# Effect of Changes in Crop Mix Upon Consumptive Use of Irrigation Water in the Eastern Snake Plain of Idaho

Prepared by Idaho Water Resources Research Institute
In fulfillment of Task 12
of Contract # CON00762

TECHNICAL ASSISTANCE FOR EASTERN SNAKE PLAIN AQUIFER
COMPREHENSIVE AQUIFER MANAGEMENT PLAN STUDIES

for
The Idaho Water Resource Board
and
The Idaho Department of Water Resources

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## EXECUTIVE SUMMARY

The Idaho Water Resource Board is concerned about potential changes in water use that may have occurred due to changes in crop mix. One option for benefiting the aquifer water budget is to consider policy options that would affect crop mix.

Data indicate that the effect of cropping changes since 1980 has been an increase in consumptive use of about 120,000 acre feet per year. A hypothetical change in crop mix that could be achieved by an incentive program was tested. The potential benefit to the aquifer could be as much as 350,000 acre feet per year.

## INTRODUCTION

The Idaho Water Resource Board is preparing a Comprehensive Aquifer Management Plan for the Eastern Snake Plain Aquifer. As part of the data-gathering process for preparation of the plan, the Board and its advisory group have requested an evaluation of changes in crop mix. This is because crop mix may have a significant impact upon the total consumptive use of irrigation water in the Eastern Snake Plain. Water that is consumptively used from ground-water irrigation is permanently extracted from the aquifer. Water that is consumptively used from surface-water irrigation is permanently removed from availability for incidental recharge to the aquifer and return to rivers.

Anecdotal evidence suggests that over the past one or two decades, there has been an increase in acreage of alfalfa hay and silage corn, relative to other crops. Since these are high-evapotranspiration (ET) crops, it is possible that an increase in consumptive use in irrigation water has impacted the aquifer by increasing net extraction and decreasing incidental recharge.

To evaluate this possibility, Idaho Water Resources Research Institute (IWRRI) under contract with Idaho Department of Water Resources (IDWR) has calculated the mix of irrigated agricultural crops in the Eastern Snake Plain Aquifer area from 1980 through 2006. To avoid confounding the results with differences in weather patterns and crop acreage, the crop mix for each of these years has been applied to a single map of irrigated lands and a single evapotranspiration data set. An evaluation has also been made of the potential to reduce consumptive use from the aquifer by providing incentives to change cropping patterns.

## DATA SOURCES

Evapotranspiration data came from the US Bureau of Reclamation/USDA Agricultural Resource Service/USDA Natural Resource Conservation Service AGRIMET program (US Bureau of Reclamation 2008). Crop ET data for year 2006 were obtained for the stations illustrated in Figure 1.

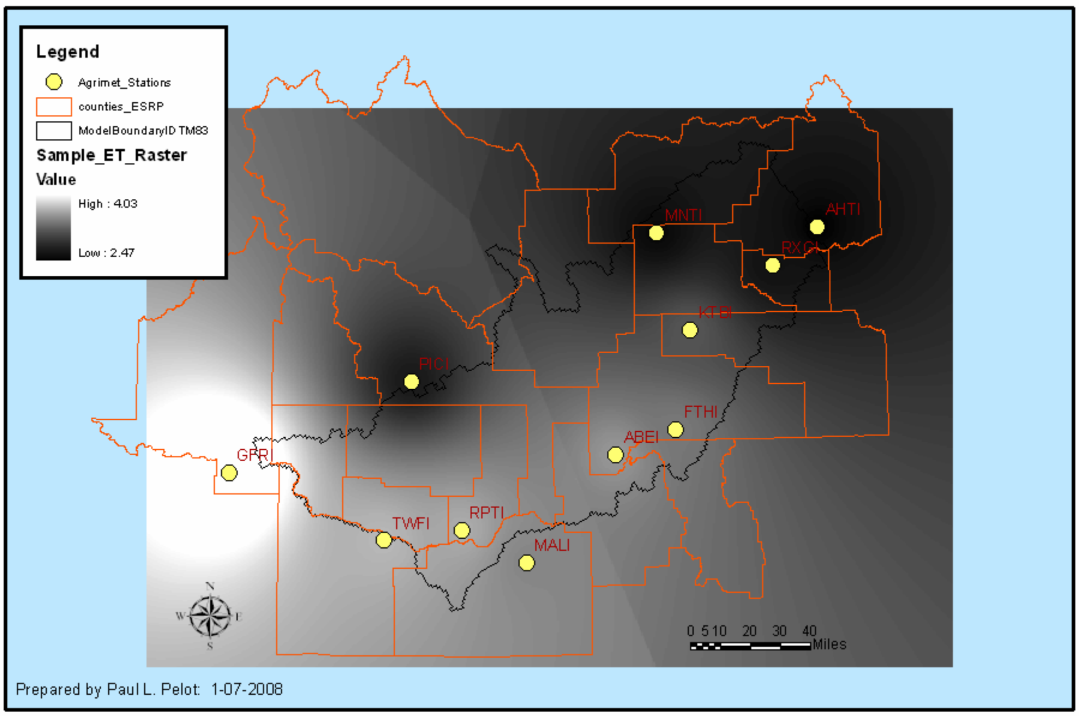


Figure 1. AGRIMET weather stations and sample crop ET raster.

