COMPARISON OF EASTERN SNAKE PLAIN AQUIFER MODEL VERSION 2.0 WITH VERSION 1.1 VIA THE CURTAILMENT SCENARIO

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INTRODUCTION

The *Hydrologic Effects of Curtailment of Groundwater Pumping* (also known as the Curtailment Scenario) was performed using the Eastern Snake Plain Aquifer Model Version 1.1 (ESPAM1.1) in 2006 (Contor, et al, 2006). This exercise was recently performed again using the Eastern Snake Plain Aquifer Model Version 2.0 (ESPAM2.0). This report presents the results of the ESPAM2.0 Curtailment Scenario, compares the results from ESPAM2.0 to the results from ESPAM1.1, discusses the differences, and provides a summary of what can be interpreted from the comparison.

Overview of ESPAM1.1 Curtailment Scenario

The ESPAM1.1 Curtailment Scenario (Contor, et al, 2006) modeled the effects on spring discharge and Snake River gains and losses resulting from curtailment of all groundwater rights within the ESPAM1.1 model boundary that were junior to five selected priority dates. Three analyses were performed for each priority date.

1. Prediction of response to continuous curtailment at steady state.
2. Prediction of transient response to continuous curtailment for 150 years using the annual average stress.
3. Prediction of transient response to continuous curtailment for 10 years using the seasonal average stress.

The curtailment scenario was modeled using a numerical superposition version of ESPAM1.1. Average annual precipitation from 1961-1990 and average annual evapotranspiration from 1980-2001 were used to calculate applied stress for the steady state analyses and transient analyses of long-term curtailment. The average annual precipitation and evapotranspiration were applied to the irrigated season for the seasonal transient analyses.

For the superposition version of ESPAM1.1, all drain cells were converted to river cells. Twenty-nine river cells were removed from the superposition model, because they were perched at baseline conditions. Initial river stage elevations were set to zero. River bottom elevations were set to -700 feet. All starting heads were set to an elevation of zero.

The ESPAM2.0 Curtailment Scenario was modeled using a similar approach to facilitate comparison of results with the ESPAM1.1 Curtailment Scenario.

METHODS

Numerical Superposition Model

A numerical superposition version of ESPAM2.0 was created by modifying the ESPAM2.0 final calibration (IDWR, draft) files as follows.

1. Drain cells were converted to river cells.
2. River cells were evaluated based on modeled conditions using the average water budget from November 1998 through October 2008 to identify perched river cells. Twenty-two perched river cells were removed from the superposition river file.
3. Starting heads, river stage, and general head boundary stage elevations were set to zero.
4. River bottom elevations were set to -700 feet.

Comparison of results from the numerical superposition model version with results from a fully populated model version was performed by the Idaho Department of Water Resources (IDWR) and is documented in a separate report (Sukow, 2012).

Simulation of Curtailment with ESPAM2.0

Curtailment was simulated by injecting water in each model cell containing lands irrigated with junior priority groundwater rights. The volume of water injected in each model cell was calculated using the Curtailment IAR Tool in ESPAM2 Recharge Tools V1.4. Water right priority dates and point of diversion data used to calculate the fraction of junior priority groundwater irrigated lands were from the 2012 point of diversion (POD) file, which was based on data retrieved from the IDWR water rights database on January 20, 2012.

The most recent irrigated lands data set from year 2008 was used to delineate irrigated areas. Average groundwater fractions were applied to the 2008 irrigated lands data set to delineate areas irrigated by groundwater. The average groundwater fractions were equal to the fractions used for calibration of ESPAM2.0, except where groundwater irrigation was represented as surface water irrigation to allow modeling of canal seepage in areas served by offsite wells, and where groundwater fractions had been intentionally inflated during calibration to avoid potential calculation of deficit irrigation on mixed source lands (Contor, 2010).

Where groundwater irrigation from an offsite source had been modeled as surface water irrigation during calibration (Figure 1), the groundwater fractions were modified to represent groundwater irrigation. This adjustment increases the modeled average groundwater irrigated area by approximately 50,000 acres in the Mud Lake and Monteview irrigation entities.

Where groundwater fractions were intentionally inflated for calibration (Figure 1), the groundwater fractions were replaced with average groundwater fractions based on average surface water availability between 1980 and 2008. This adjustment decreases the modeled average groundwater irrigated acres by approximately 49,000 acres in fifteen irrigation entities.

The two adjustments result in only a small change in the total number of surface water and groundwater irrigated acres within the model domain, but are necessary to correct the spatial distribution of groundwater irrigated lands for curtailment scenarios. The adjustments applied to groundwater fractions are shown in Figure 2. The average groundwater fraction raster used in the curtailment scenarios is shown in Figure 3.

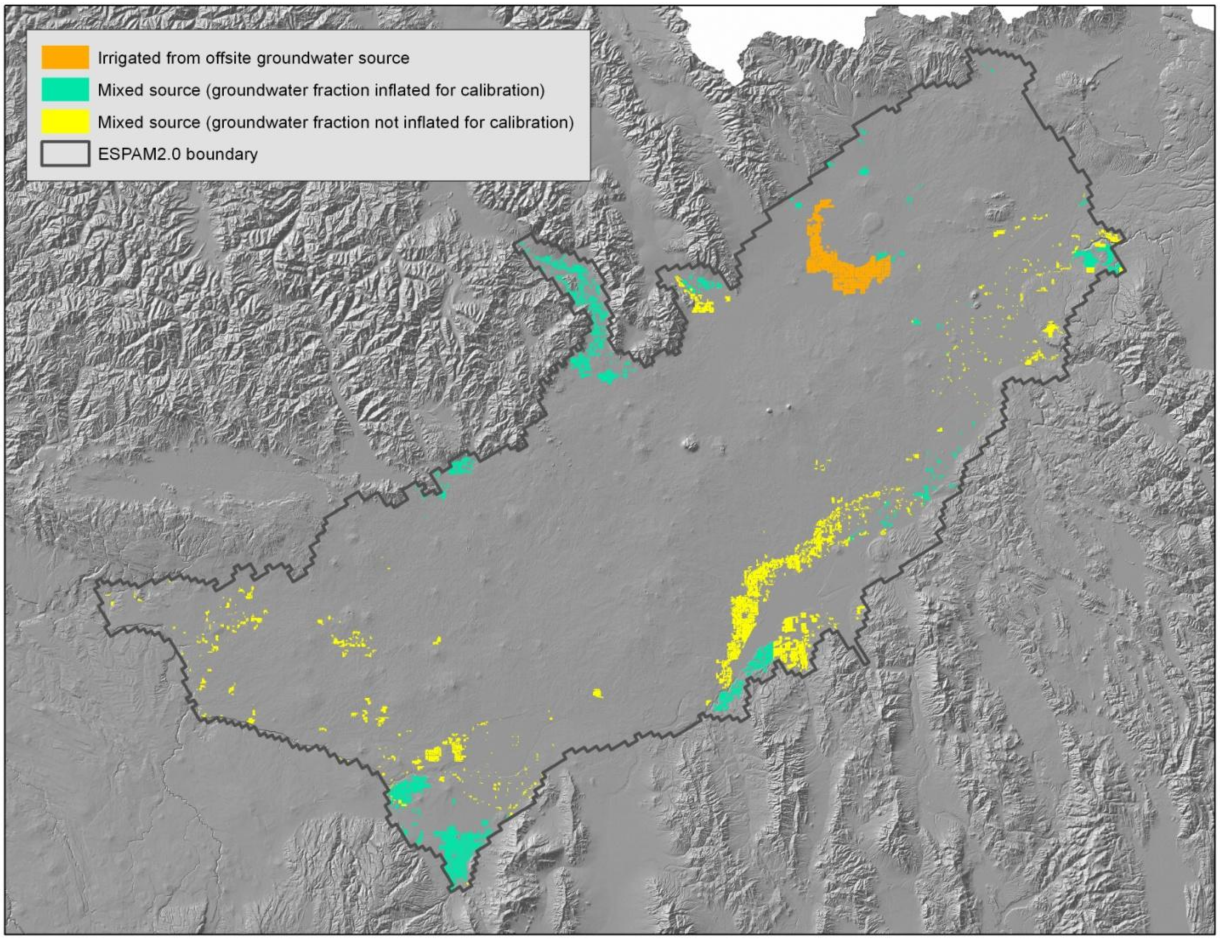

Figure 1. Mixed source irrigated lands and areas irrigated from offsite groundwater sources.

