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Contents

LIST OF TABLES

LIST OF FIGURES

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EXECUTIVE SUMMARY

Increasing greenhouse gas concentrations in the atmosphere, resulting in climate impacts, are raising concerns over the hydrologic cycle and its effects upon agricultural productivity. If rainfall patterns change, meeting an increased demand for fruits and vegetables will pose a challenge for domestic production regions in the United States (U.S.). Information on potential water supply scarcity in the current production regions provides decision makers with critical information for risk mitigation for future production. We used a hydrologic balance-based model of historic and future water availability to evaluate risk of available irrigation water to support major fruit and vegetable production the US. The purpose of this work was to develop and demonstrate a method for assessing the risk of irrigation water availability to climate change.

The risk to irrigation water availability for fruits and vegetables in the US were analyzed based on annual water balance in 31 ASDs across five ARS regions, covering 15 states Agricultural Statistics Districts (ASDs) through different climate change scenarios. Analysis of ASDs required aligning them with sub-basin hydrologic process using an area-based allocation rule set to upscale the analyses of water scarcity from 603 HUC8 sub-basins the 31 selected ASDs. We used the USGS-USFS WaSSI model linked with five IPCC climate scenarios in a water risk framing to forecast irrigation water scarcity risk.

Results of the risk assessment identified 44 of the 248 ASD future scenarios (18 percent) had P-values of less than 0.05 and thus predicted statistically significant change in available irrigation water (ASDiw) compared to that ASD's HIST (Appendix B). The Midwest has the most ASDs with significant changes in ASDiw (six ASDs with 20 significant scenarios). The Pacific West, despite being the region with the most ASDs, only has three ASDs with significant scenarios, though 14 scenarios in the region were significantly different. The Northeast, Plains, and Southeast regions each had one ASD with significantly different irrigation water availability.

The major conclusion from this risk assessment is that for more than 38% (12 of 31) ASDs, the surface water available for irrigation use from 2040 to 2070 is projected to be less than it was in 1981 to 2010. More than 75% of the 248 modelled ASD scenarios have a trend towards decreasing values over time, with 58% projected average available irrigation water were significantly lower (α=0.05). The Midwest has the most ASDs with significant changes in ASDiw (six ASDs with 20 significant scenarios). The Pacific West, despite being the region with the most ASDs, only has three ASDs with significant scenarios, though 14 scenarios in the region were significantly different. The Northeast, Plains, and Southeast regions each had one ASD with significantly different scenarios.

1. INTRODUCTION

Increasing greenhouse gas concentrations in the atmosphere, resulting in climate impacts, are raising concerns over the hydrologic cycle and its effects upon agricultural productivity. If rainfall patterns change, meeting an increased demand for fruits and vegetables will pose a challenge for domestic production regions in the United States (U.S.). Previous studies have shown that climate change will result in changes in both precipitation and temperature resulting in change to the available water supply (Cisneros, Blanca, Oki, 2014; Dahlman, 2018; Duan et al., 2016; Roy et al., 2012). Large areas of croplands across the central U.S. are predicted to be threatened by rising temperature and decreasing water availability for irrigation (Duan et al., 2017). California and Florida are the leading domestic sources of many vegetable and fruit crops, but climate change as well as increased competition for land, water, and other natural resources have the potential to limit production in these current major centers of production. Over the entire continental United States (CONUS), temperature is projected to have a greater role than precipitation in an ever-warming future.

The availability of water has a major impact on the yield and quality of selected crops in current conditions. The projected shifts in surface water availability are not uniform across the U.S. (Averyt et al., 2013; Seager et al., 2013; US EPA, 2016). The uncertainty associated with water resource availability will impact decisions on investment in infrastructure to support agricultural supply chains, especially fruits and vegetables (Averyt et al, 2013).

Information on potential water supply scarcity in the current production regions provides decision makers with critical information for risk mitigation for future production. We used a hydrologic balance-based model of historic and future water availability to evaluate risk of changes in available irrigation water to support major fruit and vegetable production in 31 USDA Agricultural Statistics Districts (ASDs) through different climate change scenarios. The ASDs were chosen because they collectively represent a majority of the fruit and vegetable regions in the US: potatoes, tomatoes, sweet corn, strawberries, carrots, spinach, oranges, and green beans. The purpose of this work was to develop and demonstrate a method for assessing the risk to crop production due to irrigation water availability under climate change scenarios.

2. APPROACH

In order to analyze risk to irrigation water availability for fruits and vegetables in the US we analyzed the annual water balance in 31 ASDs across five ARS regions, covering 15 states (Figure 1, Table 1). The water balance model used to evaluate future water available for allocation to irrigation was the Water Supply Stress Index (WaSSI) (Caldwell, Sun et al., 2019). The scale of accounting in WASSI is 8-digit hydrologic unit code (HUC8, roughly 1800 km^2), generally referred to as sub-basin scale. The ASDs are much larger than this so overlay multiple HUC8 sub-basins, and the boundaries rarely align. In order to align the sub-basin accounting with ASDs we developed an area-based allocation rule set to upscale the analyses of water scarcity from 603 HUC8 sub-basins the 31 selected ASDs. This section describes the WaSSI model, climate scenarios analyzed, water risk method, upscaling rules from HUC8 to ASD scales, irrigation water scarcity risk assessment.

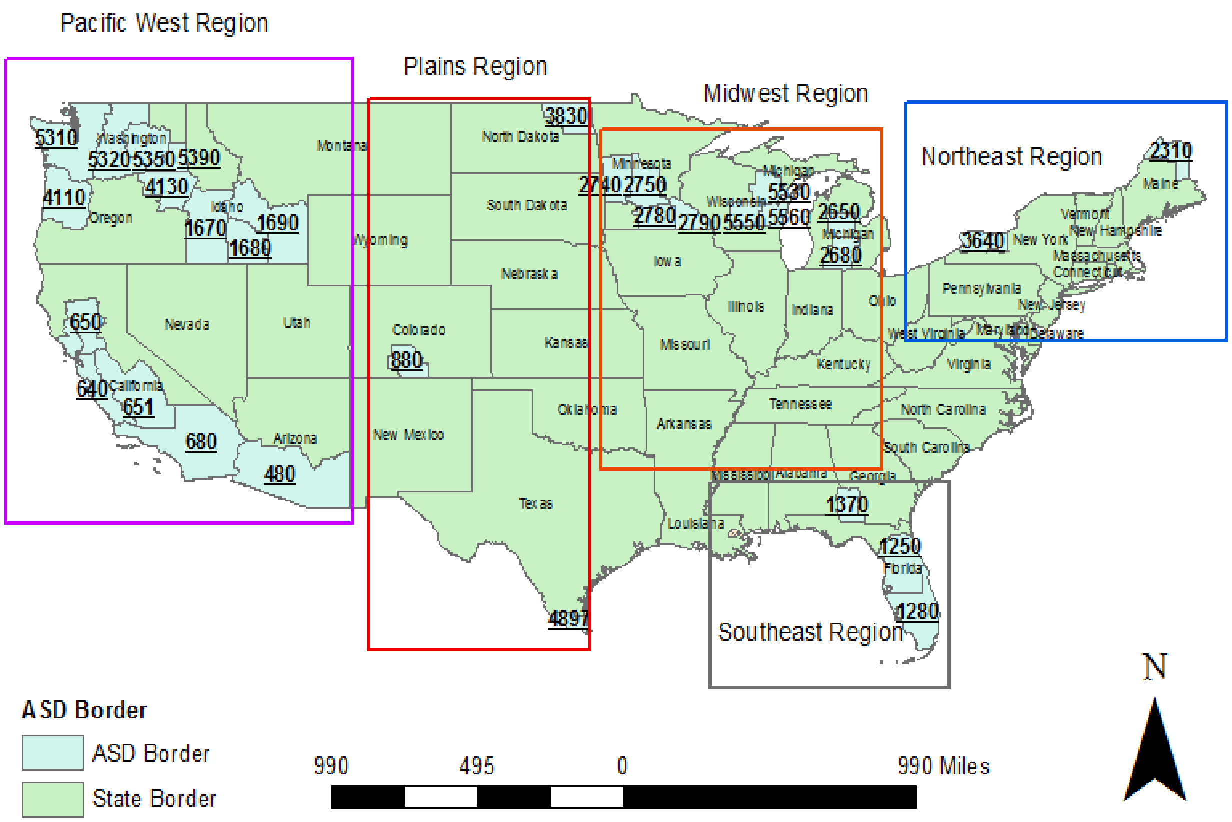


Figure 1. Location of 31 Agricultural Statistics Districts (ASDs) analyzed for future irrigation water risk within five Agricultural Research Service (ARS) regions.

Table 1. Listing of ASDs selected for future available irrigation water analysis by state and ARS region, with number of HUC8s intersected by each ASD.

Agricultural Research Service (ARS) region / state	State Agricultural Statistics District (ASD)	Number of HUC8s intersecting ASD
Midwest		
Michigan	MI2650	9
Michigan	MI2680	12
Minnesota	MN2790	12
Minnesota	MN2780	13
Minnesota	MN2740	16
Minnesota	MN2750	17
Wisconsin	WI5560	9
Wisconsin	WI5530	9
Wisconsin	WI5550	7
Northeast		
Maine	ME2310	9
New York	NY3640	9
Pacific West		
Arizona	AZ480	42
California	CA651	38
California	CA680	40
California	CA640	32
California	CA650	28
Idaho	ID1690	40
Idaho	ID1670	30
Idaho	ID1680	16
Oregon	OR4110	28
Oregon	OR4130	17
Washington	WA5320	26
Washington	WA5350	12
Washington	WA5310	41
Washington	WA5390	11
Plains		
Colorado	CO880	15
North Dakota	ND3830	11
Texas	TX4897	4
Southeast		
Florida	FL1280	19
Florida	FL1250	18
Georgia	GA1370	13

2.1. Water Supply Stress Index (WaSSI)

The Water Supply Stress Index (WaSSI) is a water mass balance model developed to analyze the effects of climate change, forest land change, and water withdrawals on water supply stress, river flows, and carbon dynamics across the conterminous U.S., Rwanda, Burundi, and Mexico (USFS, 2019). The water balance model operates on a monthly time step at the 8-digit HUC watershed scale across the US. Annual United States Geological Survey (USGS) water demand is estimated for eight categories of human use: public supply, domestic, irrigation, thermoelectric power, self-supplied industrial, mining, livestock, and aquaculture. Estimates of category demands are adjusted for the population, disaggregated to the monthly time step, and compared to the surface and groundwater supply to assess stress on the water supply. Consumptive use is subtracted from stream flow in the river network. WaSSI uses geographic information system (GIS) data to characterize land use, evapotranspiration (ET), infiltration, snow accumulation, snow melt, soil storage, surface runoff, and base flow within each basin (Figure 2). The required inputs for each watershed include monthly precipitation (PPT), mean monthly leaf area index (LAI), and temperature (T) for each land cover class, impervious cover fraction by land cover, soil properties, and land cover distribution. This allows for effective and efficient analyses across large regions and over multiple climate scenarios.

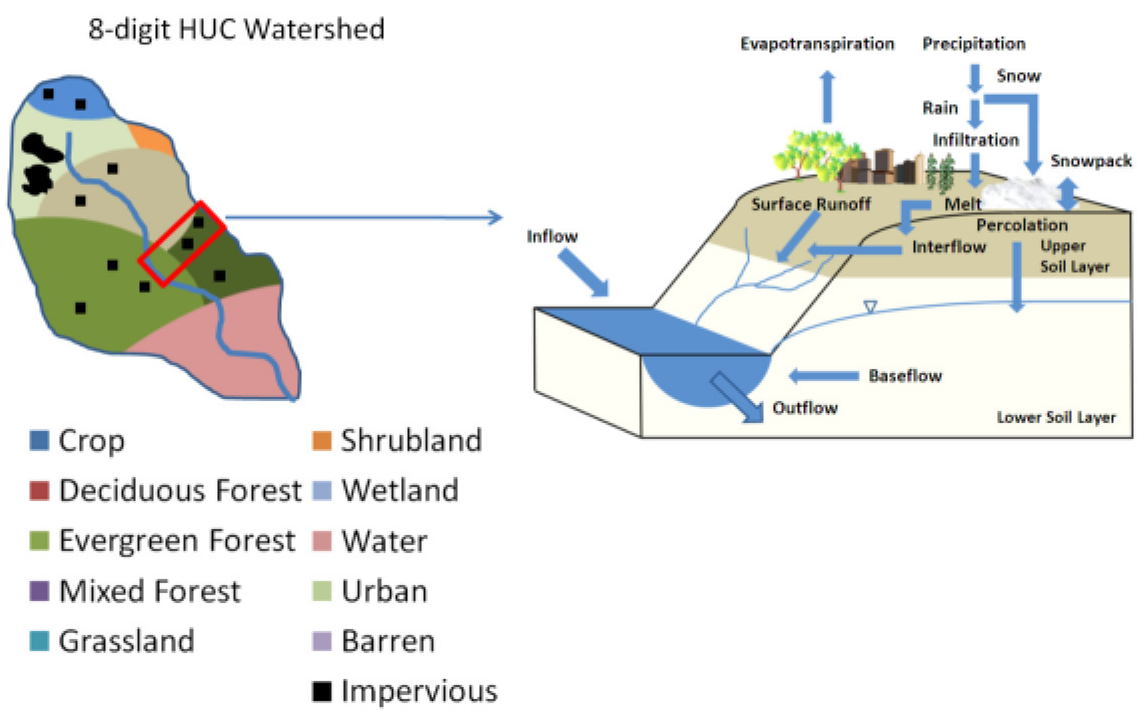


Figure 2. Land cover classes and hydrologic processes simulated by WaSSI. Reprinted with permission from *WaSSI Services Model User Guide v1*.2 by P. Caldwell and G. Sun et al., 2019, USDA.

2.2. CLIMATE SCENARIOS ANALYZED

Two climate datasets were used to provide inputs to WaSSI: monthly temperature and precipitation for 1981-2010 from the Parameter-elevation Relationships on Independent Slopes Model (PRISM) dataset, and monthly precipitation, solar radiation, wind speed, specific humidity, and maximum and minimum temperature from the Multivariate Adaptive Constructed Analogs (MACA) datasets (MACAv2-LIVNEH dataset). The downscaling of MACA weather data from grid to HUC8 was performed by Duan et al. (2017).

In order to develop an inclusive estimator of future weather patterns across the US, we averaged projected monthly rainfall and temperature conditions from five General Circulation Models (GCMs) developed by the fifth phase of the Coupled Model Inter-comparison Project (CMIP5) for the simulation periods for each of the 603 sub-basins. These five scenarios were GFDL-ESM2M (GCM1), HadGEM2-ES365 (GCM2), IPSL-CM5A-LR (GCM3), MIROC-ESM-CHEM (GCM4), and NorESM1-M (GCM5) (Bopp et al., 2013). Representative Concentration Pathways (RCPs) RCP4.5 and RCP8.5 were used from each of the GCMs to simulate the range of potential impacts, from intermediate and high climate change impact. These RCPs correspond to climate forcing functions such as aerosols and greenhouse gas emissions projected into a future where radiative forcing reaches 4.5 and 8.6 W/m^2 in the year 2100, respectively (Moss et al, 2010; IPCC, 2014). Scenarios using RCP4.5 were classified as Intermediate Stress (IS) and those using RCP8.5 were classified as High Stress (HS). We analyzed scenarios from 2021-2050 for near future (F1), and 2041-2070 for far future (F2) (Lamarque et al., 2011).

We used two population scenarios to estimate municipal and industrial demand for water. The first is an "as is" population (A1) based on county resolution IPCC SRES A1 projections (Zarnoch et al, 2010). This is equivalent to the current official U.S Bureau of Census national projection for 2010. This scenario was downscaled from county resolution to the HUC8 level within WaSSI. The annual population estimates were calculated through linear interpolation between the decadal data. Population data after the year 2060 is kept constant to avoid hyper-extrapolation. We also analyzed IPCC SRES A2 population projection, representing a continuous population growth to over 10 billion by 2050 (Nakicenovic et al., 2000). The A1 and A2 scenarios are conventionally used as bookends to population-driven climate impacts; we abbreviate A1 as Scenario B, and A2 as Scenario A (Table 2).

The analytic matrix resulting from these scenarios, Intermediate (IS) and high (HS) climate stress, current (B) and high (A) population growth, and near (F1) and far (F3) futures creates eight discrete scenarios (Table 2). The historical scenario makes nine total scenarios, analyzed across 31 ASDs, resulting in a total of 279 discrete analyses, 248 of them being future scenarios. All scenarios were analyzed to determine if irrigation water resources were more or less scarce over the scenario conditions.

Table 2 . Summary of historical (1981-2010) and future (2021-2050, 2040-2070) scenarios of irrigation water supply stress and projected irrigation water availability

Scenario Description	Scenario Abbreviation	Climate Energy	Population Projection	Timeframe
Historical	HIST	PRISM	USGS Census	1988-2010
High Stress AF1	HSAF1	RCP 8.5	SRES A2	2021-2050
High Stress BF1	HSBF1	RCP 8.5	SRES A1	2021-2050
Intermediate Stress AF1	ISAF1	RCP 4.5	SRES A2	2021-2050
Intermediate Stress BF1	ISBF1	RCP 4.5	SRES A1	2021-2050
High Stress AF2	HSAF2	RCP 8.5	SRES A2	2040-2070
High Stress BF2	HSBF2	RCP 8.5	SRES A1	2040-2070
Intermediate Stress AF2	ISAF2	RCP 4.5	SRES A2	2040-2070
Intermediate Stress BF2	ISBF2	RCP 4.5	SRES A1	2040-2070

2.3. UPSCALING HUC8 TO ASD SCALES

In order to calculate irrigation water available within HUC8 sub-basins by ASD we used an area-weighting method to allocate water flow in and through each ASD (upscaling). We created modified ASD maps to represent this water allocation process (Figure 3), referred to as ASD Watershed Borders. If the majority of a HUC8 was contained in an ASD it was fully attributed to the ASD. We created HUC8 routing tables for the entire US to capture flow routing for the 31 ASDs (Appendix A). Each HUC was based on flow characteristics. A flow classification value of 1 means that the HUC is either ‘isolated’ or ‘downstream’. An isolated HUC does not receive flow from an upstream HUC or contribute flow to a downstream HUC. A downstream HUC means that the HUC is receiving flow from an upstream HUC in the ASD but not contributing flow to a downstream HUC in the ASD. A flow classification of 2 means it is a ‘flow-through’ watershed, which both receives flow and contributes flow to other watersheds. Water in a HUC with a flow classification of 2 is not considered available to the ASD in this upscaling approach since its outlet streamflow is counted in each downstream watershed. Water that flows through HUCs are abstractions from available water and thus are not counted towards the overall ASD water availability. In the hydrologic mass balance, only water that is available for consumptive use is counted as available for allocation in sub-basins within ASDs.

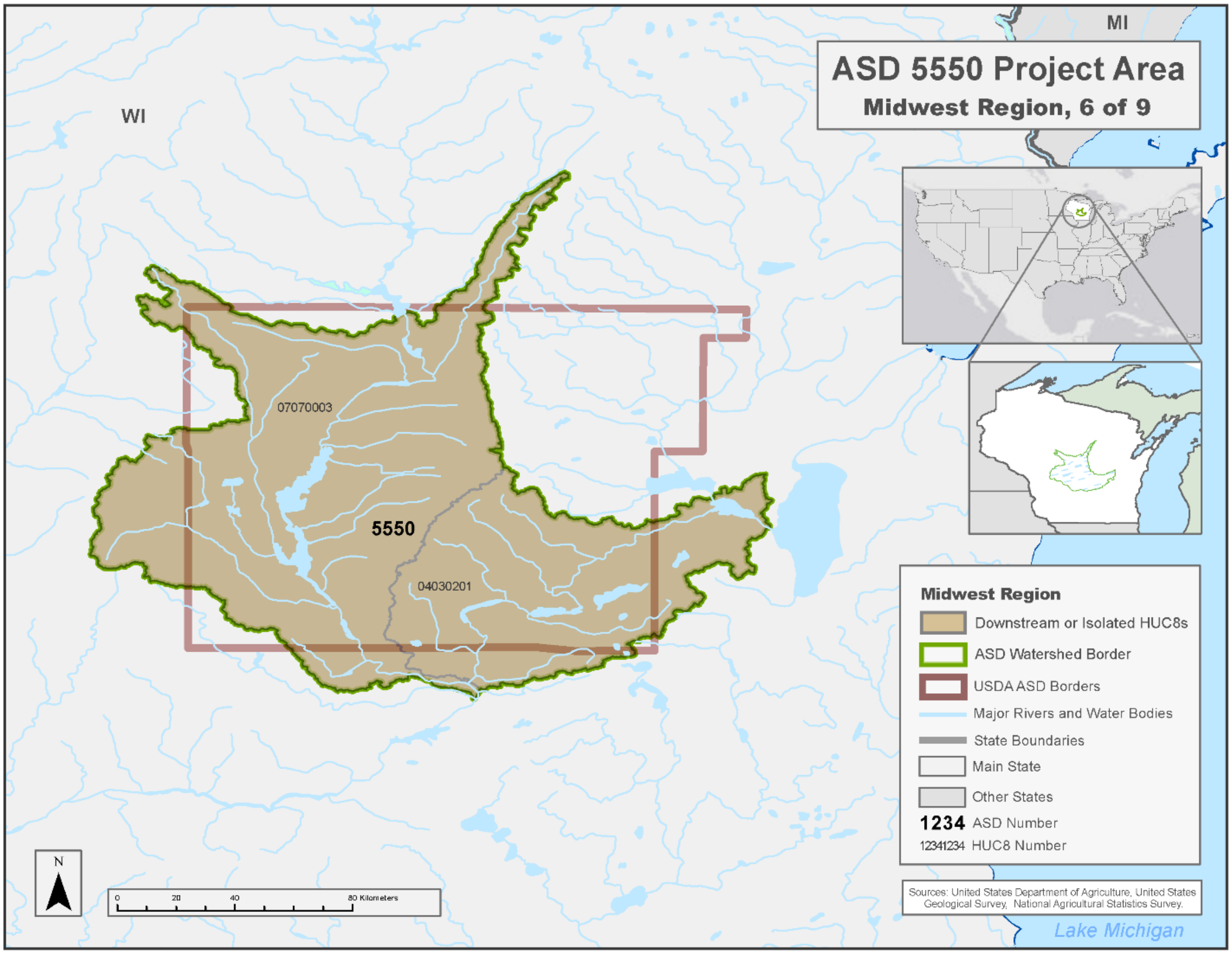


Figure 3. Midwest Region ASD 5550 with watershed borders. The borders of the ASD and the HUC8 sub-basin boundaries illustrate the limitations to an area approach to upscaling to non-hydrologic boundaries. The water available to irrigation is the sum of available water from the two HUC8 sub-basins within the ASD boundary.

