# Engineering Assumptions:
## SCS Blaney-Criddle crop growth stage coefficients


COLORADO
Division of Water Resources
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# “Rumor” that the State has a “new policy” or directive

- No new policy or directive
- The SEO and DEO are simply looking at engineering in detail in SWSP Requests and in Court Cases

# Motivation behind SWSP comments:

- Authority is under purview of the Court (CRS 37-92-308)

- The general assembly gave the SEO the authority to approve SWSP requests **IF**:

> "*the operation and administration of such plan will replace all out-of-priority stream depletions in time, location, and amount in a manner that will prevent injury…*"

# Motivation behind court case comments:

- To bring forth legal and factual concerns to the attention of the Water Court so that a decree will adhere "*to correct rules for the allotment and administration of water*" (Wadsworth v. Kuiper)

Keywords:

- Allotment
- Administration

# What administrative issues are at the center of attention for the DEO?

*"I would say that the DEO has a plethora …"*

ACCOUNTING

- Track the movement of water (records)
- Admin tool; DEO can require changes (prevent injury)
- Minimum Requirements: depletion, replacement, net river balance (see guidelines)

EXCHANGES

- 48 hours advanced notice and prior approval from the water commissioner, "or as otherwise requested"

# What allotment issues are at the center of attention for the DEO?

- **HCU Analysis**. We have focused on the following in our review of SWSP requests and Court cases:

    1. HCU analysis should use standard practices (i.e. StateCU, Glover, etc.)

    2. Are assumptions based upon specific facts?

    3. Are assumptions supported by literature?

# A common reoccurring issue regarding engineering assumptions:

- **Crop Coefficients (SCS Blaney-Criddle)**
  - HCU is directly proportionate to the Coefficient
  - Selecting Coefficients requires “Engineering Judgment”
  - SCS TR-21 vs. calibrated coefficients

# A common reoccurring issue regarding engineering assumptions:

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  - **SCS TR-21 vs. calibrated coefficients**

# We Hear Many Arguments Against SCS TR-21 and for Calibrated Coefficients

1. “Nobody” knows where TR-21 came from
2. They were developed in a “Coffee shop”
3. Calibrated Coefficients are better; rely upon ASCE Stnd. Ref. ET Eqn., which is a “superior” ET equation
4. Calibrated Coefficients are State “approved”
5. SCS TR-21 coefficient are “too low”

# Any Good Arguments for Using SCS TR-21 Coefficients?

1. SCS TR-21 are seen as conservative, in favor of the river
2. Uncontested, Easy (min data), Quick (less expensive)
3. Suitable for monthly or annual estimates
4. Calibrated Coefficients are not state “approved”
5. Can be corrected for elevation using Pochop (1984), “consistent with calibrated coefficients”

# Investigation & Analysis (Santistevan, 2013)

*Goal: To find the truth regarding the best coefficients for use in the SCS Blaney-Criddle; Basis for our comments*

I. Technical Review of Pochop (1984)

II. Identified the source of TR-21 and performed a “Forensic” Analysis

III. Evaluated Upper Plains Calibrated Coefficient for Pasture Grasses

# I. Pochop (1984)

1. Researchers indicated a trend of an elev adjustment of 10% per 1,000m for the SCS Blaney-Criddle

2. Pochop set out to verify

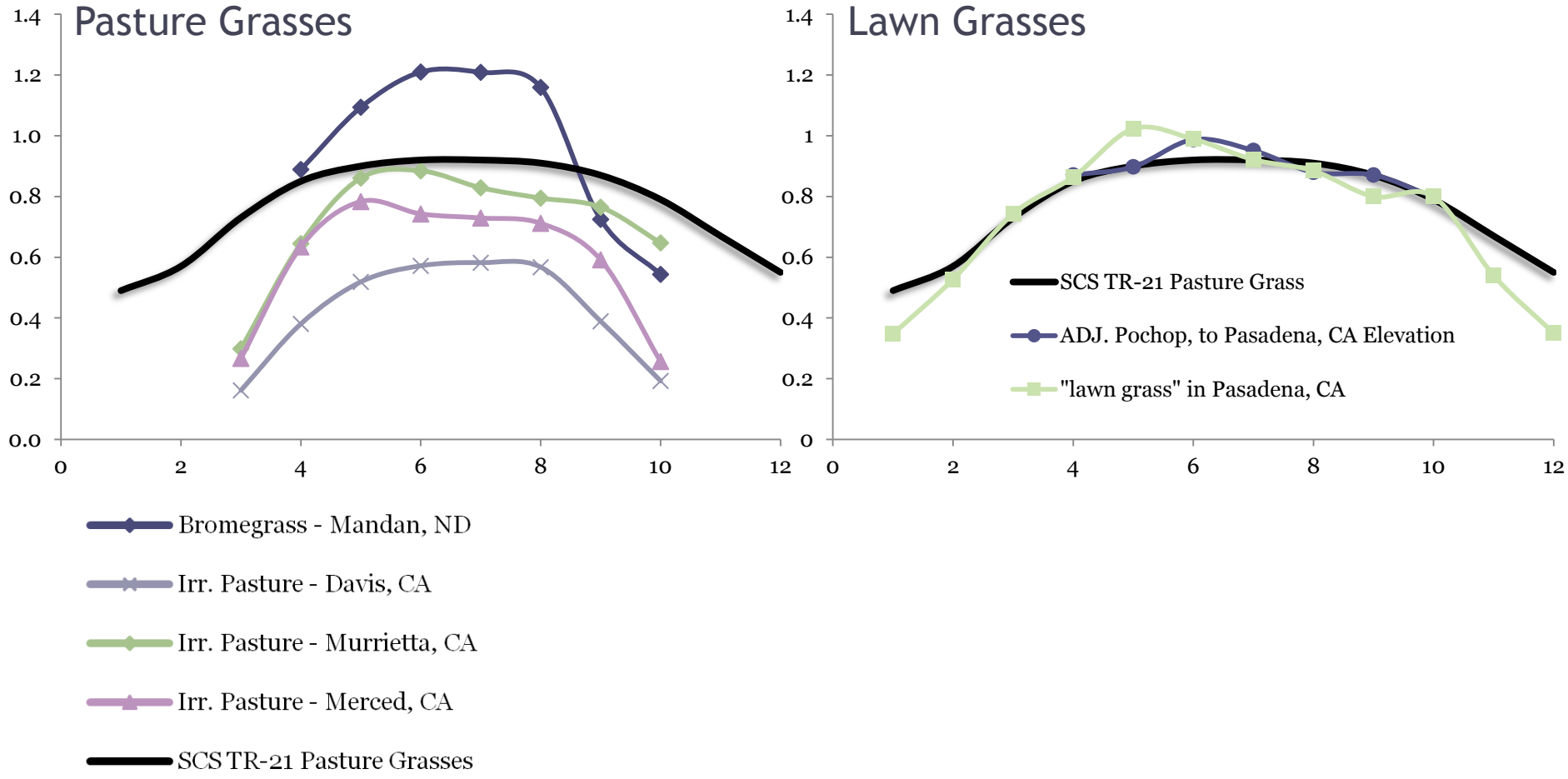
    a. Evaluated alfalfa & Kentucky Bluegrass. Results are specific to alfalfa & Kentucky Bluegrass