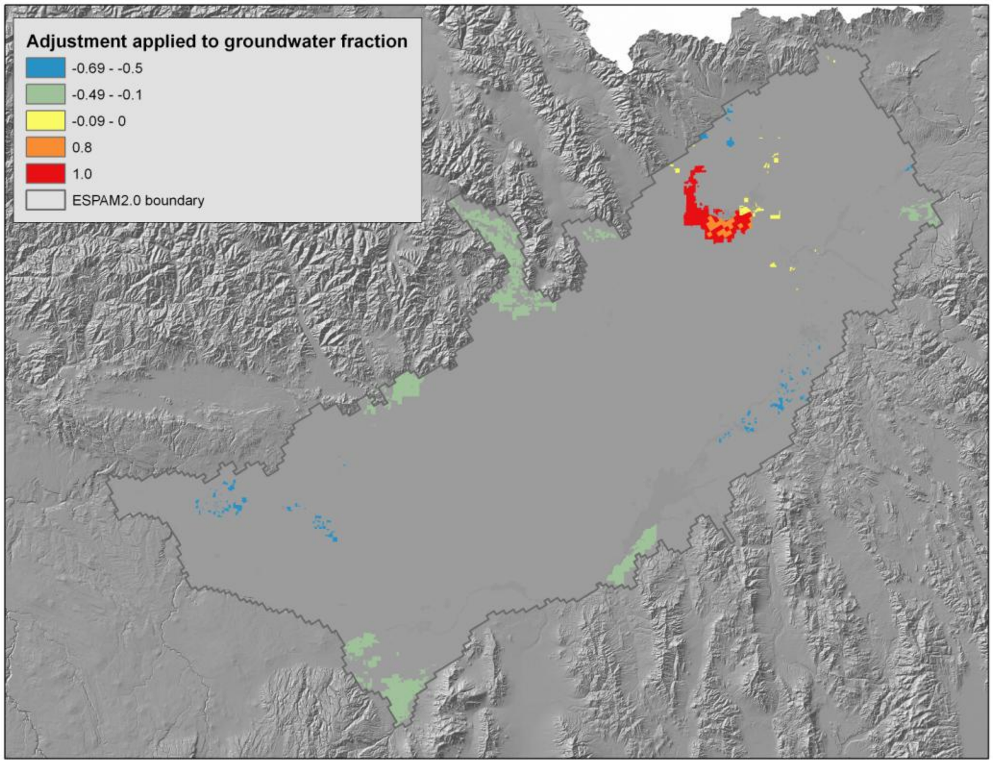

Figure 2. Adjustments applied to groundwater fractions for curtailment scenarios.

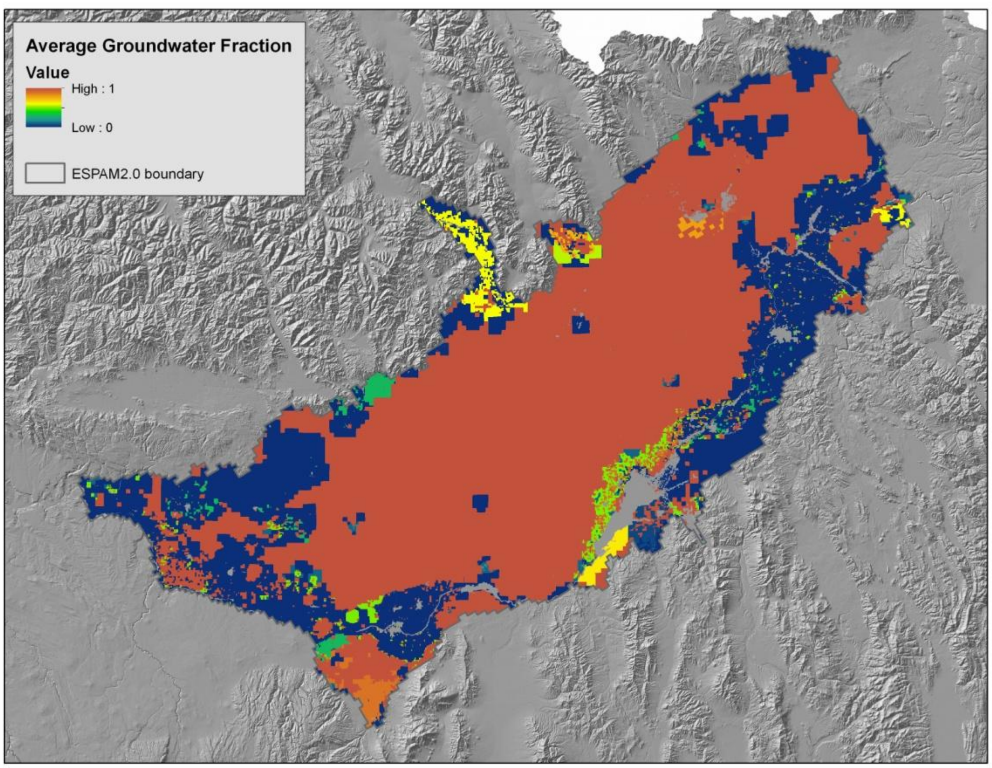

Figure 3. Average groundwater fraction raster.

Average evapotranspiration and precipitation from the last 10 years of the model calibration period (November 1998 through October 2008) were used to calculate the crop irrigation requirement for groundwater irrigated lands. Calibrated evapotranspiration adjustment factors from ESPAM2.0 were applied by groundwater entity.

Curtailment of groundwater irrigation throughout the ESPAM2.0 model domain was simulated for water rights junior or subordinate to five priority dates. Subordinate water rights include enlargement water rights, which despite having a priority date based on the date of enlargement, are subordinate to all water rights senior to April 12, 1994.

1. January 1, 1870
2. January 1, 1949
3. January 1, 1961
4. January 1, 1973
5. January 1, 1985

Three simulations were run for each curtailment date.

1. Steady state prediction of response.
2. Long term transient prediction of response for 150 years of curtailment, assuming continuous stress based on average annual consumptive use.
3. Short term seasonal transient prediction of response for 10 years, assuming monthly stress based on average monthly consumptive use.

The results of these analyses illustrate differences in predictions based on differences in representations of irrigated lands, evapotranspiration, precipitation, and water rights data, in addition to differences resulting from model structure and calibrated model parameters (aquifer transmissivity and storativity, riverbed and drain conductance). In order to evaluate differences resulting only from model structure and model parameters, the steady state simulations were also run using stress files from the ESPAM1.1 curtailment scenarios, which were downloaded from http://www.if.uidaho.edu/~johnson/ifiwrri/projects.html#model.

RESULTS AND DISCUSSION

Steady State Simulations

Results for three types of steady state simulations are presented for each curtailment date (Appendix B).