2.4. Water Balance at ASD Scale

Determining the water available for irrigation use in the future required disaggregating water use allocation by category in WaSSI, projecting demands across all categories except irrigation, and subtracting water demands from available water for all nine scenarios. The change in water available for irrigation was determined by analyzing average water available for irrigation from historic analysis (HIST) compared to the eight future scenarios (Table 2). For each scenario, HUC8 routed flows for each ASD were aggregated to create a monthly water balance in million cubic meters per year (Equation 1, Mm^3/yr):

$$Q_{out} = \Sigma Q_{in} + Y - \Sigma CU \quad (1)$$

where Q_{out} is water available for irrigation or downstream flows from an ASD, ΣQ_{in} is the cumulative flow into the ASD from upstream watersheds, Y is the water yield generated in each HUC8 from rainfall runoff and groundwater, and ΣCU is the sum of consumptive water uses in the USGS water inventory use categories less irrigation (since irrigation is the water use we are analyzing). The environmental water requirement (EWR), or amount of water necessary to maintain aquatic life and other designated water body uses, was estimated as the EWR constant (EWR_c) times the values of Q_{out} for each HUC8. The EWR_c was estimated at 0.20 (Smakhtin et al., 2004). The water available for irrigation within a HUC8 sub-basing therefore is Projected Water Available (PWA) for other uses (Equation 2).

$$\text{PWA} = Q_{out} * (1 - EWR_c) \tag{2}$$

The PWA, measured in million cubic meters (Mm^3, the same as cubic hectometers (hm^3)) per year, is aggregated from each HUC within an ASD (n) for every year simulated to calculate an overall water volume available for irrigation for each ASD (ASD_{iw}) (Equation 3).

$$\text{ASDiw} = \sum_{i=1}^{n} \text{PWA} \tag{3}$$

2.5. IRRIGATION WATER SCARCITY RISK ASSESSMENT

The scenarios that predicted significant changes in ASD_{iw} were calculated by comparing each future scenario ASD_{iw} (eight configurations, Table 2) from historic irrigation water availability (HIST). The ASD_{iw} for each HIST was the average of 30 years of historic data, and each future scenario was the averages of five future weather simulations (CMIP5, Section 2.2) over the time span of each scenario (30 years). The difference between HIST and eight scenarios for 31 ASDs (248 future scenarios) were analyzed using Analysis of Variance (ANOVA, $\alpha = 0.05$).The ASD_{iw} scenarios that were statistically significant from HIST were analyzed further using simple linear regression of ASD_{iw} over time. The slope of the regression lines indicated if the ASD_{iw} was predicted to increase or decrease based upon each scenario criteria. The probability of significance of the slope (p) and coefficient of determination (R^2) were calculated for each significant scenario. Finally, the 95 percent confidence intervals for the regression lines were calculated to quantify uncertainty in the regression projections. We expected that the largest changes in available irrigation water would occur in the scenarios modelled with higher climate stress (HS climate scenario), a higher projected population (population scenario A), and the far future scenario (F2), or the HSAF2 scenarios (Table 2).

3. Results and Discussion

3.1. Analysis of Results

Results of the ANOVA found that 44 of the 248 ASD future scenarios (18 percent) had P-values of less than 0.05 and thus predicted statistically significant change in available irrigation water (ASD_{iw}) compared to that ASD's HIST (Appendix B). Twelve of the 31 ASDs analyzed had projected significant changes in available irrigation water. The Midwest has the most ASDs with significant changes in ASD_{iw} (six ASDs with 20 significant scenarios). The Pacific West, despite being the region with the most ASDs, only has three ASDs with significant scenarios, though 14 scenarios in the region were significantly different. The Northeast, Plains, and Southeast regions each had one ASD with significantly different scenarios.

The most common scenarios that simulated significant changes in ASD_{iw} were those in the far future (F2), which had 34 of the 44 significant changes. As expected, the high stress climate scenario simulations had a larger number of significant scenarios than the intermediate stress ones (26 and 18, respectively). The population parameters, however, had an equal number of significant scenarios, both with 22, suggesting that the A and B population scenarios did not drive changes in ASD_{iw}. Only four F1 significant ASD scenarios did not have an associated F2 scenario with significant changes (HSAF2 and HSBF2 for both ASD 5320 and 5350), suggesting strong continuity in projections across the near- and far-terms. Those four HS scenarios are located in the Pacific West region, the most variable of all the regions.

The simple regression analyses of ASD_{iw} with respect to time provided both the rate of change in available irrigation water over time as well as predicted ASD_{iw} for each scenario, with a 95 percent confidence of significance (n = 30 years, $\alpha = 0.05$) (Tables 3 and 4). For the significantly different scenarios, only four of the 44 had positive slopes, all of them from the IS/F2 scenarios for ASDs 5320 and 5350 (Table 4). These High Stress (HS) scenarios for these four intermediate stress (IS) scenarios did not differ significantly from HIST.

Table 3. The probability of significance (α = 0.05) for slopes of LSD regression analyses for ASD_{iw} scenarios. Bold numbers indicate significant slopes (95 percent confident they are not 0).

ASD\Scenario	Historical	HSAF1	HSBF1	ISAF1	ISBF1	HSAF2	HSBF2	ISAF2	ISBF2
Midwest									
2650	0.500	0.525	0.185	0.199	0.077	0.089	0.377	0.415	0.500
2680	0.140	0.134	0.063	0.059	**0.005**	**0.004**	0.151	0.142	0.140
2740	0.121	0.115	0.129	0.123	**0.000**	**0.000**	**0.009**	**0.009**	0.121
2750	0.148	0.156	0.103	0.108	**0.001**	**0.001**	**0.014**	**0.015**	0.148
2780	0.062	0.060	0.119	0.115	**0.001**	**0.001**	**0.022**	**0.021**	0.062
2790	0.160	0.164	0.092	0.094	**0.001**	**0.001**	**0.018**	**0.018**	0.160
5530	0.772	0.770	0.571	0.572	0.382	0.384	0.816	0.818	0.772
5550	0.488	0.487	0.190	0.190	0.059	0.059	0.305	0.306	0.488
5560	0.396	0.395	0.128	0.127	**0.048**	**0.048**	0.273	0.272	0.396
Northeast									
2310	0.108	0.108	0.302	0.302	0.247	0.247	0.123	0.123	0.108
3640	0.482	0.488	0.218	0.221	**0.030**	**0.031**	0.227	0.233	0.482
Pacific West									
480	0.440	0.993	0.185	0.584	0.076	0.211	0.370	0.732	0.440
640	0.647	0.691	0.337	0.369	0.069	0.080	0.264	0.297	0.647
650	0.409	0.438	0.170	0.187	**0.035**	**0.040**	0.135	0.154	0.409
651	0.925	0.919	0.702	0.858	0.104	0.147	0.468	0.599	0.925
680	0.433	0.339	0.493	0.388	0.426	0.487	0.760	0.681	0.433
1670	0.168	0.171	0.263	0.267	0.766	0.780	0.280	0.289	0.168
1680	0.234	0.238	0.326	0.332	0.906	0.921	0.386	0.397	0.234
1690	0.111	0.113	0.120	0.122	0.749	0.761	0.173	0.179	0.111
4110	0.082	0.081	0.134	0.133	0.376	0.372	0.149	0.147	0.082
4130	0.061	0.061	0.136	0.135	0.526	0.524	0.115	0.114	0.061
5310	0.072	0.070	0.123	0.120	0.226	0.220	0.133	0.129	0.072
5320	**0.009**	**0.009**	**0.011**	**0.011**	0.064	0.064	**0.014**	**0.013**	**0.009**
5350	**0.017**	**0.017**	**0.023**	**0.023**	0.138	0.139	**0.029**	**0.029**	**0.017**
5390	0.165	0.167	0.246	0.249	0.833	0.842	0.284	0.290	0.165
Plains									
880	0.164	0.163	0.072	0.072	0.675	0.680	0.366	0.362	0.164
3830	**0.027**	**0.026**	0.325	0.324	**0.000**	**0.000**	**0.003**	**0.003**	**0.027**
4897	0.770	0.806	0.773	0.738	0.655	0.686	0.471	0.502	0.770
Southeast									
1250	0.868	0.905	0.560	0.589	0.092	0.079	0.785	0.734	0.868
1280	0.486	0.445	0.799	0.844	**0.007**	**0.005**	0.183	0.157	0.486
1370	0.832	0.842	0.594	0.585	0.310	0.302	0.567	0.556	0.832

The ASDs in the Pacific West region were the most dynamic and variable for future ASD_{iw}. Of the 248 total ASD scenarios analyzed, 105 (42 percent) had an increase in the average water availability values from HIST, though not significant (Appendix B). Seventy nine of the projected ASD scenarios with increased ASD_{iw} were in the in the Pacific West. For those ASD scenarios with significant differences, the average projected increase in ASD_{iw} was 12.9% and the average decrease was -22.3%, with an average total change of -12.7%. These average changes are across three ASDs within the Pacific West region (Table 4).

The scenarios with the highest annual rate of loss of irrigation water were in ASD650 in the Pacific West region (Table 4), with a loss of 479 Mm^3/yr (Table 5). The 12 significant ASD scenarios in ASDs 5320 and 5350 that showed increased ASD_{iw} all had very low R^2, indicating extremely variable annual predictions, with notable oscillations between wet and dry years. The only significant scenarios with near future (F1) changes were in ASDs 5320 and 5350 (Table 4), all with negative slopes, but two far future (F2) scenarios from those ASDs (ISA and ISB) showed positive slopes..

Table 4. Slope Values for Regression Lines for Statistically Significant ($p<0.05$) Scenarios. Units are in Mm^3/yr.

ASD\Scenario		HSAF1	HSBF1	ISAF1	ISBF1	HSAF2	HSBF2	ISAF2	ISBF2
Midwest									
	2680	----	----	----	----	-8.6	-8.7	----	----
	2740	----	----	----	----	-84.1	-84.1	-14.4	-14.8
	2750	----	----	----	----	-135.5	-135.8	-21.0	-21.5
	2780	----	----	----	----	-41.4	-41.4	-24.0	-24.2
	2790	----	----	----	----	-190.5	-191.4	-20.9	-22.1
	5560	----	----	----	----	-17.2	-17.2	----	----
Northeast									
	3640	----	----	----	----	-16.2	-16.1	----	----
Pacific West									
	650	----	----	----	----	-479.0	-479.0	----	----
	5320	-346.7	-345.7	-425.8	-424.9	----	----	86.8	85.3
	5350	-290.0	-289.9	-264.2	-264.0	----	----	50.6	49.0
Plains									
	3830	-5.7	-5.7	----	----	-23.7	-23.7	-8.0	-8.0
Southeast									
	1280	----	----	----	----	-205.4	-207.1	----	----

Table 5. Difference between the 30 year average of available irrigation water in statistically significant ($p<0.05$) scenarios and the Historical scenario. Units are in Mm^3/yr.

ASD\Scenario	HSAF1	HSBF1	ISAF1	ISBF1	HSAF2	HSBF2	ISAF2	ISBF2
Midwest								
2680	----	----	----	----	-600	-607	----	----
2740	----	----	----	----	-2,601	-2,620	-1,793	-1,816
2750	----	----	----	----	-4,016	-3,989	-2,816	-2,792
2780	----	----	----	----	-2,052	-2,063	-1,422	-1,435
2790	----	----	----	----	-5,644	-5,645	-3,981	-3,985
5560	----	----	----	----	-606	-607	----	----
Northeast								
3640	----	----	----	----	-685	-681	----	----
Pacific West								
650	----	----	----	----	-12,634	-12,277	----	----
5320	17,614	17,654	16,477	16,516	----	----	15,526	15,550
5350	10,572	10,583	9,742	9,753	----	----	9,137	9,130
Plains								
3830	-372	-372	----	----	-650	-651	-490	-491
Southeast								
1280	----	----	----	----	-3,867	-4,002	----	----

3.2. ASD Results

The results for each ASD from scenarios with significant changes in available irrigation water (ASD_{iw}) are presented by region. The tables of analyses of the results provide the average irrigation water for each scenario, the range (highest year minus lowest year projected irrigation water for each scenario over 30 years), and the slope and coefficient of determination (R^2) the regression analyses over time. The projected irrigation water availability by scenario with the LSD regression line bounded by 95% confidence intervals for the regression line are presented.

3.2.1. Midwest

ASD 2680: Projections for ASD_{iw} for ASD 2680 showed a decrease in average available irrigation water for all scenarios but the HS F2 scenarios were most significant (Figures 4 and 5, Table 6).

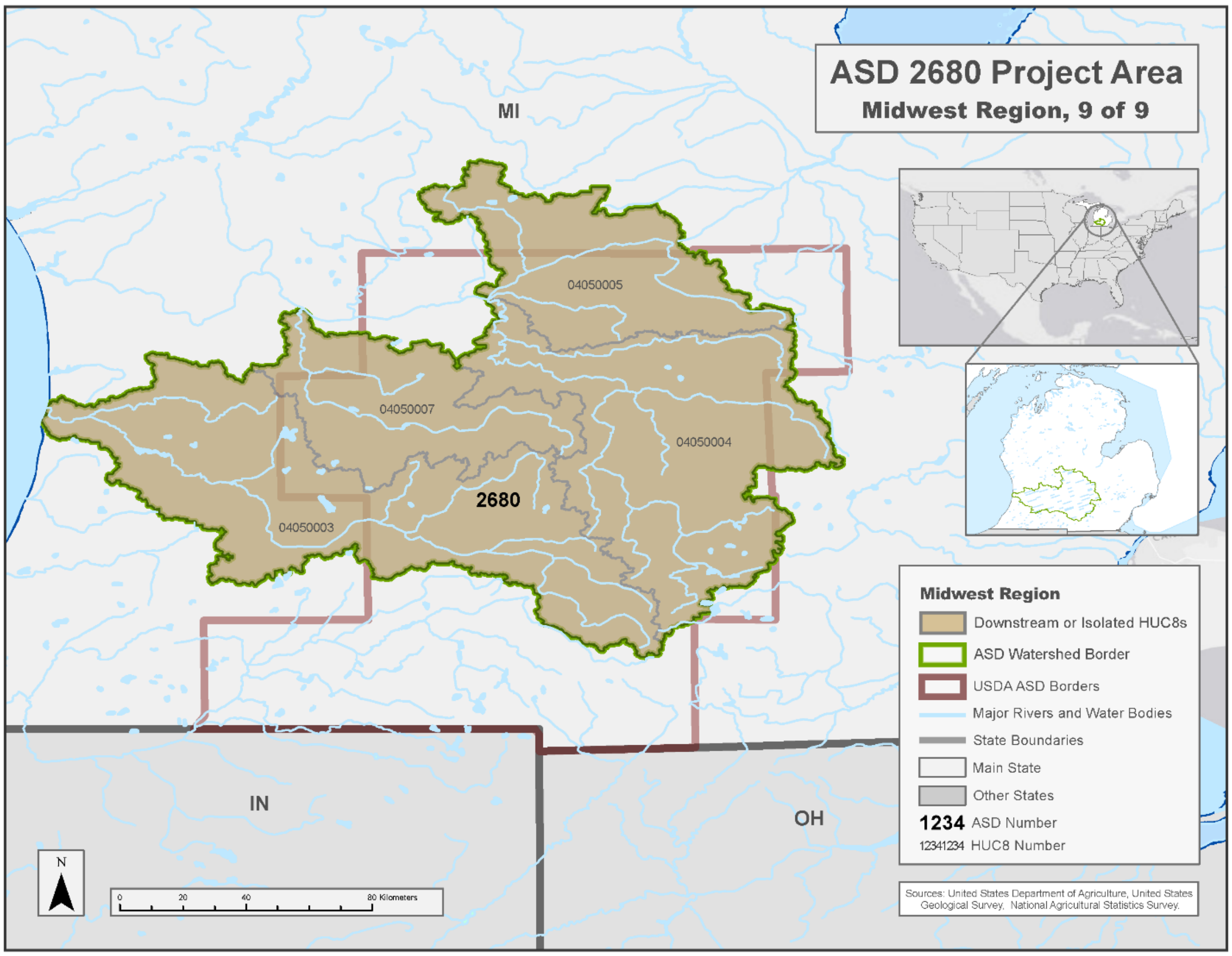
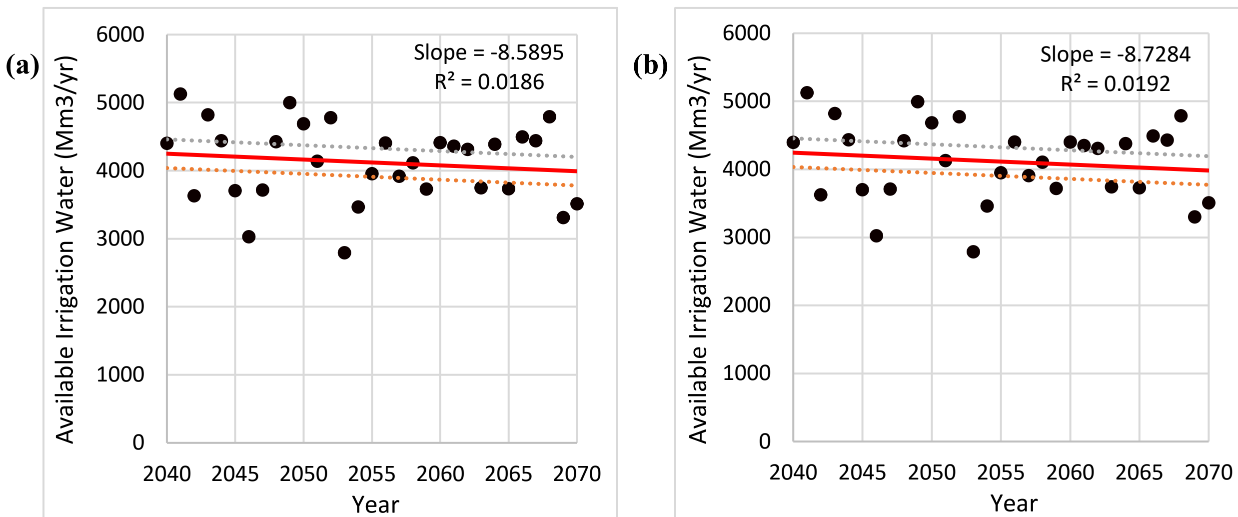


Figure 4. ASD 2680 Watershed Borders: the borders of the ASD modified to include streamflow for HUC8s meeting inclusion criteria.

Table 6. Irrigation Water Availability Results and Analysis for ASD 2680. Units are in Mm^3/yr. Results for the statistically significant scenarios ($p<0.05$) are in bold.

Parameter\Scenario	Historical	HSAF1	HSBF1	ISAF1	ISBF1	HSAF2	HSBF2	ISAF2	ISBF2
Average	4,721	4,408	4,403	4,343	4,338	**4,121**	**4,114**	4,424	4,417
Range	2,851	2,448	2,449	2,103	2,104	**2,333**	**2,337**	2,249	2,254
Change from Historical	----	-313	-318	-378	-383	**-600**	**-607**	-297	-303
Slope	----	----	----	----	----	**-8.6**	**-8.7**	----	----
R2	----	----	----	----	----	**0.019**	**0.019**	----	----

Figure 5. Scenarios for ASD 2680 with a statistically significant ($p < 0.05$) change in available irrigation water over the scenario's time period: (a) HSAF2, (b) HSBF2



ASD 2740: Projections for ASD 2740 showed significant decrease in ASD_{iw} for all four scenarios,(HSAF2, HSBF2, ISAF2 and ISBF2) (Figures 6 and 7, Table 7).

