

# EVALUATING EFFECTS OF MEADOW RESTORATION ON SUMMER STREAMFLOWS

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## RESULTS OF WIDESPREAD MEADOW EROSION:

- Removal of meadow alluvium
- Loss of meadow groundwater
- Alteration of streamflow regimen
- Adverse effects to wildlife, fisheries, forage production, fuel loading



Images from the Wieslander Vegetation Type Mapping Collection are courtesy of the Marian Koshland Bioscience and Natural Resources Library, University of California, Berkeley, [www.lib.berkeley.edu/BIOS/vtm/](http://www.lib.berkeley.edu/BIOS/vtm/).

“No national forest shall be established except to improve and protect the forest within the boundaries, or for the purpose of securing favorable conditions of water flows...”

Organic Administration Act, 1897



“You will see to it that the water, wood, and forage of the reserves are conserved and wisely used ...”

“The continued prosperity of the agricultural, lumbering, mining, and livestock interests is directly dependent upon a permanent and accessible supply of water...”

Transfer Act, 1905



USFS efforts to restore meadows began in the 1930's and have accelerated in the past decade as a result of external funding



# Hydrologic effects of erosion and restoration are of concern to stakeholders and potential funding partners



Meadow block diagrams provided by Steve Loheide, University of Wisconsin

# USFS SIERRA NEVADA MEADOW HYDROLOGIC ASSESSMENT--OVERVIEW

- Funding: NFWF, DWR
- Partners: UC Merced, UC Davis, USGS
- Geographic Scope: 10 Sierra Nevada National Forests
- Timeline: June 2010 to March 2013
- Objective: Estimate the increase in groundwater retention that could support summer streamflow as a result of meadow restoration on National Forest lands in the Sierra Nevada



# APPROACH

- TASK 1—Synthesize existing information (handouts)
- TASK 2—Delineate meadows on national forests and develop sample pool
- TASK 3—Field check meadow locations and areas
- TASK 4—Assess extent of meadow erosion
- TASK 5—Monitor selected meadows and develop water budgets and groundwater models
- TASK 6—Summarize results in final report



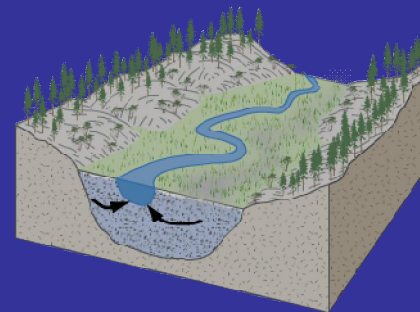
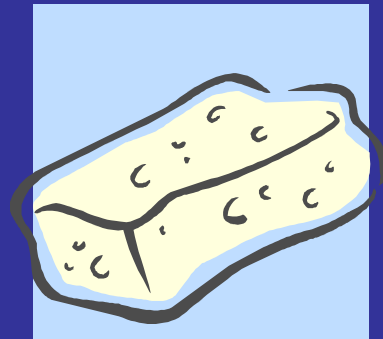
# WORKING HYPOTHESES

- Meadows that appear to be similar landforms may vary in their hydrologic responses to restoration
- Groundwater flow between meadows and surrounding watersheds is a major control on meadow hydrology
- Meadows can usefully be categorized with respect to restoration effects into 3 conceptual models



# CONCEPTUAL MODELS –the “sponge”

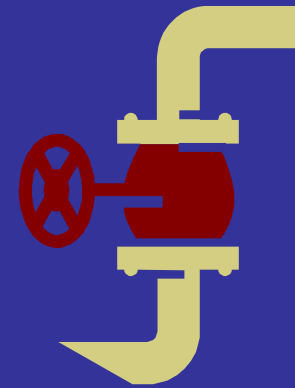
- Meadows store runoff during spring snowmelt and release water to streams and plants gradually during dry summers
- Meadows may be connected to regional groundwater flow systems and if so are equally or more highly permeable than bedrock
- Restoration effects will be achieved relatively quickly



Meadow block diagrams provided by Steve Loheide, University of Wisconsin

# CONCEPTUAL MODELS –the “valve”

- Meadows regulate the discharge of groundwater from regional flow systems through bedrock
- Meadows are part of regional groundwater flow systems and are less permeable than surrounding bedrock
- Restoration effects may have a “lag time” of one or more years



# CONCEPTUAL MODELS – the “drain”

- Meadows act as groundwater recharge zones
- Meadows are connected to regional flow systems and may be more or less permeable than bedrock
- Unlikely to improve streamflow regimen after restoration



# HYDROLOGIC EFFECTS OF MEADOW EROSION

- Rapid transmission of spring snowmelt
- Lower water table
- Decreased evapotranspiration (ET)
- Changes in groundwater (GW) flow directions
- More rapid drainage of GW to stream



# HYDROLOGIC EFFECTS OF MEADOW RESTORATION

- Infiltration and retention of spring snowmelt
- Higher water table
- Increased ET
- Changes in GW flow directions
- Less rapid but more prolonged drainage to stream



## When do meadows retain water?

- Functional meadow aquifers are recharged during winter storms or spring snowmelt (for example, Wood, 1975; Loheide and others, 2009) when reservoirs are releasing water to the ocean
- Groundwater storage capacity is 100% filled by late spring
- Meadows act as discharge zones during summer (Loheide and others, 2009)
- Meadows that are filled to capacity cannot retain additional water during the summer



## How much does restoration affect ET?

- ET for wet meadows and ponds is about twice the ET of sagebrush, conifers, and grasses (about 1 foot/year; for example, Wood, 1975; Loheide and Gorelick, 2007)
- About half the water used by wet-meadow plants comes from groundwater (Lowry and Loheide, 2010)
- Only about half the total post-restoration ET can be considered a “loss” resulting from restoration



## What is the effect of ET on restored meadow GW?

- Depth of meadow alluvium affected by ET = season ET/specific yield ( $S_y$ )
- Depth of meadow alluvium affected by restoration = gully depth
- If gully depth  $>$  ET/ $S_y$ , ET “loss” will be outweighed by increased GW retention
- For typical Plumas meadows,  $S_y = 0.4$ , gully depth = 15 ft
- GW retention/unit area = 6X ET “loss”
- GW retention  $>$  ET “loss” for gully depths  $>$  2.5 ft

# How does GW retention affect streamflow?

- GW before restoration flows toward channel (Larkin and Sharp, 1992)
- GW after restoration flows down-meadow (Larkin and Sharp, 1992)
- Flow rates and duration may be affected
- Site-specific effects will depend on appropriate conceptual model, and local conditions

# Previous studies

(see handouts for references)

- Number of studies showing downstream increases in baseflow after restoration: 4
- Number of studies showing downstream decreases in baseflow after restoration: 0
- Number of studies showing increased extent or duration of baseflows within restored meadows: 5
- Number of studies showing decreased extent or duration of baseflows within restored meadows: 1

## Restoration is likely to increase summer baseflows under the following conditions:

- Regional groundwater discharge zones (“sponge” or “valve” model)
- Moderate topographic slopes
- High specific yields
- Deeply incised gullies
- High length/thickness ratios
- Low-permeability peat or clay layers breached by erosion (“valve” model)



*Meadow restoration is an important long-term goal of the USFS. Results of our current study will allow restoration priorities to be based on realistic expectations of potential hydrologic benefits.*

Contact information for meadow hydrology assessment:

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