1. Response to ESPAM2.0 stress file modeled using ESPAM2.0. This is the response calculated using the most recent available irrigated lands and water rights data, and

average crop irrigation requirement from the last 10 years of the ESPAM2.0 calibration period.
2. Response to ESPAM1.1 stress file modeled using ESPAM2.0. This is the response calculated using stress files from the Contor (2006) simulations. This simulation incorporates differences in model structure and model parameters, but excludes differences in irrigated lands and crop irrigation requirement data.
3. Response to ESPAM1.1 stress file modeled using ESPAM1.1. These are the results published by Contor (2006) and are presented for comparison with results from the ESPAM2.0 simulations.

Both ESPAM2.0 and ESPAM1.1 were calibrated to five river reaches upstream of Milner. Unlike ESPAM1.1, ESPAM2.0 was calibrated to 14 Group A or B spring targets, 36 Group C spring targets, and three spring reaches below Milner (Kimberly to Buhl, Buhl to Lower Salmon Falls, Lower Salmon Falls to King Hill). ESPAM1.1 was calibrated to six spring reaches (Cosgrove et al, 2006) that were not used in calibration of ESPAM2.0. For the purpose of comparing the steady state results with ESPAM1.1, predictions for individual springs from ESPAM2.0 were summed to approximate the six spring reaches used in ESPAM1.1 (Appendix B). Predictions from ESPAM1.1 were also summed for comparison with the three spring reaches used in ESPAM2.0.

ESPAM2.0 incorporates a number of improvements from ESPAM1.1, resulting in different simulation results. Differences in model results can be attributed to two general sources for the purposes of comparing ESPAM2.0 with ESPAM1.1.

1. Differences in model structure and model parameters. This includes differences in the model boundary, assignment of river cells and drains, and calibrated values of conductance and storativity.
2. Differences in model input data. This includes differences resulting from improved and more recent representations of irrigated lands, updates to the water right database, and use of updated evapotranspiration and precipitation data.

While the differences are grouped into two classes for comparison of model results, it should be noted that calibration of model parameters is influenced in part by the model input data used during calibration. Differences in model parameters and model input data are not independent.

Differences Attributed to Model Input Data

Results from the steady state simulations indicate that changes in model input data result in a 17% to 21% increase in curtailed consumptive use from ESPAM1.1, varying slightly with the priority date of the curtailment. This results partly from an increase in junior irrigated land area and partly from an increase in crop irrigation requirement. The junior irrigated land area calculated using ESPAM2.0 input data is 7% to 11% greater than calculated using ESPAM1.1 input data. Average consumptive use per curtailed acre calculated using ESPAM2.0 input data is 9% to 10% higher, ranging from 2.18 to 2.24 feet per year in ESPAM2.0 compared with 2.00 to 2.05 feet per year in ESPAM1.1.

Most of the increase in junior irrigated land area appears to result from improvements in geographic information system (GIS) methods used to delineate irrigated lands. The 2008 irrigated lands data set used in the ESPAM2.0 curtailment scenarios was developed using detailed GIS analysis methods to exclude non-irrigated areas, thereby reducing the uncertainty in determining irrigated land area. Irrigated lands data sets older than 2002 were developed using methods that resulted in significant non-irrigated inclusions, which were addressed by applying reduction factors (Contor, 2011). In ESPAM1.1, a reduction factor of 12% was applied to the GIS representation of year 2000 irrigated lands. During development of ESPAM2.0, this reduction factor for year 2000 was determined to be considerably lower at 5% (Contor, 2011), suggesting that the irrigated land area was underestimated in ESPAM1.1. Figure 4 compares the 2008 irrigated lands data set with the 1980 through 2006 data sets used for calibration of ESPAM2.0, and with the 2000 data set used in the ESPAM1.1 curtailment scenario.

Other factors that may contribute to differences in junior irrigated area include use of more recent irrigated lands data, more recent water rights data, and use of different methods for determining groundwater fraction (Contor, 2010).

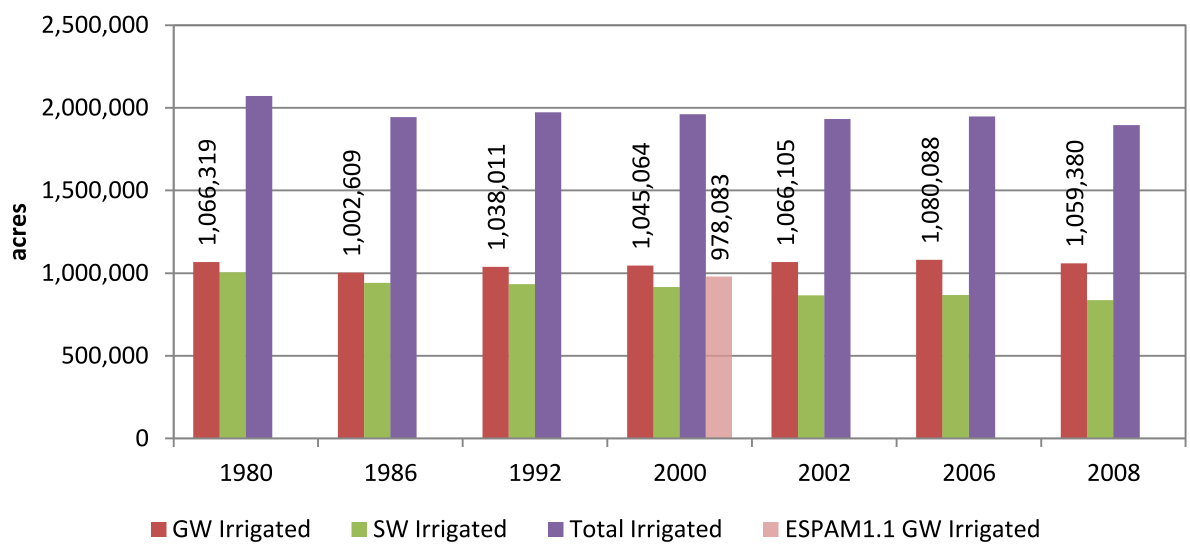

Figure 4. Comparison of 2008 irrigated lands data set with 1980-2006 data sets used for calibration of ESPAM2.0 and the 2000 data set from ESPAM1.1.

The increase in consumptive irrigation requirement results from a combination of changes in periods used to calculate average precipitation and evapotranspiration, evapotranspiration adjustment factors, and sprinkler fractions. In the ESPAM1.1 curtailment scenarios, the average annual precipitation from 1961-1990 and average annual evapotranspiration from 1980-2001 were used to calculate crop irrigation requirement. In the ESPAM2.0 scenarios, both averages were from November 1998 through October 2008.

Figure 5 shows annual precipitation in the Eastern Snake Plain and tributary basins from 1934 through 2008 (PRISM Climate Group). The 1961-1990 mean precipitation was higher than 1998-2008 mean used in the ESPAM2.0 curtailment scenarios. The 1998-2008 mean is closer to the long term average than the 1961-1990 mean.

Annual evapotranspiration on irrigated lands in ESPAM2.0 is shown in Figure 6. The 1998-2008 mean annual evapotranspiration used for the ESPAM2.0 curtailment scenario is similar to the 1980-2008 average. Both are slightly higher than the average annual evapotranspiration from the years 1980-2001, which was the period used for the ESPAM1.1 curtailment scenario.