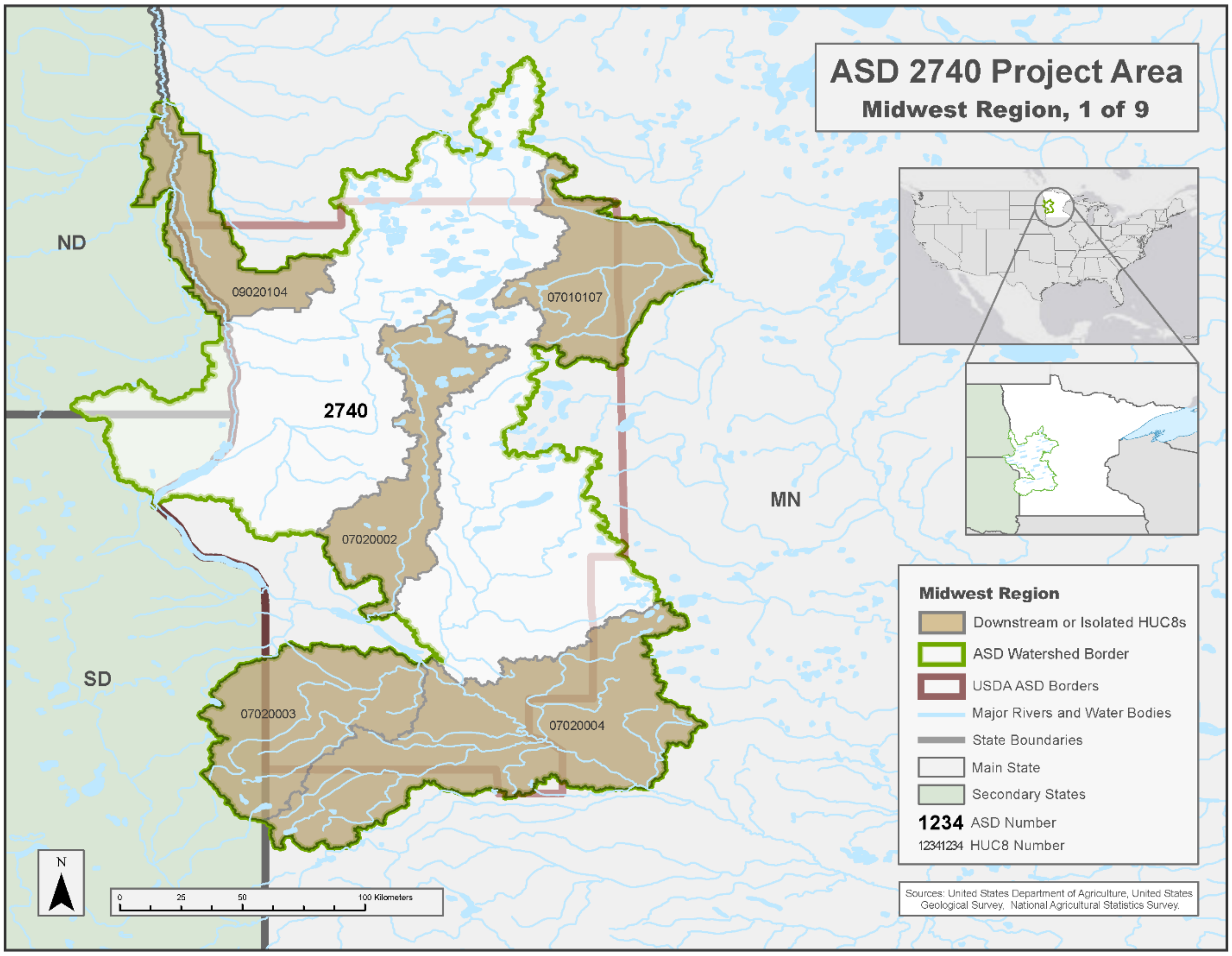
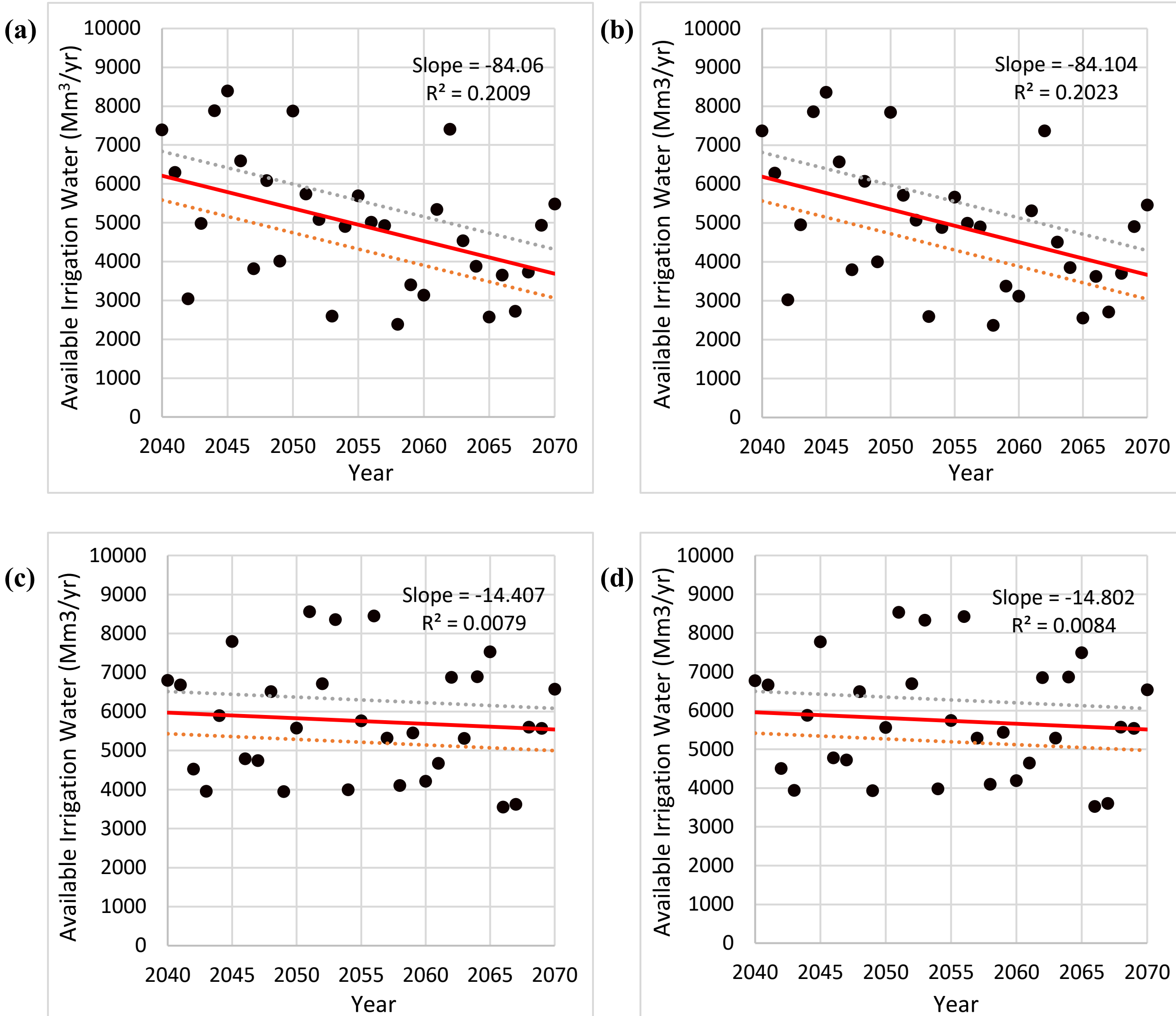


Figure 6. ASD 2740 Watershed Borders: the borders of the ASD modified to include HUC8s meeting inclusion criteria.

Table 7. Irrigation Water Availability Results and Analysis for ASD 2740. Units are in Mm^3/yr. Results for the statistically significant scenarios ($p<0.05$) are in bold.

Parameter\Scenario	Historical	HSAF1	HSBF1	ISAF1	ISBF1	HSAF2	HSBF2	ISAF2	ISBF2
Average	7,550	6,425	6,407	6,477	6,459	**4,949**	**4,929**	**5,756**	**5,733**
Range	13,302	8,163	8,153	6,571	6,555	**6,011**	**5,988**	**5,010**	**5,010**
Change from Historical	----	-1,125	-1,142	-1,073	-1,091	**-2,601**	**-2,620**	**-1,793**	**-1,816**
Slope	----	----	----	----	----	**-84.1**	**-84.1**	**-14.4**	**-14.8**
R2	----	----	----	----	----	**0.201**	**0.202**	**0.008**	**0.008**

Figure 7. Scenarios for ASD 2740 with a statistically significant ($p < 0.05$) change in available irrigation water over the scenario's time period: (a) HSAF2, (b) HSBF2, (c) ISAF2, (d) ISBF2



ASD 2750: Projections for ASD 2750 showed significant decrease in ASD_{iw} for all four scenarios,(HSAF2, HSBF2, ISAF2 and ISBF2) (Figures 8 and 9, Table 8).

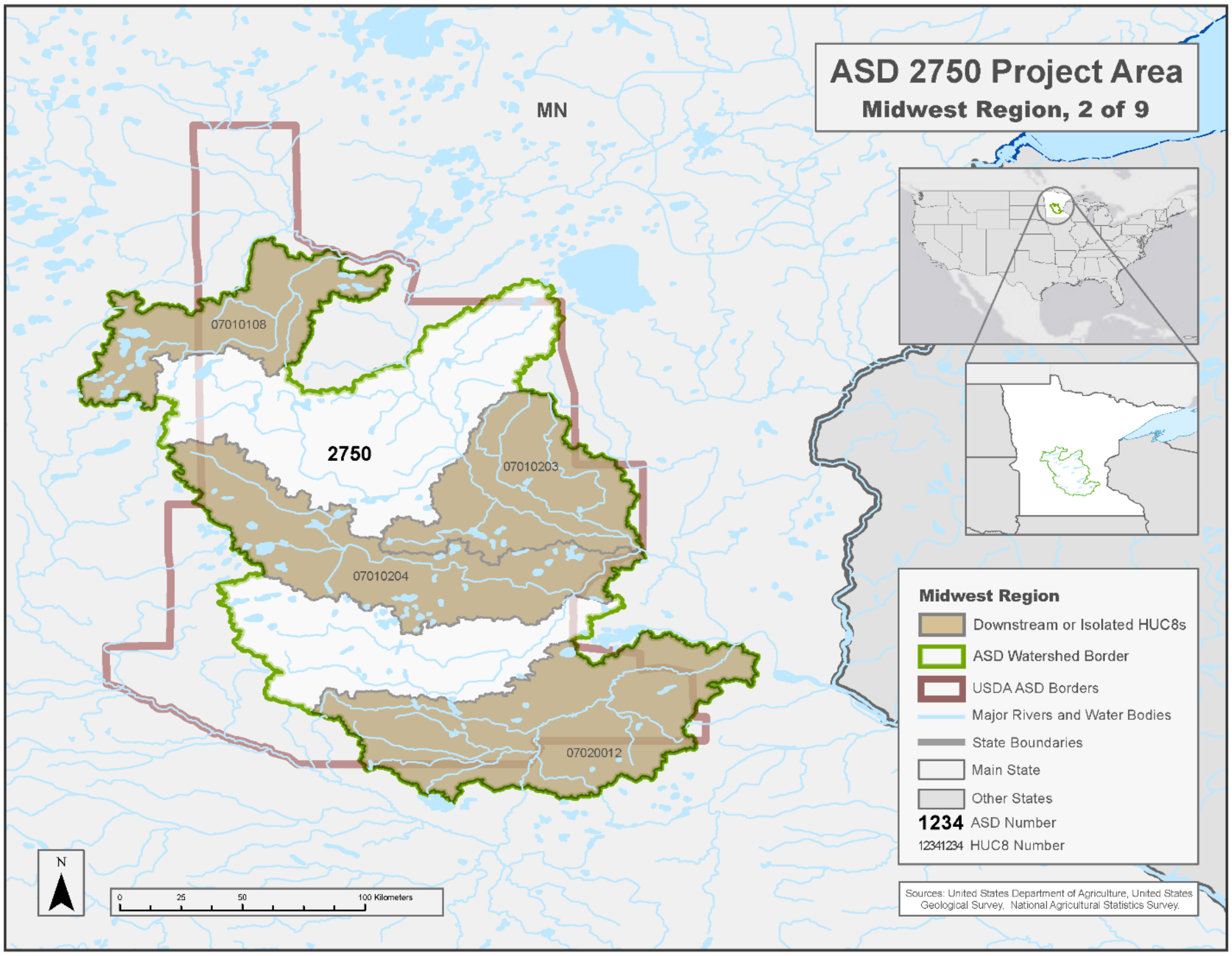
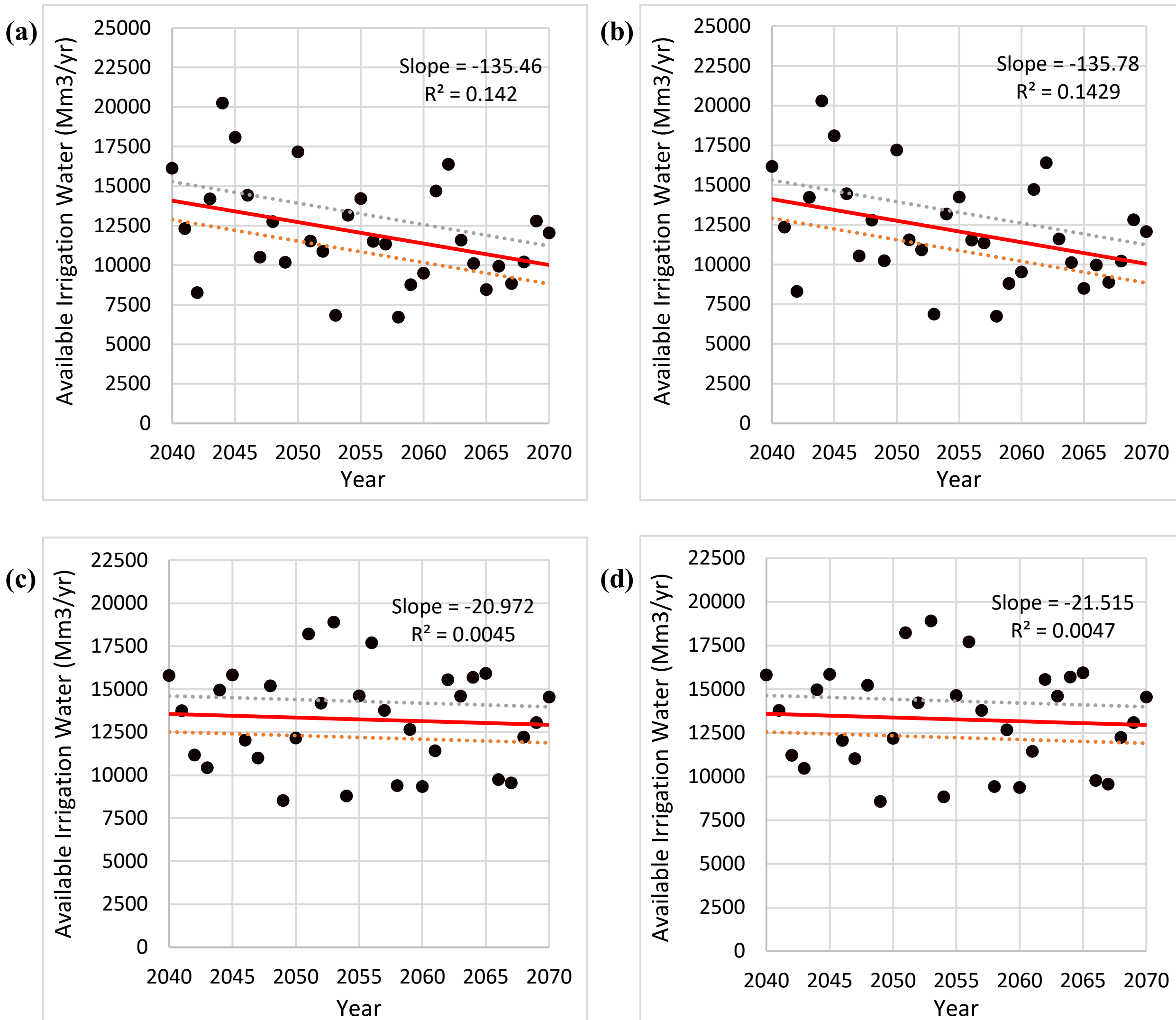


Figure 8. ASD 2750 Watershed Borders: the borders of the ASD modified to include HUC8s meeting inclusion criteria.

Table 8. Irrigation Water Availability Results and Analysis for ASD 2750. Units are in Mm^3/yr. Results for the statistically significant scenarios ($p<0.05$) are in bold.

Parameter\Scenario	Historical	HSAF1	HSBF1	ISAF1	ISBF1	HSAF2	HSBF2	ISAF2	ISBF2
Average	16,065	14,318	14,351	14,186	14,218	**12,049**	**12,076**	**13,249**	**13,273**
Range	22,788	13,415	13,412	10,692	10,688	**13,543**	**13,538**	**10,357**	**10,343**
Change from Historical	----	-1,747	-1,714	-1,879	-1,847	**-4,016**	**-3,989**	**-2,816**	**-2,792**
Slope	----	----	----	----	----	**-135.5**	**-135.8**	**-21.0**	**-21.5**
R2	----	----	----	----	----	**0.142**	**0.143**	**0.005**	**0.005**

Figure 9. Scenarios for ASD 2750 with a statistically significant ($p < 0.05$) change in available irrigation water over the scenario's time period: (a) HSAF2, (b) HSBF2, (c) ISAF2, (d) ISBF2



ASD 2780: Projections for ASD 2750 showed significant decrease in ASD_{iw} for all four scenarios,(HSAF2, HSBF2, ISAF2 and ISBF2) (Figures 10 and 11, Table 9).

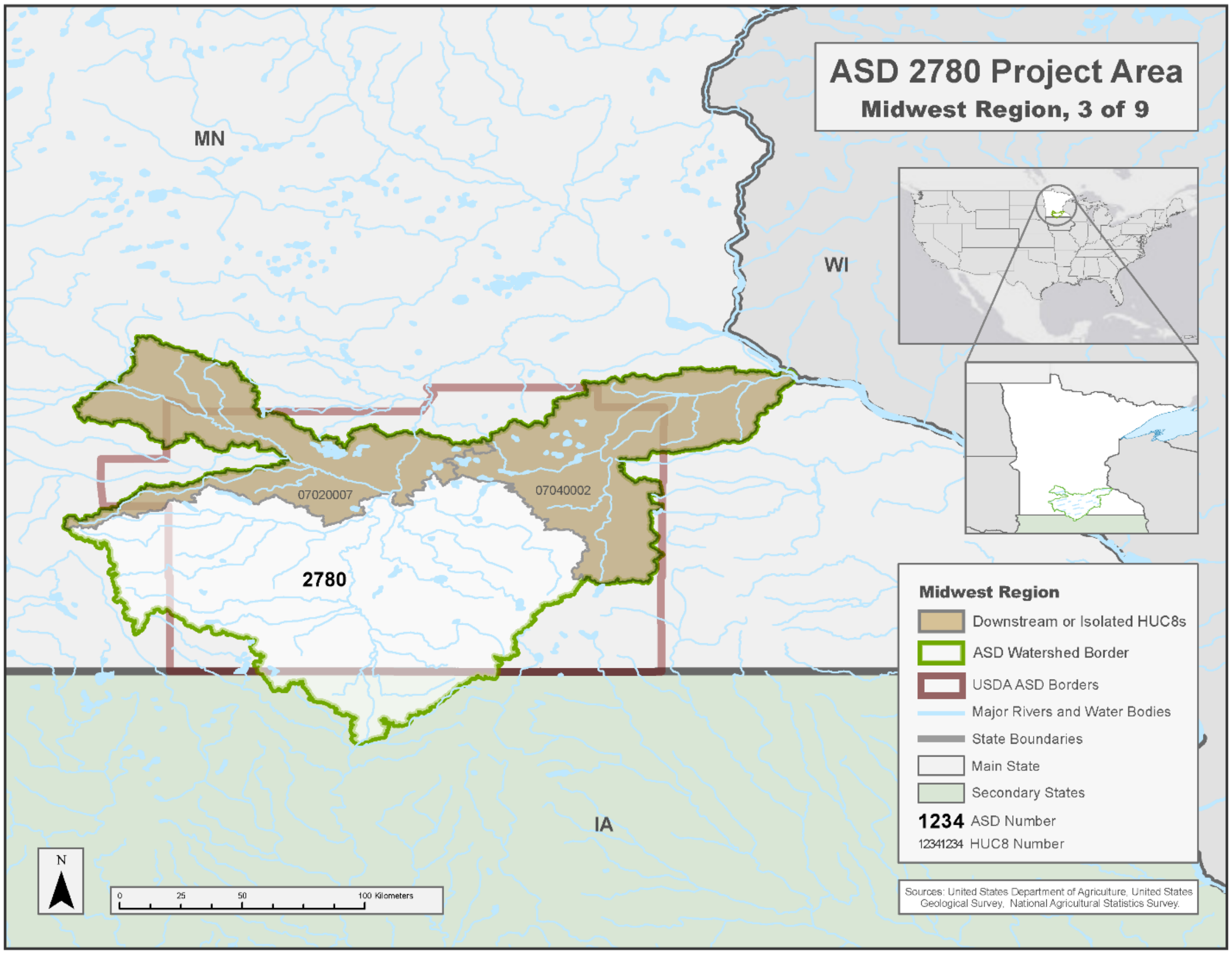
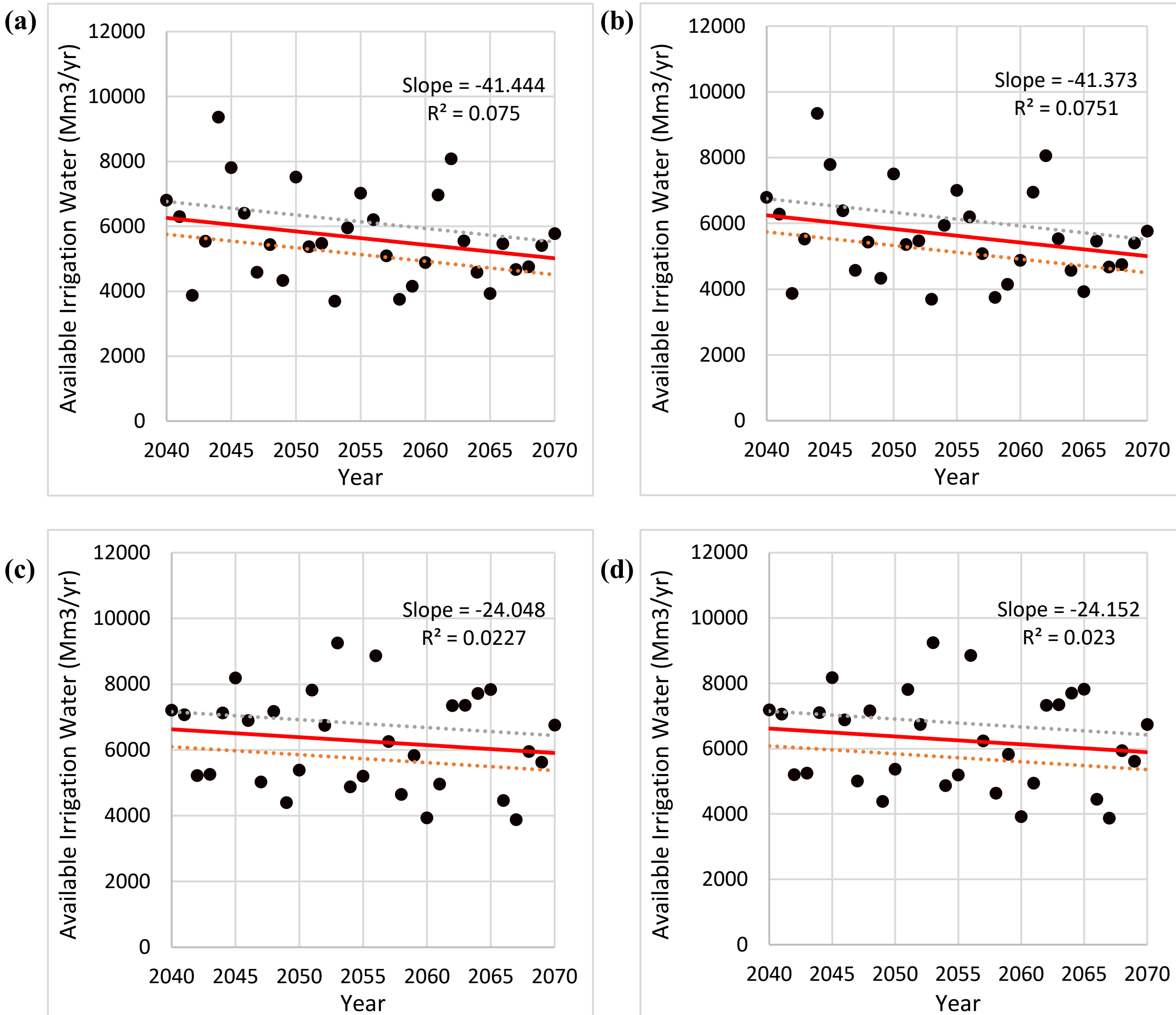


Figure 10. ASD 2780 Watershed Borders: the borders of the ASD modified to include HUC8s meeting inclusion criteria.

Table 9. Irrigation Water Availability Results and Analysis for ASD 2780. Units are in Mm^3/yr. Results for the statistically significant scenarios ($p<0.05$) are in bold.

