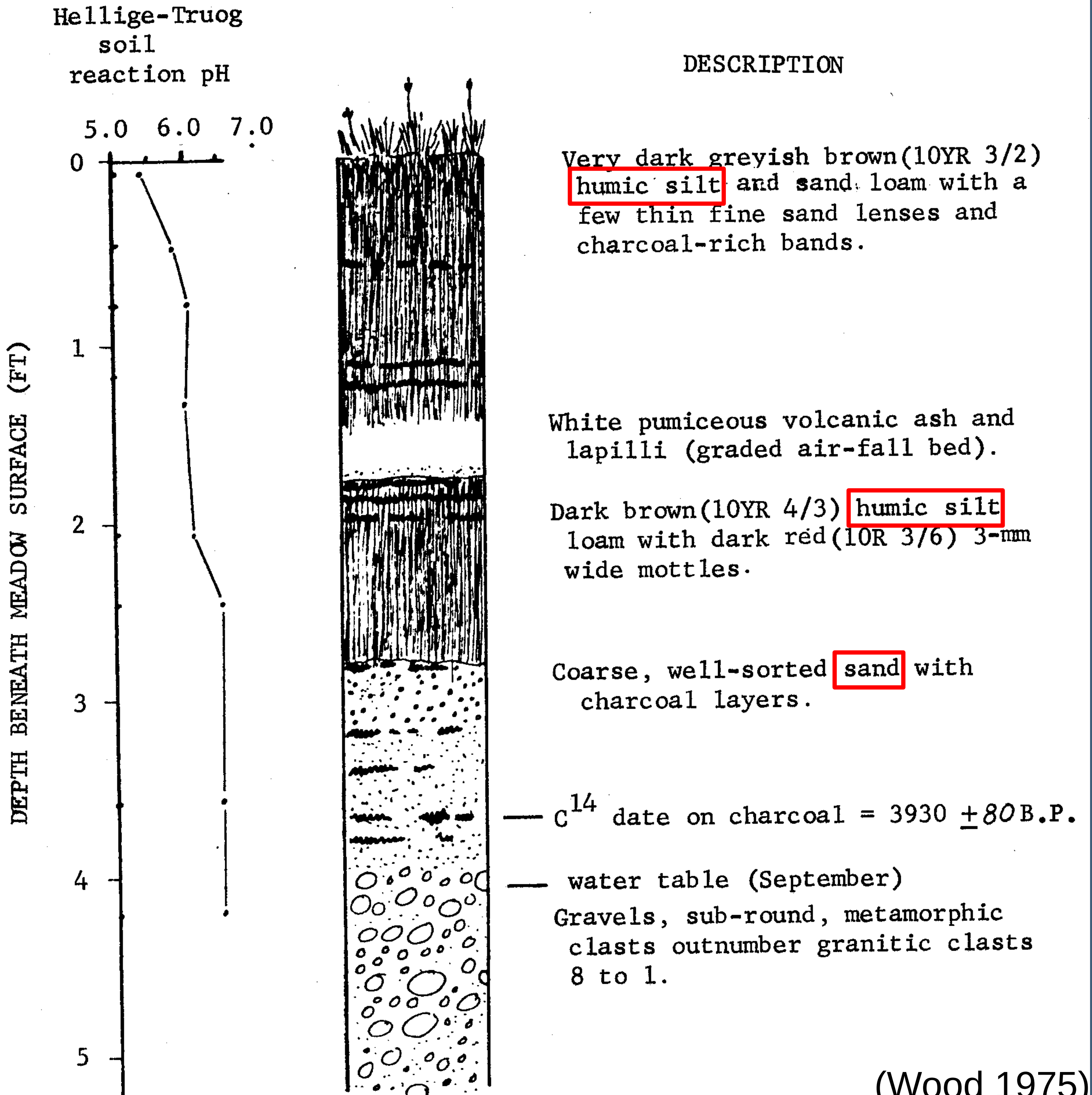




<u>Wet-block average (incl. well 3):</u>
45 days within 30 cm

<u>Dry-block average (incl. well 1):</u>
9 days within 30 cm





(Wood 1975)