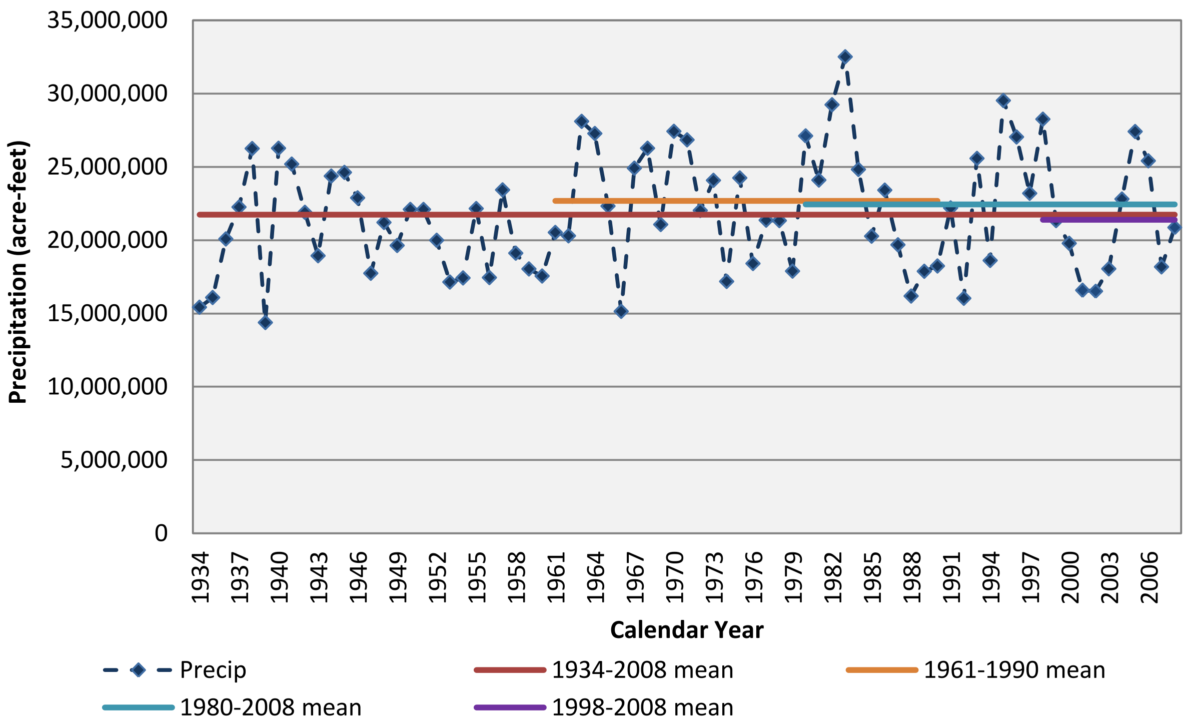

Figure 5. Annual precipitation on Eastern Snake Plain and tributary basins.

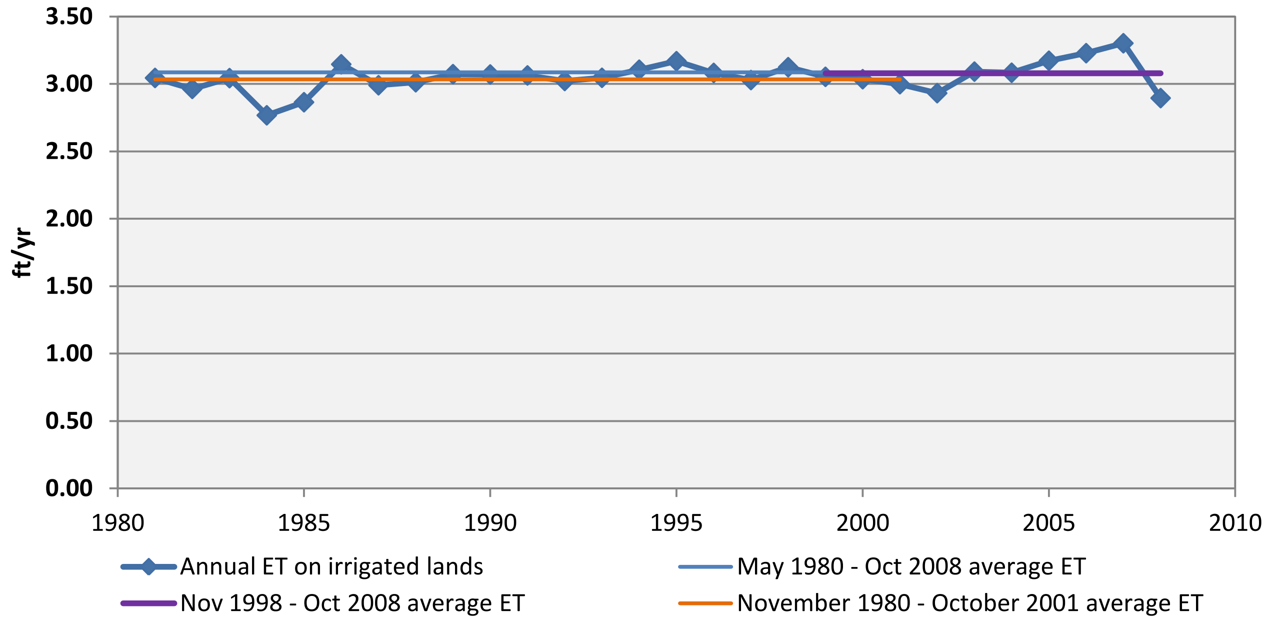

Figure 6. Annual evapotranspiration on irrigated lands within ESPAM2.0 boundary.

Differences Attributed to Model Structure and Parameters

Results from the steady state simulations run with the ESPAM1.1 stress files show changes in the relative responses of some reaches resulting from changes in model parameters and structure. Results are tabulated in Appendix B. Changes in calibrated model parameters result from a combination of changes in calibration targets, model boundary conditions, water budget input data, and other improvements implemented in ESPAM2.0.

Results from simulations with the ESPAM1.1 stress file (Appendix B) show the response at Ashton to Shelley is similar to ESPAM1.1, but the response at Ashton to Rexburg is lower in ESPAM2.0, while the response at Heise to Shelley is higher in ESPAM2.0. The response in the Shelley to Near Blackfoot reach is similar to ESPAM1.1, but the response in the near Blackfoot to Neeley reach is higher, while the response in the Neeley to Minidoka reach is lower.

Results from simulations with the ESPAM1.1 stress file (Appendix B) show substantial decreases (29% to 31%) in the collective response of springs in the Kimberly to Buhl (Devil's Washbowl to Buhl) reach, and substantial increases in the collective response of springs in the ESPAM1.1 Buhl to Thousand Springs and Thousand Springs to Malad (Billingsley Creek) reaches (52% to 66% and 484% to 540%, respectively). The collective response of springs downstream of Milner increased approximately 7%.

The ESPAM2.0 includes general head boundaries to represent baseflow (underflow) that discharges from the ESPA to the Snake River in the spring reaches without daylighting as surficial spring flow. The ESPAM1.1 conceptual model did not include this baseflow. The response to the curtailment scenarios at the general head boundaries is reported in Appendix B.

There are several differences between ESPAM2.0 and ESPAM1.1 that may contribute to the differences in the model predictions. In ESPAM2.0, calibration targets for springs below Milner were significantly different than in ESPAM1.1. ESPAM2.0 was calibrated to 14 Class A or B spring targets, 36 Class C spring targets, and three spring reaches below Milner (Kimberly to Buhl, Buhl to Lower Salmon Falls, Lower Salmon Falls to King Hill). ESPAM1.1 was calibrated to six spring reaches that were not used in calibration of ESPAM2.0. For the purpose of comparing the calibration targets, targets for individual springs from ESPAM2.0 were summed to approximate the six spring reaches used in ESPAM1.1 (Table 1).

In addition to changes in the magnitude of some spring targets, ESPAM2.0 represented spring elevations differently from ESPAM1.1 and had a greater number of transient calibration targets representing the seasonal fluctuation in spring targets (IDWR, draft). Improvements in spring calibration targets and in modeling seasonal fluctuation in spring discharge likely contributed to changes in model parameters and modeled responses. Differences in calibrated transmissivity between ESPAM2.0 and ESPAM1.1 are illustrated in Figure 7 through Figure 10.