Parameter\Scenario	Historical	HSAF1	HSBF1	ISAF1	ISBF1	HSAF2	HSBF2	ISAF2	ISBF2
Average	7,689	6,495	6,484	6,724	6,713	**5,637**	**5,626**	**6,267**	**6,254**
Range	12,939	5,880	5,876	5,675	5,667	**5,665**	**5,651**	**5,372**	**5,368**
Change from Historical	----	-1,195	-1,205	-965	-976	**-2,052**	**-2,063**	**-1,422**	**-1,435**
Slope	----	----	----	----	----	**-41.4**	**-41.4**	**-24.0**	**-24.2**
R2	----	----	----	----	----	**0.075**	**0.075**	**0.023**	**0.023**

Figure 11. Scenarios for ASD 2780 with a statistically significant ($p < 0.05$) change in available irrigation water over the scenario's time period: (a) HSAF2, (b) HSBF2, (c) ISAF2, (d) ISBF2



ASD 2790: Projections for ASD 2790 showed significant decrease in ASDiw for all four scenarios (HSAF2, HSBF2, ISAF2 and ISBF2) (Figures 12 and 13, Table 10).

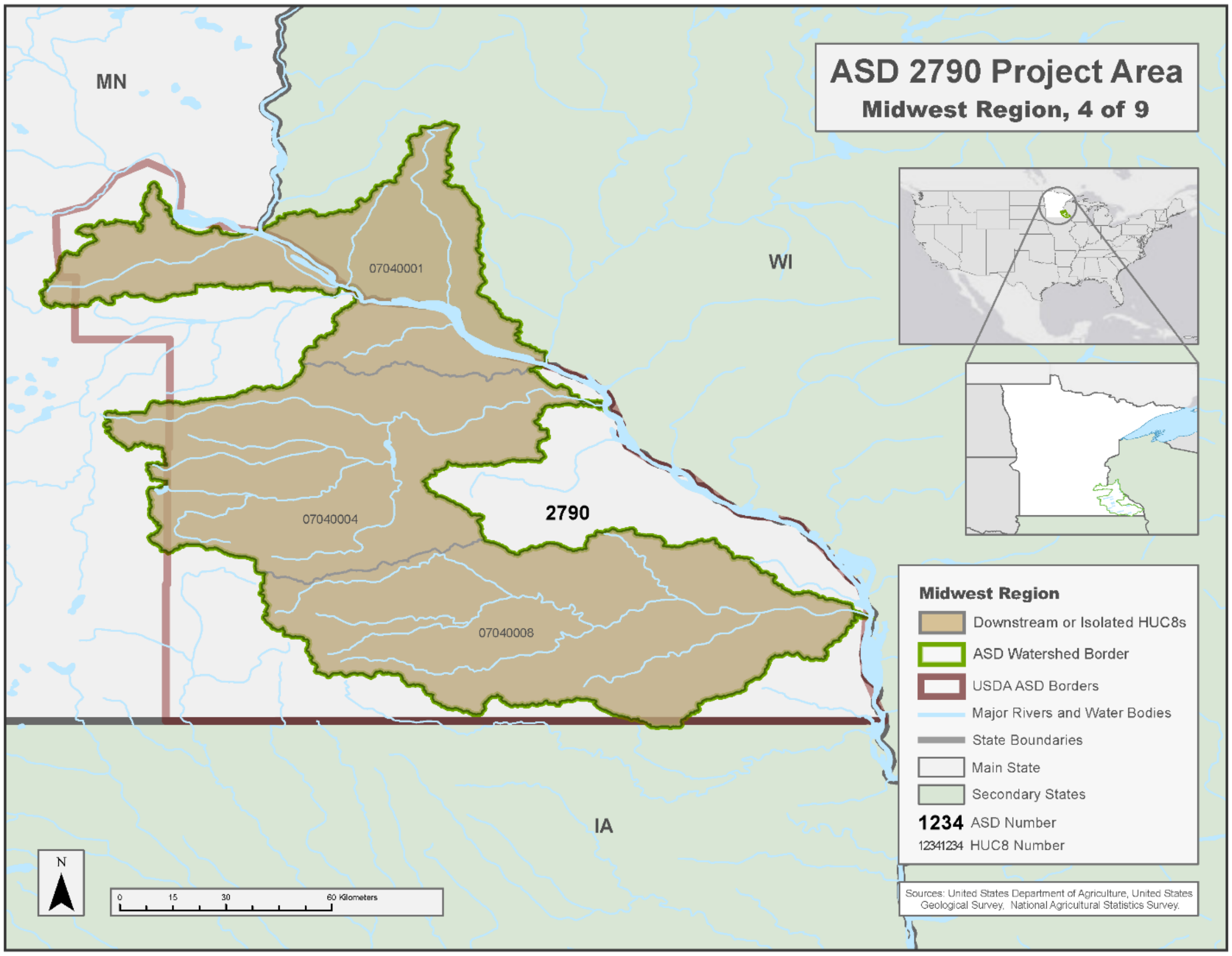
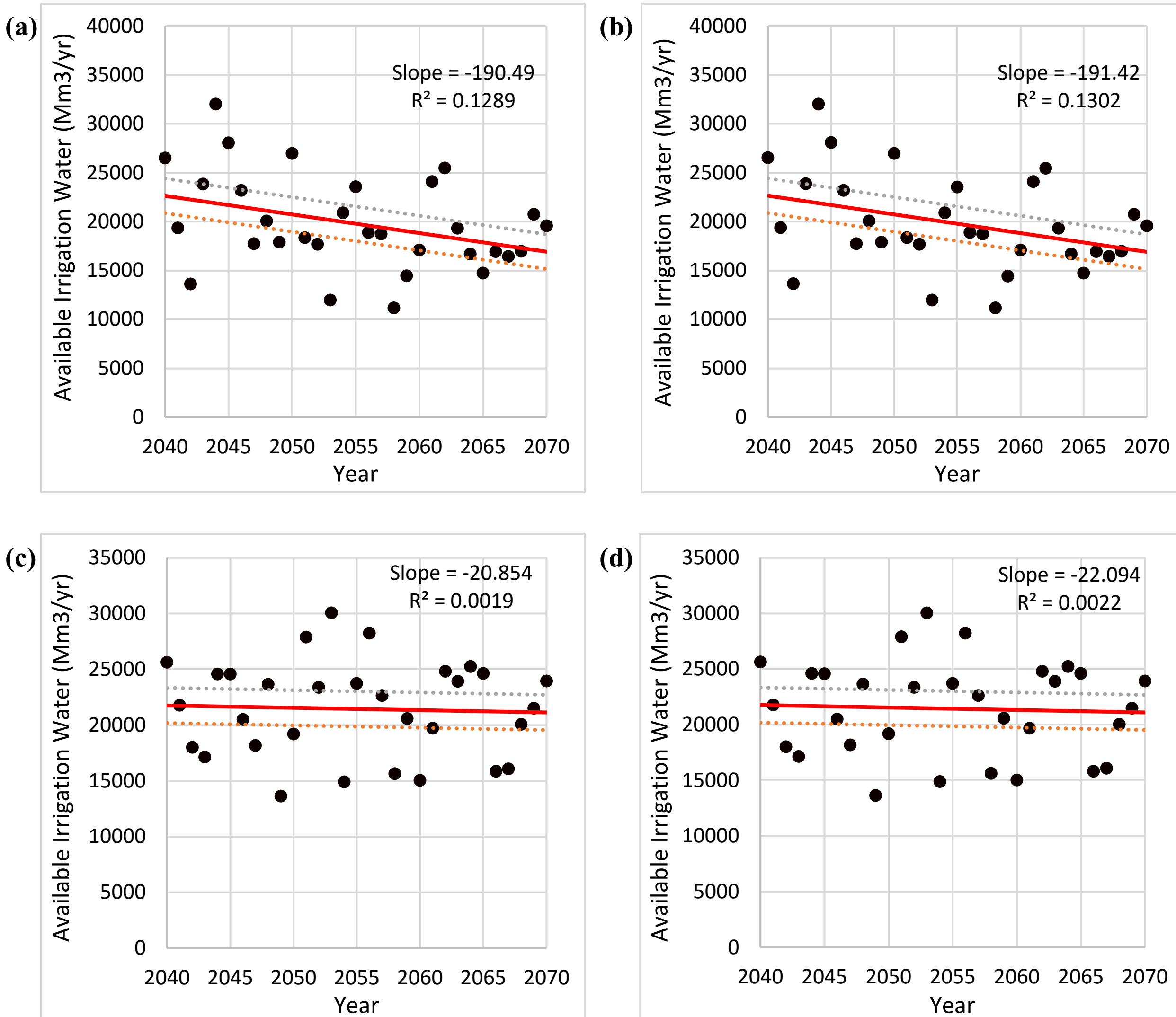


Figure 12. ASD 2790 Watershed Borders: the borders of the ASD modified to include HUC8s meeting inclusion criteria.

Table 10. Irrigation Water Availability Results and Analysis for ASD 2790. Units are in Mm^3/yr. Results for the statistically significant scenarios ($p<0.05$) are in bold.

Parameter\Scenario	Historical	HSAF1	HSBF1	ISAF1	ISBF1	HSAF2	HSBF2	ISAF2	ISBF2
Average	25,425	22,938	22,957	22,575	22,594	**19,782**	**19,781**	**21,444**	**21,440**
Range	33,753	20,378	20,378	16,485	16,495	**20,842**	**20,845**	**16,415**	**16,395**
Change from Historical	----	-2,487	-2,468	-2,850	-2,831	**-5,644**	**-5,645**	**-3,981**	**-3,985**
Slope	----	----	----	----	----	**-190.5**	**-191.4**	**-20.9**	**-22.1**
R2	----	----	----	----	----	**0.129**	**0.130**	**0.002**	**0.002**

Figure 13. Scenarios for ASD 2790 with a statistically significant ($p < 0.05$) change in available irrigation water over the scenario's time period: (a) HSAF2, (b) HSBF2, (c) ISAF2, (d) ISBF2



ASD 5560: Projections for ASD 5560 showed significant decrease in ASDiw for two scenarios,(HSAF2, HSBF2) (Figures 14 and 15, Table 11).

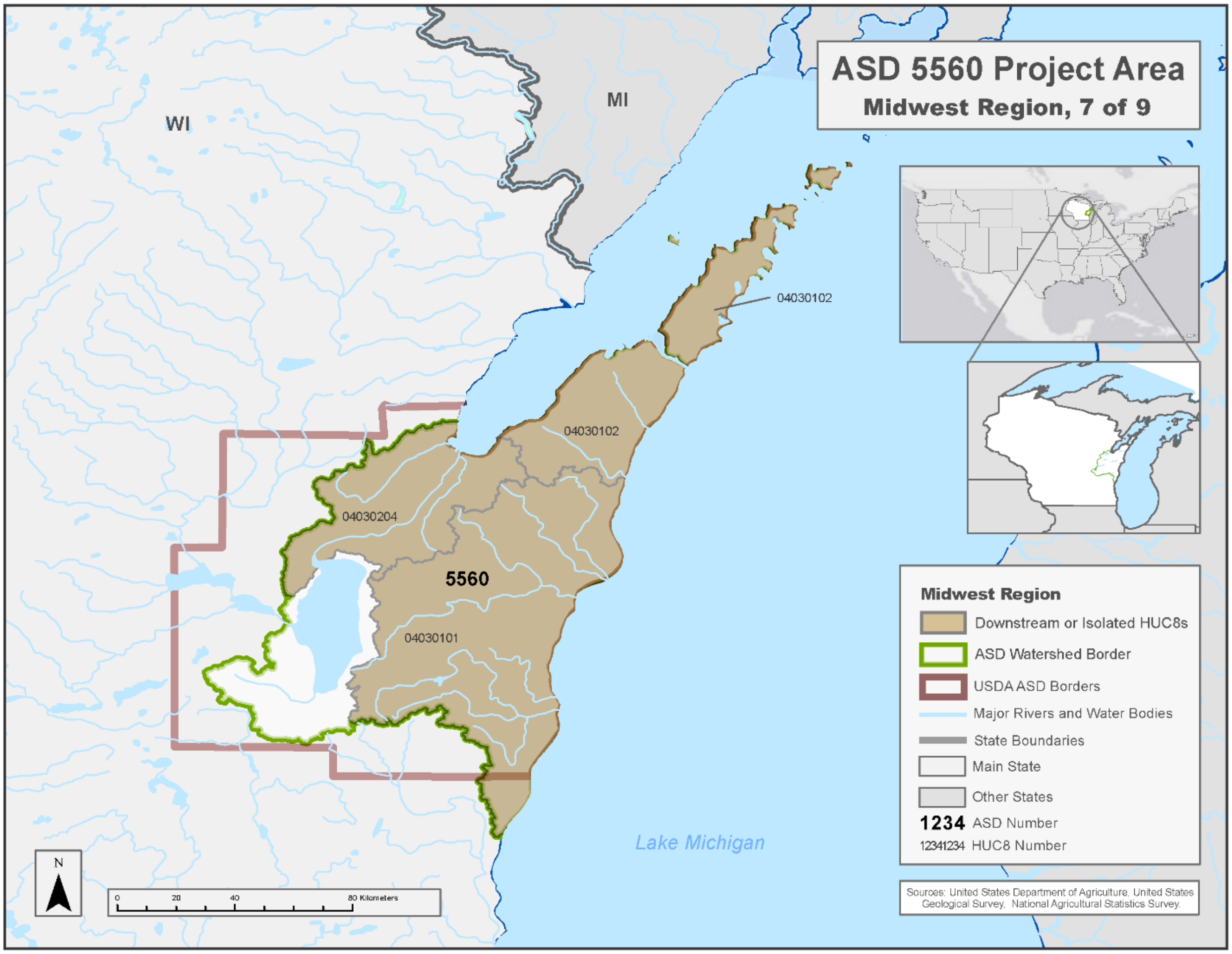
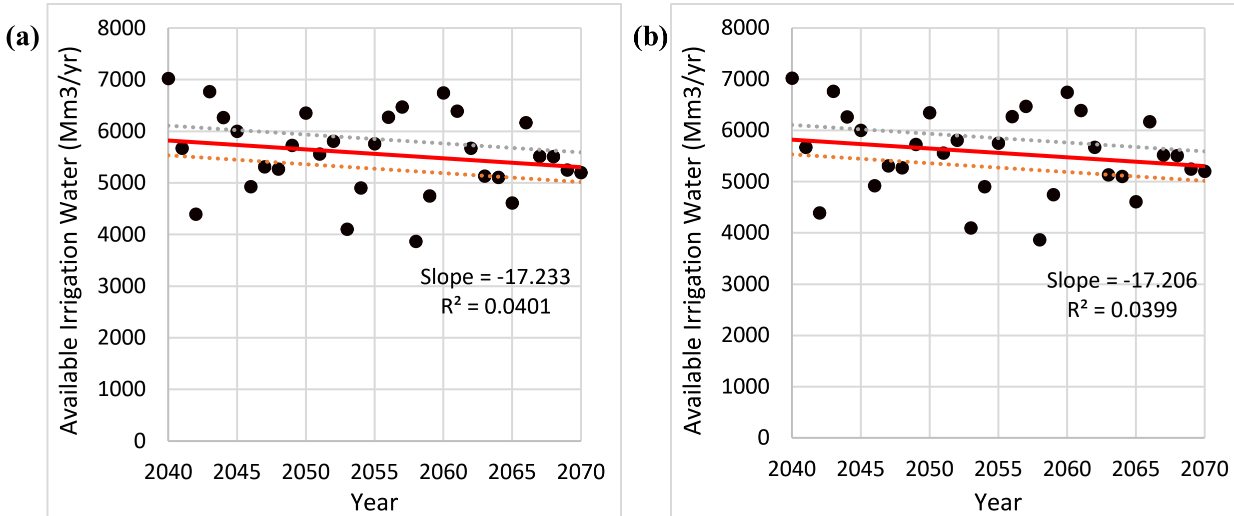


Figure 14. ASD 5560 Watershed Borders: the borders of the ASD modified to include HUC8s meeting inclusion criteria.

Table 11. Irrigation Water Availability Results and Analysis for ASD 5560. Units are in Mm³/yr. Results for the statistically significant scenarios (p<0.05) are in bold.

Parameter\Scenario	Historical	HSAF1	HSBF1	ISAF1	ISBF1	HSAF2	HSBF2	ISAF2	ISBF2
Average	6,169	5,900	5,900	5,701	5,700	**5,562**	**5,562**	5,827	5,826
Range	5,673	3,514	3,514	2,517	2,517	**3,157**	**3,156**	3,595	3,594
Change from Historical	----	-268	-269	-468	-469	**-606**	**-607**	-342	-342
Slope	----	----	----	----	----	**-17.2**	**-17.2**	----	----
R2	----	----	----	----	----	**0.040**	**0.040**	----	----

Figure 15. Scenarios for ASD 5560 with a statistically significant ($p < 0.05$) change in available irrigation water over the scenario's time period: (a) HSAF2, (b) HSBF2



3.2.2. Northeast

ASD 3640: Projections for ASD 3640 showed significant decrease in ASDiw for two scenarios (HSAF2, HSBF2) (Figures 16 and 17, Table 12).

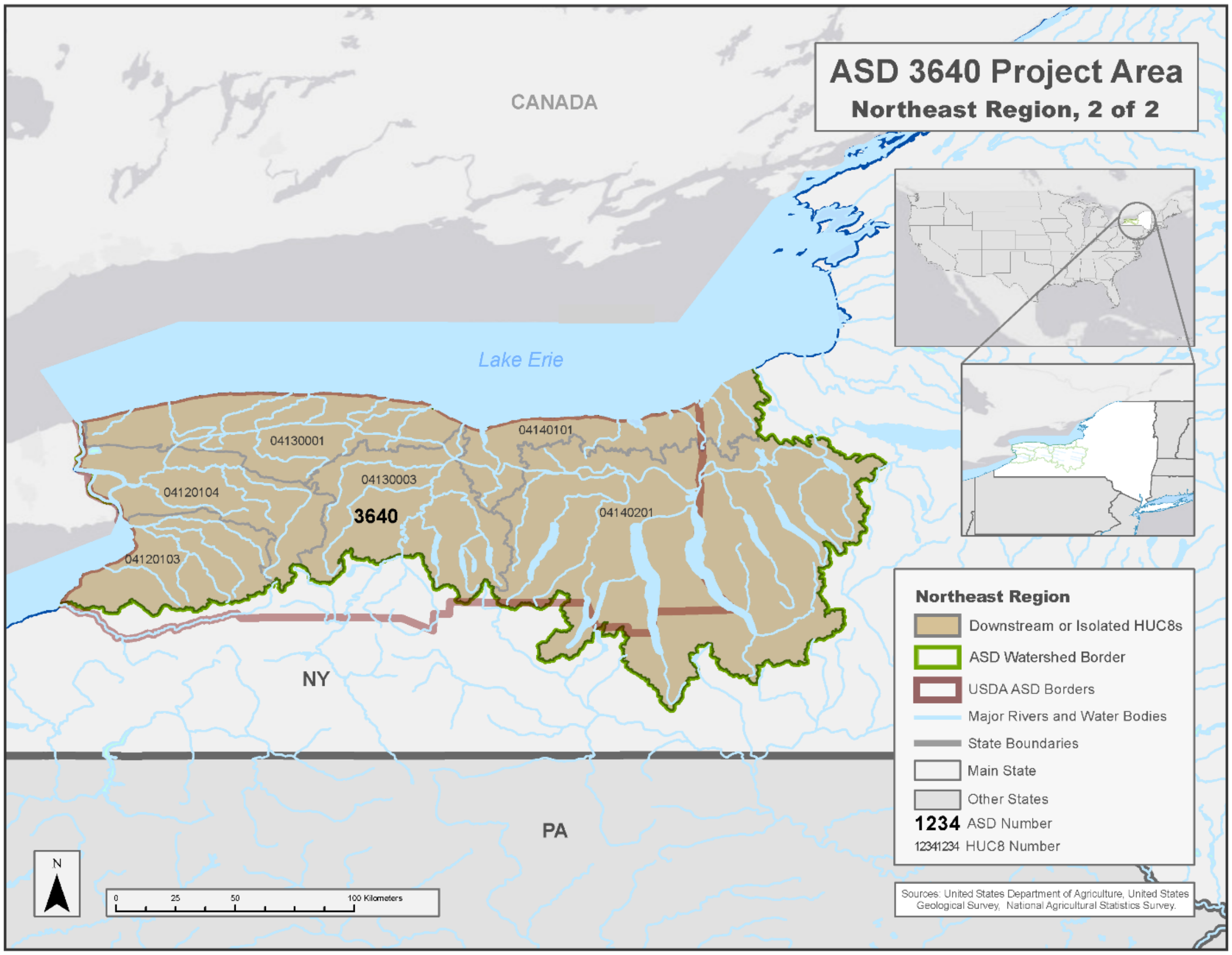
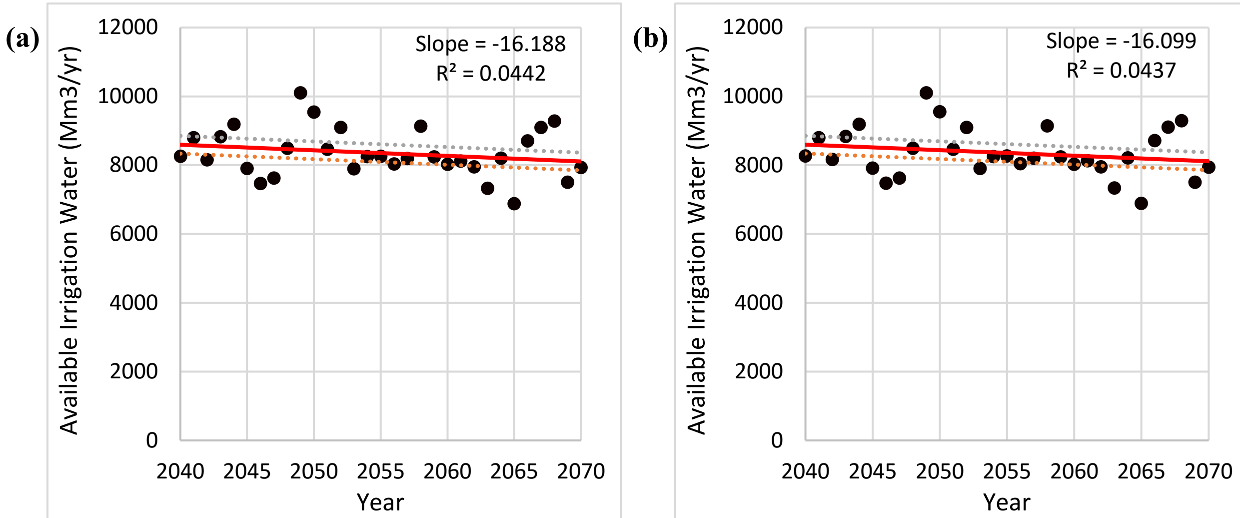


Figure 16. ASD 3640 Watershed Borders: the borders of the ASD modified to include HUC8s meeting inclusion criteria.

