Understanding Irrigation Effects on Surface Water and Ground Water

Introduction
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Montana State University
Irrigation Effects on Ground Water
What you do depends on your question.

• What is your question?
Water Balance

\[(\text{In} = \text{Out} + - \text{Storage})\]

- Simple Accounting
- Modeling Is a Fancy Way of Accounting
- Terms in the equation can be rearranged
- Usually, all error is assembled in the Evaporation or Ground-Water Term
$$P = I + AET + OF + \Delta SM + \Delta GWS + GWR$$

$P =$ precipitation; $I =$ interception; $AET =$ actual evapotranspiration; $OF =$ overland flow; $\Delta SM =$ change in soil moisture; $\Delta GWS =$ change in groundwater storage; $GWR =$ groundwater runoff.
Water Balance at the Basin Scale
Flint Creek
Kauffman, 1999

\[ \text{GW}_{\text{recharge}} = \]

\[ (P_{\text{in}} + SW_{\text{in}} + IRR_{\text{in}} + GW_{\text{in}}) \]

\[ - (P_{\text{of}} + ET + SW_{\text{out}} + GW_{\text{out}} + E_{\text{res}} + IRR_{\text{out}}) \]

\[ \pm \Delta S_{\text{sw}} \]
where $GW_{recharge} = \text{ground water recharge}$, $P_{in} = \text{total precipitation}$, $SW_{in} = \text{surface water inflow}$, $IRR_{in} = \text{irrigation inflow}$, $GW_{in} = \text{ground water inflow}$, $P_{of} = \text{precipitation as overland flow}$, $ET = \text{evapotranspiration}$, $SW_{out} = \text{surface water outflow}$, $GW_{out} = \text{ground water outflow}$, $E_{res} = \text{evaporation from reservoirs}$, and $IRR_{out} = \text{irrigation water exported out}$, and $\Delta S_{sw} = \text{the change in surface water storage}$ (Dingman, 1994; Fetter, 1994).
Real Parameters in Irrigation Problem

• Water Balance
• (In=Out +- Storage)
• Parameters
  – In
    • Rain
    • Snow-Melt
    • Stream Flow
    • Irrigation Ditch
    • Irrigation
      – Flood
      – Wheel Line
      – Center Pivot
    • Ground Water
      – Alluvial
      – Range Front
      – Well Injection
  – Out
    • AET by plants
    • Well Withdrawal
    • Diversions
    • ET from Ditch
    • ET from Pond/Lake
    • Ground Water
    • Stream
  – Storage
    • Soil
    • Ground Water
    • Ponds
    • Stream Channel
When evaluating the terms **ERROR** is worth thinking about.
Estimates of potential error

Dingman, 1993 after Winter, 1981

<table>
<thead>
<tr>
<th>Time Interval</th>
<th>Precipitation</th>
<th>Streamflow Inputs b</th>
<th>Streamflow Outputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily</td>
<td>60–75</td>
<td>5–15 (50)</td>
<td>5 (15)</td>
</tr>
<tr>
<td>Monthly</td>
<td>10–25</td>
<td>5–15 (50)</td>
<td>5 (15)</td>
</tr>
<tr>
<td>Seasonal/annual</td>
<td>5–10</td>
<td>5–15 (30)</td>
<td>5 (15)</td>
</tr>
</tbody>
</table>

a Values are percentages of the true values. Those without parentheses are for “best” methodology; those in parentheses are “commonly used” methodology.
Precipitation

• Average Isohyetal (NRCS Snow Survey Unit; PRISM) Provides average precipitation estimate.

• Station contouring. Remember spatial variability of precipitation.
  – Recall that error drops as longer term averages are used (see previous slide).
Cottonwood Creek, West of Bridgers

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Value</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>( P )</td>
<td>8,340</td>
<td>20% Error</td>
</tr>
<tr>
<td>( I_{sw} )</td>
<td>6,730</td>
<td>5% Error</td>
</tr>
<tr>
<td>( ET )</td>
<td>7,720</td>
<td>40% Error</td>
</tr>
<tr>
<td>( O_{gw} )</td>
<td>1,300</td>
<td>100% Error</td>
</tr>
<tr>
<td>( O_{sw} )</td>
<td>832</td>
<td>5% Error</td>
</tr>
<tr>
<td>( U_{IRR} )</td>
<td>48</td>
<td>50% Error</td>
</tr>
<tr>
<td>( ET_D )</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>( R_{GW} )</td>
<td>5,100</td>
<td>75% Error</td>
</tr>
</tbody>
</table>