ESPAM1.1 Spring Reach	ESPAM1.1 Discharge Target (cfs)	ESPAM1.1 Proportion of Milner to King Hill Discharge	Sum of Average ESPAM2.0 Discharge Targets (cfs)	ESPAM2.0 Proportion of Milner to King Hill Discharge
Devil's Washbowl to Buhl	1,002	0.18	840	0.14
Buhl to Thousand Springs	1,584	0.28	1,431	0.24
Thousand Springs	1,749	0.31	811	0.13
Thousand Springs to Malad (Billingsley Creek)	77	0.01	223	0.04
Malad	1,117	0.20	1,070	0.18
Malad to Bancroft	91	0.02	103	0.02
Baseflow, Kimberly to King Hill (ESPAM2.0 only)	--	--	1,537	0.26
Sum	5,620	1.00	6,015	1.00

Table 1. Comparison of calibration targets for springs below Milner.

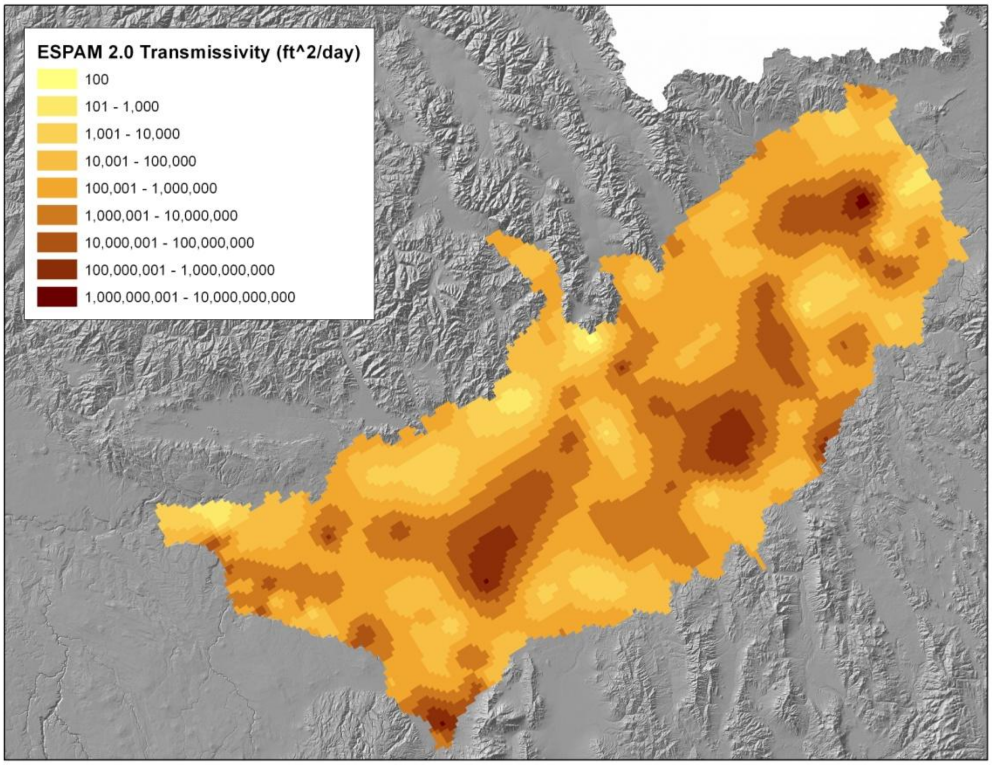

Figure 7. ESPAM2.0 calibrated aquifer transmissivity.

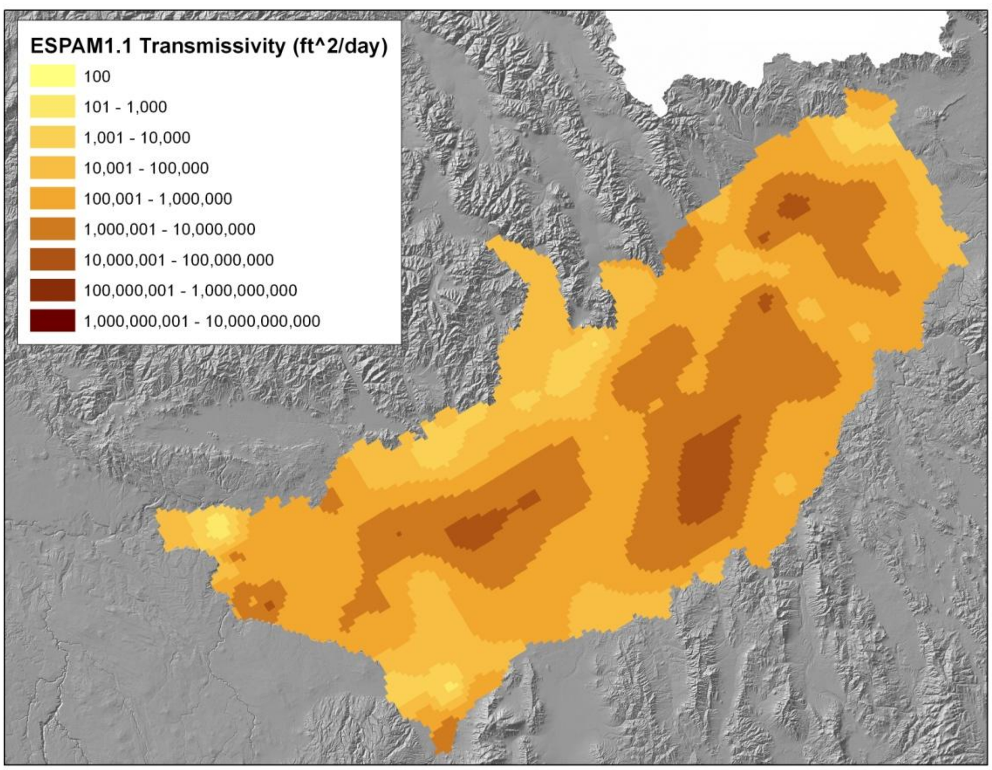

Figure 8. ESPAM1.1 calibrated aquifer transmissivity.

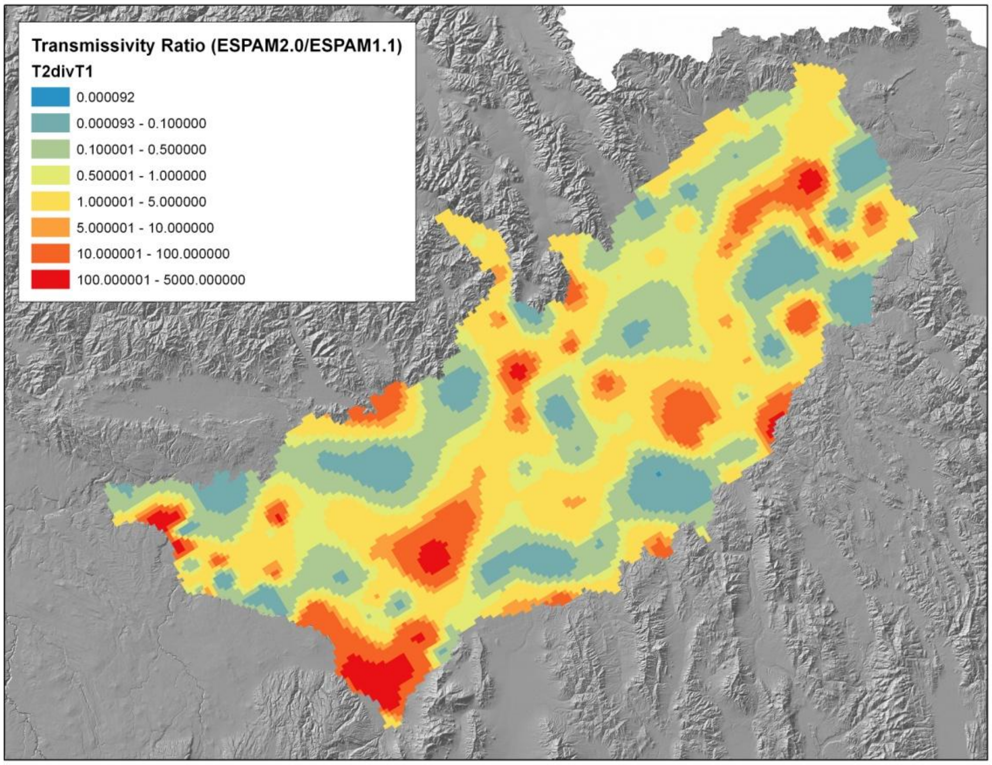

Figure 9. Ratio of ESPAM2.0 transmissivity to ESPAM1.1 transmissivity.