Table 12. Irrigation Water Availability Results and Analysis for ASD 3640. Units are in Mm^3/yr. Results for the statistically significant scenarios ($p<0.05$) are in bold.

Parameter\Scenario	Historical	HSAF1	HSBF1	ISAF1	ISBF1	HSAF2	HSBF2	ISAF2	ISBF2
Average	9,036	8,809	8,812	8,644	8,647	**8,351**	**8,355**	8,655	8,660
Range	6,178	3,324	3,324	2,744	2,744	**3,217**	**3,215**	2,537	2,538
Change from Historical	----	-227	-224	-392	-389	**-685**	**-681**	-381	-376
Slope	----	----	----	----	----	**-16.2**	**-16.1**	----	----
R2	----	----	----	----	----	**0.044**	**0.044**	----	----

Figure 17. Scenarios for ASD 3640 with a statistically significant ($p < 0.05$) change in available irrigation water over the scenario's time period: (a) HSAF2, (b) HSBF2



3.2.3. Pacific West

ASD 0650: Projections for ASD 0650 showed significant decrease in ASDiw for two scenarios (HSAF2, HSBF2) (Figures 18 and 19, Table 13).

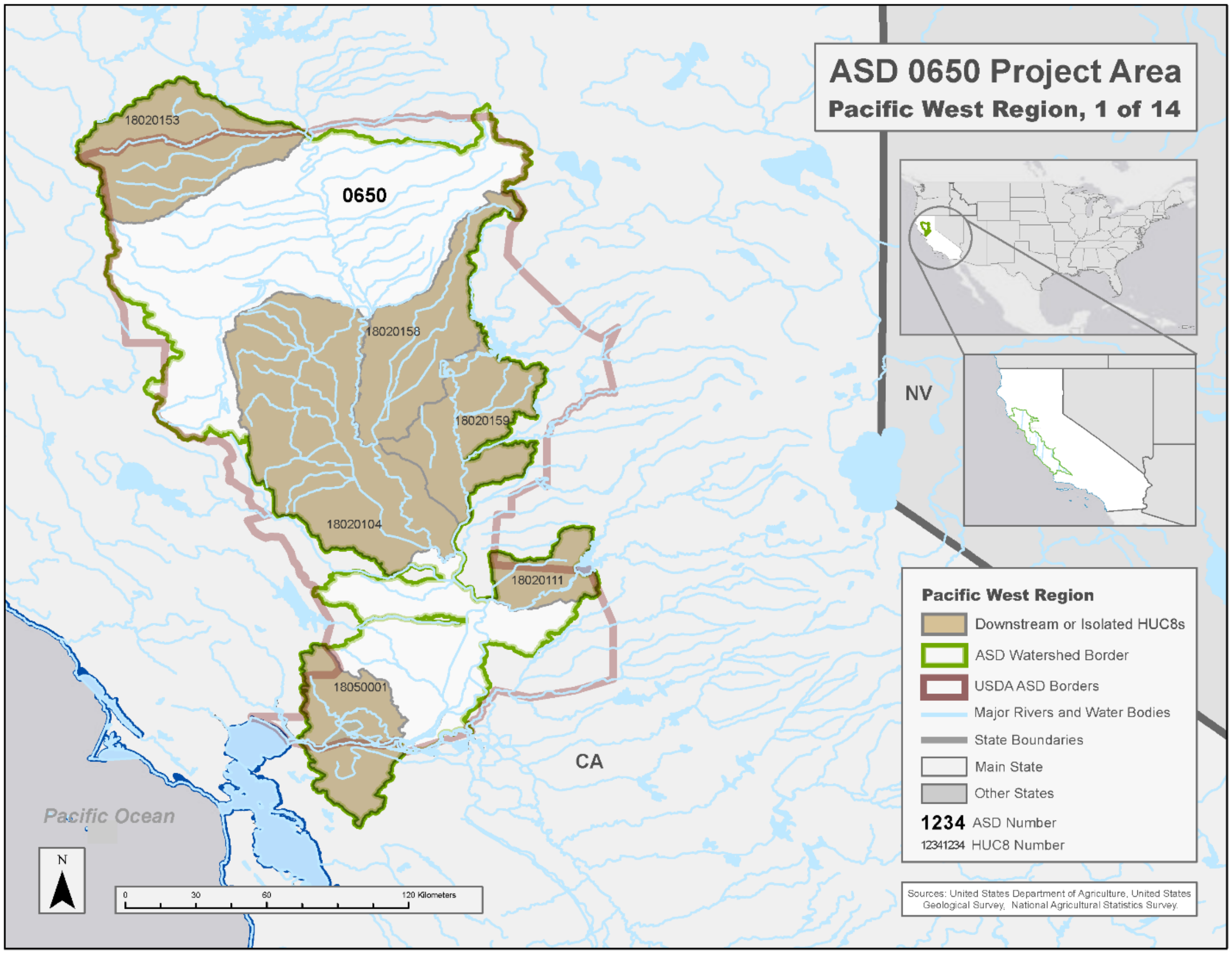
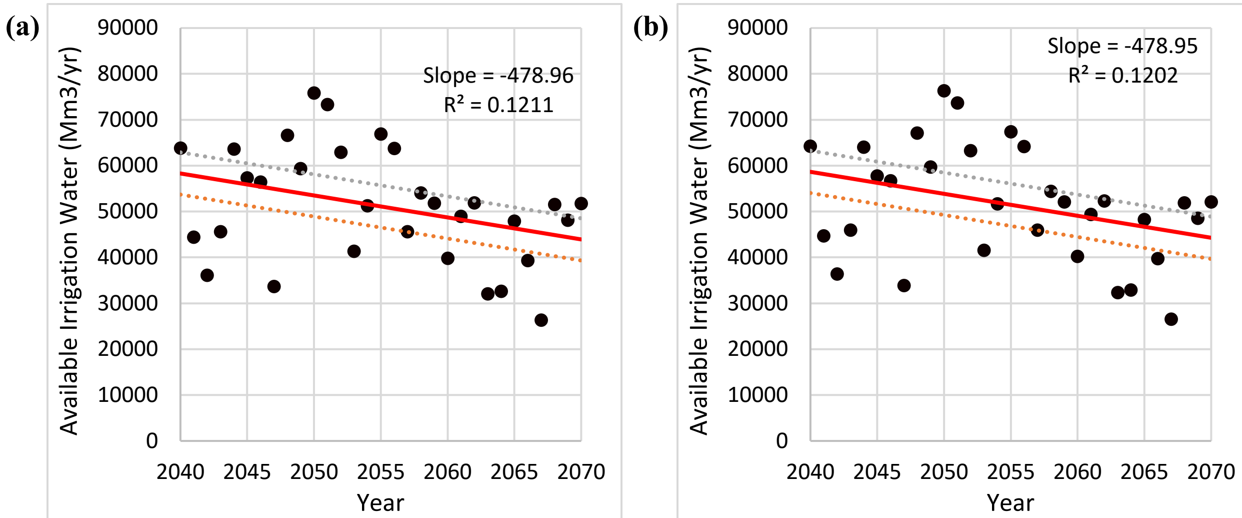


Figure 18. ASD 0650 Watershed Borders: the borders of the ASD modified to include HUC8s meeting inclusion criteria.

Table 13. Irrigation Water Availability Results and Analysis for ASD 0650. Units are in Mm^3/yr. Results for the statistically significant scenarios ($p<0.05$) are in bold.

Parameter\Scenario	Historical	HSAF1	HSBF1	ISAF1	ISBF1	HSAF2	HSBF2	ISAF2	ISBF2
Average	63,745	58,727	59,034	55,668	55,978	**51,111**	**51,468**	55,161	55,548
Range	112,694	62,150	62,293	46,438	46,215	**49,489**	**49,751**	38,133	38,227
Change from Historical	----	-5,018	-4,711	-8,077	-7,766	**-12,634**	**-12,277**	-8,583	-8,197
Slope	----	----	----	----	----	**-479.0**	**-479.0**	----	----
R2	----	----	----	----	----	**0.121**	**0.120**	----	----

Figure 19. Scenarios for ASD 0650 with a statistically significant ($p < 0.05$) change in available irrigation water over the scenario's time period: (a) HSAF2, (b) HSBF2



ASD 5320: Projections for ASD 5320 showed significant positive changes (increases) in ASD_{iw} for four F1 scenarios (Figures 20 and 21, Table 14). The amount increase projected in this ASD_{iw} was less than 15% for all scenarios (Figures 20 and 21, Table 14). The R2 for all these projections were less than 0.1, a measure of the high variability between years in projected ASD_{iw}, and an indication of high variability in the hydrologic system under climate change stress.

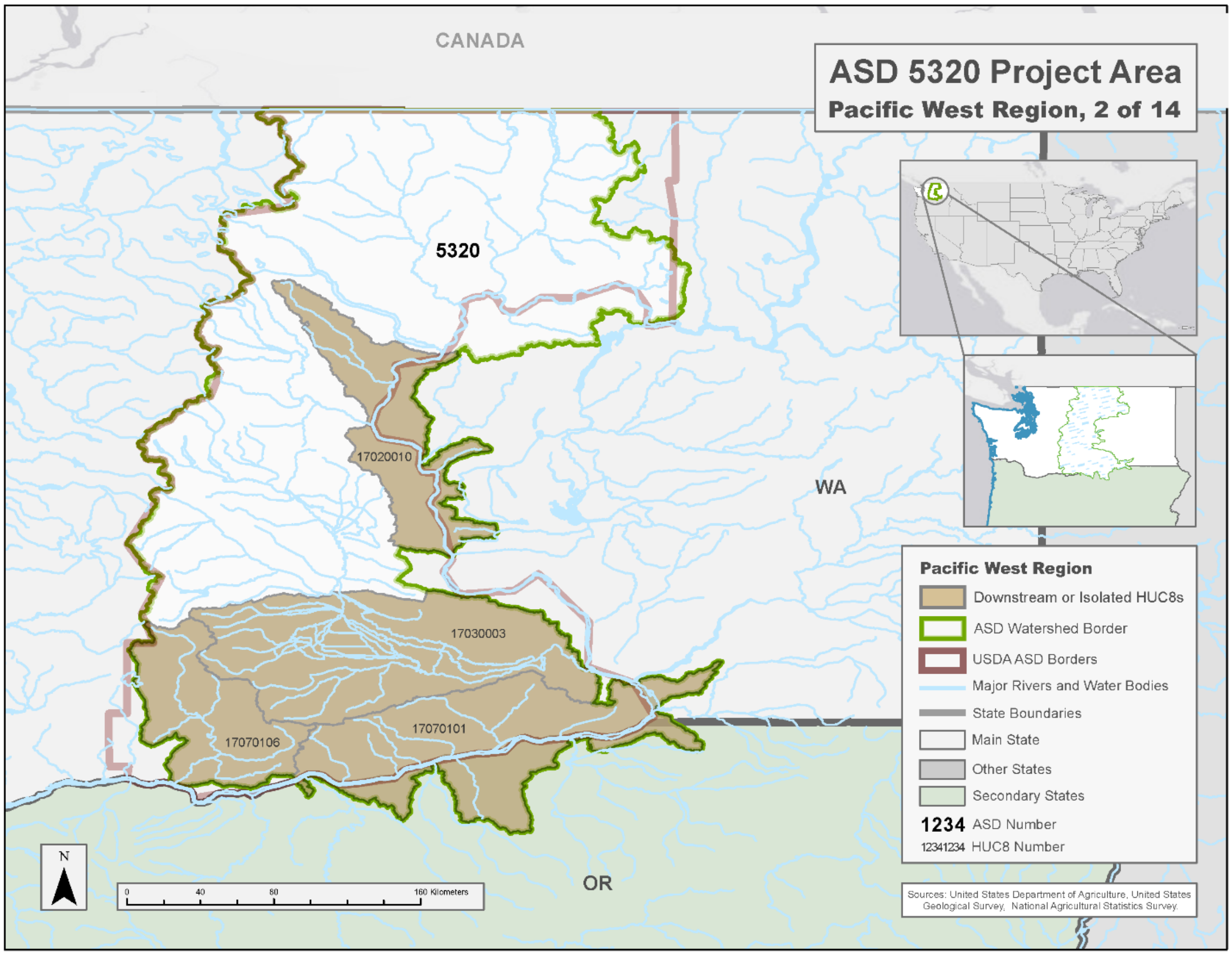
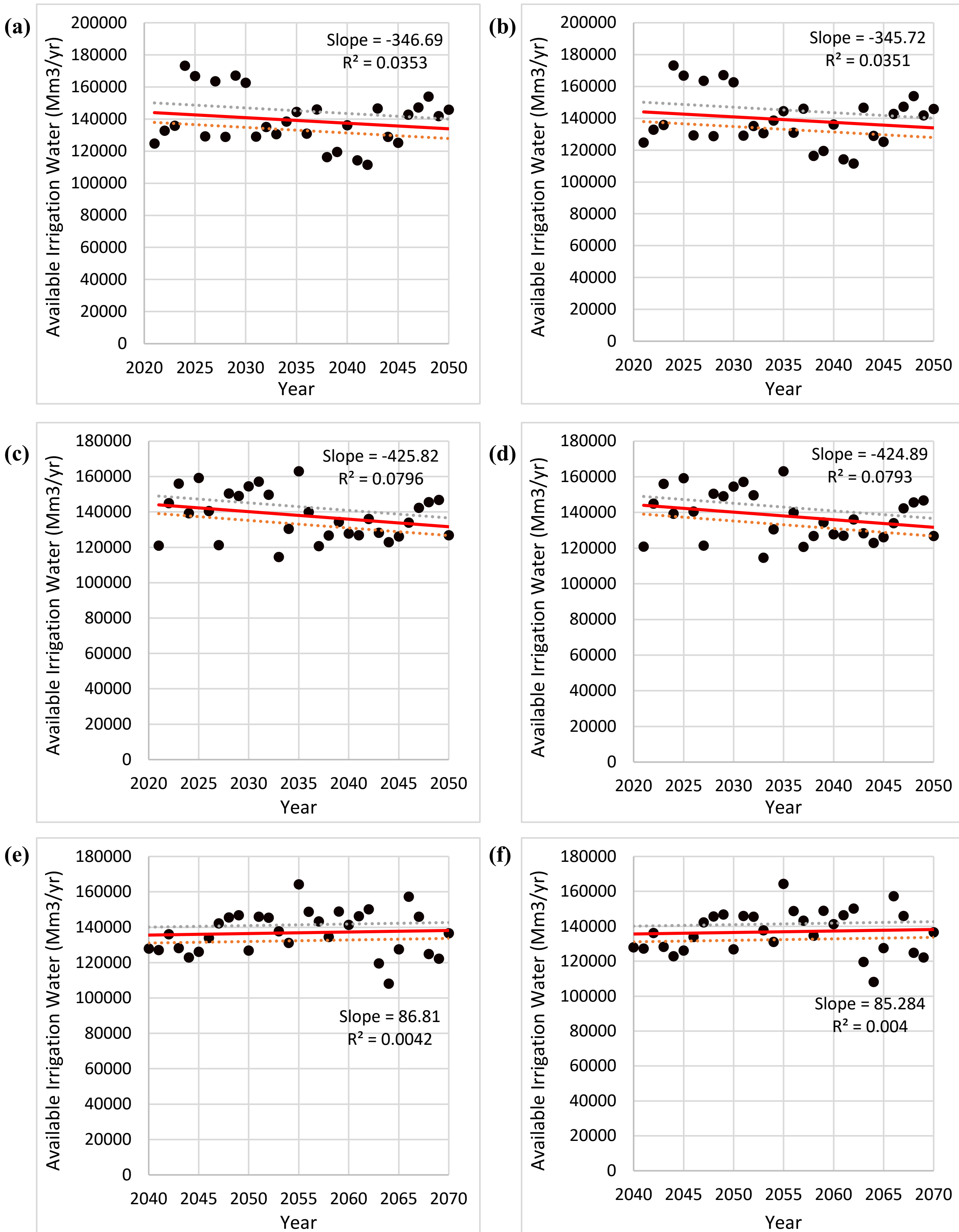


Figure 20. ASD 5320 Watershed Borders: the borders of the ASD modified to include HUC8s meeting inclusion criteria.

Table 14. Irrigation Water Availability Results and Analysis for ASD 5320. Units are in Mm^3/yr. Results for the statistically significant scenarios ($p<0.05$) are in bold.

Parameter\Scenario	Historical	HSAF1	HSBF1	ISAF1	ISBF1	HSAF2	HSBF2	ISAF2	ISBF2
Average	121,340	**138,954**	**138,994**	**137,817**	**137,857**	133,405	133,430	**136,866**	**136,890**
Range	138,752	**61,741**	**61,697**	**48,443**	**48,437**	60,586	60,572	**56,205**	**56,197**
Change from Historical	----	**17,614**	**17,654**	**16,477**	**16,516**	12,065	12,090	**15,526**	**15,550**
Slope	----	**-346.7**	**-345.7**	**-425.8**	**-424.9**	----	----	**86.8**	**85.3**
R2	----	**0.035**	**0.035**	**0.080**	**0.079**	----	----	**0.004**	**0.004**

Figure 21. Scenarios for ASD 5320 with a statistically significant ($p < 0.05$) change in available irrigation water over the scenario's time period: (a) HSAF1, (b) HSBF1, (c) ISAF1, (d) ISBF1, (e) ISAF2, (f) ISBF2



ASD 5350: Projected ASD 5320 ASD_{iw} showed significant increases (Figures 22 and 23, Table 15). The amount increase projected in this ASD_{iw} was less than 13% for all scenarios The R2 for all these projections were less than 0.1, a measure of the high variability between years in projected ASD_{iw}, and an indication of high variability in the hydrologic system under climate change stress.

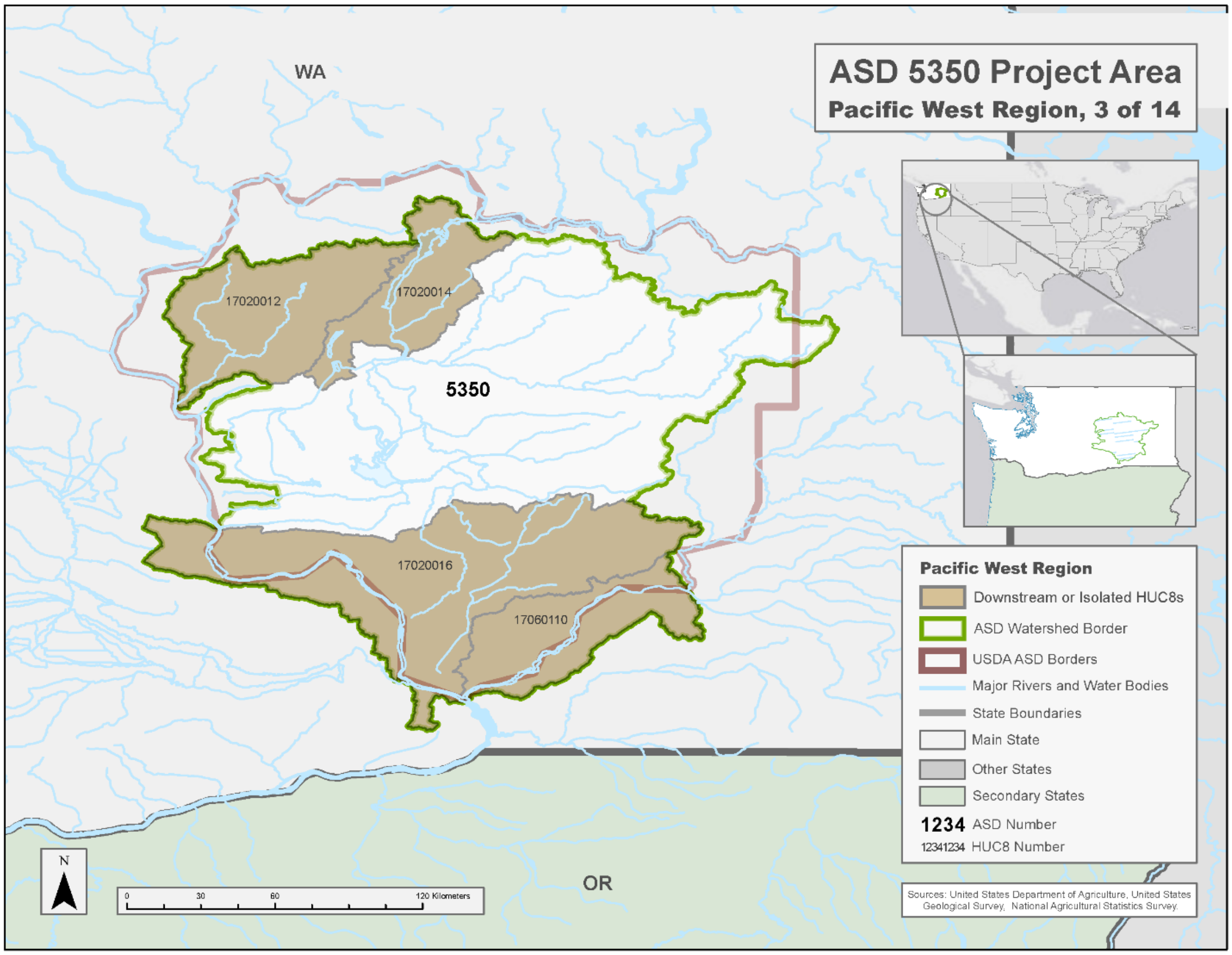
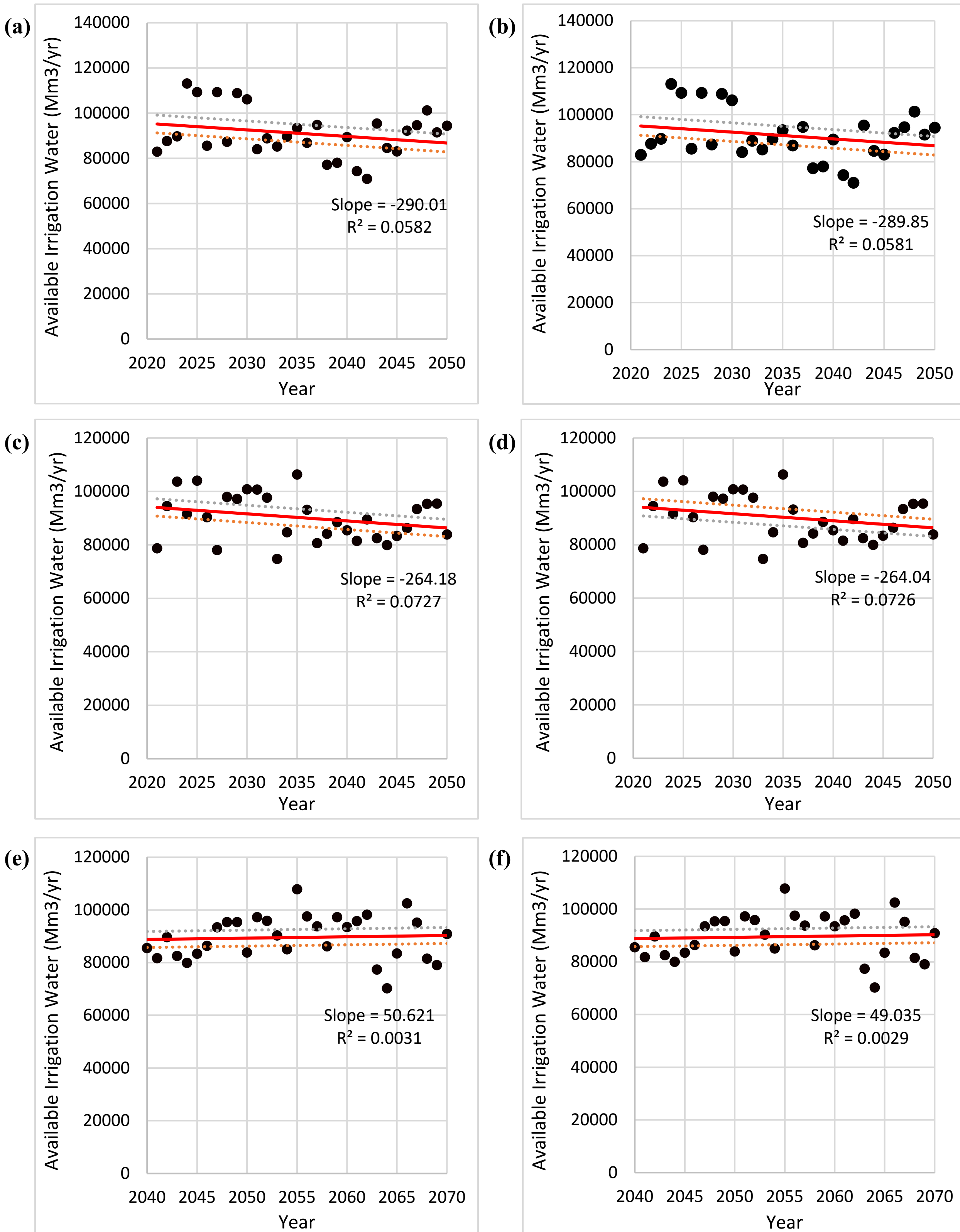


Figure 22. ASD 5350 Watershed Borders: the borders of the ASD modified to include HUC8s meeting inclusion criteria.