3. Findings: An adjustment is appropriate from the elevation at which the coefficients were developed

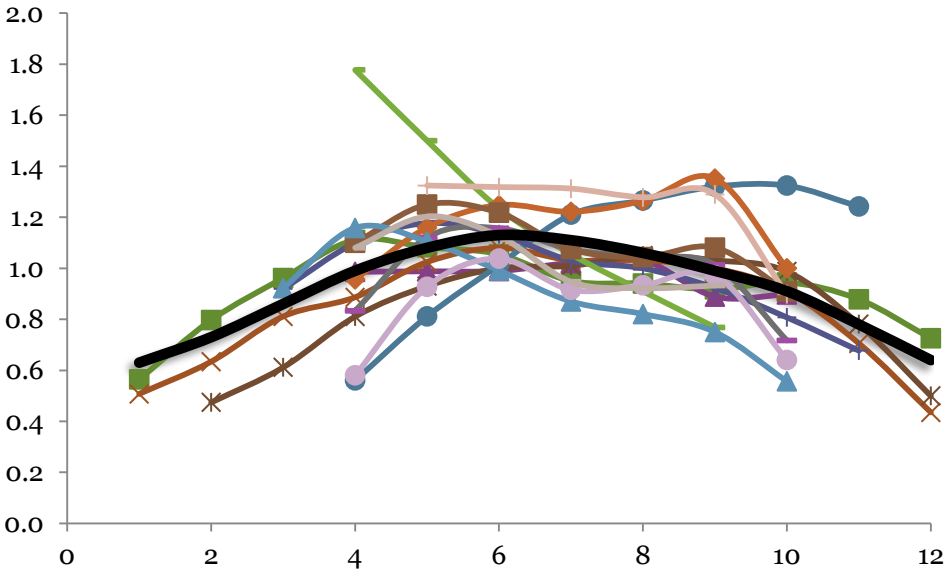
# II. SCS TR-21 Coefficients

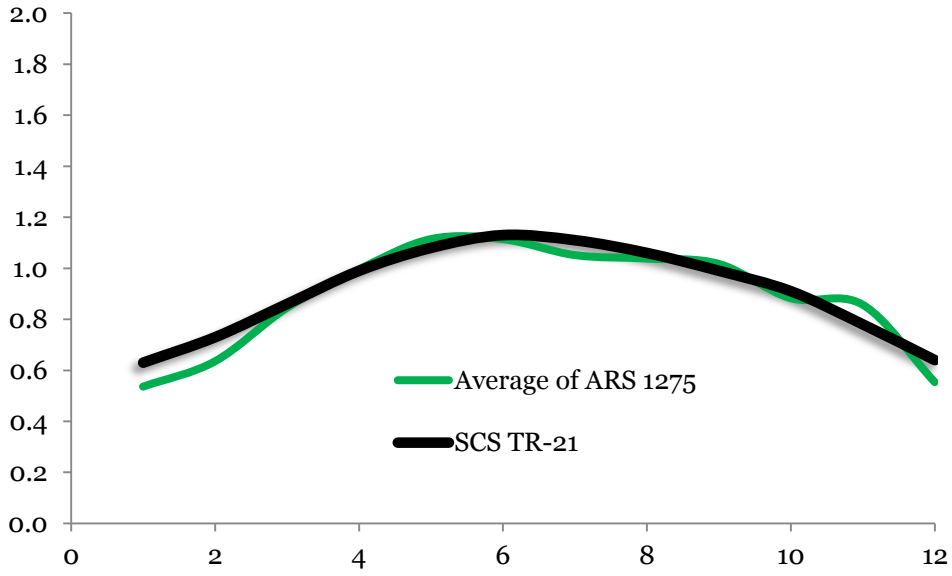
a. Source is USDA-ARS Technical Bulletin No.1275 (Blaney & Haise, 1962) a revision of SCS-TP-96
    a. Originally published as k values. Had to convert to $k_c$
    b. Developed using scientific procedure
b. SCS TR-21 Crop Curves evaluated by regression analysis
    a. Attempted to identify the crop & elevation that $k_c$ represents
c. Some interesting findings…

# SCS TR-21 Crop Growth Stage Coefficients – Pasture Grasses?



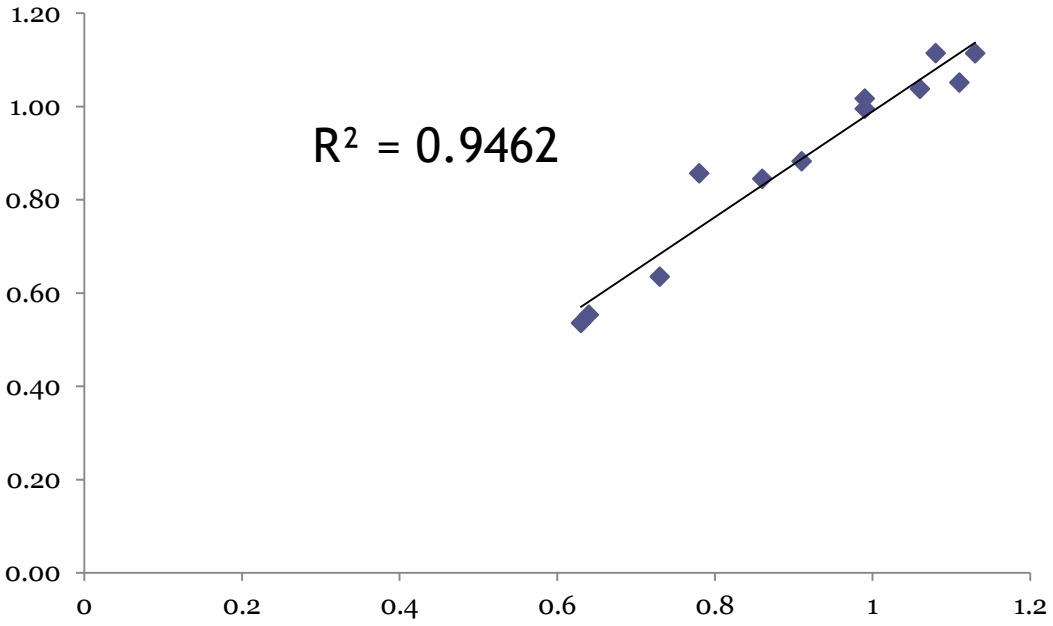
There were 14 data sets for Alfalfa, which included “Alfalfa-Grass” and Clovers at an average elevation of 1,520’ above sea level …



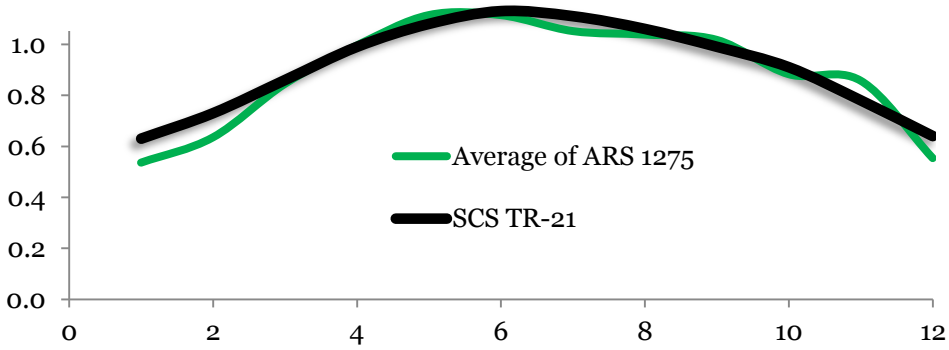




*“k values are taken from smoothed curves plotted from available measured consumptive use data”* (Woodward, 1963)