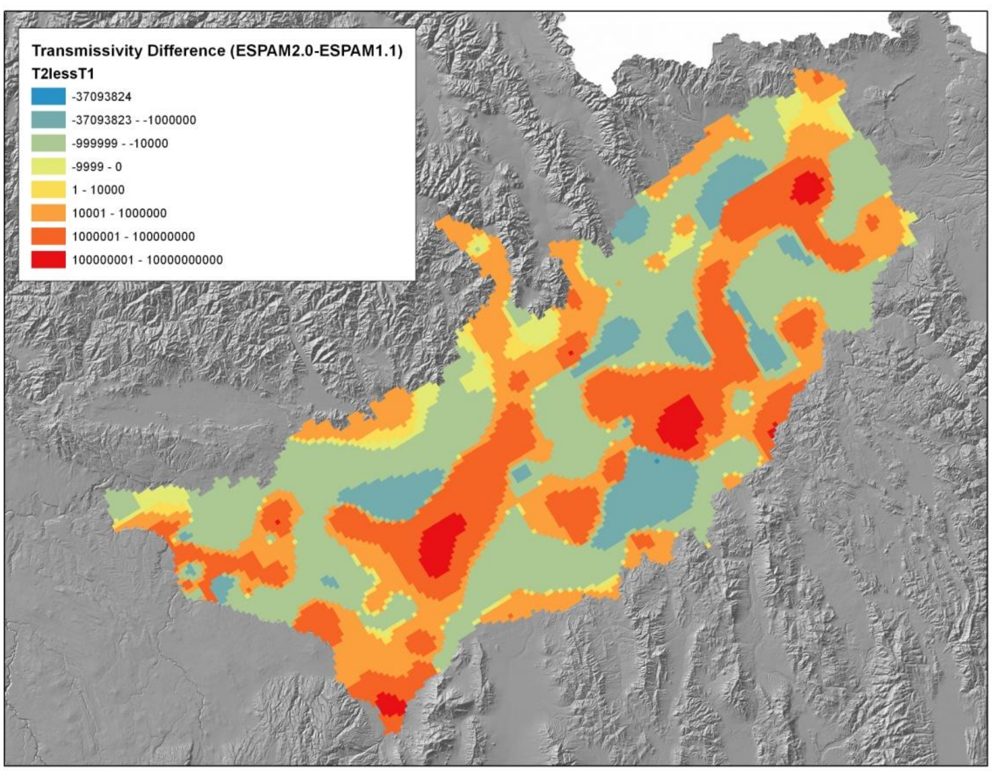

Figure 10. Difference between ESPAM2.0 and ESPAM1.1 transmissivity.

Long Term Transient Simulations

Results for three types of long term transient simulations are presented for each curtailment date.

1. Response to ESPAM2.0 stress file model using ESPAM2.0 (Appendix C). This is the response calculated using the most recent available irrigated lands and water rights data, and average crop irrigation requirement from the last 10 years of the ESPAM2.0 calibration period.
2. Response to ESPAM1.1 stress file modeled using ESPAM2.0 (Appendix D). This is the response calculated using stress files from the Contor (2006) simulations. This simulation incorporates differences in model structure and model parameters, but excludes differences in irrigated lands and crop irrigation requirement data.
3. Response to ESPAM1.1 stress file modeled using ESPAM1.1 (Appendices C and D). These are the results published by Contor (2006) and are presented for comparison with results from the ESPAM2.0 simulations.

Because the long term transient simulations were performed by applying a continuous stress at the average annual consumptive use rate, there is no seasonal variation in the results. The time to reach 90% of the steady state response is indicated on the graphs in Appendices C and D for both the ESPAM2.0 and ESPAM1.1 simulations.

In addition to the differences examined in the steady state simulations, the long term transient simulations indicate differences in the time required to reach 90% of the steady state response. In the ESPAM2.0 curtailment simulations, the time to reach 90% of steady state ranged from 18 to 26 years for river reaches upstream of Milner and from 10 to 14 years for springs aggregated by reach downstream of Milner. In the ESPAM1.1 curtailment scenarios, the time to reach 90% of steady state ranged from 17 to 36 years for river reaches upstream of Neeley, 55 to 65 years for the Neeley to Minidoka reach, and 34 to 61 years for springs aggregated by reach downstream of Milner. In ESPAM2.0, the time to reach 90% steady state is slightly longer at the Ashton to Rexburg and Heise to Shelley reaches and slightly shorter at the Shelley to near Blackfoot reach. The time required to reach 90% of steady state is significantly shorter at the near Blackfoot to Neeley and Neeley to Minidoka river reaches, and for the Kimberly to Buhl, Buhl to Lower Salmon Falls, and Lower Salmon Falls to King Hill springs.

Differences in the rate at which responses approach steady state result from differences in calibrated aquifer transmissivity and specific yield. Differences in calibrated transmissivity between ESPAM2.0 and ESPAM1.1 are illustrated in Figure 7 through Figure 10. Differences in calibrated specific yield between ESPAM2.0 and ESPAM1.1 are illustrated in Figure 11 through Figure 14. Improvements in spring calibration targets and in modeling seasonal fluctuation in spring discharge likely contributed to changes in model parameters and modeled transient responses at springs in the Kimberly to King Hill reaches. ESPAM2.0 represented spring elevations differently from ESPAM1.1, and had a greater number of transient calibration targets representing the seasonal fluctuation in spring targets (IDWR, draft).

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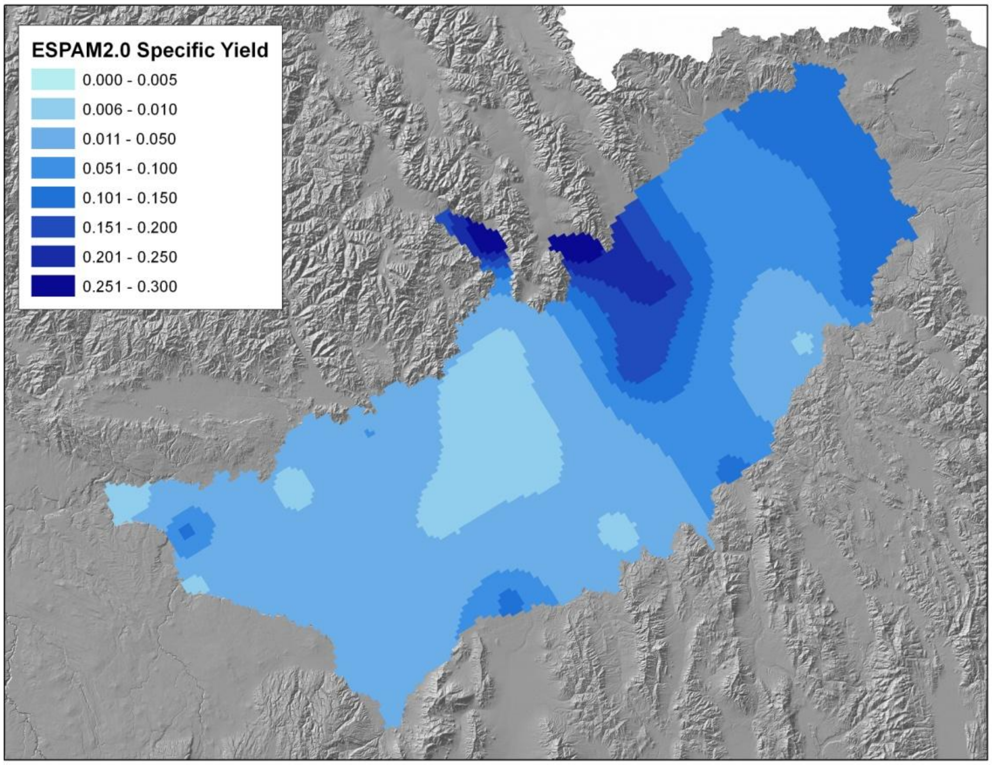