Table 15. Irrigation Water Availability Results and Analysis for ASD 5350. Units are in Mm^3/yr. Results for the statistically significant scenarios are in bold.

Parameter\Scenario	Historical	HSAF1	HSBF1	ISAF1	ISBF1	HSAF2	HSBF2	ISAF2	ISBF2
Average	80,406	**90,978**	**90,989**	**90,148**	**90,159**	86,834	86,828	**89,543**	**89,536**
Range	89,663	**42,113**	**42,102**	**31,650**	**31,646**	39,488	39,512	**37,555**	**37,561**
Change from Historical	----	**10,572**	**10,583**	**9,742**	**9,753**	6,428	6,422	**9,137**	**9,130**
Slope	----	**-290.0**	**-289.9**	**-264.2**	**-264.0**	----	----	**50.6**	**49.0**
R2	----	**0.058**	**0.058**	**0.073**	**0.073**	----	----	**0.003**	**0.003**

Figure 23. Scenarios for ASD 5350 with a statistically significant ($p < 0.05$) change in available irrigation water over the scenario's time period: (a) HSAF1, (b) HSBF1, (c) ISAF1, (d) ISBF1, (e) ISAF2, (f) ISBF2



3.2.4. Plains

ASD 3830: Projections for ASD 3830 showed significant decrease in ASDiw for six scenarios (Figures 24 and 25, Table 13).

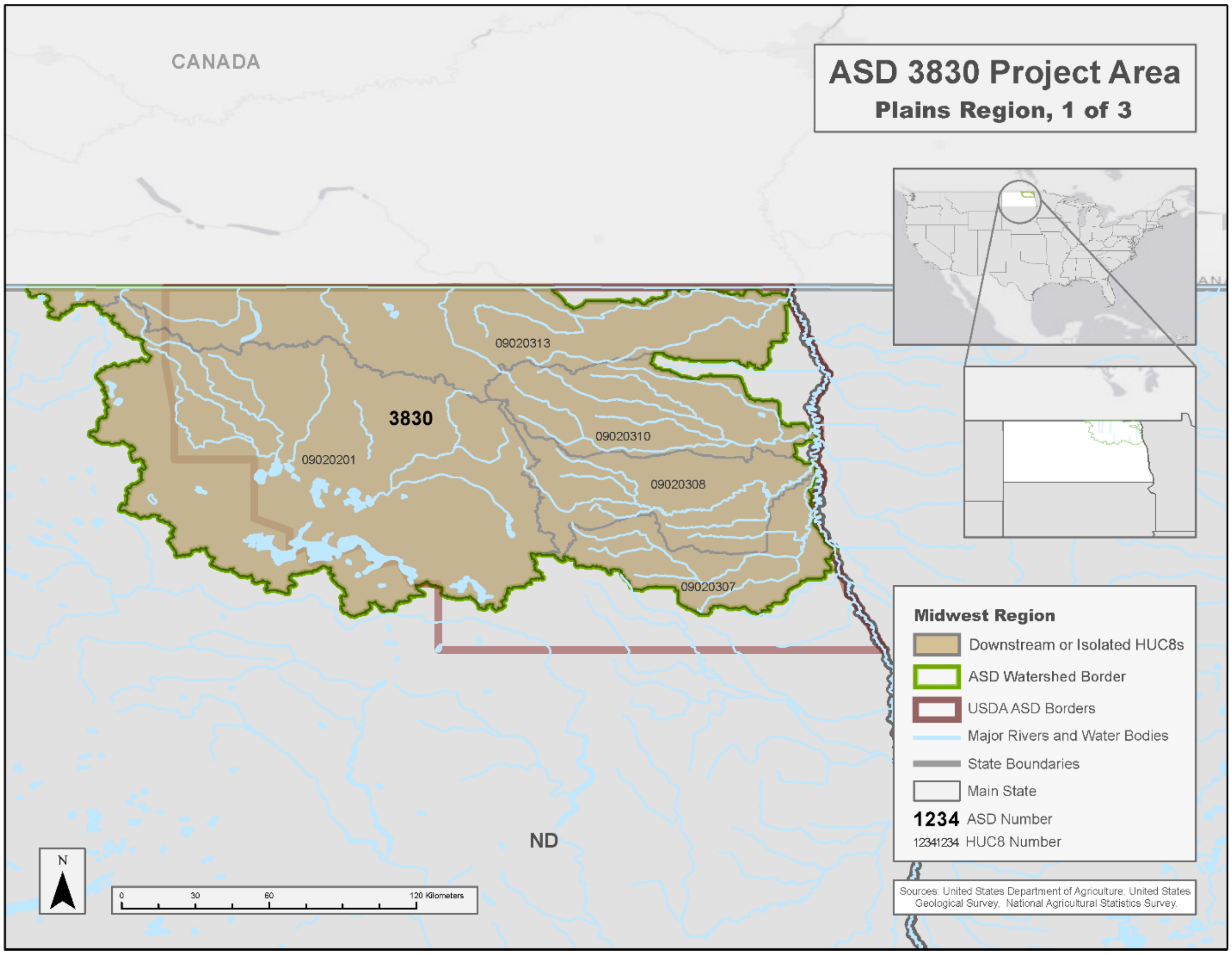
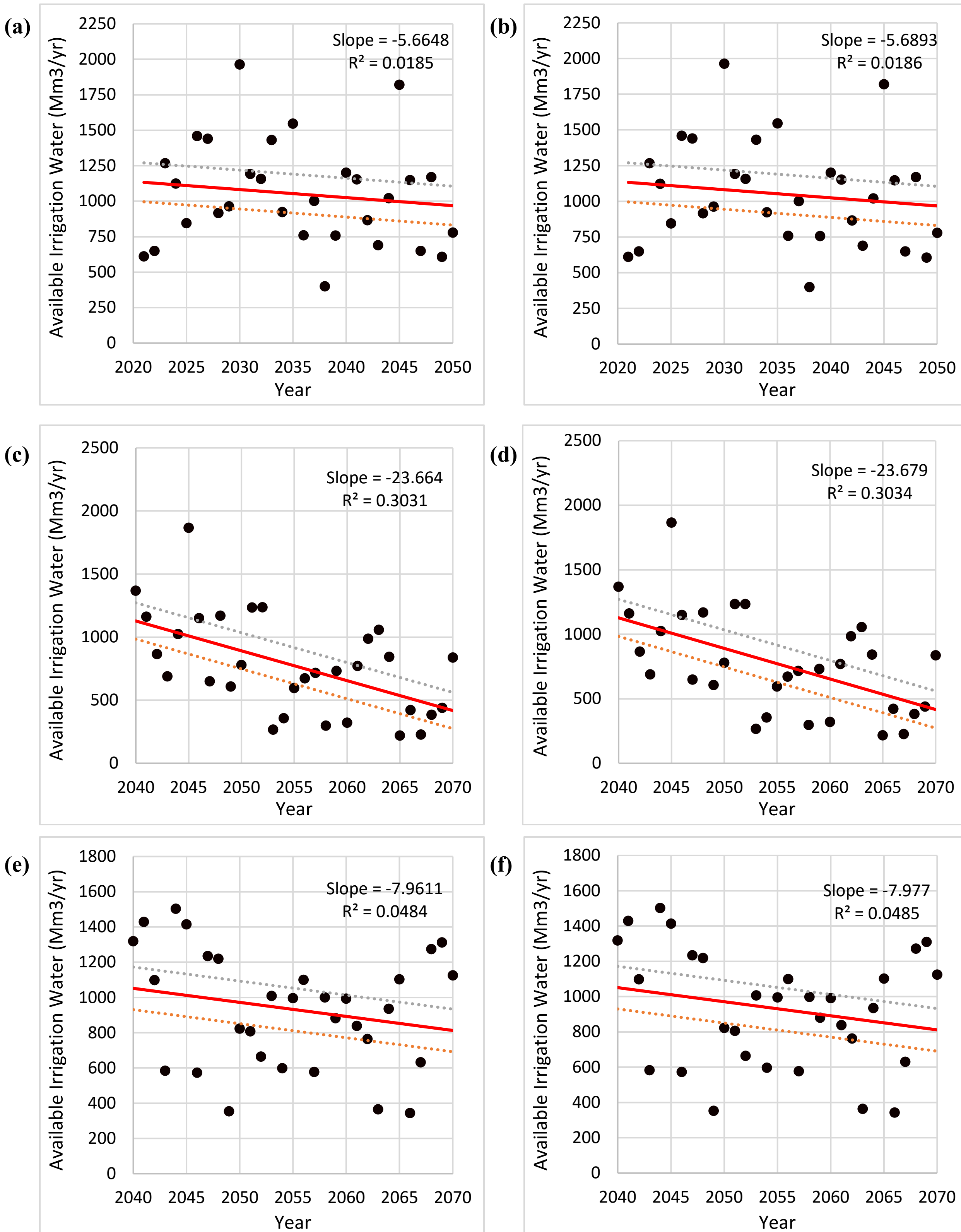


Figure 24. ASD 3830 Watershed Borders: the borders of the ASD modified to include HUC8s meeting inclusion criteria.

Table 16. Irrigation Water Availability Results and Analysis for ASD 3830. Units are in Mm^3/yr. Results for the statistically significant scenarios ($p<0.05$) are in bold.

Parameter\Scenario	Historical	HSAF1	HSBF1	ISAF1	ISBF1	HSAF2	HSBF2	ISAF2	ISBF2
Average	1,423	**1,051**	**1,050**	1,251	1,250	**773**	**772**	**932**	**931**
Range	3,096	**1,563**	**1,564**	1,720	1,720	**1,648**	**1,648**	**1,160**	**1,160**
Change from Historical	----	**-372**	**-372**	-172	-172	**-650**	**-651**	**-490**	**-491**
Slope	----	**-5.7**	**-5.7**	----	----	**-23.7**	**-23.7**	**-8.0**	**-8.0**
R2	----	**0.019**	**0.019**	----	----	**0.303**	**0.303**	**0.048**	**0.049**

Figure 25. Scenarios for ASD 3830 with a statistically significant ($p < 0.05$) change in available irrigation water over the scenario's time period: (a) HSAF1, (c) HSBF1, (c) HSAF2, (d) HSBF2, (e) ISAF2, (f) ISBF2



3.2.5. Southeast

ASD 1280: Projections for ASD 1280 showed significant decrease in ASDiw for two scenarios (HSAF2, HSBF2) (Figures 26 and 27, Table 17).

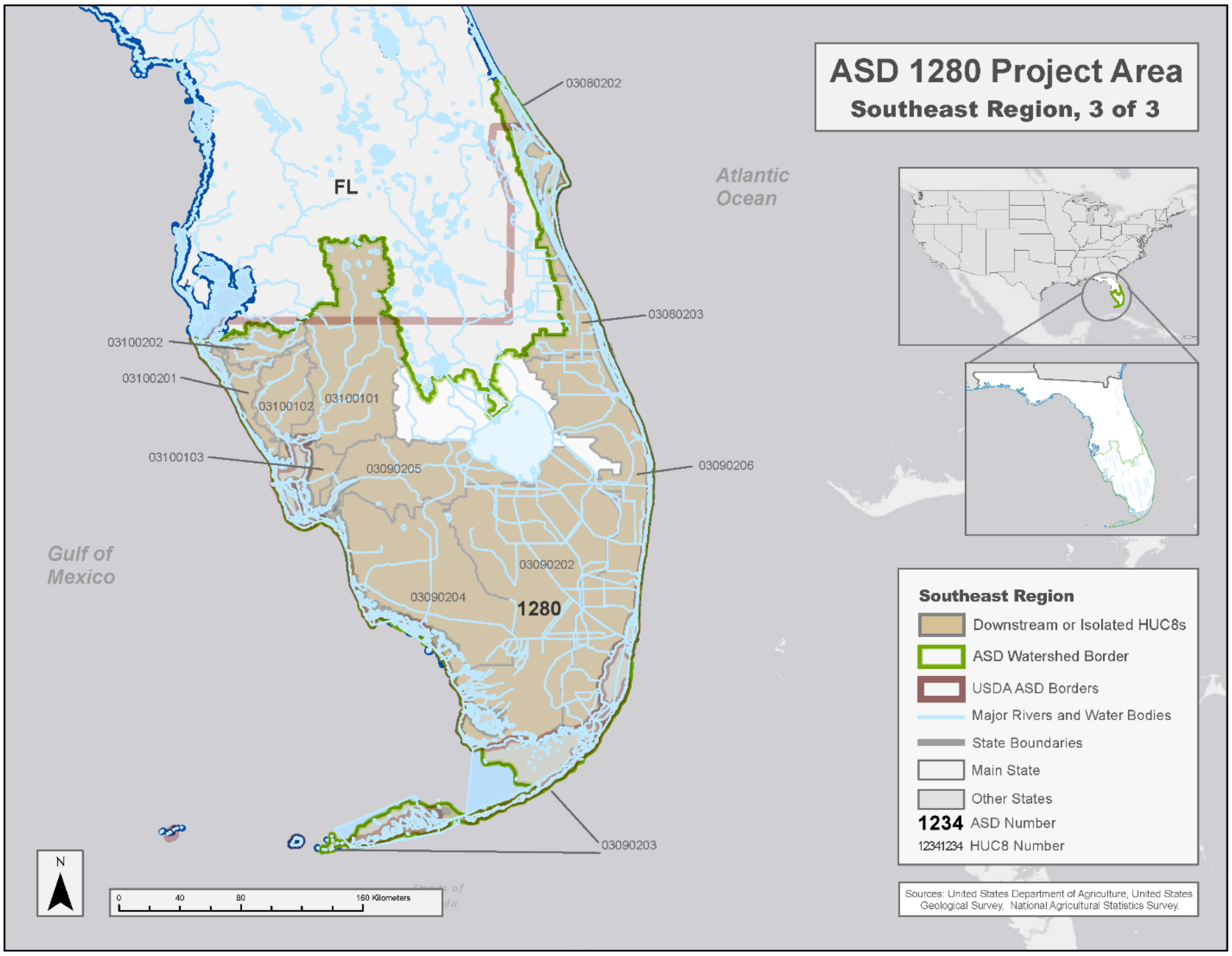
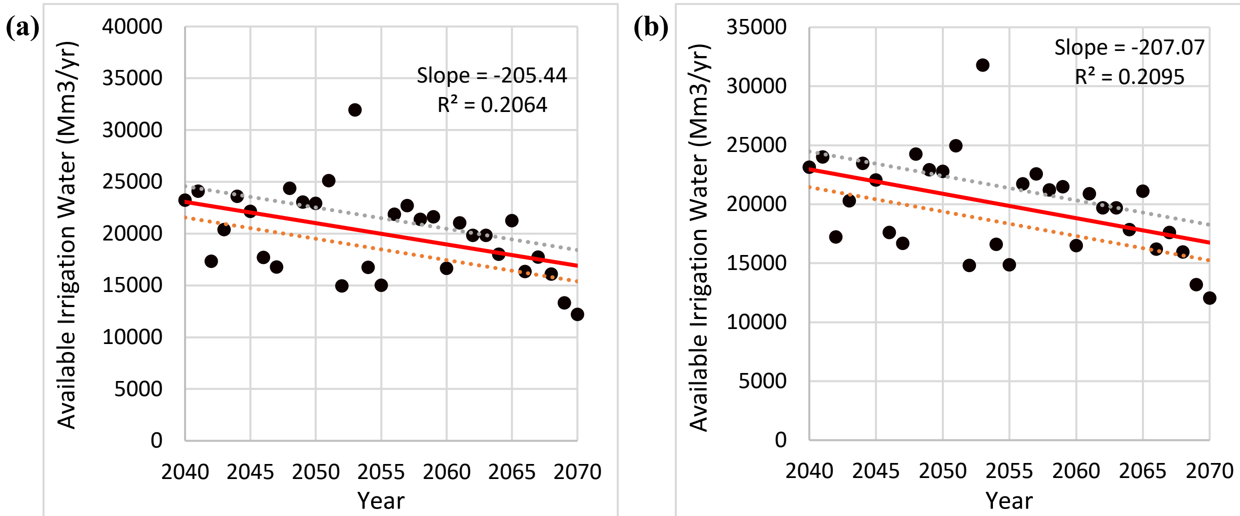


Figure 26. ASD 1280 Watershed Borders: the borders of the ASD modified to HUC8s meeting inclusion criteria.

Table 17. Irrigation Water Availability Results and Analysis for ASD 1280. Units are in Mm^3/yr. Results for the statistically significant scenarios ($p<0.05$) are in bold.

Parameter\Scenario	Historical	HSAF1	HSBF1	ISAF1	ISBF1	HSAF2	HSBF2	ISAF2	ISBF2
Average	23,855	22,884	22,790	24,270	24,176	**19,988**	**19,854**	21,727	21,590
Range	24,093	19,034	19,072	23,749	23,764	**19,749**	**19,753**	23,632	23,624
Change from Historical	----	-971	-1,066	415	321	**-3,867**	**-4,002**	-2,128	-2,265
Slope	----	----	----	----	----	**-205.4**	**-207.1**	----	----
R2	----	----	----	----	----	**0.206**	**0.210**	----	----

Figure 27. Scenarios for ASD 1280 with a statistically significant ($p < 0.05$) change in available irrigation water over the scenario's time period: (a) HSAF2, (b) HSBF2



4. CONCLUSION

The major conclusion from this risk assessment is that for more than 38% (12 of 31) ASDs, the surface water available for irrigation use from 2040 to 2070 is projected to be less than it was in 1981 to 2010. More than 75% of the 248 modelled ASD scenarios have a trend towards decreasing values over time, with 58% projected average available irrigation water were significantly lower (α=0.05). The largest change in the magnitude of available irrigation water values is between the two time periods, with the F2 input generally resulting in a greater change in average available water from the Historical scenario (77%).

Of the portfolio of 248 scenarios, 44 (18%) had P-values of less than 0.05 and thus predicted statistically significant change in available irrigation water (ASD_{iw}) compared to that ASD's HIST (Appendix B). However, only 16 scenarios in six ASDs had significant slopes (α=0.05) that resulted in impactful potential changes in ASD_{iw} (greater than 0.1 percent). The Midwest has the largest number ASDs with significant changes in ASD_{iw} (six ASDs with 20 significant scenarios). The Pacific West, despite being the region with the most ASDs, only has three ASDs with significant scenarios, though 14 scenarios in the region were significantly different. The Northeast, Plains, and Southeast regions each had one ASD with significantly different scenarios.

The simulations of far future (F2) projected 34 of the 44 significant changes in ASD_{iw}. The high stress climate scenario simulations had more significant scenarios than the intermediate stress ones (26 and 18, respectively). The population parameters, however, had an equal number of significant scenarios, both with 22, suggesting that the A and B population scenarios did not drive changes in ASDiw. Only four F1 significant ASD scenarios did not have an associated F2 scenario with significant changes (HSAF2 and HSBF2 for both ASD 5320 and 5350), suggesting strong continuity in projections across the near- and far-terms. These four ASD scenarios are. Those four HS scenarios are located in the Pacific West region, the most variable of all the regions.

There were strong regional trends in results from these analyses. The Pacific West accounted for 75% of the 105 ASD scenarios that projected an increase in average water availability. However only two ASDs (5320 and 5350), located in the middle of the Cascade Mountain Range in Washington, had statistically significant increases in average available irrigation water. These findings support the need to improve water use efficiency across all sectors but more importantly, reduce global GHG emissions to reduce the projected radiative forcing posed by these scenarios to lessen the potential impact on US crop systems.

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APPENDIX A: EXPANDED METHODS

Routing

In order to most accurately project surface water supply in the ASDs using output from WaSSI, the same routing data between HUC8s needed to be used that the WaSSI model uses. The format of the routing matrix in the WaSSI model is seen in Table A-1 Each number corresponds to an ID number for each HUC8. The -9999 values are blank values that do not correspond to a HUC.

Table A-1. Screen capture of routing data read by Fortran code. Entire Matrix is 1245 rows X 33 columns

1	2	-9999
1	3	-9999
4	-9999	-9999
5	-9999	-9999
16	-9999	-9999
17	10	6
-9999	10	8
-9999	10	9
-9999	13	12
18	13	11
18	15	14
19	-9999	-9999
20	-9999	-9999
21	-9999	-9999
23	-9999	-9999
27	22	-9999
27	24	-9999
27	25	-9999
27	26	-9999

Table A-2. Routing matrix with ID numbers replaced by 8-digit HUC codes

1010001	1010002		
1010001	1010003		
1010004			
1010005			
1050001			
1050002	1020005	1020001	1020002
	1020005	1020003	
	1020005	1020004	
	1030003	1030002	
1050003	1030003	1030001	
1050003	1040002	1040001	
1060001			
1060002			
1060003			
1070002			
1070006	1070001		
1070006	1070003		
1070006	1070004		
1070006	1070005		
		1080106	1080105
		1080106	1080107
	1080201	1080202	
	1080201	1080203	

The ID numbers were replaced with the 8-digit codes to give a table like that shown in Table A-1.