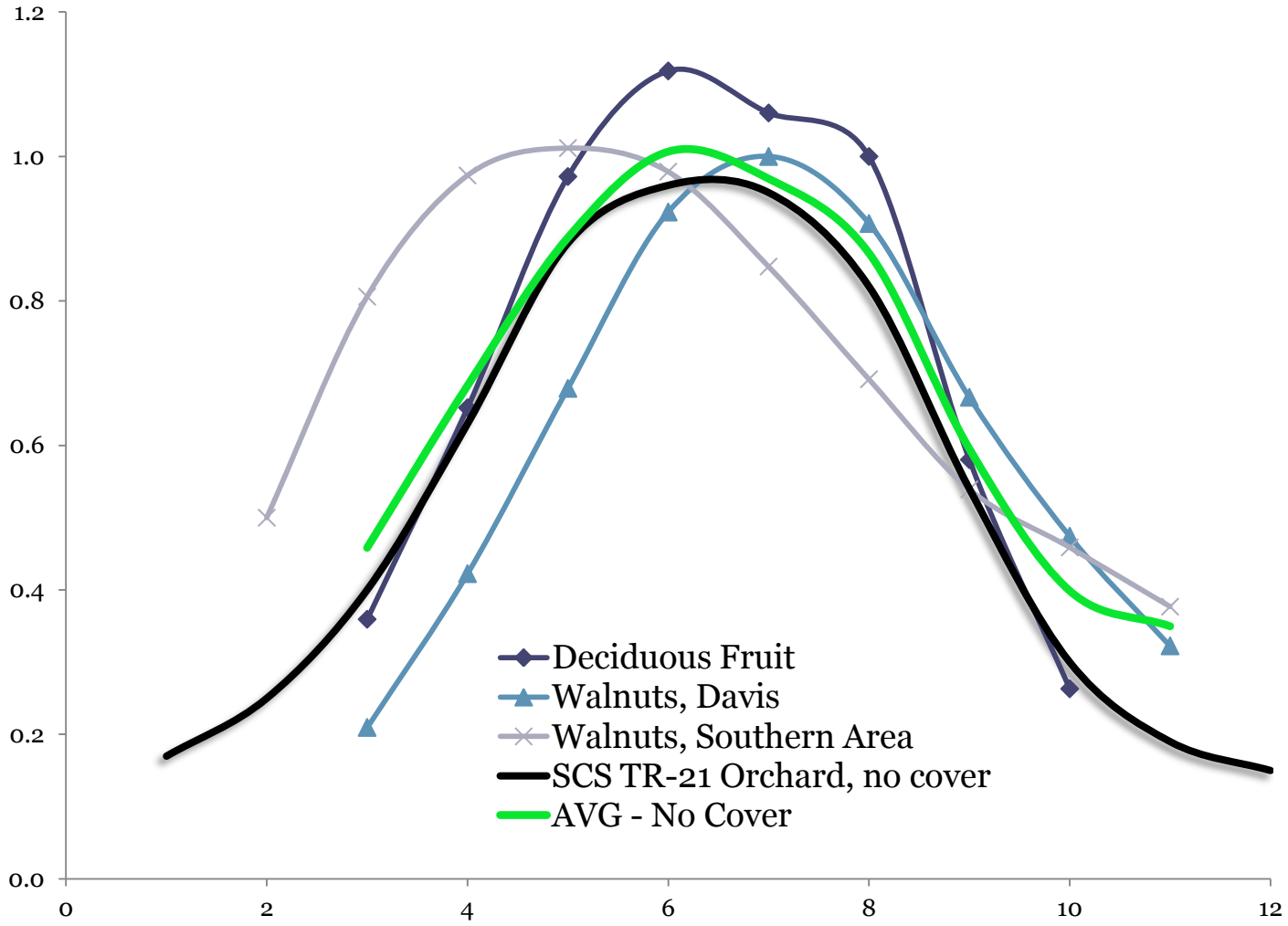
# Even with “smoothing,” linear regression analysis shows a strong correlation …



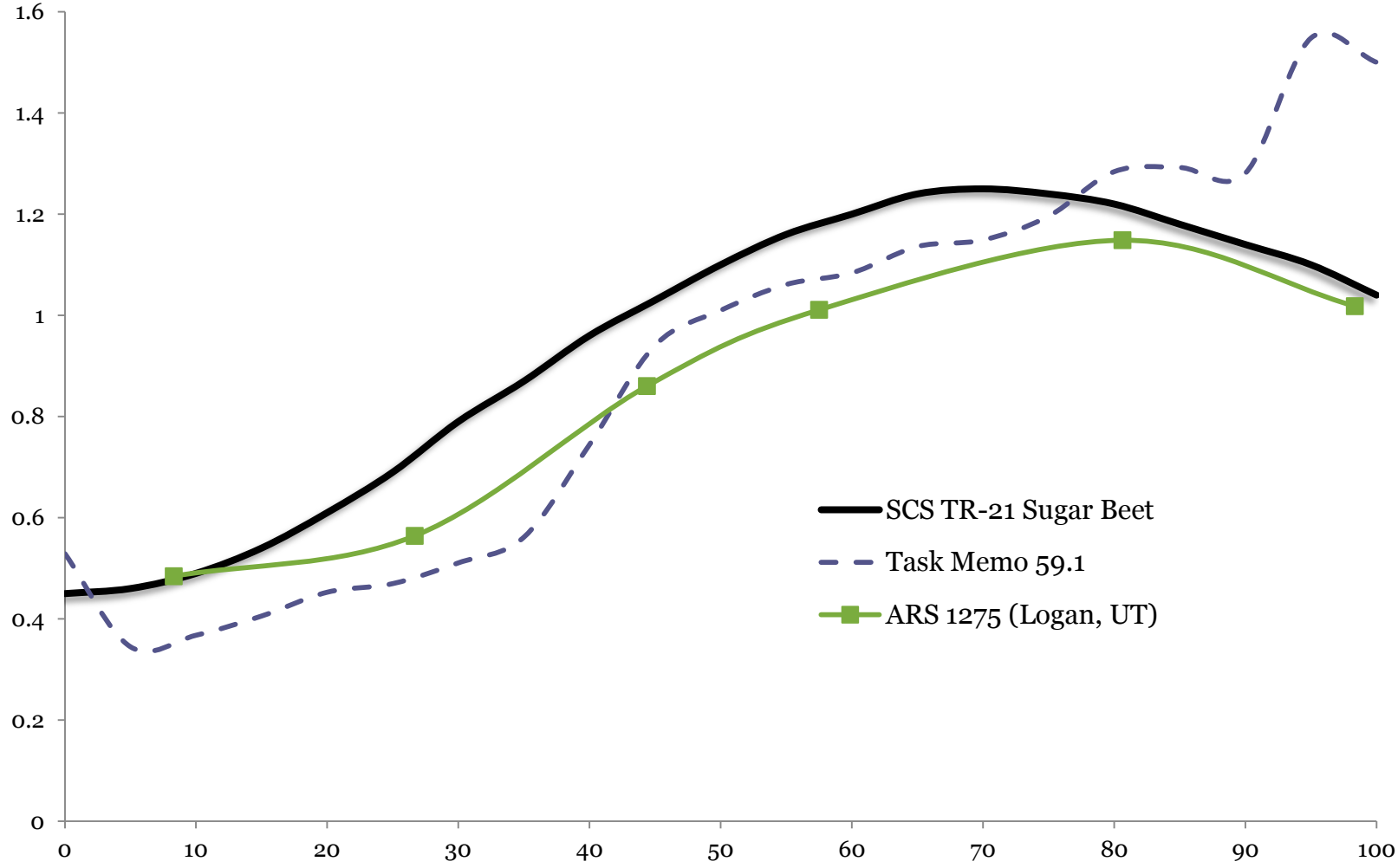

ARS-1275 Alfalfa (avg) vs. SCS TR-21 Alfalfa



"Orchards" appear to represent "deciduous fruit" and walnuts near sea level (in California)…