Tuolumne Meadows soil stratigraphy

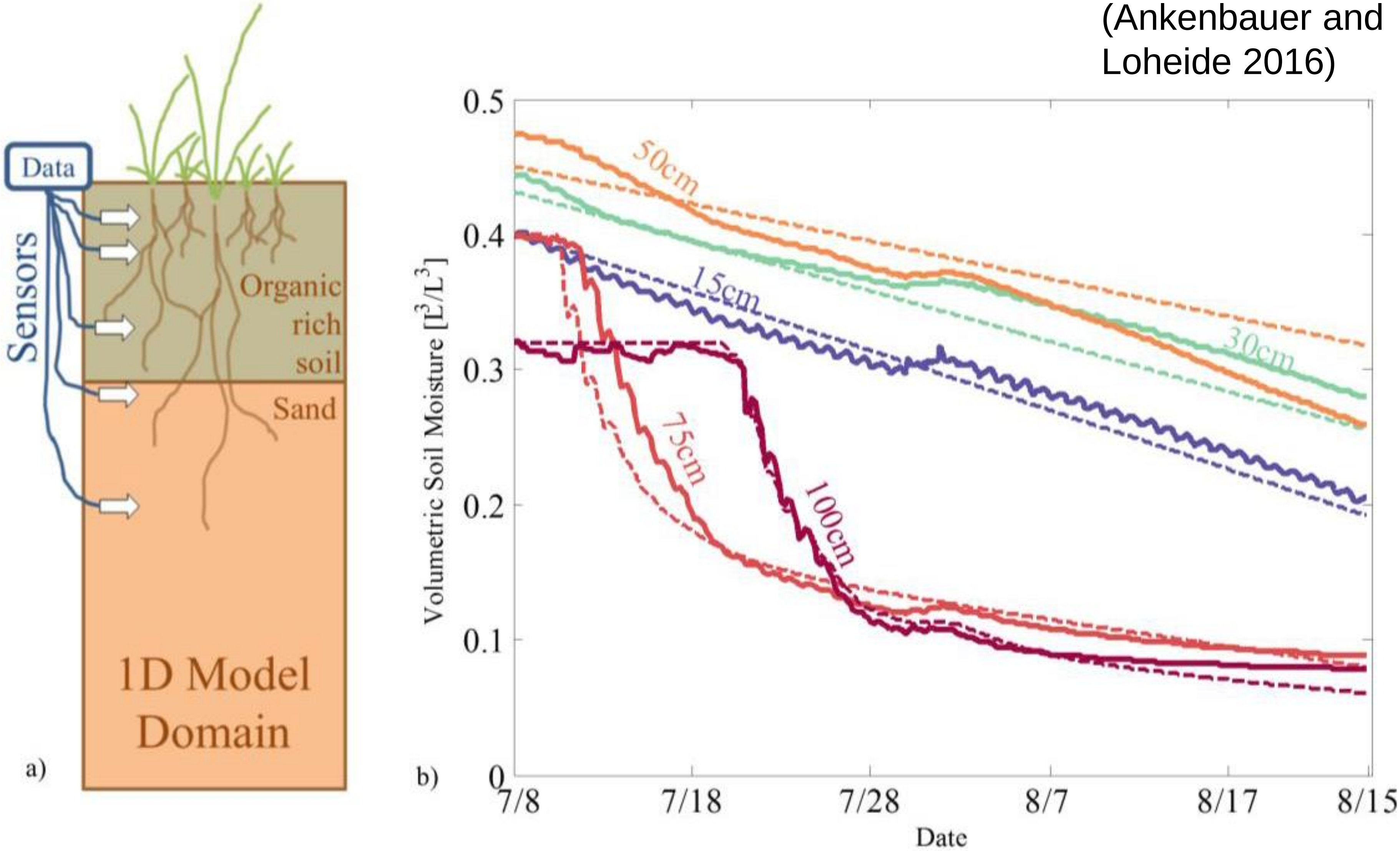
~20% Organic matter

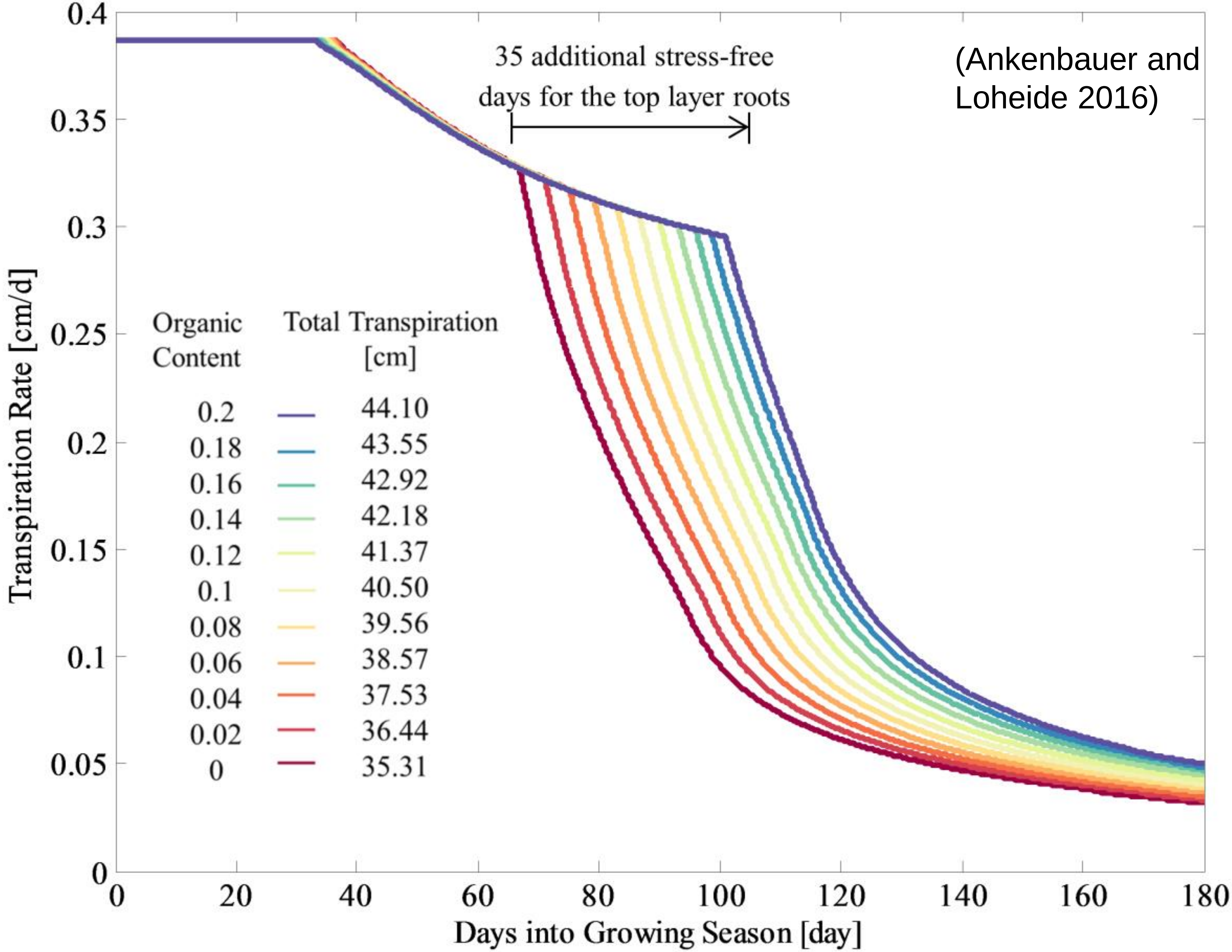
1200 yrs BP ash layer found at 40-70 cm depth in well holes

Base of meadow sediments estimated @ 2300 yrs BP

Organic matter sponge

(Ankenbauer and Loheide 2016)




35 additional stress-free days for the top layer roots
(Ankenbauer and Loheide 2016)
Organic Content
Total Transpiration [cm]
0.2 44.10
0.18 43.55
0.16 42.92
0.14 42.18
0.12 41.37
0.1 40.50
0.08 39.56
0.06 38.57
0.04 37.53
0.02 36.44
0 35.31
Transpiration Rate [cm/d]
Days into Growing Season [day]
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
20
40
60
80
100
120
140
160
180