The table is meant to be read from right to left with headwater HUC8s starting on the right and ocean or international boundaries in the leftmost column. Each column of the table was then pasted in a reverse order to give a mirror image of the data so that the data could be read from left to right. This way the column all the way on the right would be the HUCs flowing into oceans or international boundaries. This action was done to allow for a new table of two columns to be created at the end of this table. The table of two columns contains a 'FROM' and a 'TO' column. The 'FROM' column corresponds to the

HUC that the water is leaving and the 'TO' column corresponds to the HUC that is receiving water (if applicable). Table A-3 shows what part of the newly created table looks like.

Table A-3. Flow FROM and flow TO table example

FROM	TO
18100204	None
12040101	12040104
11080003	11080006
11140306	11140304
5030104	5030101
12070101	12070104
6010107	6010201
15020014	15020013
14070004	14070001
12100303	12100204
14080106	14080105
9030004	9030008
15020018	15020016
18100100	18100204
16060002	None
16060012	None
8010202	8010100
9010003	None
15080102	None
2080203	2080205
16020306	None
3060103	3060106
15080101	None

Table A-4. Resulting Flow FROM and flow TO table with duplicate routing data removed. Entire matrix is 2100 rows X 2 columns

18100203	18100204
18100100	18100204
18090208	18070203
18090202	18090203
18070304	18070305
18070202	18070203
18070105	18070106
18070104	18070106
18070102	0
18070102	0
18060012	18060006
18060007	18060008
18050004	18050002
18050001	0
18050001	0
18030010	18030012
18030009	18030012
18030007	18030012
18030006	18030012
18030005	18030012
18030004	18030012
18030003	18030012
18010211	18010209
18010210	18010209
18010206	0
18010206	0
18010206	0

The column on the left is the 'FROM' column and the column on the right is the 'TO' column. If there is a zero in the left column it means that the HUC is not receiving upstream flow. After this table was created all duplicate routing pairs needed to be removed. For example, 18010206 to 0 is shown three times when it only needs to be counted once. After removing all duplicates, the resulting table represents the same routing data used for the coterminous U.S. that the WaSSI Model uses. An image from the table is shown in Table A-4. This table was used to find all flow out values (water leaving the outlet of the HUC) for the HUCs and is described in more detail later.

APPENDIX B: ANALYTICAL RESULTS

Table B-1. Slope values for the linear line of best fit for water availability for each scenario in each ASD, with scenarios that have statistically significant p-values ($p < 0.05$) in bold.

ASD\Scenario	**Historical**	**HSAF1**	**HSBF1**	**ISAF1**	**ISBF1**	**HSAF2**	**HSBF2**	**ISAF2**	**ISBF2**
Midwest									
2650	-10.6	-18.9	-18.4	2.7	3.1	-4.6	-4.4	1.3	1.5
2680	0.2	-20.8	-20.9	10.3	10.3	**-8.6**	**-8.7**	-4.2	-4.3
2740	122.0	-67.3	-67.5	-7.3	-7.6	**-84.1**	**-84.1**	**-14.4**	**-14.8**
2750	28.4	-96.0	-96.2	-4.2	-4.3	**-135.5**	**-135.8**	**-21.0**	**-21.5**
2780	27.9	-57.2	-57.4	10.8	10.5	**-41.4**	**-41.4**	**-24.0**	**-24.2**
2790	28.3	-126.7	-127.6	1.7	0.8	**-190.5**	**-191.4**	**-20.9**	**-22.1**
5530	-34.8	-13.1	-13.1	7.7	7.7	-32.2	-32.2	7.9	7.9
5550	-27.9	-27.5	-27.5	8.6	8.7	-33.6	-33.6	5.2	5.3
5560	-20.3	-22.4	-22.4	9.1	9.1	**-17.2**	**-17.2**	2.5	2.6
Northeast									
2310	166.0	-20.7	-20.7	14.7	14.7	8.0	8.0	18.3	18.3
3640	41.3	-30.6	-30.5	5.1	5.2	**-16.2**	**-16.1**	-9.1	-9.1
Pacific West									
480	-138.8	-54.7	-65.0	-9.0	-19.5	-36.7	-44.9	2.9	-4.9
640	-305.1	-311.9	-303.2	167.4	176.7	-379.0	-382.0	-150.1	-152.7
650	-421.0	-362.7	-355.4	178.5	186.5	**-479.0**	**-479.0**	-150.7	-150.2
651	-108.3	-141.7	-135.0	60.5	67.8	-135.1	-140.4	-95.2	-99.9
680	-432.0	-341.1	-355.3	14.2	-0.2	-226.5	-235.8	-161.4	-170.2
1670	-402.9	-288.9	-289.8	-112.7	-113.7	-181.2	-182.3	20.4	19.3
1680	-83.8	-73.5	-73.6	-35.4	-35.6	-48.4	-48.8	2.6	2.2
1690	-172.8	-128.3	-128.7	-56.0	-56.5	-97.2	-97.7	-0.4	-0.8
4110	-1577.2	-670.8	-665.9	-612.0	-607.2	-772.5	-770.8	101.7	103.1
4130	-56.2	-23.0	-23.0	-9.5	-9.4	-22.8	-22.9	2.5	2.5
5310	-864.0	-198.5	-195.0	-376.1	-372.6	-437.2	-436.8	67.5	67.7
5320	-930.6	**-346.7**	**-345.7**	**-425.8**	**-424.9**	-317.9	-319.4	**86.8**	**85.3**
5350	-600.7	**-290.0**	**-289.9**	**-264.2**	**-264.0**	-231.4	-232.8	**50.6**	**49.0**
5390	-357.9	-252.7	-253.3	-117.3	-117.9	-175.6	-176.3	16.0	15.2
Plains									
880	-32.0	-23.0	-22.9	-11.1	-11.1	-18.1	-18.1	-9.9	-9.8
3830	40.0	**-5.7**	**-5.7**	-9.2	-9.2	**-23.7**	**-23.7**	**-8.0**	**-8.0**
4897	-80.8	-36.3	-36.6	-25.8	-26.2	-29.2	-28.9	-31.2	-30.8
Southeast									
1250	-39.3	-24.2	-26.4	-157.1	-159.4	-139.8	-141.0	-146.1	-147.3
1280	-11.8	-149.5	-151.6	-244.0	-246.1	**-205.4**	**-207.1**	-180.9	-182.5
1370	13.4	-14.5	-14.7	-31.0	-31.3	-42.6	-42.6	-29.1	-29.1

Table B-2. R^2 values for the linear line of best fit for water availability for each scenario in each ASD, with scenarios that have statistically significant p-values ($p < 0.05$) in bold.

ASD\Scenario	Historical	HSAF1	HSBF1	ISAF1	ISBF1	HSAF2	HSBF2	ISAF2	ISBF2
Midwest									
2650	0.009	0.086	0.082	0.004	0.005	0.007	0.007	0.001	0.001
2680	0.000	0.093	0.094	0.035	0.035	**0.019**	**0.019**	0.005	0.005
2740	0.099	0.095	0.096	0.001	0.002	**0.201**	**0.202**	**0.008**	**0.008**
2750	0.002	0.057	0.057	0.000	0.000	**0.142**	**0.143**	**0.005**	**0.005**
2780	0.007	0.098	0.098	0.005	0.005	**0.075**	**0.075**	**0.023**	**0.023**
2790	0.001	0.044	0.045	0.000	0.000	**0.129**	**0.130**	**0.002**	**0.002**
5530	0.032	0.013	0.013	0.006	0.006	0.096	0.096	0.006	0.006
5550	0.011	0.031	0.031	0.004	0.004	0.061	0.060	0.001	0.001
5560	0.015	0.050	0.050	0.011	0.011	**0.040**	**0.040**	0.001	0.001
Northeast									
2310	0.184	0.023	0.023	0.012	0.012	0.004	0.004	0.026	0.026
3640	0.054	0.111	0.111	0.004	0.004	**0.044**	**0.044**	0.013	0.012
Pacific West									
480	0.154	0.101	0.135	0.004	0.019	0.063	0.091	0.001	0.002
640	0.014	0.064	0.060	0.029	0.032	0.116	0.117	0.030	0.030
650	0.015	0.053	0.051	0.022	0.024	**0.121**	**0.120**	0.020	0.020
651	0.017	0.115	0.105	0.029	0.036	0.109	0.114	0.088	0.095
680	0.087	0.208	0.221	0.001	0.000	0.114	0.123	0.115	0.126
1670	0.066	0.172	0.173	0.044	0.044	0.071	0.072	0.002	0.001
1680	0.043	0.206	0.206	0.063	0.063	0.077	0.078	0.000	0.000
1690	0.067	0.212	0.213	0.046	0.047	0.094	0.095	0.000	0.000
4110	0.046	0.034	0.034	0.050	0.049	0.059	0.059	0.002	0.002
4130	0.123	0.054	0.054	0.018	0.018	0.069	0.069	0.001	0.001
5310	0.034	0.008	0.007	0.047	0.046	0.053	0.052	0.003	0.003
5320	0.067	**0.035**	**0.035**	**0.080**	**0.079**	0.032	0.032	**0.004**	**0.004**
5350	0.063	**0.058**	**0.058**	**0.073**	**0.073**	0.038	0.039	**0.003**	**0.003**
5390	0.059	0.129	0.129	0.045	0.046	0.063	0.064	0.001	0.001
Plains									
880	0.119	0.177	0.177	0.041	0.041	0.085	0.085	0.045	0.044
3830	0.187	**0.019**	**0.019**	0.028	0.028	**0.303**	**0.303**	**0.048**	**0.049**
4897	0.109	0.049	0.051	0.021	0.022	0.025	0.024	0.053	0.052
Southeast									
1250	0.004	0.004	0.005	0.090	0.092	0.122	0.124	0.071	0.073
1280	0.000	0.108	0.111	0.123	0.125	**0.206**	**0.210**	0.078	0.079
1370	0.002	0.007	0.008	0.031	0.032	0.059	0.059	0.020	0.020

Table B-3. Average available irrigation water for each scenario for each ASD. Bold numbers indicate significant statistically significant ($p<0.05$) scenarios. Units are in Mm^3/yr.

ASD\Scenario	Historical	HSAF1	HSBF1	ISAF1	ISBF1	HSAF2	HSBF2	ISAF2	ISBF2
Midwest									
2650	4,252	4,110	4,118	3,989	3,998	3,891	3,905	4,072	4,086
2680	4,721	4,408	4,403	4,343	4,338	**4,121**	**4,114**	4,424	4,417
2740	7,550	6,425	6,407	6,477	6,459	**4,949**	**4,929**	**5,756**	**5,733**
2750	16,065	14,318	14,351	14,186	14,218	**12,049**	**12,076**	**13,249**	**13,273**
2780	7,689	6,495	6,484	6,724	6,713	**5,637**	**5,626**	**6,267**	**6,254**
2790	25,425	22,938	22,957	22,575	22,594	**19,782**	**19,781**	**21,444**	**21,440**
5530	6,672	6,778	6,779	6,472	6,473	6,363	6,364	6,590	6,591
5550	8,871	8,528	8,528	8,241	8,240	7,960	7,960	8,372	8,372
5560	6,169	5,900	5,900	5,701	5,700	**5,562**	**5,562**	5,827	5,826
Northeast									
2310	14,892	15,968	15,968	15,577	15,577	15,651	15,651	15,895	15,895
3640	9,036	8,809	8,812	8,644	8,647	**8,351**	**8,355**	8,655	8,660
Pacific West									
480	6,631	6,140	6,625	5,810	6,294	5,532	5,858	6,092	6,426
640	46,728	44,581	44,862	42,364	42,648	38,310	38,613	41,766	42,097
650	63,745	58,727	59,034	55,668	55,978	**51,111**	**51,468**	55,161	55,548
651	17,269	17,127	17,421	16,710	17,006	14,825	15,084	16,230	16,517
680	30,326	32,416	32,879	32,105	32,564	28,264	28,525	31,076	31,338
1670	42,552	46,406	46,378	45,571	45,544	43,367	43,319	45,423	45,374
1680	12,145	12,986	12,978	12,825	12,818	12,228	12,215	12,742	12,729
1690	16,640	18,524	18,514	18,461	18,451	17,020	17,001	18,222	18,202
4110	254,620	277,977	278,026	273,785	273,834	266,002	266,111	272,429	272,535
4130	4,288	4,866	4,867	4,714	4,715	4,475	4,476	4,735	4,735
5310	181,324	196,695	196,786	193,895	193,986	191,183	191,307	193,071	193,193
5320	121,340	**138,954**	**138,994**	**137,817**	**137,857**	133,405	133,430	**136,866**	**136,890**
5350	80,406	**90,978**	**90,989**	**90,148**	**90,159**	86,834	86,828	**89,543**	**89,536**
5390	43,454	47,154	47,136	46,424	46,407	44,007	43,976	46,161	46,130
Plains									
880	3,042	3,285	3,285	3,358	3,358	2,966	2,967	3,192	3,194
3830	1,423	**1,051**	**1,050**	1,251	1,250	**773**	**772**	**932**	**931**
4897	7,857	7,719	7,741	7,998	8,020	7,635	7,656	7,533	7,556
Southeast									
1250	19,398	19,594	19,538	20,172	20,117	17,336	17,247	19,026	18,937
1280	23,855	22,884	22,790	24,270	24,176	**19,988**	**19,854**	21,727	21,590
1370	9,038	9,167	9,159	8,710	8,702	8,416	8,406	8,675	8,665

Table B-4. Difference between the modeled and HIST average available irrigation water. Bold numbers indicate significant statistically significant ($p<0.05$) scenarios. Units are in Mm^3/yr.

ASD\Scenario	Historical	HSAF1	HSBF1	ISAF1	ISBF1	HSAF2	HSBF2	ISAF2	ISBF2
Midwest									
2650	----	-142	-134	-263	-254	-361	-347	-180	-166
2680	----	-313	-318	-378	-383	**-600**	**-607**	-297	-303
2740	----	-1,125	-1,142	-1,073	-1,091	**-2,601**	**-2,620**	**-1,793**	**-1,816**
2750	----	-1,747	-1,714	-1,879	-1,847	**-4,016**	**-3,989**	**-2,816**	**-2,792**
2780	----	-1,195	-1,205	-965	-976	**-2,052**	**-2,063**	**-1,422**	**-1,435**
2790	----	-2,487	-2,468	-2,850	-2,831	**-5,644**	**-5,645**	**-3,981**	**-3,985**
5530	----	106	107	-200	-200	-309	-308	-83	-81
5550	----	-344	-344	-631	-631	-912	-911	-499	-499
5560	----	-268	-269	-468	-469	**-606**	**-607**	-342	-342
Northeast									
2310	----	1,075	1,075	685	685	759	759	1,003	1,003
3640	----	-227	-224	-392	-389	**-685**	**-681**	-381	-376
Pacific West									
480	----	-491	-6	-821	-337	-1,100	-773	-539	-205
640	----	-2,147	-1,867	-4,364	-4,080	-8,418	-8,115	-4,962	-4,631
650	----	-5,018	-4,711	-8,077	-7,766	**-12,634**	**-12,277**	-8,583	-8,197
651	----	-142	152	-559	-263	-2,444	-2,184	-1,038	-752
680	----	2,090	2,553	1,779	2,238	-2,062	-1,801	750	1,012
1670	----	3,853	3,826	3,019	2,992	815	767	2,871	2,822
1680	----	841	833	680	672	83	70	597	584
1690	----	1,884	1,875	1,821	1,812	381	361	1,582	1,563
4110	----	23,358	23,407	19,165	19,214	11,382	11,491	17,809	17,916
4130	----	578	578	426	427	186	187	446	447
5310	----	15,371	15,462	12,571	12,663	9,860	9,983	11,747	11,869
5320	----	**17,614**	**17,654**	**16,477**	**16,516**	12,065	12,090	**15,526**	**15,550**
5350	----	**10,572**	**10,583**	**9,742**	**9,753**	6,428	6,422	**9,137**	**9,130**
5390	----	3,699	3,682	2,970	2,952	553	522	2,707	2,675
Plains									
880	----	244	244	317	317	-76	-74	151	152
3830	----	**-372**	**-372**	-172	-172	**-650**	**-651**	**-490**	**-491**
4897	----	-138	-116	140	163	-222	-201	-324	-302
Southeast									
1250	----	196	141	775	719	-2,061	-2,151	-372	-461
1280	----	-971	-1,066	415	321	**-3,867**	**-4,002**	-2,128	-2,265
1370	----	129	121	-327	-335	-622	-632	-363	-373

APPENDIX C: RESULTS FOR ASDS WITH NON-SIGNIFICANT CHANGES IN IRRIGATION WATER

Each ASD has a section with a map of the ASD Watershed Borders, a summary table of the analysis of the results, discussion of the results, and for the significant scenarios, a scatterplot of the projected values with a line of best fit bounded by above and below by 95% confidence intervals. This section has the results for individual ASDs that do not have any scenarios with a significant P-value, $p<0.05$. This comprises of 19 ASDs in total: three ASDs in the Midwest, one in the Northeast, eleven in the Pacific West, one in the Plains, and two in the Southeast.

C.1. Midwest

ASD 2650

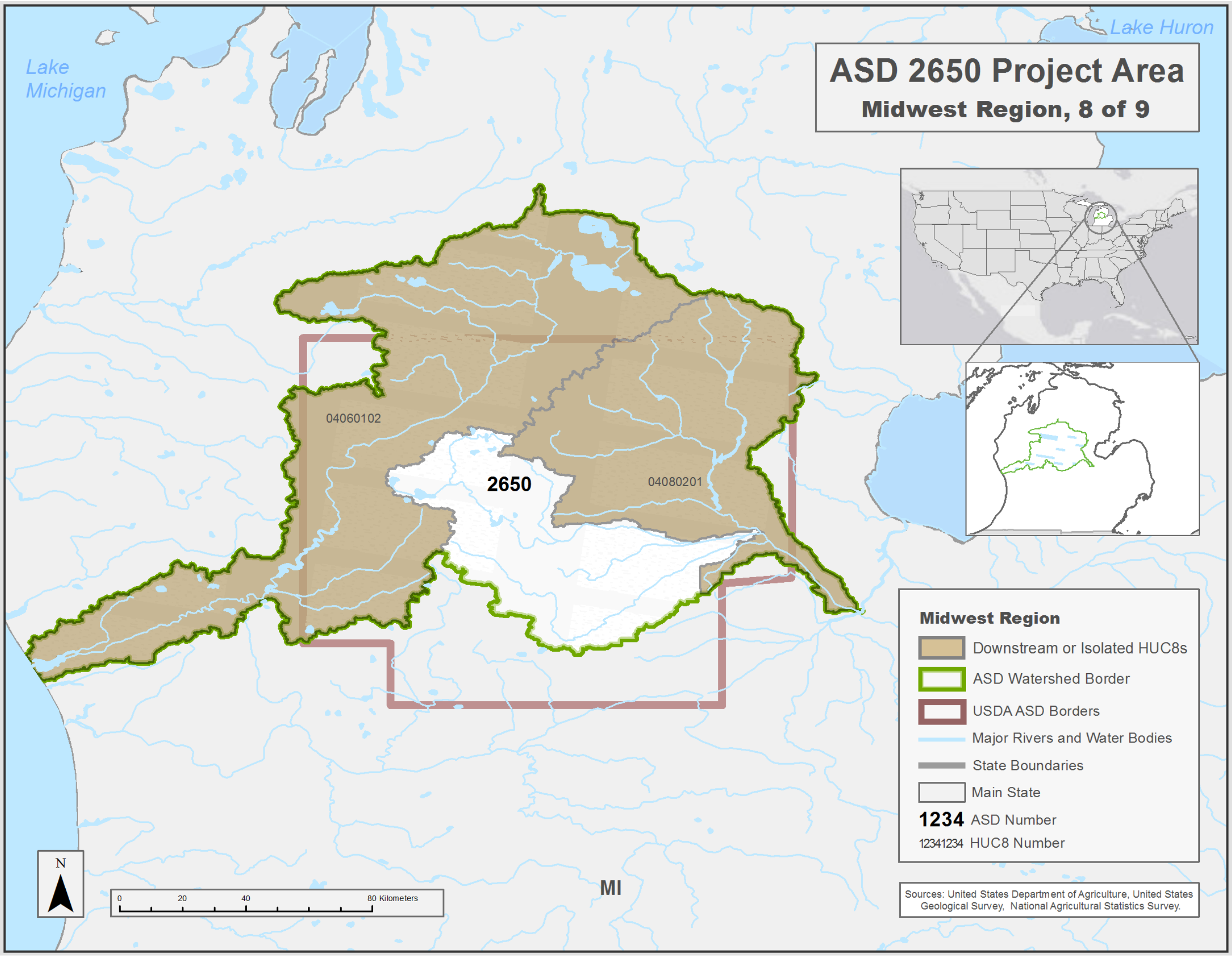

Figure C-1. ASD 2650 Watershed Borders: the borders of the ASD modified to include streamflow only for HUC8s that were mostly within its original borders.

ASD 2650 has a decrease in average available irrigation water for every modelled scenario and no significant scenarios.