Crop data for 1980 through 2001 were obtained from the Eastern Snake Plain Aquifer Model data files (IWRRI 2007) described in the report <u>Determination of Crop Mix, Revision One</u> (Contor 2003). Data for 2002 through 2006 were obtained from the <u>Idaho Agricultural Statistics</u> series (USDA National Agricultural

Statistics Service and Idaho State Department of Agriculture 2003-2007). Earlier years in this series were heavily relied upon in the Aquifer Model data files.

## METHODS

### Historical Changes in Crop Mix

AGRIMET data provide a daily evapotranspiration (ET) depth for each important crop in the area of each individual AGRIMET weather station. Data for 2006 were summed into an annual total depth of ET, with missing crops for some stations supplied from the nearest station which had the particular crop reported. Using Geographical Information Systems (GIS) processing, the average annual ET depth for each crop was calculated for each county.

The crop acreage data were converted to a percentage for each crop, for each county. In some cases, the USDA reports do not report an individual crop by county, to avoid identifying individual producers. In those cases, the county acreage for this project was estimated based upon prior years' data. Potato data for 2006 are not yet available, so 2005 data were used as estimates for 2006.

Using GIS, the irrigated acreage for each county based on year-2000 LANDSAT data from Eastern Snake Plain modeling data (Contor 2002) was also calculated.

The equivalent ET volume that would have occurred, had the individual crop mixes from 1980 through 2006 occurred on the year-2000 irrigated lands with 2006 ET, was calculated for each county. For each crop and county, the volume was calculated using:

ET Volume (acre feet) =
(county irrigated acres) x (ET depth in feet) x (crop percentage)

For each county, the county volume was the sum of all crop volumes, and for the plain as a whole, the total volume was the sum of all the counties.

For counties that partly overlie the Aquifer, only the acreage above the aquifer was considered. For Elmore and Custer Counties, which have only small acreage overlying the aquifer, the crop mix from an adjacent county (Gooding County or Butte County) was used.

### Potential Induced Changes in Crop Mix

A possible action that could be taken to benefit the aquifer would be to induce a change in crop mix from higher-consumptive to lower-consumptive crops. Another potential action would be to induce temporary fallowing of lands in lieu of growing the lowest-value crop in a crop rotation. For many years in Idaho, growers contracted to reduce small-grains acreage in exchange for USDA marketing support and commodity programs. While this often resulted in planting higher-consumptive crops such as alfalfa, it is an illustration of the willingness of growers to adjust planting mix in response to carefully-crafted programs and policies. It also illustrates that the administrative mechanisms and procedures to enroll and verify changes in cropping have already been invented, tested and refined.

To test the potential effect of inducing changes in crop mix, the 2006 crop mix was modified in the following ways:

1. 10% of alfalfa acreage was converted to barley.
2. 10% of silage corn acreage was converted to barley.
3. A reduction of barley acreage, equivalent to 50% of the potato acreage, was applied. The reasoning behind this reduction was that barley is often grown in rotation with potatoes primarily for agronomic, rather than economic, reasons. Fallow is equally beneficial in a crop rotation, and the economic return of barley (at least with historically-normal small-grains prices) is often low enough that inducements to fallow might feasible.

For this study, the ET of the hypothetical crop mix was compared with the 2006 crop mix, to assess the potential impact of adjusting crop-mix ratios as a management option.

## RESULTS

### Historical Changes in Crop Mix

Figures 2 through 4 show the equivalent consumptive use in acre feet for each county, if the historical crop mix for each year had been experienced with the year-2000 irrigated acreage and the year-2006 AGRIMET ET.