Figure 11. ESPAM2.0 calibrated specific yield.

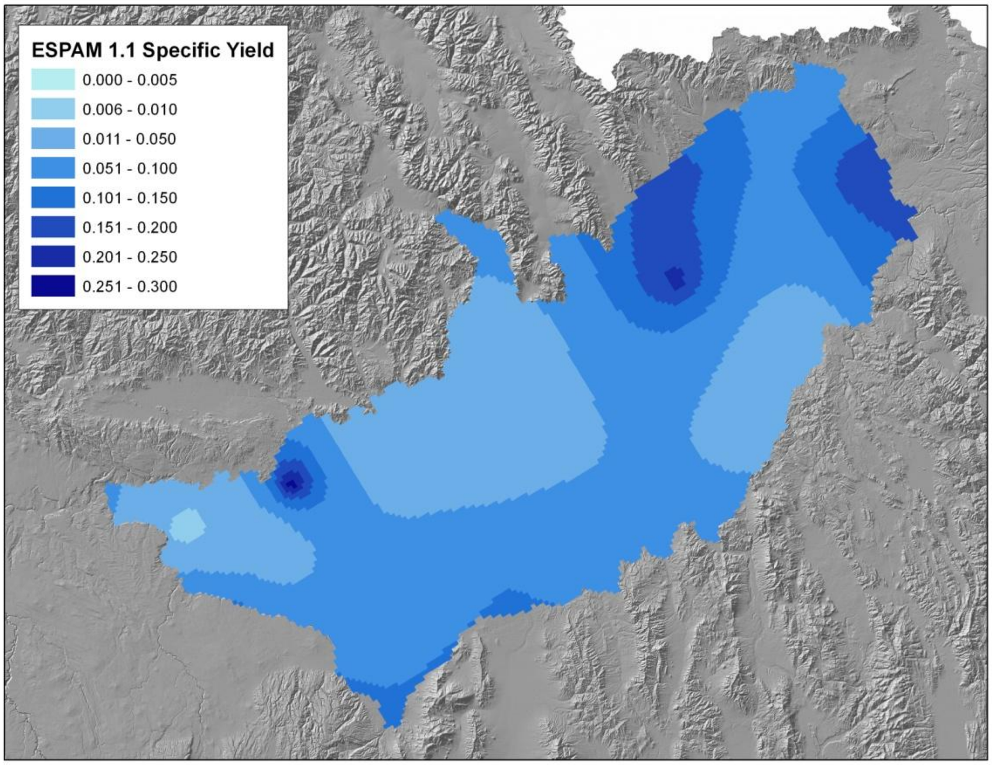

Figure 12. ESPAM1.1 calibrated specific yield.

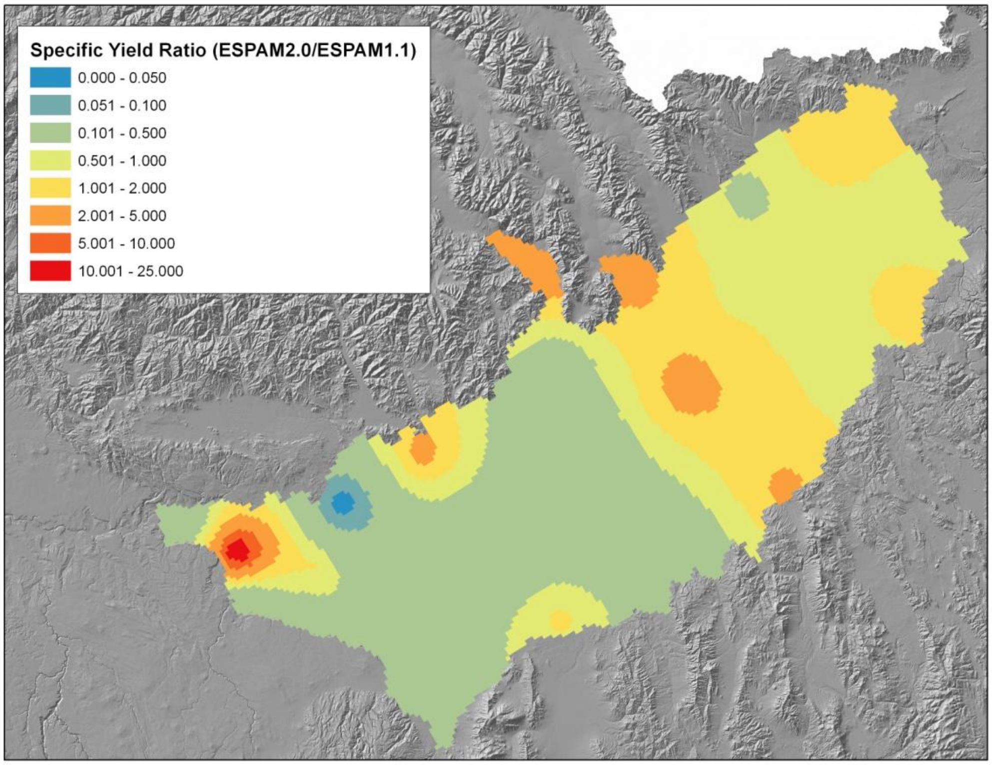

Figure 13. Ratio of ESPAM2.0 specific yield to ESPAM1.1 specific yield.