# Not all SCS TR-21 coefficients may be "too low." Sugar Beets at Logan, UT (4,500' above sea level) …



# III. Task Memo 59.1

1. Evaluated upper plains calibrated coefficients for pasture grass in Kersey, CO (1993-2008)

    a. TM59.1 used FTC, GLY, FTL

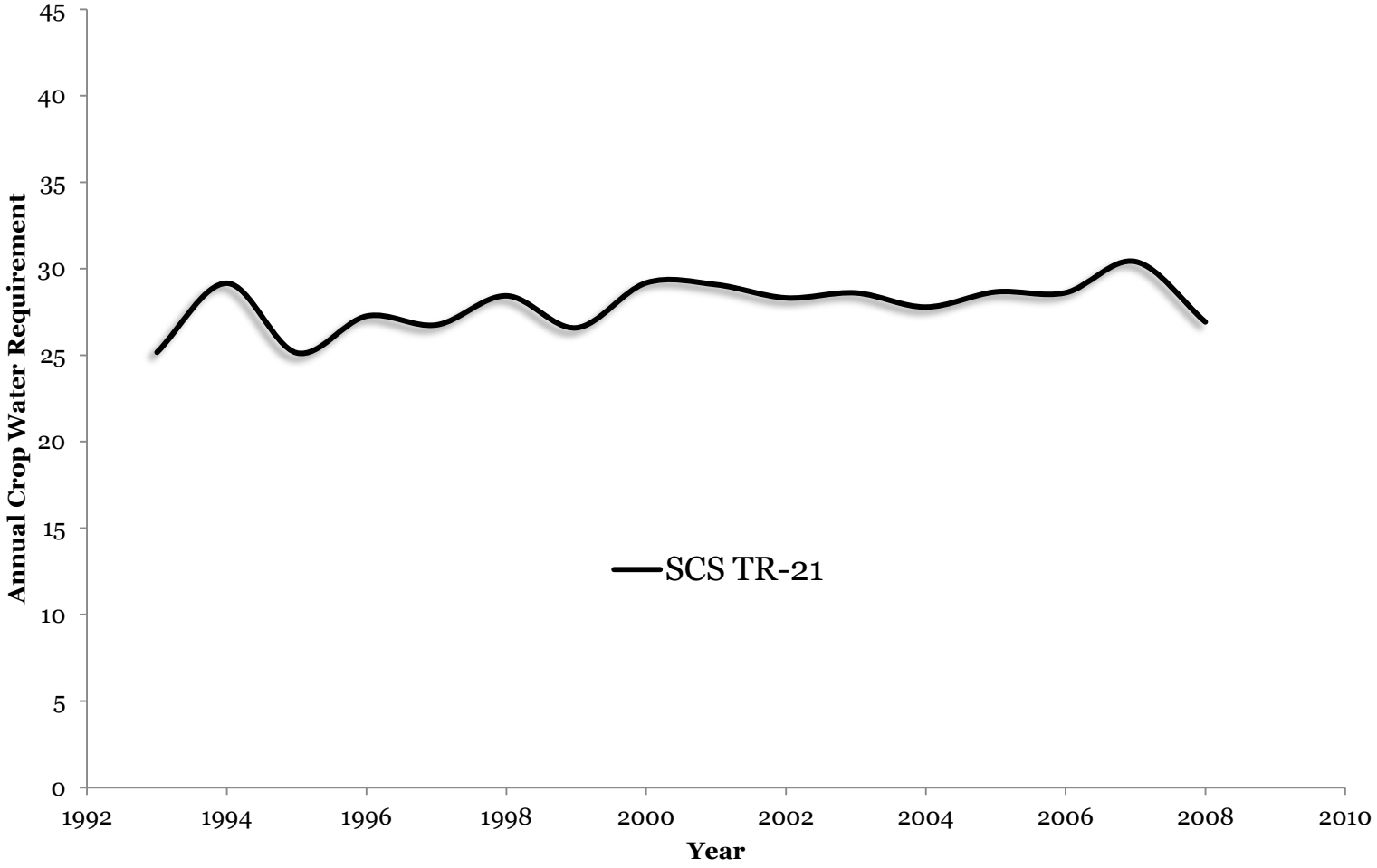
2. Calculated crop water requirement using,

    a. SCS Blaney-Criddle with TR-21 coefficients

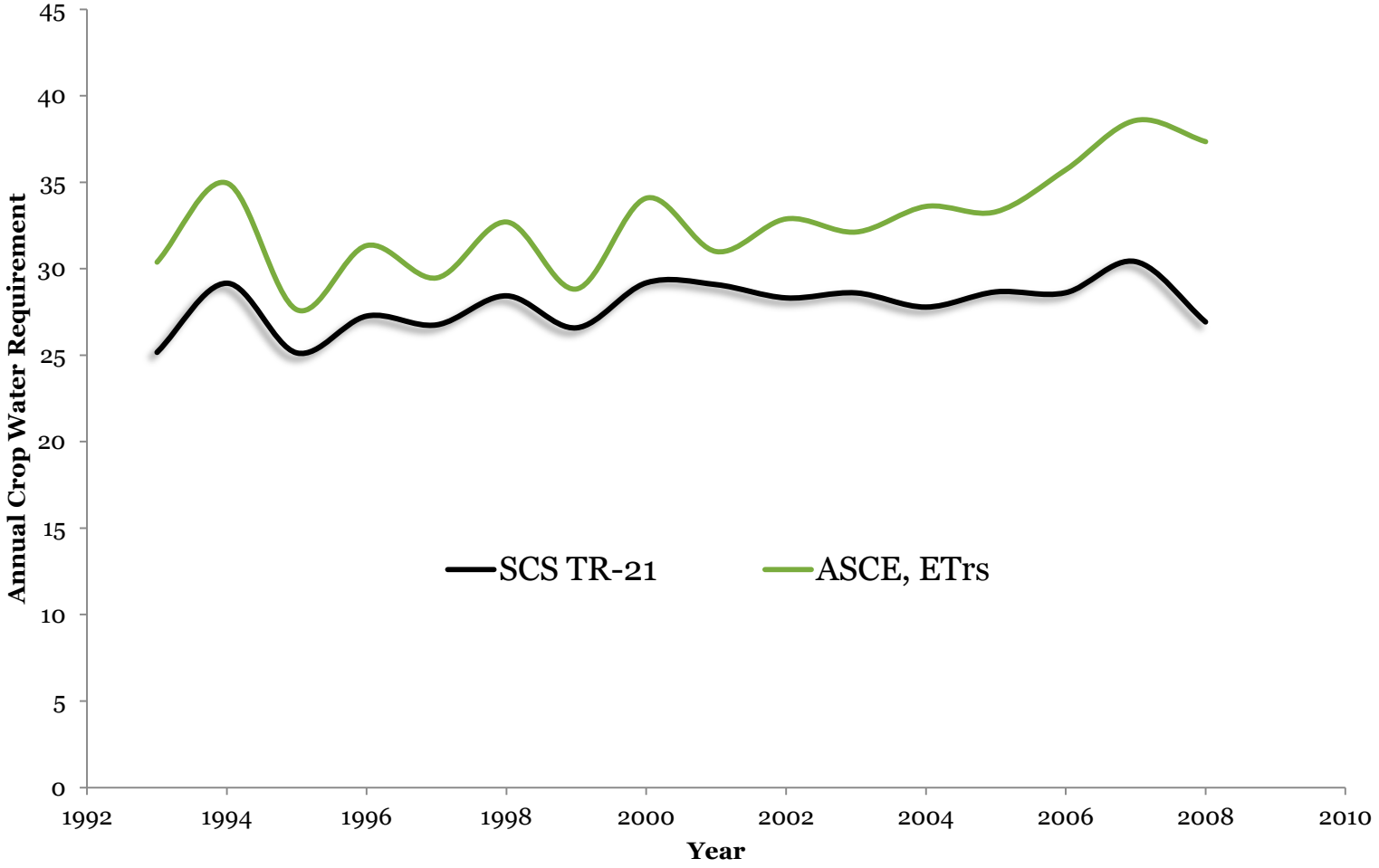
    b. SCS Blaney-Criddle with Task Memo 59.1 coeffs.