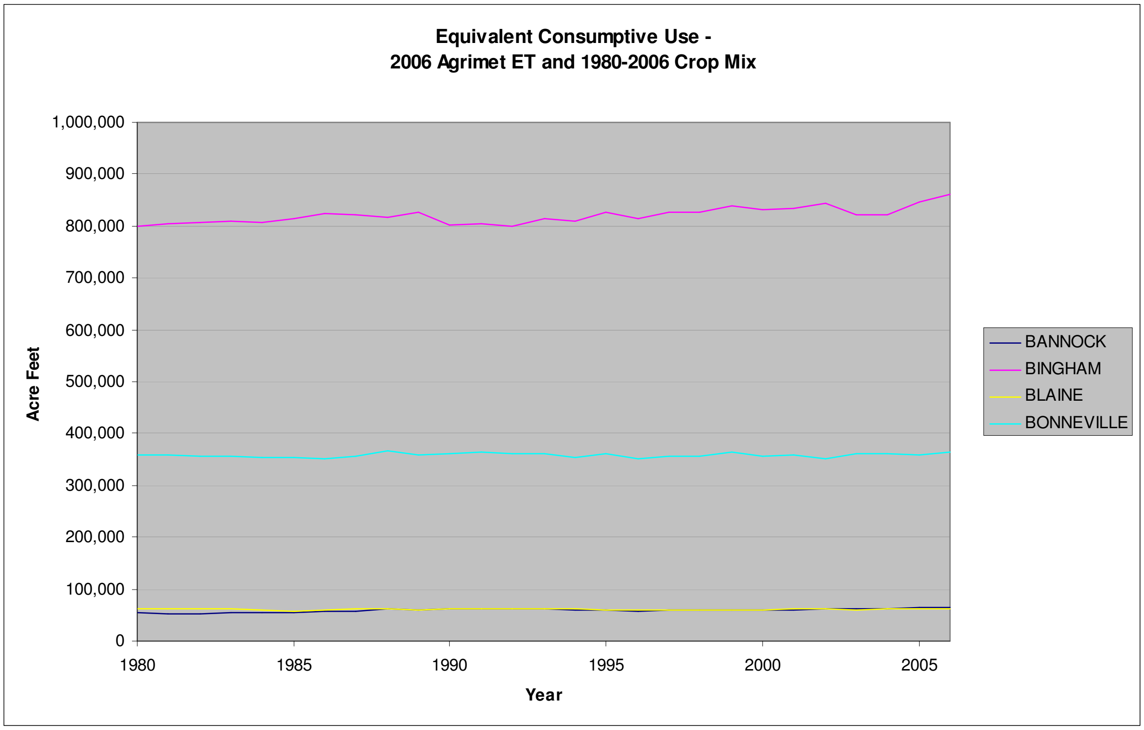


Figure 2

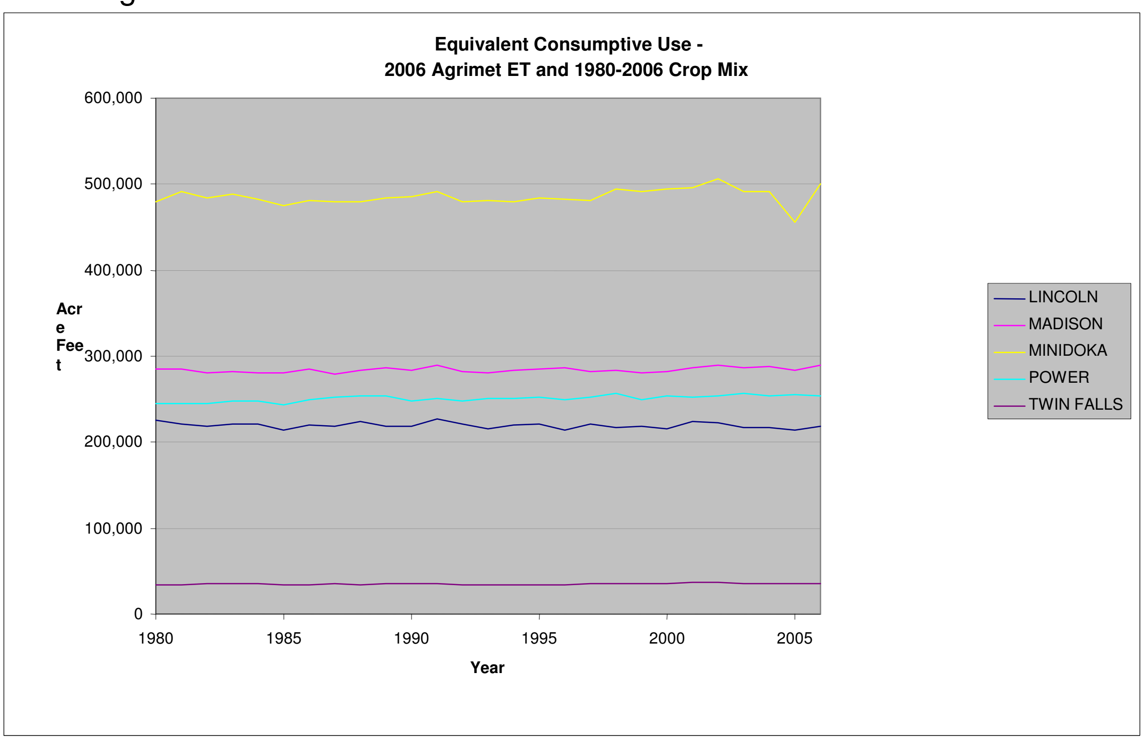


Figure 3

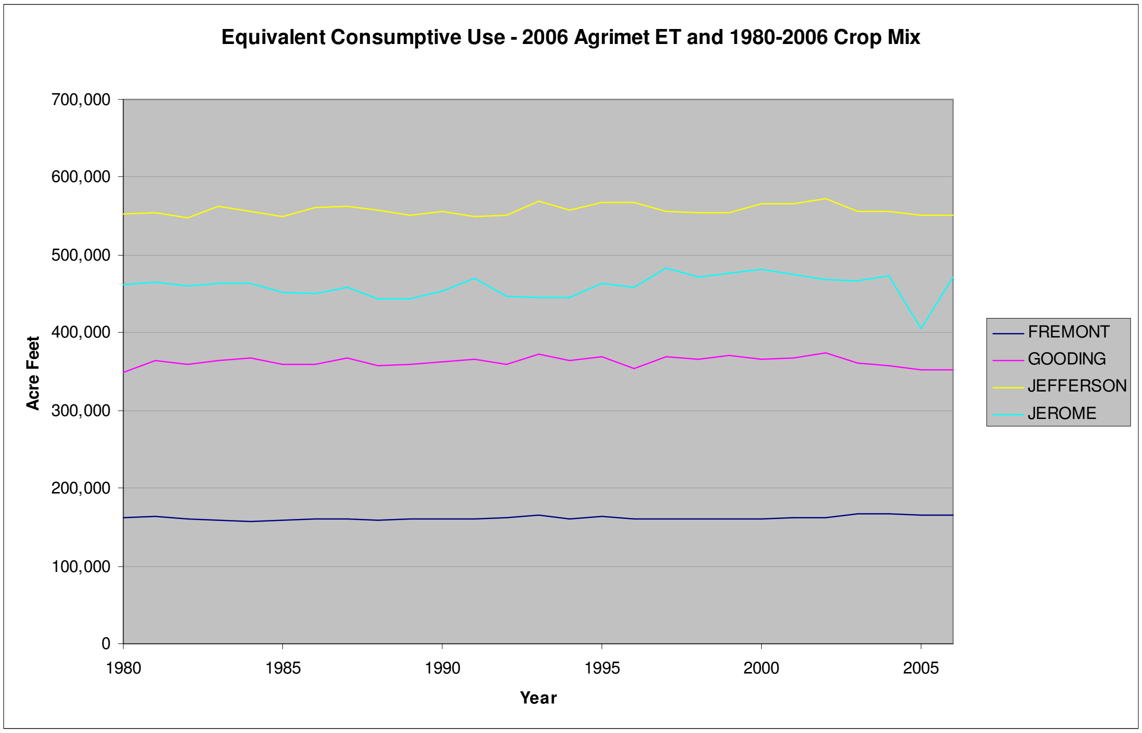