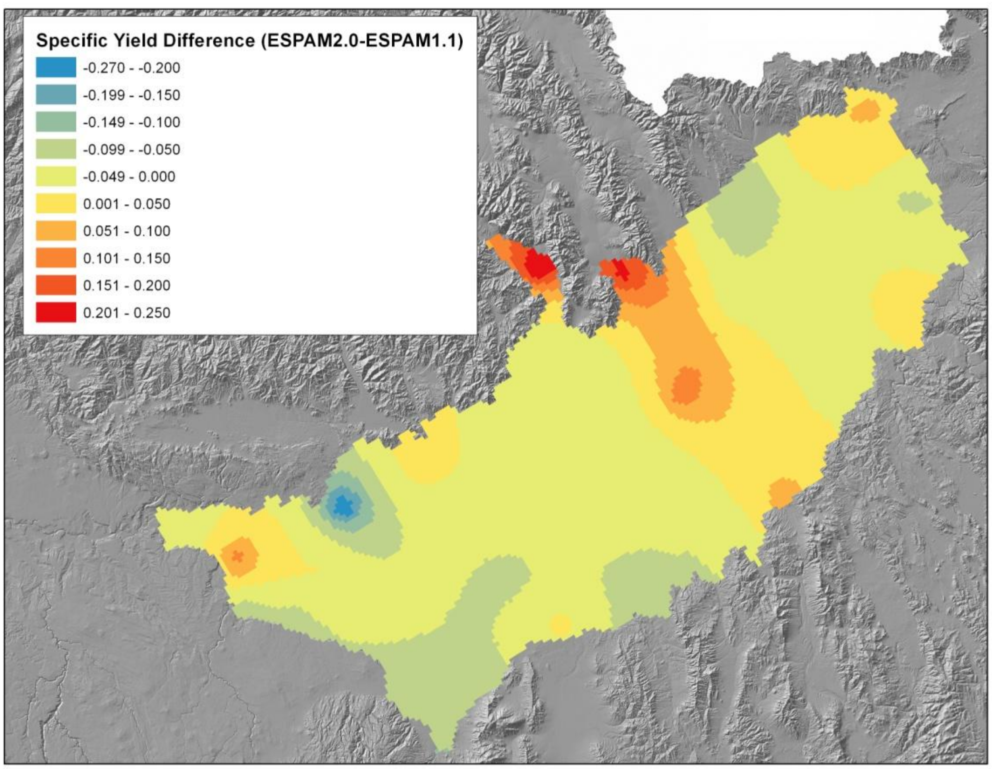

Figure 14. Difference between ESPAM2.0 specific yield and ESPAM1.1 specific yield.

Water Level Responses at Selected Locations

Aquifer head responses were evaluated at six locations for the long term transient simulation of curtailment of groundwater rights junior to January 1, 1870. The predicted response to the ESPAM2.0 stress file and the ESPAM1.1 stress file (modeled with ESPAM2.0) are presented with the responses predicted by the ESPAM1.1 simulations in Appendix E. The six locations were selected by Contor (2006) and are shown in Figure 15.

Water level responses predicted by the ESPAM2.0 simulation are greater than those predicted by the ESPAM1.1 simulation at all six locations. The increase results partly from the increase in applied stress and partly from changes in model parameters and structure, as discussed in previous sections of this report.

Water level responses to the ESPAM1.1 stress file are greater when modeled with ESPAM2.0 than with ESPAM1.1 at five of the six locations. The water level response at the point within A&B Irrigation District is slightly lower at the end of the 150 year simulation.

In the ESPAM2.0 simulations, the water level response approaches steady state more quickly at the points near American Falls, within A&B Irrigation District, near Craters of the Moon, and in the Thousand Springs area compared to the ESPAM1.1 simulation. At the points near Mud Lake and near Idaho Falls, the water level response approaches steady state at similar rates in the ESPAM2.0 and ESPAM1.1 simulations.

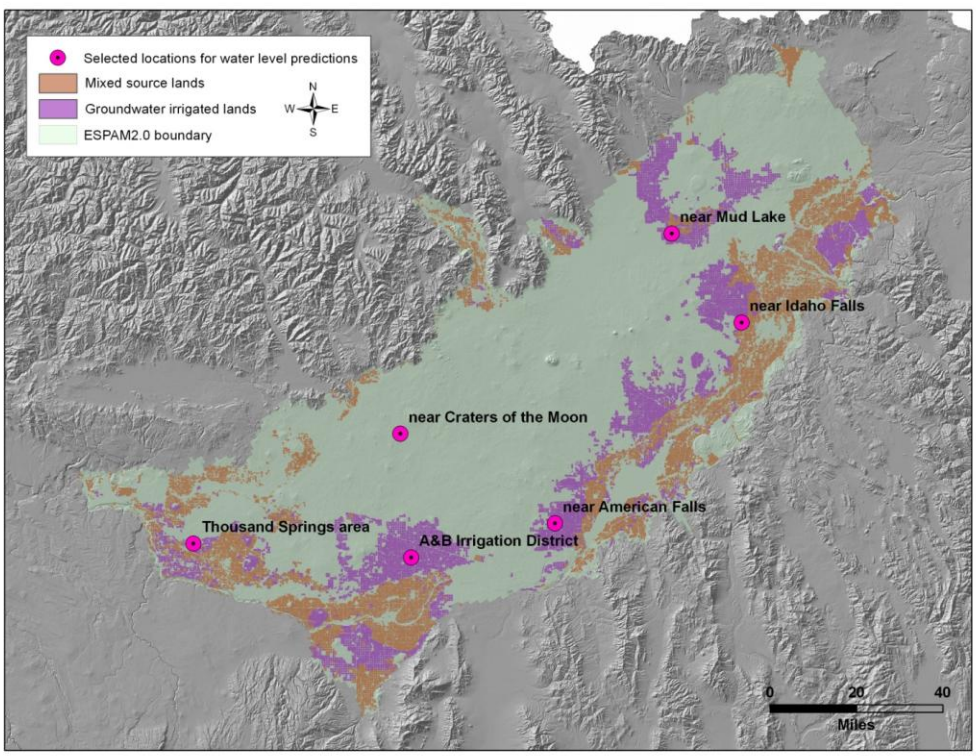

Figure 15. Selected locations for water level predictions.

Short Term Seasonal Transient Simulations

Results from ESPAM2.0 simulations of short term seasonal transient response to curtailment for 10 years are provided in Appendix F. These simulations model average monthly consumptive use and show seasonal variations in response. Results from the ESPAM1.1 seasonal curtailment simulations are shown in Appendix F for comparison. The ESPAM1.1 simulations modeled consumptive use averaged over a 6-month irrigation season beginning May 1.

In addition to the differences in the magnitude and timing of responses examined in the steady state and long term transient simulations, the short term seasonal transient results show differences in the shape of the seasonal response patterns. This results from the use of monthly crop irrigation requirement data in ESPAM2.0, as opposed to averaging the consumptive use over a 6-month period in ESPAM1.1.

In the ESPAM1.1 simulations, the seasonal response to curtailment was lowest at the end of April, prior to the beginning of the irrigation season, and peaked in November following the end of the 6-month irrigation season. In the ESPAM2.0 simulations, the seasonal response to curtailment was lowest at the beginning of the irrigation season (April to early May), and peaked in September for most reaches, following the peak consumptive use months of June through August. The peak response occurred in November for the Ashton to Rexburg reach.

SUMMARY AND CONCLUSIONS

Comparison of the results of the ESPAM2.0 and ESPAM1.1 steady state curtailment simulations (Appendix B) shows a 17% to 21% increase in the magnitude of the curtailed consumptive use for a given priority date. The increase in curtailed consumptive use appears to be the result of improvements in analytical methods used to determine irrigated land area and the use of updated data on evapotranspiration, precipitation, and water rights.

Comparison of the steady state simulations also shows changes in the relative responses of some spring and river reaches. These relative changes in response are the result of changes in calibrated model parameters (aquifer transmissivity and storativity, riverbed and drain conductance) and model structure. Changes in model parameters result from a combination of changes in calibration targets, model boundary conditions, water budget input data, and other improvements implemented in ESPAM2.0.

Transient ESPAM2.0 simulation results (Appendix C) indicate that the time required to reach 90% of steady state ranges from 18 to 26 years for river reaches upstream of Milner and from 10 to 14 years for springs aggregated by reach downstream of Milner. Comparison with results from ESPAM1.1 simulations indicates that the time required to reach 90% of steady state has decreased substantially at the near Blackfoot to Minidoka reach and at springs downstream of Milner. Similar trends are observed in simulated water level responses (Appendix E), which approach steady state more quickly in the ESPAM2.0 simulations in the western portion of the model domain.

Seasonal transient simulation results (Appendix F) illustrate the change in the seasonal response patterns resulting from the change from 6-month stress periods in ESPAM1.1 to monthly stress periods in ESPAM2.0.

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