Hay, 1997

Figure 17. Actual physical water-budget quantities. No scale implied.
Variable Definitions for Hay

\( R_{\text{GW}} = \) ground water recharge (also equivalent to the change in ground water storage), \( P = \) precipitation, \( I_{\text{SW}} = \) surface water inflow, \( I_{\text{GW}} = \) ground-water inflow, \( \text{ET} = \) evapotranspiration, \( \text{ET}_D = \) evapotranspirative loss from septic discharge, \( \text{E}_R = \) evaporation from reservoirs, \( O_{\text{SW}} = \) surface water outflow, \( O_{\text{GW}} = \) ground-water outflow, \( U_{\text{IRR}} = \) lawn irrigation, and \( S_{\text{SW}} = \) the change in surface water storage.
Many Assume Pumping = Septic System Recharge ($ET_D=0$) No Consumption

- Hay, 1997; Perkins, 1989; Fetter, 1993

- Is it significant?
  - Discuss
  - Does scale influence acceptable error?
Type of Irrigation Is Expected to Matter and Has Error
Irrigation Efficiency

• Water the plant used/water applied
  – Depends on the crop irrigated
  – Depends upon type of irrigation
  – Depends on irrigation practice
  – Depends on the soil irrigated
    • Loam
    • Gravel
Flood Irrigation

- 15-30% efficient
Single Big Sprinkler

- 55-60% efficient
Sprinkler (Wheel Line)

- 65% efficient
- 12 h sets
- 4” in 12 hours
- 10-11 days between sets (depends on operator) can be as low as 48 hours between sets.
Sprinkler (Center Pivot)

- 85-90% efficient
- 1.25 inches of water every fourth day
- Designed for crop need
- Little to ground water
- Little to Evaporation since head is low to ground (less wind drift)
A range of values can be inserted in the accounting system

Kauffman, 1999

<table>
<thead>
<tr>
<th>Land-use</th>
<th>Net recharge (in/season)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sprinkler irrigation</td>
<td>0 - 8</td>
</tr>
<tr>
<td>Flood irrigation</td>
<td>13 - 21</td>
</tr>
</tbody>
</table>
Estimates of irrigation recharge depends upon estimates of irrigated acreage and type.

- Used aerial photo interpretation from photos in NRCS office. Need to talk to people who are on the ground.
Uncertainty
(What Type of Irrigation Here?)
(What Type of Irrigation Here?)

Spatial variability of loss and input (soil maps, AET)
House Irrigation (Sprinkler; Drip)
Some assume consumptive use is same as agricultural irrigation.
Is this true of recharge? Discuss
Ditch Loss

Not all ditches are created equal in terms of loss to the ground-water system.
Ditch Loss Estimate

• Farmer’s Canal -- Marsh Mc Birney Midsection Method 0.4 up from bottom; 0.6 depth
• Replicate Measurements
  – Error expected 5% or better
• Stage held constant over measurement period.
• Most hydrologists measure once.
# Concrete to Lehrkind and Lehrkind to Log

<table>
<thead>
<tr>
<th>Blackwood Concrete</th>
<th>Farmer's Canal</th>
<th>DownStrCoral</th>
<th>LehrkindRoad</th>
<th>Log6000</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>28.56</td>
<td>22.69</td>
<td>29.90</td>
<td>30.16</td>
</tr>
<tr>
<td>2</td>
<td>26.72</td>
<td>25.86</td>
<td>28.36</td>
<td>30.66</td>
</tr>
<tr>
<td>3</td>
<td>27.64</td>
<td></td>
<td>Wader overtop + Veg</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>27.64</td>
<td>24.28</td>
<td>29.13</td>
<td>30.41</td>
</tr>
<tr>
<td>st dev</td>
<td>1.30</td>
<td>2.25</td>
<td>1.09</td>
<td>0.35</td>
</tr>
<tr>
<td>% error</td>
<td>4.71</td>
<td>9.25</td>
<td>3.75</td>
<td>1.15</td>
</tr>
</tbody>
</table>