    c. ASCE Standardized Ref. ET Eqn. (2005)

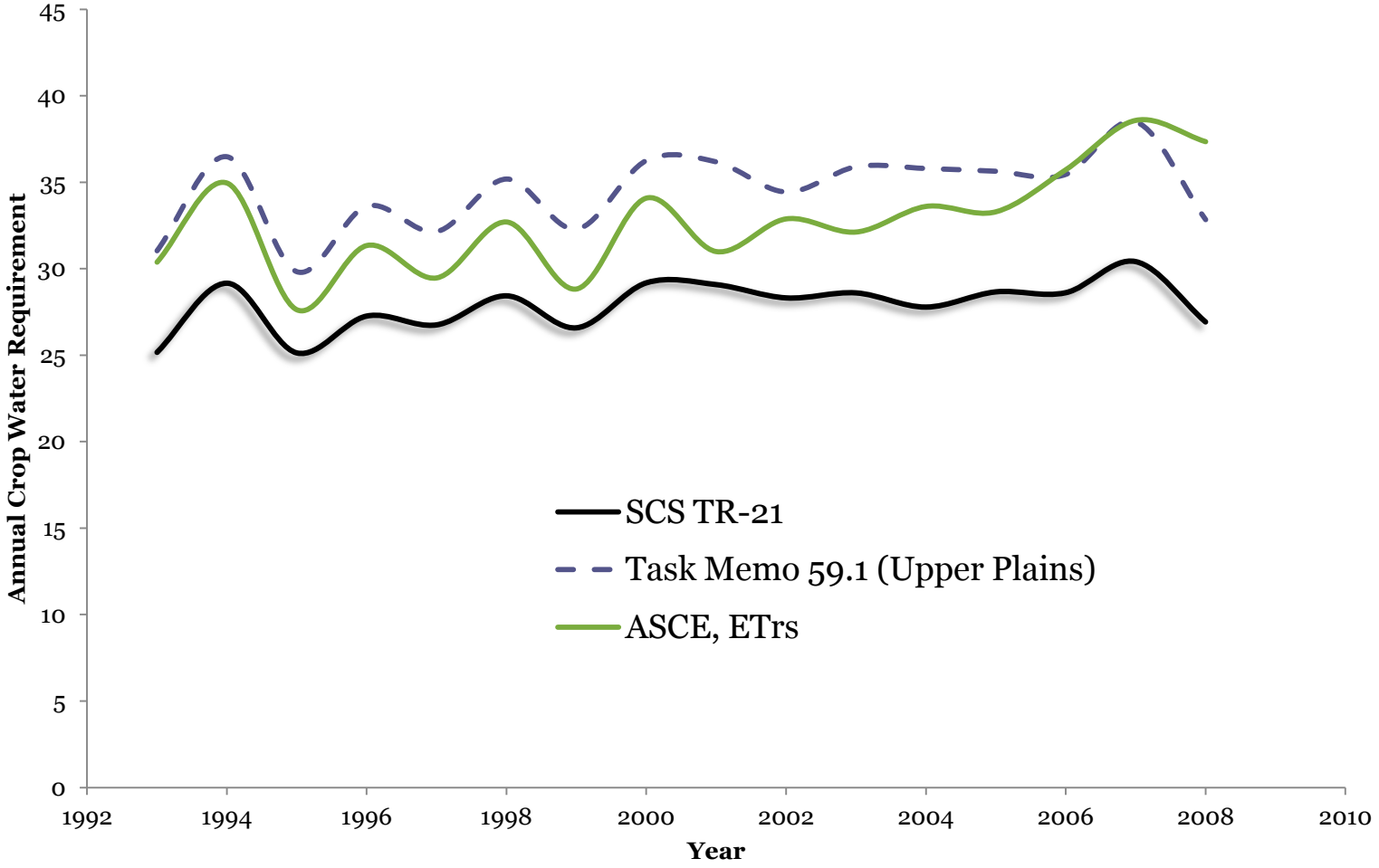
# We started by calculating CU using the SCS TR-21 coefficients…



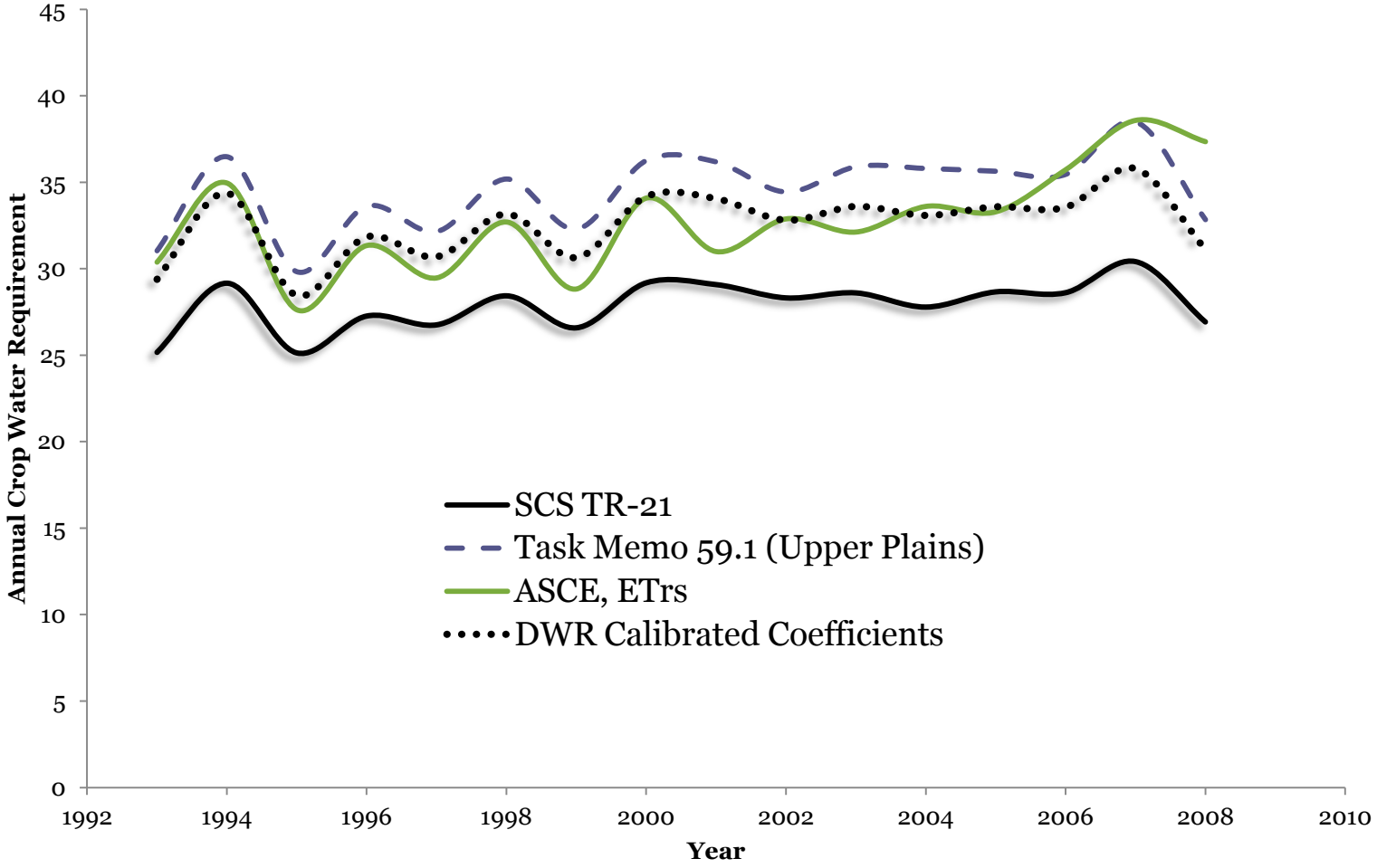
… then calculated CU using the ASCE Stnd. Ref ET Eqn…