Figure 4

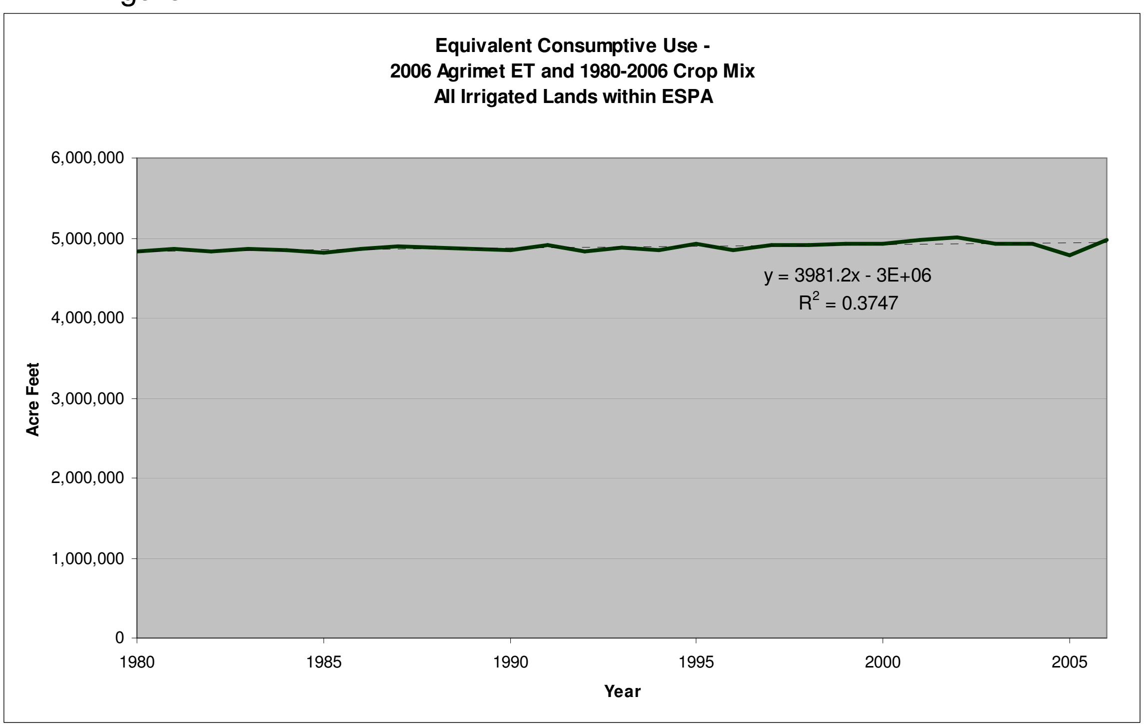


Figure 5

Figures 6 through 10 illustrate the same data on a percentage basis.