**Flow Direction**
- Concrete to Lehrkind: -1.49
- Lehrkind to Log: -1.28
Beck-Border Ditch  Flume

• Measurements at flume
  – Flume Measurement  7.23 cfs
    • 7 foot throat; 0.43 ft stage; Q = 7.23 cfs
    • 7 foot throat; 0.41 ft stage; Q = 6.72 cfs
      – Difference = 0.51 cfs or 7.3 % error
      – Note difference is higher than error anticipated for current meter value.
• Need to measure a length of ditch/stream that produces more loss than the error in the measurement.

• BUT Loss is variable and likely occurs in short zones.

• Look for wet spots below ditch
Same error principle applies to seepage runs to find gaining and losing reaches of a river
River Measurement Complicated by Anabranche Character
(See Mark Schaffer’s Talk Friday)
Water Level Response in study area West of Bridgers

Observed Ground-Water Level Change
Mountain-Front-Stream-Loss Recharge (no irrigation)
Figure 22. Potentiometric difference map for August 1995–March 1996. Contours locations dotted where approximate.
Ground-Water Flux (Mountain Front)
Mountain Front Recharge II

• Hay for example, assumed this term is negligible from Metamorphic Rock
  – Primary porosity and permeability negligible
  – Secondary Porosity less than 1%
  – $K \text{ } 10^{-7} \text{ cm/s or less}$ (compression of fractures as depth goes up)
  – On the other hand gradients at the mountain front are high.
  – Inflows are assumed negligible.
Water Level Response
(Change in Ground-Water Storage)

Four Corners Area, Gallatin Valley

Sensors are better than just hand measurements, but more expensive
Hand Measure | Sensor + Hand
River Dominated

Stage 222830

- River Stage
- Snow Melt
- GW Elevation
- Stage

Legend:
- Ground Water Elevation (ft)
- USGS Stage (ft)
Snow Melt April

Mean Air Temperature 224109

- Mean Air Temperature
- GW Elevation

Temperature (°F)

Elevation ASL (ft)

Legend:
- Blue line: Mean Air Temp (°F)
- Red line: Ground Water Elevation (ft)
Or Was It Rain in April?
River and Irrigation (Delayed)
River and Delayed Irrigation
Air Temperature (Snow Melt)
Ground-Water Parameters
(T, K, S, S_y, dh/dl)
Concerns

- Multiple well or single well (Storage or no storage)
- Screened or unscreened
- How water is produced
  - Bail Poor
  - Air lift not different from pump
  - Pump is desirable
- How long water is produced (1h, 2h, 5h, 24h, 72 h)
- Choice of aquifer and aquifer thickness
- Bias to lower T units (Pump size available)
## Repeatability

Kauffman, 1999; Voeller and Warren, 1997

<table>
<thead>
<tr>
<th></th>
<th>Q</th>
<th>Pump time</th>
<th>T</th>
<th>S</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pump 1</td>
<td>13.04</td>
<td>12.6</td>
<td>4840</td>
<td>2.1</td>
</tr>
<tr>
<td>(Water Lev.1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pump 2</td>
<td>28.2</td>
<td>10</td>
<td>6310</td>
<td>4.5</td>
</tr>
<tr>
<td>(Water Lev.6’ deeper)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Extrapolation of T using Specific Capacity