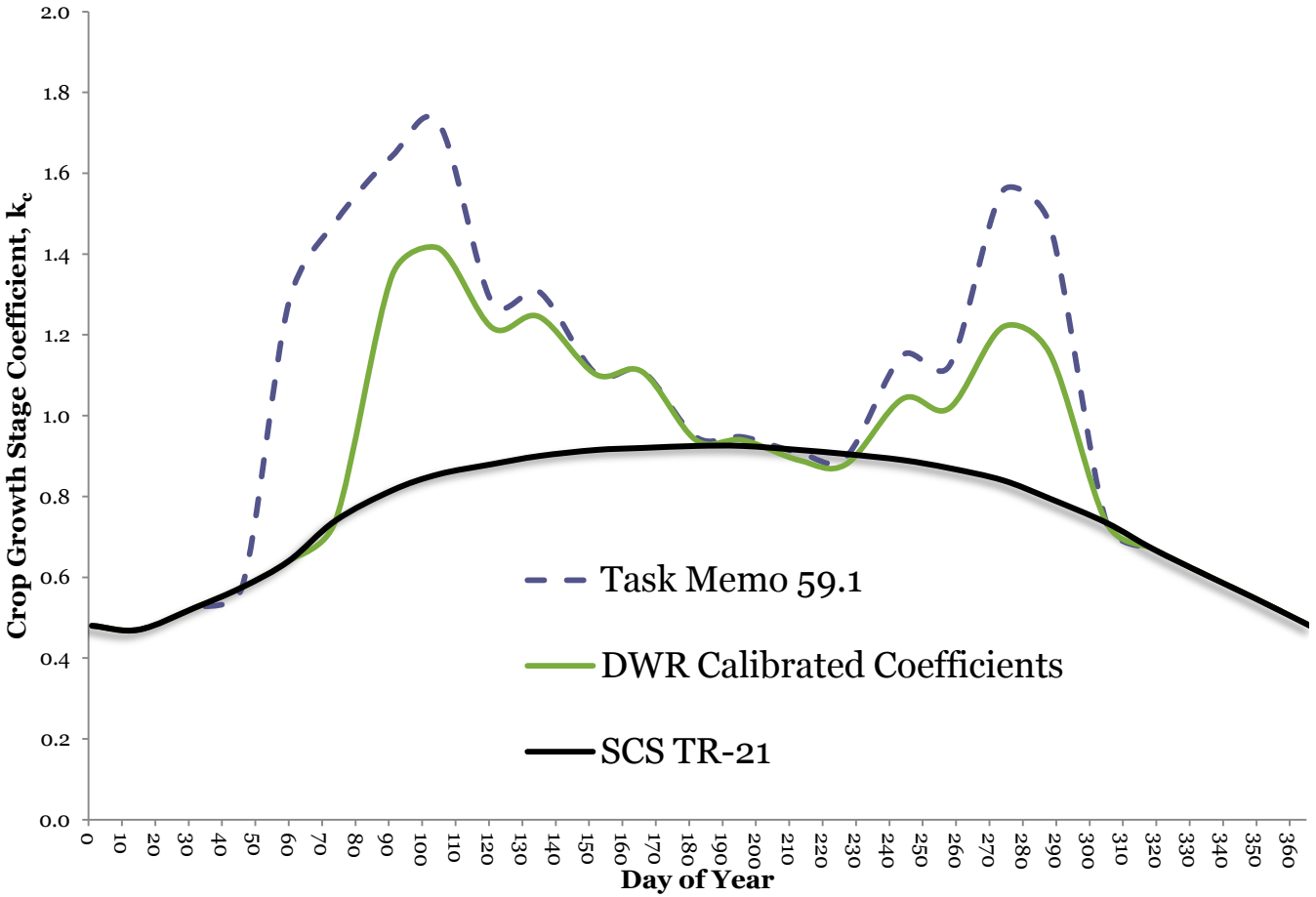
… and finally used the upper plains coefficients.