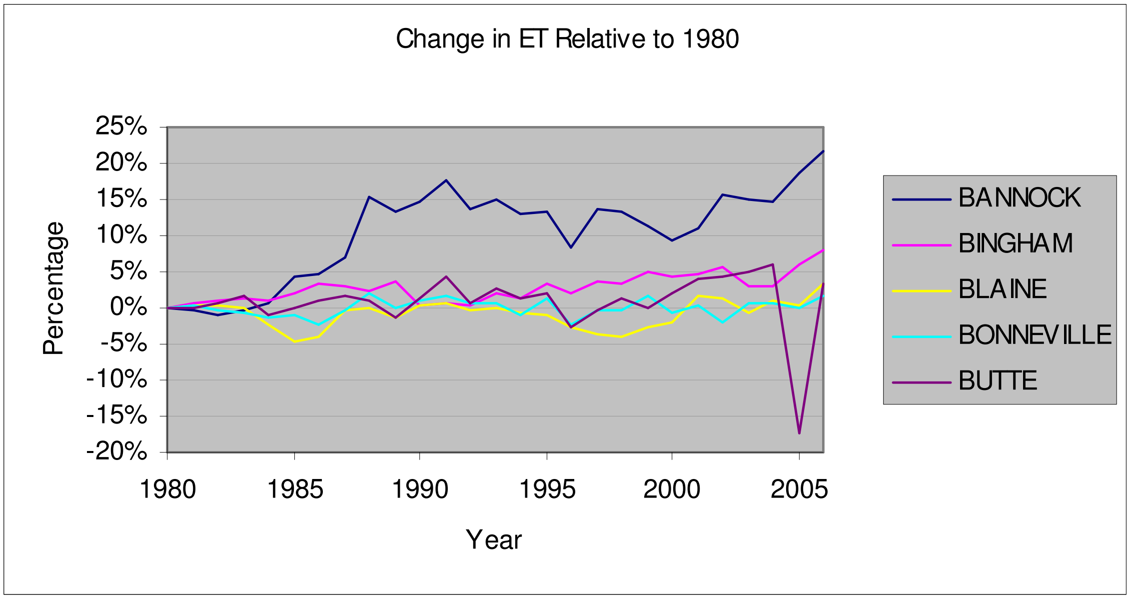


Figure 6

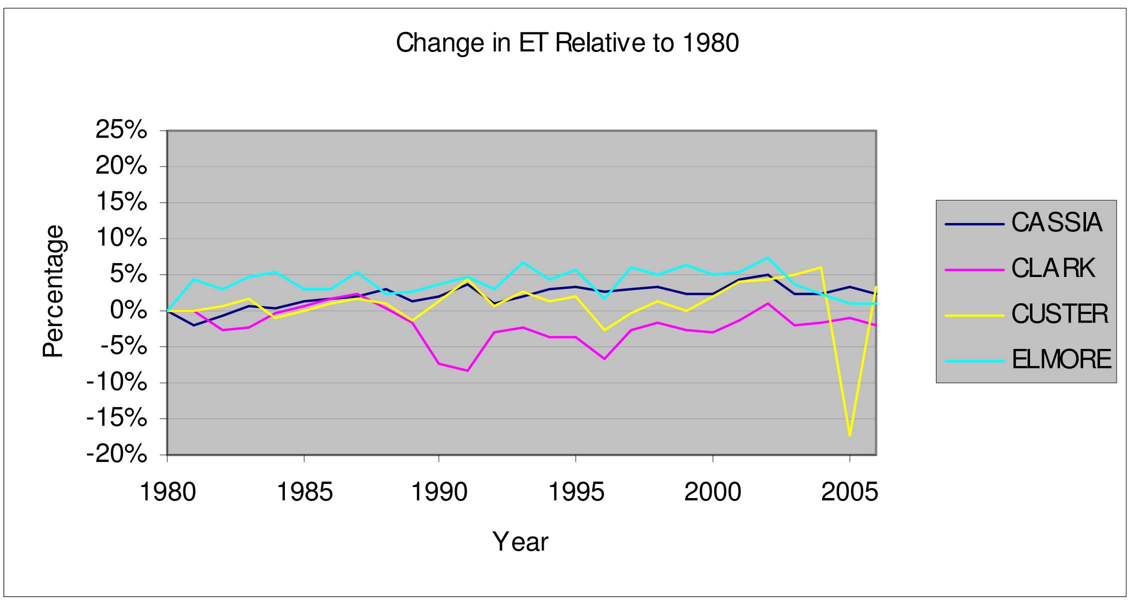


Figure 7

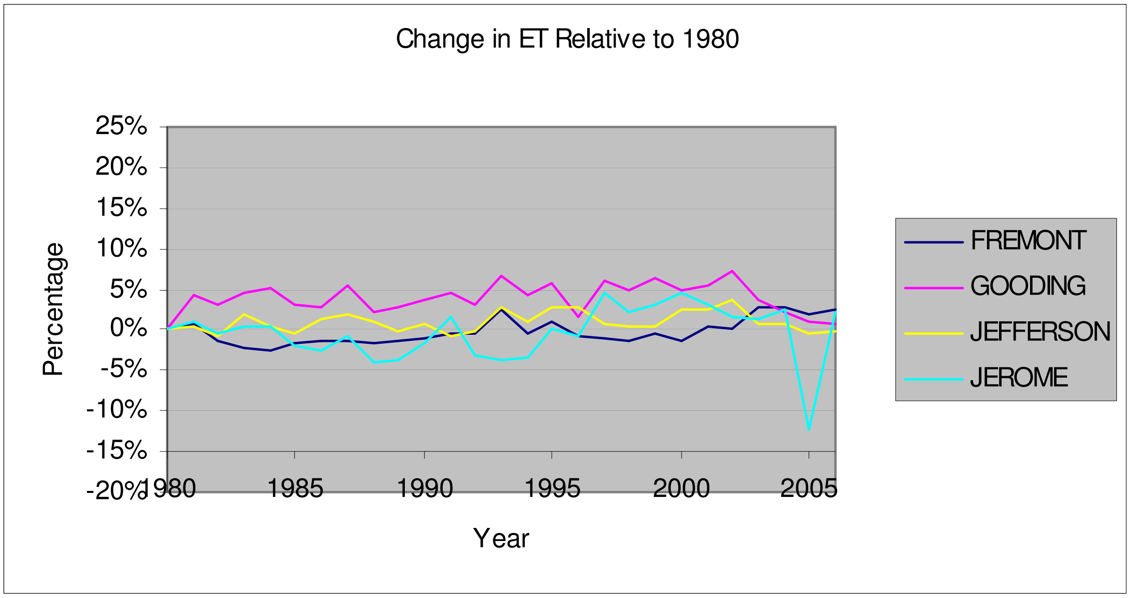


Figure 8

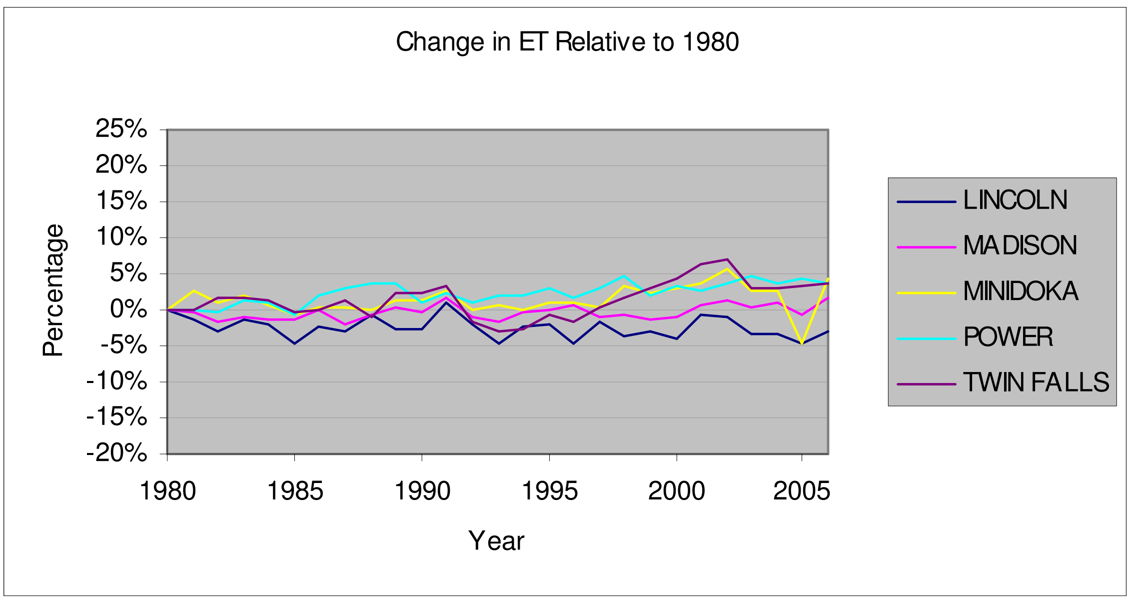


Figure 9

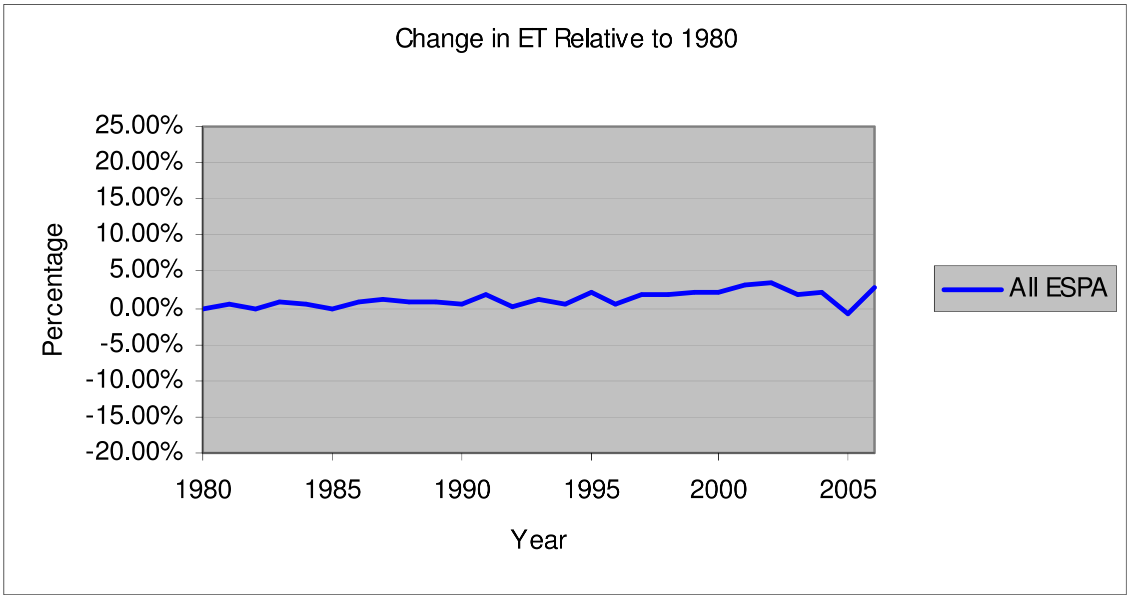


Figure 10

Table 1 shows the departure from the 1980 crop mix for each county, for the last five years of the test period.

Table 1
Departure in Evapotranspiration from
1980 Crop Mix. Acre Feet per Year for
Irrigated Lands Lying Over the Eastern Snake Plain Aquifer.
Year-2000 Acreage and Year-2006 ET Values Used with Each Crop Mix

| **COUNTY** | **2002** | **2003** | **2004** | **2005** | **2006** |
|---|---|---|---|---|---|
| BANNOCK | 8,424 | 8,004 | 7,913 | 9,881 | 11,537 |