- Limited multiple well pump tests.
- Many specific capacities from wells
- Lever data from few to many
Dixon, 2002 Gallatin Valley
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>All wells</td>
<td></td>
<td></td>
<td>yes</td>
<td>31</td>
<td>50,715</td>
<td>222</td>
<td>6,527</td>
<td>12,596</td>
</tr>
<tr>
<td>All wells</td>
<td></td>
<td></td>
<td>no</td>
<td>20</td>
<td>22,434</td>
<td>29</td>
<td>4,630</td>
<td>5,976</td>
</tr>
<tr>
<td>Alluvium</td>
<td></td>
<td></td>
<td>yes</td>
<td>16</td>
<td>50,715</td>
<td>489</td>
<td>8,354</td>
<td>15,042</td>
</tr>
<tr>
<td>Alluvium</td>
<td></td>
<td></td>
<td>no</td>
<td>11</td>
<td>22,434</td>
<td>196</td>
<td>4,914</td>
<td>6,399</td>
</tr>
<tr>
<td>Gravel cap</td>
<td></td>
<td></td>
<td>yes</td>
<td>1</td>
<td>36,602</td>
<td>36,602</td>
<td>4,886</td>
<td>n/a</td>
</tr>
<tr>
<td>Gravel cap</td>
<td></td>
<td></td>
<td>no</td>
<td>1</td>
<td>9,651</td>
<td>9,651</td>
<td>9,651</td>
<td>n/a</td>
</tr>
<tr>
<td>Deep</td>
<td></td>
<td></td>
<td>yes</td>
<td>13</td>
<td>13,352</td>
<td>222</td>
<td>2,446</td>
<td>3,563</td>
</tr>
<tr>
<td>Deep</td>
<td></td>
<td></td>
<td>no</td>
<td>8</td>
<td>17,408</td>
<td>29</td>
<td>3,612</td>
<td>5,791</td>
</tr>
</tbody>
</table>
## Storativity

**Kauffman, 1999 Flint Creek Valley**

<table>
<thead>
<tr>
<th>Aquifer</th>
<th>Aquifer Test</th>
<th>Water Balance</th>
<th>Published Tables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alluvial</td>
<td>0.004-0.025</td>
<td>0.14</td>
<td>0.01-0.46</td>
</tr>
<tr>
<td>Gravel Cap</td>
<td>0.0011</td>
<td></td>
<td>0.0000015</td>
</tr>
<tr>
<td>Deep Aquifer</td>
<td>0.00018</td>
<td>0.0003-0.000006</td>
<td>0.13-0.44 Sy</td>
</tr>
<tr>
<td>Tertiary</td>
<td></td>
<td>0.006-0.000001</td>
<td>0.01-0.18 Sy</td>
</tr>
</tbody>
</table>
Table 22. Acceptable range, initial estimate and calibrated values of parameters assigned in the model

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Acceptable Range(^1)</th>
<th>Initial Estimate</th>
<th>Calibrated Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>T (gpd/ft)</td>
<td>Quaternary Alluvium - Lower Willow Creek</td>
<td>200 - 86,100</td>
<td>5,000</td>
<td>10,500</td>
</tr>
<tr>
<td>T (gpd/ft)</td>
<td>Quaternary Alluvium - Flint Creek, northeast</td>
<td></td>
<td></td>
<td>19,400</td>
</tr>
<tr>
<td>T (gpd/ft)</td>
<td>Quaternary Alluvium - Flint Creek, southwest</td>
<td></td>
<td></td>
<td>29,800</td>
</tr>
<tr>
<td>T (gpd/ft)</td>
<td>QT(?) gravel cap</td>
<td>9,700 - 36,600</td>
<td>15,000</td>
<td>15,000</td>
</tr>
<tr>
<td>T (gpd/ft)</td>
<td>QT(?) gravel cap - north end of west bench</td>
<td></td>
<td></td>
<td>1,500</td>
</tr>
<tr>
<td>T (gpd/ft)</td>
<td>Tertiary clay</td>
<td>4x10(^{-6}) - 4x10(^3)</td>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td>T (gpd/ft)</td>
<td>Tertiary deep aquifer</td>
<td>30 - 17,400</td>
<td>60</td>
<td>300</td>
</tr>
<tr>
<td>S(_x) (dimensionless)</td>
<td>Quaternary Alluvium - Lower Willow Creek</td>
<td>0.004 - 0.46</td>
<td>0.02</td>
<td>0.1</td>
</tr>
<tr>
<td>S(_x) (dimensionless)</td>
<td>Quaternary Alluvium - Flint Creek, northeast</td>
<td></td>
<td></td>
<td>0.1</td>
</tr>
<tr>
<td>S(_x) (dimensionless)</td>
<td>Quaternary Alluvium - Flint Creek, southwest</td>
<td></td>
<td></td>
<td>0.2</td>
</tr>
<tr>
<td>S(_x) (dimensionless)</td>
<td>QT(?) gravel cap</td>
<td>0.13 - 0.44</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>S(_x) (dimensionless)</td>
<td>QT(?) gravel cap - north end of west bench</td>
<td></td>
<td></td>
<td>0.1</td>
</tr>
<tr>
<td>S(_y) (ft(^{-1}))</td>
<td>Tertiary clay</td>
<td>8x10(^{-4}) - 6x10(^{-3})</td>
<td>7x10(^{-4})</td>
<td>7x10(^{-6})</td>
</tr>
<tr>
<td>S(_y) (ft(^{-1}))</td>
<td>Tertiary deep aquifer</td>
<td>1x10(^{-6}) - 3x10(^{-4})</td>
<td>3x10(^{-5})</td>
<td>5x10(^{-6})</td>
</tr>
<tr>
<td>R (in/season)</td>
<td>Sprinkler</td>
<td>0 - 8</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>R (in/season)</td>
<td>Flood</td>
<td>13 - 21</td>
<td>20</td>
<td>18</td>
</tr>
<tr>
<td>R (in/season)</td>
<td>Unirrigated - Riparian and dry pastures</td>
<td></td>
<td></td>
<td>0</td>
</tr>
</tbody>
</table>