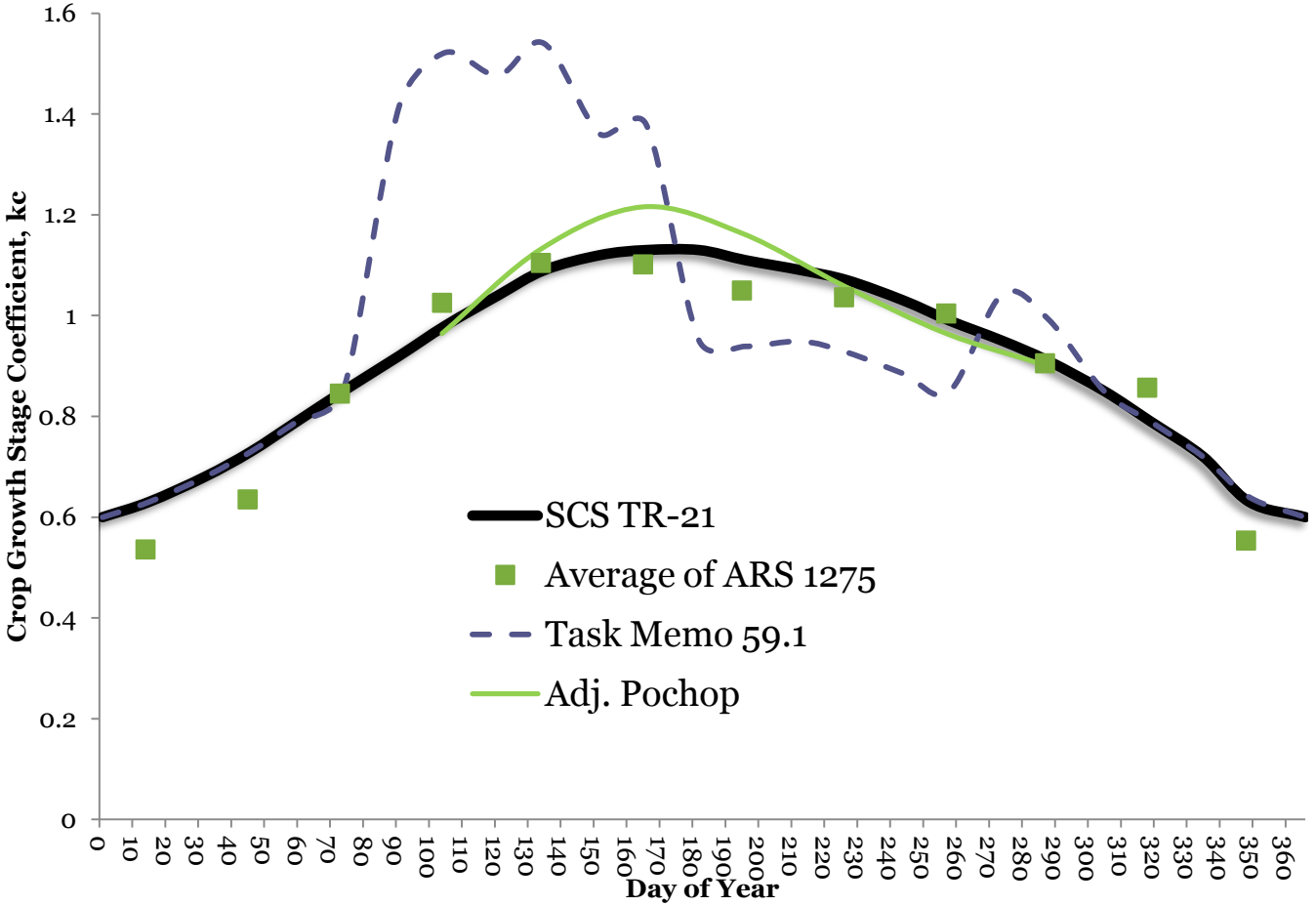
# Then we did our own calibration…



We compared $k_c$ values in Task Memo 59.1 to data sets. Pasture grass…



# … and Alfalfa…


Crop Growth Stage Coefficient, kc
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280 290 300 310 320 330 340 350 360
Day of Year
SCS TR-21
Average of ARS 1275
Task Memo 59.1
Adj. Pochop

# Findings from TM59.1 Evaluation:

1. The calibration appears to produce $k_c$ curves that are exaggerated during the shoulder months.

    a. Similar to Dr. Pochop's work? May be explained by meteorological effects – high daytime and low nighttime temps. The ASCE Stnd. Ref. Eqn. would account for these effects

2. While the methodology in Task Memo 59.1 appears reasonable, independent calibrations should be performed using nearby climate data

# In summary:

1. An elevation adjustment to SCS Blaney-Criddle should be from the elevation at which the coefficients were developed

2. We have a better understanding of what SCS TR-21 crop coefficients represent. Engineering Judgment should apply

3. We agree with the disclaimer in Task Memo 59.1 and question the use of upper plains coefficients in change proceedings

   *"information should not be relied upon in any legal proceeding."*

4. Our findings are not gospel. We are always open to new data, findings, and facts

# Engineering Assumptions:
## Other Assumptions Including Efficiency

COLORADO
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# Application Efficiency (aka Irrigation Efficiency)

- "The ratio of the volume of irrigation water used in evapotranspiration (HCU) to the volume of water delivered to an area (FHD)"
  - Amer. Soc. Agron. Monograph, 1967

# Historical Consumptive Use Model


100AF -20 = 80AF-32 = 48AF

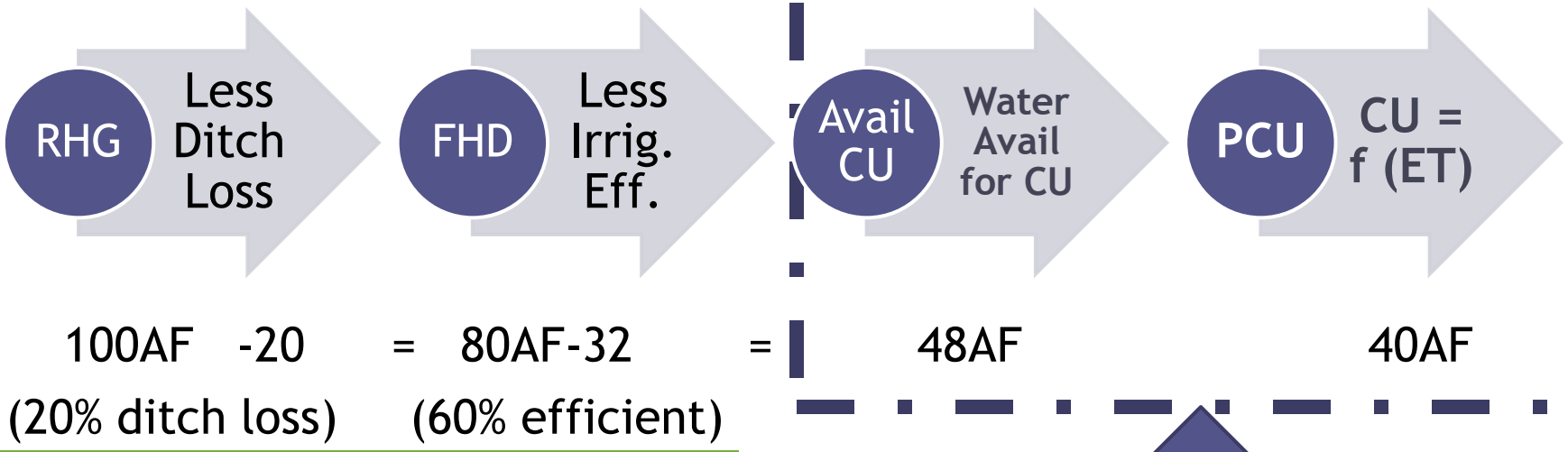
(20% ditch loss) (60% efficient)

Please substantiate this max efficiency number

# Model Application Efficiency Definitions

- IDSCU
  - Application Efficiency [maximum], set by user for each field;
  - Definition: the efficiency of irrigation for surface ditch water is represented using values between 0 and 1. The portion of water beyond the efficiency (1 - efficiency) is assumed not to be used by crops but is deep percolation or surface runoff.
- StateCU
  - wizard default efficiencies are 45% and 75% for flood and sprinkler.
  - Uses “maximum application efficiency”

# Historical Consumptive Use Model




HCU = Min(Avail CU, PCU)
HCU = 40 AF
Calculated Efficiency
= 40/80AF = 50%

Available CU compared to PCU is important

# Assumed Irrigation Efficiency

- Application efficiencies such as 60% for flood and 80% are sometimes assumed with no justification
  - Not all farms are created equal