| BINGHAM | 46,566 | 23,607 | 23,607 | 48,104 | 63,597 |
| BLAINE | 864 | -422 | 592 | 191 | 2,114 |
| BONNEVILLE | -7,279 | 2,192 | 2,192 | -69 | 5,586 |
| BUTTE | 6,932 | 7,888 | 9,254 | -26,860 | 5,384 |
| CASSIA | 21,620 | 9,947 | 9,947 | 15,051 | 10,627 |
| CLARK | 1,071 | -2,614 | -2,142 | -1,294 | -2,289 |
| CUSTER | 1,599 | 1,820 | 2,135 | -6,196 | 1,242 |
| ELMORE | 958 | 469 | 303 | 145 | 113 |
| FREMONT | 115 | 4,754 | 4,754 | 2,986 | 4,146 |
| GOODING | 25,188 | 12,347 | 7,969 | 3,808 | 2,961 |
| JEFFERSON | 19,578 | 3,875 | 3,875 | -1,785 | -791 |
| JEROME | 7,300 | 5,873 | 11,870 | -56,295 | 9,888 |
| LINCOLN | -2,265 | -7,751 | -7,751 | -10,878 | -6,426 |
| MADISON | 3,894 | 1,113 | 3,316 | -2,050 | 4,925 |

| COUNTY | 2002 | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|
| MINIDOKA | 27,003 | 12,409 | 12,409 | -22,954 | 21,275 |
| POWER | 8,911 | 11,653 | 9,078 | 10,782 | 8,902 |
| TWIN FALLS | 2,485 | 1,005 | 1,005 | 1,175 | 1,323 |
| | | | | | |
| Total | 172,963 | 96,166 | 100,325 | -36,258 | 144,115 |

The trend line in Figure 4 is statistically significant[1], though the $r^2$ value (indicative of predictive power) is low. Several of the counties show a sharp dip in consumptive use for the year 2005. There are three possible explanations:

1. Expectations of reduced water availability affected planting decisions.
2. There is a problem in the underlying data.
3. Adjustments by IWRRI for missing data introduced an error.