Note: T=transmissivity, S\(_x\)=specific yield, S\(_x\)=specific storage, R=recharge; \(^1\) transmissivity values are from Table 5, specific yield and specific storage values are from Table 11, and recharge values are from Table 15 in this thesis.
Augmenting Quantity Methods with Water Quality Data
(Time permitting, toward end of workshop.)

- Topic is not Augmentation in the sense used in recent committee hearings
- Chloride Mass Balance
- Nitrate Data
- Specific Electrical Conductance
  - (Note some of this will be discussed during the main meeting by Mark Schaffer)
- Temperature
  - Constanz and collaborators
- There are many others, but there is no time
Acknowledgements

• Students
  – Jim Hay
  – Martha Kauffman
  – Mark Schaffer
  – Joe Scyphers
• Irrigation Slides from Natural Resources Conservation Service
• Aquatech
stop
Chloride Mass Balance

- Chloride is non-reactive
- Chloride is concentrated by evapotranspiration
- Dettinger (1989) suggests that the part of the precipitation that recharges the ground water can be estimated.

\[
R_{GW} = P \left( \frac{C_P}{C_R} \right) + S \left( \frac{C_S}{C_R} \right) - Q \left( \frac{C_Q}{C_R} \right)
\]

\(C\) = Chloride concentration; \(S\) = Surface Water; 
\(P\) = Precipitation; \(Q\) = Average runoff; \(R\) = Recharge
\[ P = 8,340 \pm 1,700 \text{ ac. ft.} \]
\[ C_p = 0.08 \text{ mg/l} \]
\[ S = 6,730 \pm 340 \text{ ac. ft.} \]
\[ C_s = 1.1 \text{ mg/l} \]
\[ Q = 832 \pm 43 \text{ ac. ft.} \]
\[ C_Q = 1.1 \text{ mg/l} \]
\[ C_R = 2.3 \text{ mg/l} \]

\[ R = 3,000 \pm 1,700 \text{ ac. ft.} \]
Cottonwood Creek, West of Bridgers

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P$</td>
<td>8,340 ± 1,700 ac. ft.</td>
<td>20%</td>
</tr>
<tr>
<td>$I_{sw}$</td>
<td>6,730 ± 340 ac. ft.</td>
<td>5%</td>
</tr>
<tr>
<td>$ET$</td>
<td>7,720 ± 3,100 ac. ft.</td>
<td>40%</td>
</tr>
<tr>
<td>$O_{gw}$</td>
<td>1,300 ± 1,300 ac. ft.</td>
<td>100%</td>
</tr>
<tr>
<td>$O_{sw}$</td>
<td>832 ± 43 ac. ft.</td>
<td>5%</td>
</tr>
<tr>
<td>$U_{IRR}$</td>
<td>48 ± 24 ac. ft.</td>
<td>50%</td>
</tr>
<tr>
<td>$ET_D$</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>$R_{gw}$</td>
<td>5,100 ± 3,800 ac. ft.</td>
<td>75%</td>
</tr>
</tbody>
</table>