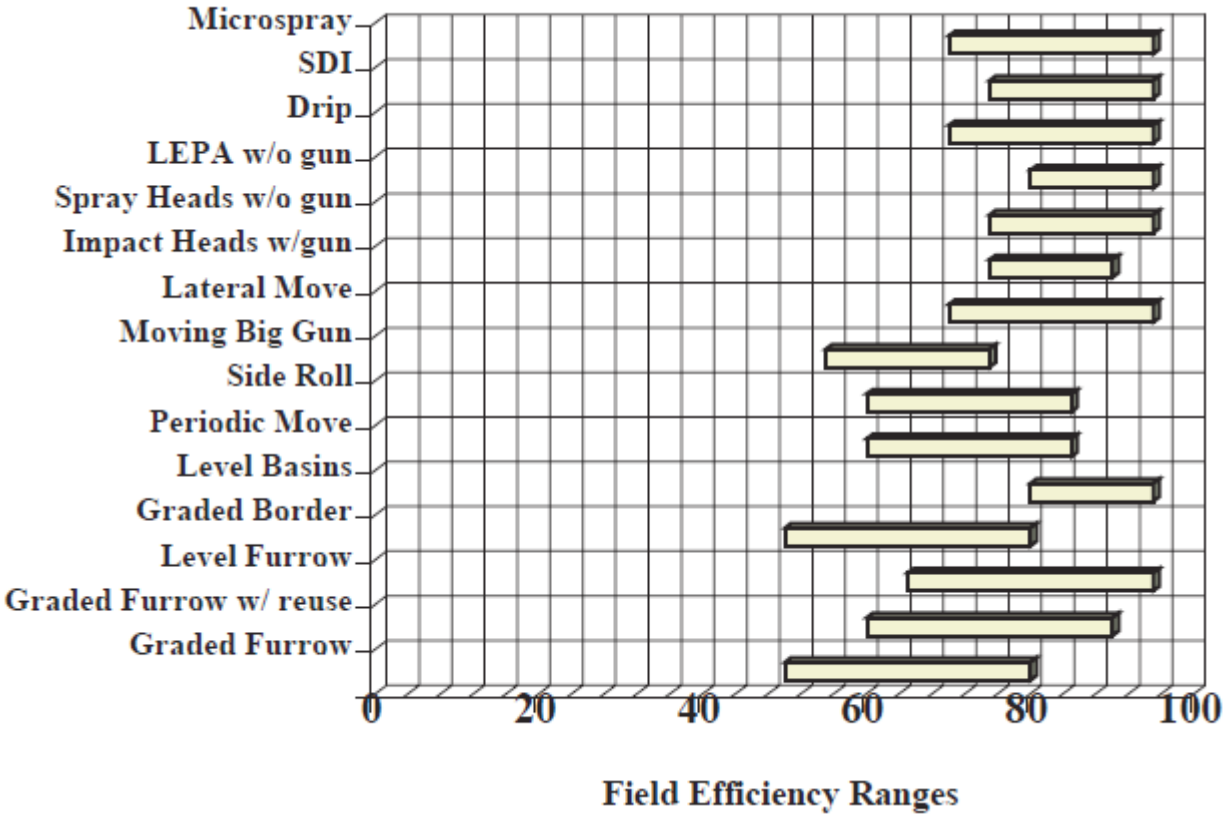
# Assumed Irrigation Efficiency

- Depending on site specific information & management practices, efficiencies can vary widely.
- The efficiency used in a previous case for the same ditch may not apply to the farm in question.

# Design efficiency adjusted to application efficiency

- A range of potential literature sources can be consulted by engineers
- Literature efficiencies are typically “design efficiency”
  - Assumes ideal conditions: uniform grade, uniform soil textures, even discharge rates, optimal management.
  - Considers modern equipment and methods for irrigation that weren’t available in the early 1900s.
- Design efficiencies should be reduced to account for non-ideal physical & management considerations

# Design Efficiency Ranges




Colorado High Plains Irrigation Practices Guide

# What about wild flooding?

- Efficiency information for wild flooding is not in the literature
  - These systems are “disadvantageous for their low efficiency and uniformity”, Colorado High Plains Irrigation Practices Guide (2004)
  - “Wild flooding is probably the least efficient of all methods” Blaney & Criddle (1962)

# Study period

- Study period should be representative of the full period of record including periods of full, diminished, and nonuse
  - Exclude years of undecreed use authorized by statute and nonuse beyond the water user's control.

- Estimate the average annual use until recent times. If recent years are not included, describe if water use continued in the same manner after the end of the study period.

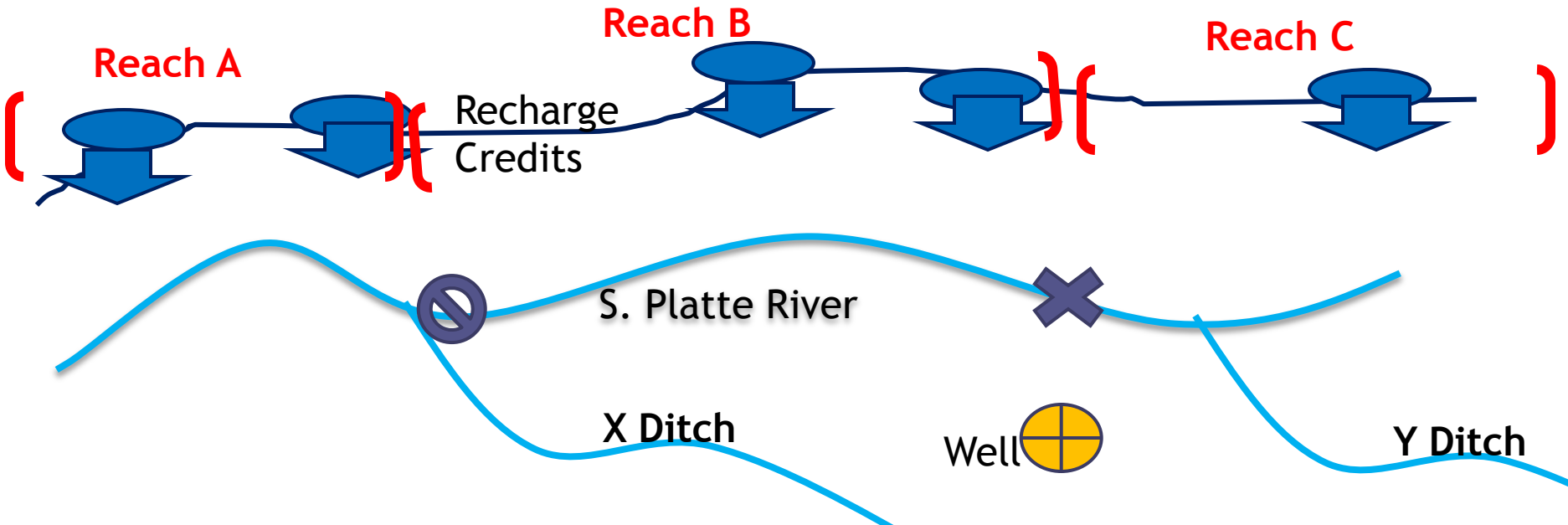
# Storage in soil moisture reservoir

List all model assumptions and technical references in the engineering report. If each assumption isn't listed, provide model files for review.

a. Management allowed Depletion (MAD).
b. Winter soil moisture carry-over from precipitation and surface water.
c. Does excess effective precipitation during irrigation season fill the soil moisture profile?
d. Available Water Holding Capacity (AWC) – NRCS Web Soil Survey, etc.

# Specify Locations

- Section, Township, Range, UTM, etc.
  - The location (or reach) where well depletions impact the stream and the location (or reach) where return flows are owed to the stream.
  - The location where replacement water is discharged to the stream and the location (or reach) were LIRFs accrue to the stream.



# In summary:

1. List engineering assumptions in reports and/or provide model files.

2. Claimed maximum application irrigation efficiencies should be supported by site specific information – both physical & management.

3. Clearly specify locations of depletions and replacements.

Questions??