The statistical tests were repeated for the 1980-2004 crop-mix representations, in case the dip in 2005 represents a data problem rather than a real phenomenon. The analyses generally agreed, as shown in Table A1 in the appendix. Using the regressions to remove random effects in the beginning or ending years, it appears that the change in crop mix over the period increased consumptive use by about 0.04% to 0.14% per year. Though this is a small percentage, over the 27 year period it amounts to an increase of about 120,000 acre feet per year in consumptive use.

Hypothetical Induced Change in Crop Mix

Table 2 shows the potential reduction in ET associated with the hypothetical crop mix based on an assumption of fallowing some rotation acres and replacing some high-ET crops with low-ET crops. About 300,000 acre feet of this benefit is from the fallowing of barley acres and approximately 50,000 acre feet is due to substituting barley for alfalfa and silage.

[1] The data were tested using the Durbin-Watson test statistic (Ott 1993) and autocorrelation was not found to be a problem. This is important on time series data because it is possible to declare a relationship to be statistically significant when in fact it is not, if autocorrelation is severe enough to violate the assumptions of the regression equations (VanKirk 2007).

Table 2
Reduction in ET from Replacing
10% of Alfalfa Acres with Barley, 10% of Silage Corn Acres with Barley,
and Fallowing Barley Acres Equal to 50% of Potato Acres.
Acre Feet per Year. Only irrigated lands overlying the ESPA are considered.

| County | 2006 Crop Mix | Hypothetical Crop Mix | Reduction |
|---|---|---|---|
| BANNOCK | 64,896 | 61,145 | 3,751 |
| BINGHAM | 861,915 | 786,088 | 75,826 |
| BLAINE | 63,081 | 60,874 | 2,207 |
| BONNEVILLE | 363,810 | 332,204 | 31,607 |
| BUTTE | 160,491 | 156,466 | 4,025 |
| CASSIA | 447,138 | 416,632 | 30,506 |
| CLARK | 119,359 | 111,983 | 7,376 |
| CUSTER | 37,024 | 36,096 | 929 |
| ELMORE | 13,375 | 12,726 | 649 |
| FREMONT | 166,210 | 149,466 | 16,744 |
| GOODING | 351,783 | 334,720 | 17,063 |
| JEFFERSON | 551,635 | 523,017 | 28,618 |
| JEROME | 471,340 | 450,773 | 20,568 |
| LINCOLN | 218,726 | 213,056 | 5,670 |
| MADISON | 290,125 | 250,910 | 39,215 |
| MINIDOKA | 500,359 | 469,401 | 30,958 |
| POWER | 254,185 | 217,699 | 36,486 |
| TWIN FALLS | 36,116 | 34,773 | 1,343 |
| BANNOCK | 64,896 | 61,145 | 3,751 |
| | | | |
| TOTAL | 4,971,568 | 4,618,030 | 353,538 |

If the 10% dip in consumptive use shown in some counties for 2005 represents an actual change (rather than a data error), it is another indication of the potential to affect consumptive use by adjusting crop mix. A ten-percent reduction in annual crop consumptive use is approximately 490,000 acre feet per year potential benefit to the aquifer.

**CONCLUSIONS**

On an individual county basis, changes range from negligible to an increase in consumptive use of over 20 percent. The aggregate effect across the entire plain has been an increase of 2% to 2.5% in annual consumptive use over the 27-year period. Though this is a small percentage, it amounts to about 120,000 acre feet per year.

As a policy option for benefiting the aquifer, a modest adjustment in current crop mix could reduce consumptive use by approximately 350,000 acre feet per year across the plain. Reductions that occur on ground-water irrigated acres will without doubt produce a benefit to the aquifer. If full diversions of surface water are maintained in conjunction with reductions on surface-water irrigated acres, these reductions will also benefit the aquifer.

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**APPENDIX**

Table A1
Comparison of Trend Analyses of
Trend in ET Response to Crop Mix

| Statistic | 1980-2006 | 1980-2004 |
|---|---|---|
| Slope (lower 95% Confidence Interval), acre feet per year | 1,863 | 3,394 |
| Slope (estimated), acre feet per year | 3,981 | 5,067 |
| Slope (upper 95% Confidence Interval), acre feet per year | 6,100 | 6,741 |
| Slope range in percent of annual diversion volume (upper and lower 95%) | 0.04% - 0.12% | 0.07% - 0.14% |
| P-value[2] | 0.0007 | $2 \times 10^{-6}$ |
| r-squared | 0.37 | 0.63 |
| Durbin-Watson Statistic[3] | 2.22 | 2.20 |
| Average 27-year difference[4] | 2.1% | 2.5% |

[2] The P-value is the probability that the observed relationship could have occurred randomly.

[3] Durbin-Watson statistics between 1.5 and 2.5 generally indicate that autocorrelation is low enough to not jeopardize the drawing of conclusions from linear-regression statistics (Ott 1993).

[4] This is the percentage difference between the 1980-crop mix value and the 2006 crop-mix value *of the regression line.* Using the regression line smooths year-to-year variation and gives a total-change indication that is not influenced by variations in end-year values.