Hay, 1997

**Figure 17.** Actual physical water-budget quantities. No scale implied.
Compare Recharge

- Physical Mass Balance 5100 ac ft +/- 3800
  - Error 75%
- Chloride Mass Balance 3000 ac ft +/- 1700
  - Error 57%
Modeling Results: Indicator Kriging for Possible Contamination

Probability Nitrate-N > 3 mg/l
Estimate of ground-water recharge from different irrigation types Flint Creek using Gallatin Valley Data

Kauffman (1999) assumed 24 inches of water applied for a center pivot with Q=1000 gpm; 12 weeks, 5 days/week, 24 h/d, 130 acres; 20% loss to evaporation before ET begins.

Flood irrigation estimated based on an application of 12,500 ac-ft or approximately 54 inches, evaporative and leakage losses in ditches of 40%.
Estimate of ground-water recharge from different irrigation types for Flint Creek Basin

Table 12. Net irrigation recharge based on consumptive use for Climatic Zone 5

<table>
<thead>
<tr>
<th>Recharge Parameter</th>
<th>Sprinkler</th>
<th>Flood</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Grass</td>
<td>Alfalfa</td>
</tr>
<tr>
<td>Net irrigation (in/season)(^1)</td>
<td>19</td>
<td>19</td>
</tr>
<tr>
<td>Effective precipitation (in/season)(^2)</td>
<td>5.11</td>
<td>3.74</td>
</tr>
<tr>
<td>Net recharge (in/season)</td>
<td>8.28</td>
<td>8.41</td>
</tr>
</tbody>
</table>

Note: (1) derived earlier in thesis, (2) from Montana Irrigation Guide for Climatic Zone 5 in a normal year

Table 14. Net irrigation recharge based on consumptive use from sites similar to the Flint Creek valley (Belgrade, Montana)

<table>
<thead>
<tr>
<th>Recharge Parameter</th>
<th>Sprinkler</th>
<th>Flood</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Grass</td>
<td>Alfalfa</td>
</tr>
<tr>
<td>Net irrigation (in/season)(^1)</td>
<td>19</td>
<td>19</td>
</tr>
<tr>
<td>Effective precipitation (in/season)(^2)</td>
<td>5.11</td>
<td>3.74</td>
</tr>
<tr>
<td>Average consumptive use (in/season)(^3)</td>
<td>-20.87</td>
<td>-22.71</td>
</tr>
<tr>
<td>Net recharge (in/season)</td>
<td>3.24</td>
<td>0.03</td>
</tr>
</tbody>
</table>

Note: (1) derived earlier in thesis, (2) from Montana Irrigation Guide, Climatic Zone 5 in a normal year, (3) from Table 13 above
Topics to Be Covered

• Introduction to evaluating Irrigation Impacts
• Field Methods for Quantifying Irrigation Return Flow in Basins
• Augmenting Quantity Methods with Water Quality Data (Later if time)
Stop II
Topics to Be Covered

• Introduction
• Methods of Measurement (Peter Robinson)
• Error (Steve Custer)
• Example of System Assessment -- Flint Creek (Kirk Warren)
  – Measurement
  – Modeling
• Canal Loss – The Value of Wells and Impacts (Salinity District; Scott Brown)
• Example of Responses (Steve Custer)
Kirk Warren will address Flint Creek Study
Pete Robinson Will Talk About Measurement
Scott Brown will discuss salinity and ditch loss
What you do depends on your question.

• What is your question?
  – (Audience Response=?)

• -------

• What are some questions my students and I have been interested in?
  – Closed Basins
    • What are the effects of irrigation on stream flow?
    • What are the effects of irrigation on ground-water flow?
    • What are the effects of ground-water and irrigation withdrawal on water rights and stream flow
    • What is the role of irrigation return flow on stream flow?
    • What happens when irrigation ceases due to development?
Difference between two independent basin estimates

- Precipitation (7% = 31,000 ac ft)
- Main Gallatin (5% = 29,000 ac ft)
- Tributaries (20% = 36,000 ac ft)
- Evapotranspiration (17% = 190,000 ac ft)