Table C-1. Irrigation Water Availability Results and Analysis for ASD 2650. Units are in Mm^3/yr

Parameter\Scenario	Historical	HSAF1	HSBF1	ISAF1	ISBF1	HSAF2	HSBF2	ISAF2	ISBF2
Average	4,252	4,110	4,118	3,989	3,998	3,891	3,905	4,072	4,086
Range	3,384	2,230	2,228	1,473	1,485	2,051	2,049	1,927	1,927
Change from Historical	----	-142	-134	-263	-254	-361	-347	-180	-166
Slope	----	----	----	----	----	----	----	----	----
R2	----	----	----	----	----	----	----	----	----

ASD 5530

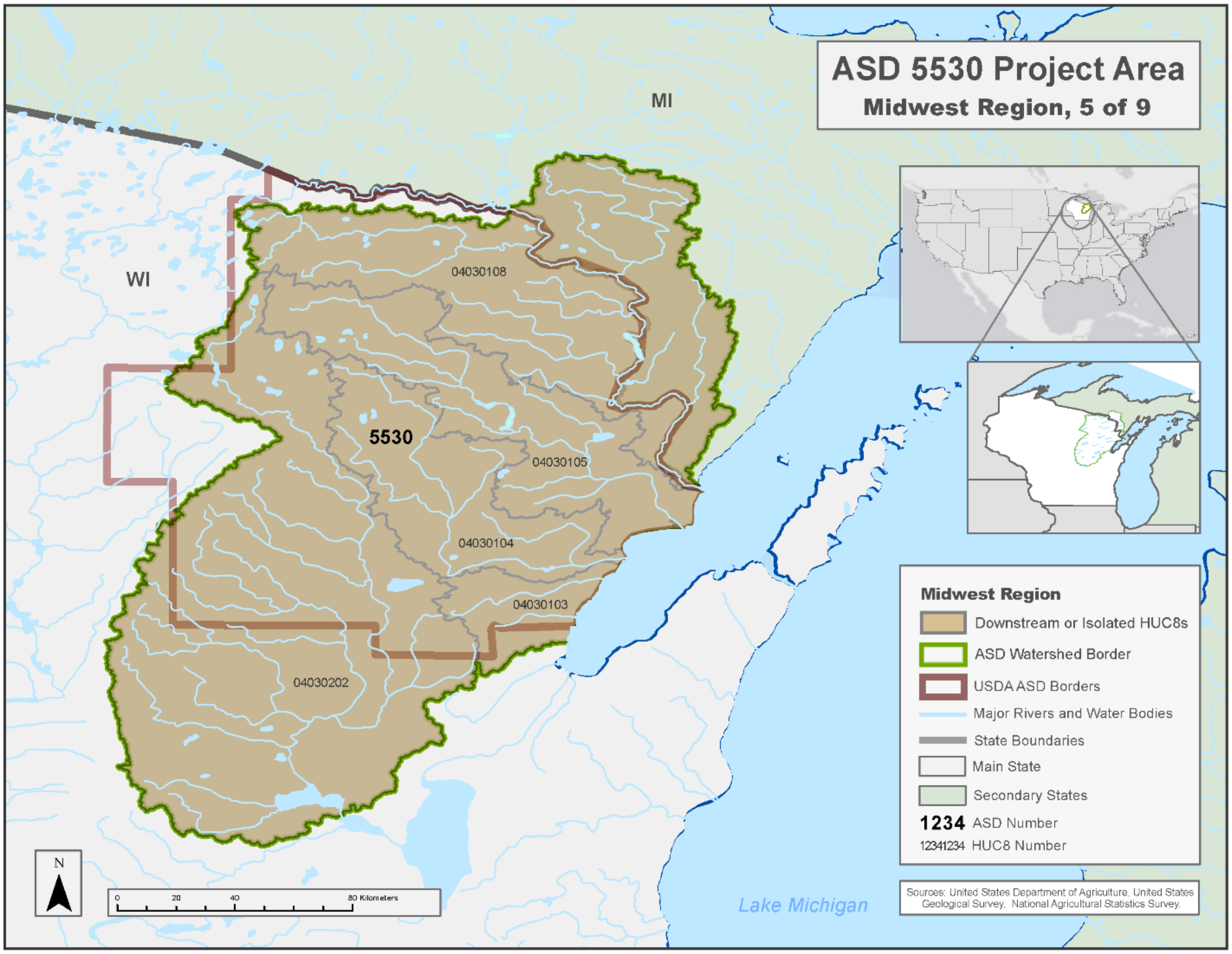

Figure C-2. ASD 5530 Watershed Borders: the borders of the ASD modified to include streamflow only for HUC8s that were mostly within its original borders.

ASD 5530 has an increase in average available irrigation water for the HS F1 scenarios but a decrease for all other scenarios. It has no scenarios with a significant change in water availability compared to the Historical scenario.

Table C-2. Irrigation Water Availability Results and Analysis for ASD 5530. Units are in Mm^3/yr.

Parameter\Scenario	Historical	HSAF1	HSBF1	ISAF1	ISBF1	HSAF2	HSBF2	ISAF2	ISBF2
Average	6,672	6,778	6,779	6,472	6,473	6,363	6,364	6,590	6,591
Range	6,202	3,431	3,431	3,065	3,065	4,532	4,531	3,492	3,492
Change from Historical	----	106	107	-200	-200	-309	-308	-83	-81
Slope	----	----	----	----	----	----	----	----	----
R2	----	----	----	----	----	----	----	----	----

ASD 5550

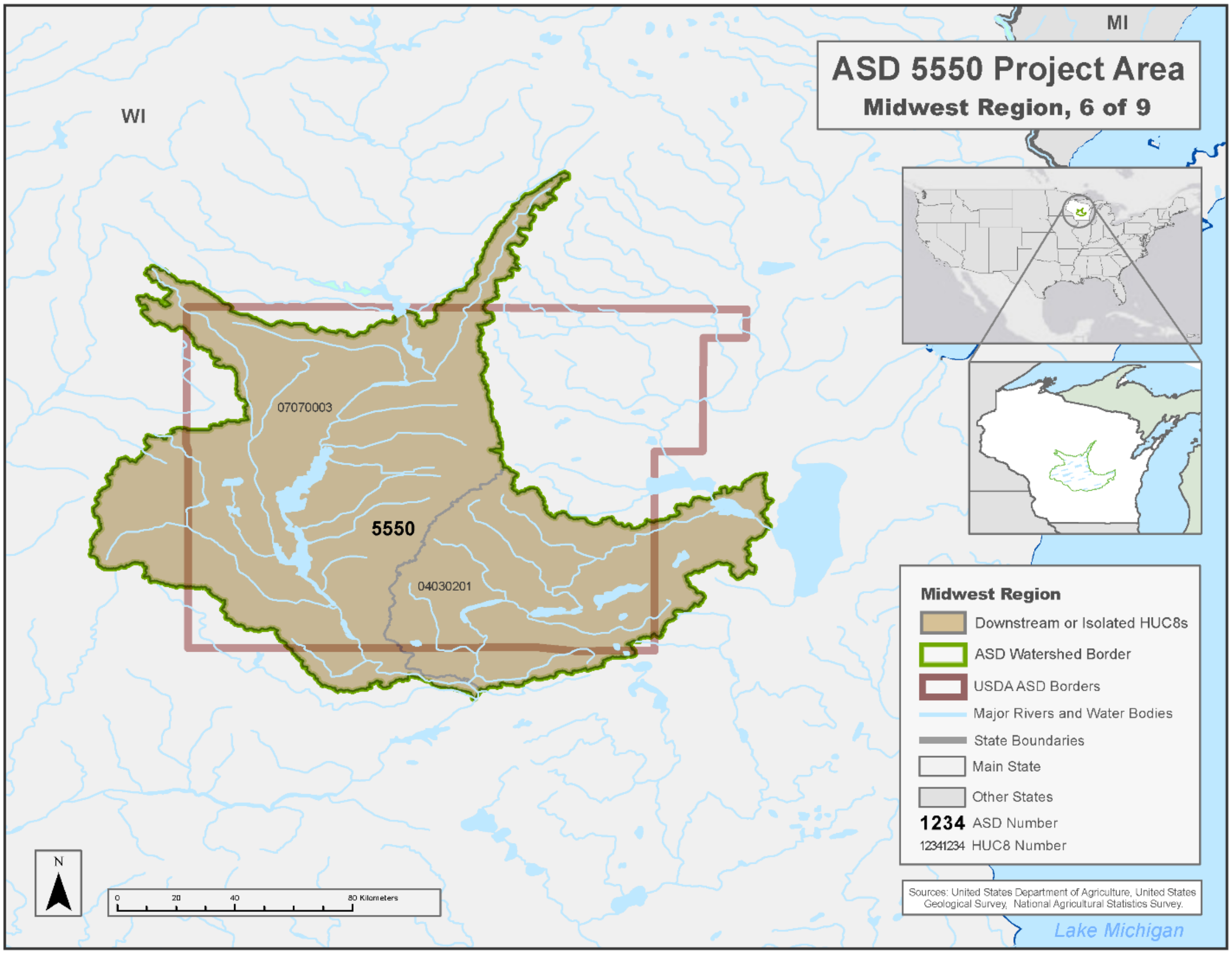

Figure C-3. ASD 5550 Watershed Borders: the borders of the ASD modified to include streamflow only for HUC8s that were mostly within its original borders.

ASD 5550 has no significant scenarios and a decrease in average available irrigation water for all scenarios.

Table C-3. Irrigation Water Availability Results and Analysis for ASD 5550. Units are in Mm^3/yr.

Parameter\Scenario	Historical	HSAF1	HSBF1	ISAF1	ISBF1	HSAF2	HSBF2	ISAF2	ISBF2
Average	8,871	8,528	8,528	8,241	8,240	7,960	7,960	8,372	8,372
Range	8,720	5,252	5,252	3,765	3,765	5,799	5,797	5,332	5,331
Change from Historical	----	-344	-344	-631	-631	-912	-911	-499	-499
Slope	----	----	----	----	----	----	----	----	----
R2	----	----	----	----	----	----	----	----	----

C.2. Northeast

ASD 2310

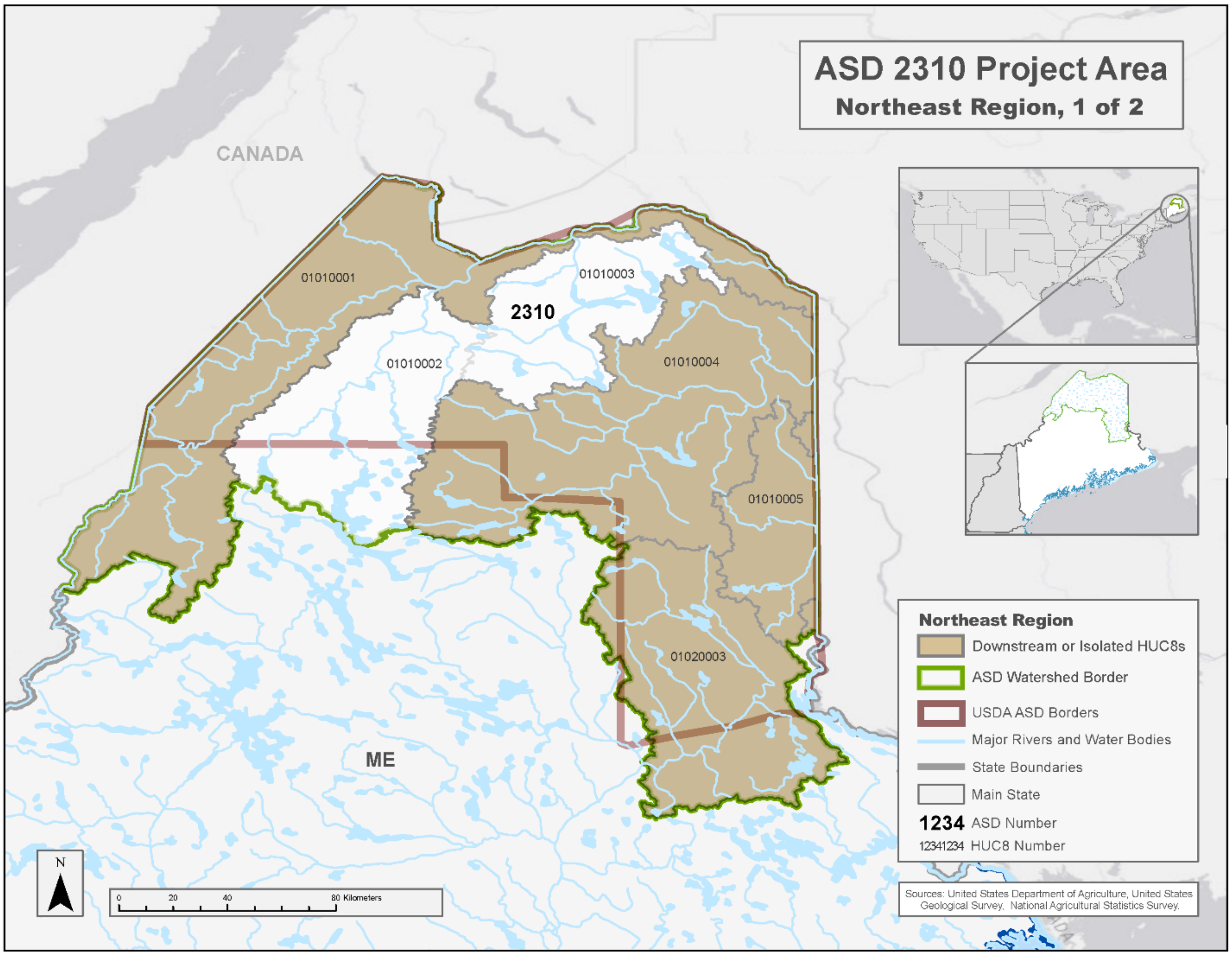

Figure C-4. ASD 2310 Watershed Borders: the borders of the ASD modified to include streamflow only for HUC8s that were mostly within its original borders.

ASD 2310 is quite hilly and has an increase in average available irrigation water for every modelled scenario. It has no significant scenarios.

Table C-4. Irrigation Water Availability Results and Analysis for ASD 2310. Units are in Mm^3/yr.

Parameter\Scenario	Historical	HSAF1	HSBF1	ISAF1	ISBF1	HSAF2	HSBF2	ISAF2	ISBF2
Average	14,892	15,968	15,968	15,577	15,577	15,651	15,651	15,895	15,895
Range	13,810	4,407	4,407	4,718	4,718	5,503	5,503	4,426	4,426
Change from Historical	----	1,075	1,075	685	685	759	759	1,003	1,003
Slope	----	----	----	----	----	----	----	----	----
R2	----	----	----	----	----	----	----	----	----

C.3. Pacific West

ASD 0480

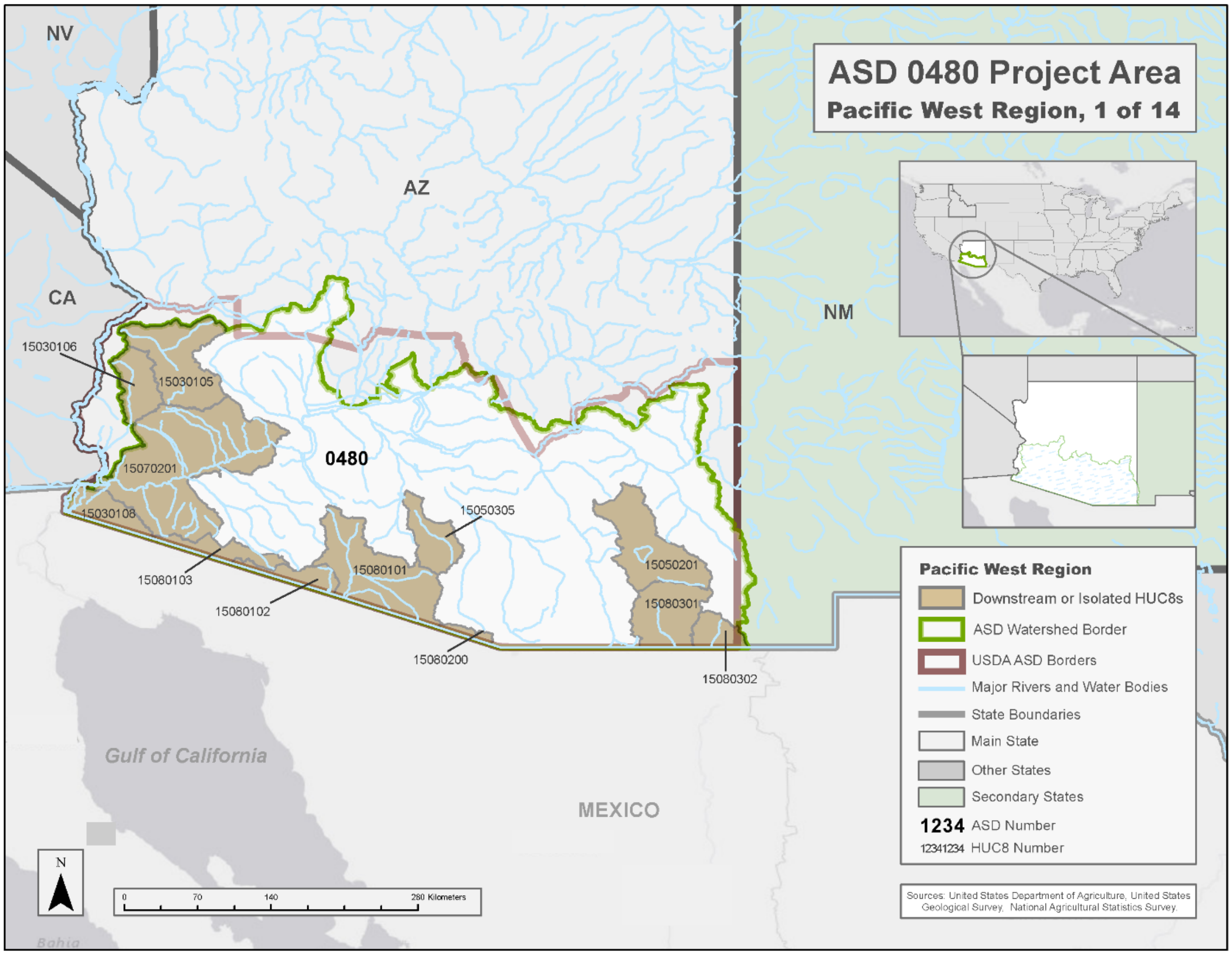

Figure C-5. ASD 0480 Watershed Borders: the borders of the ASD modified to include streamflow only for HUC8s that were mostly within its original borders.

ASD 0480 is semi-mountainous and has no scenarios with a significantly different change from the Historical. All modelled scenarios for ASD 0480 have a decrease from the Historical scenario in average available irrigation water.

Table C-5. Irrigation Water Availability Results and Analysis for ASD 0480. Units are in Mm^3/yr.

Parameter\Scenario	Historical	HSAF1	HSBF1	ISAF1	ISBF1	HSAF2	HSBF2	ISAF2	ISBF2
Average	6,631	6,140	6,625	5,810	6,294	5,532	5,858	6,092	6,426
Range	13,446	5,580	5,590	5,066	5,080	6,053	6,278	5,064	5,263
Change from Historical	----	-491	-6	-821	-337	-1,100	-773	-539	-205
Slope	----	----	----	----	----	----	----	----	----
R2	----	----	----	----	----	----	----	----	----

ASD 0640

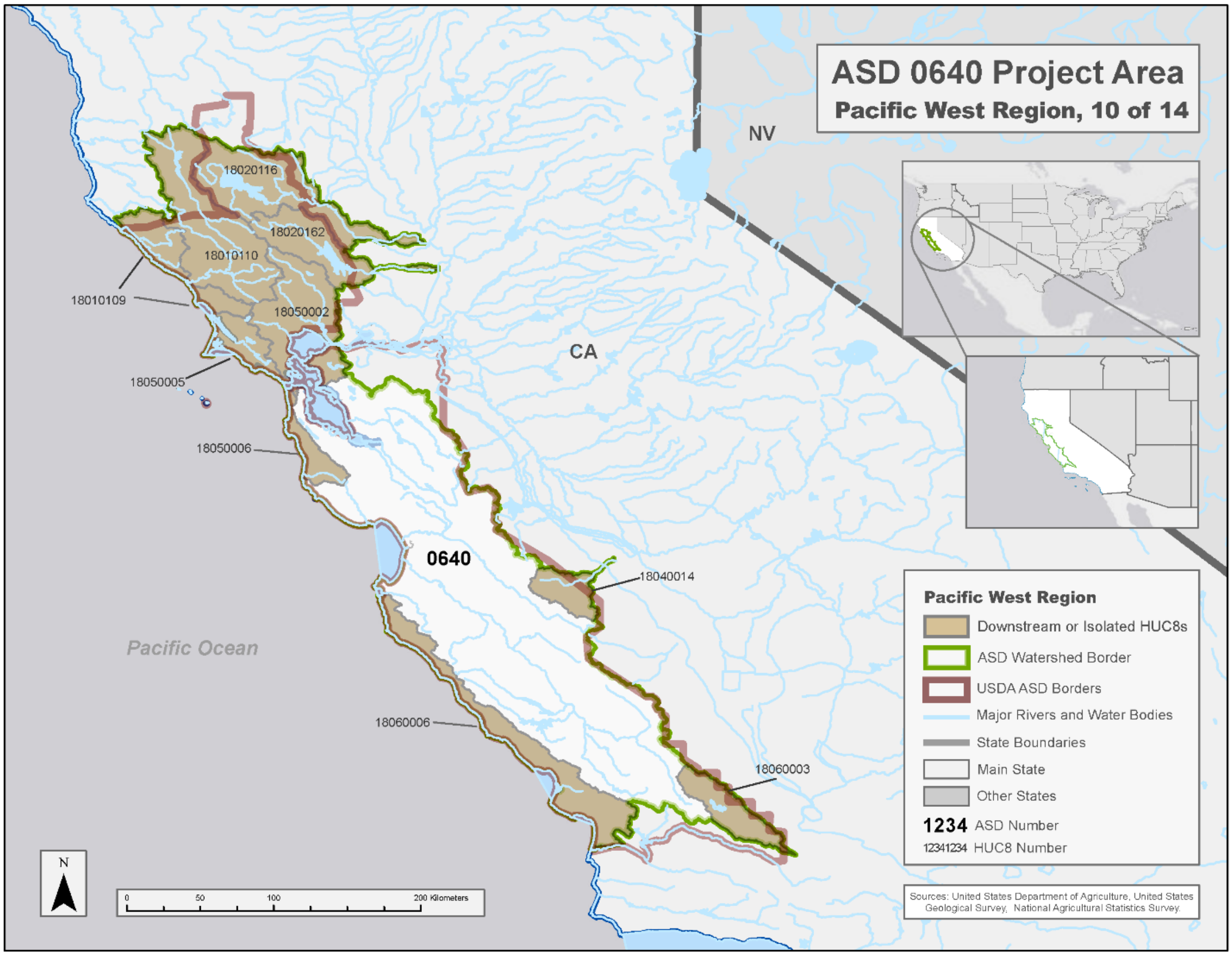

Figure C-6. ASD 0640 Watershed Borders: the borders of the ASD modified to include streamflow only for HUC8s that were mostly within its original borders.

ASD 0640 has some mountains but has a decrease in average available irrigation water for all scenarios. There are no significant scenarios for ASD 0640.

Table C-6. Irrigation Water Availability Results and Analysis for ASD 0640. Units are in Mm^3/yr.

Parameter\Scenario	Historical	HSAF1	HSBF1	ISAF1	ISBF1	HSAF2	HSBF2	ISAF2	ISBF2
Average	46,728	44,581	44,862	42,364	42,648	38,310	38,613	41,766	42,097
Range	89,848	46,506	46,592	37,907	37,676	39,782	40,102	29,105	29,196
Change from Historical	----	-2,147	-1,867	-4,364	-4,080	-8,418	-8,115	-4,962	-4,631
Slope	----	----	----	----	----	----	----	----	----
R2	----	----	----	----	----	----	----	----	----

ASD 0651

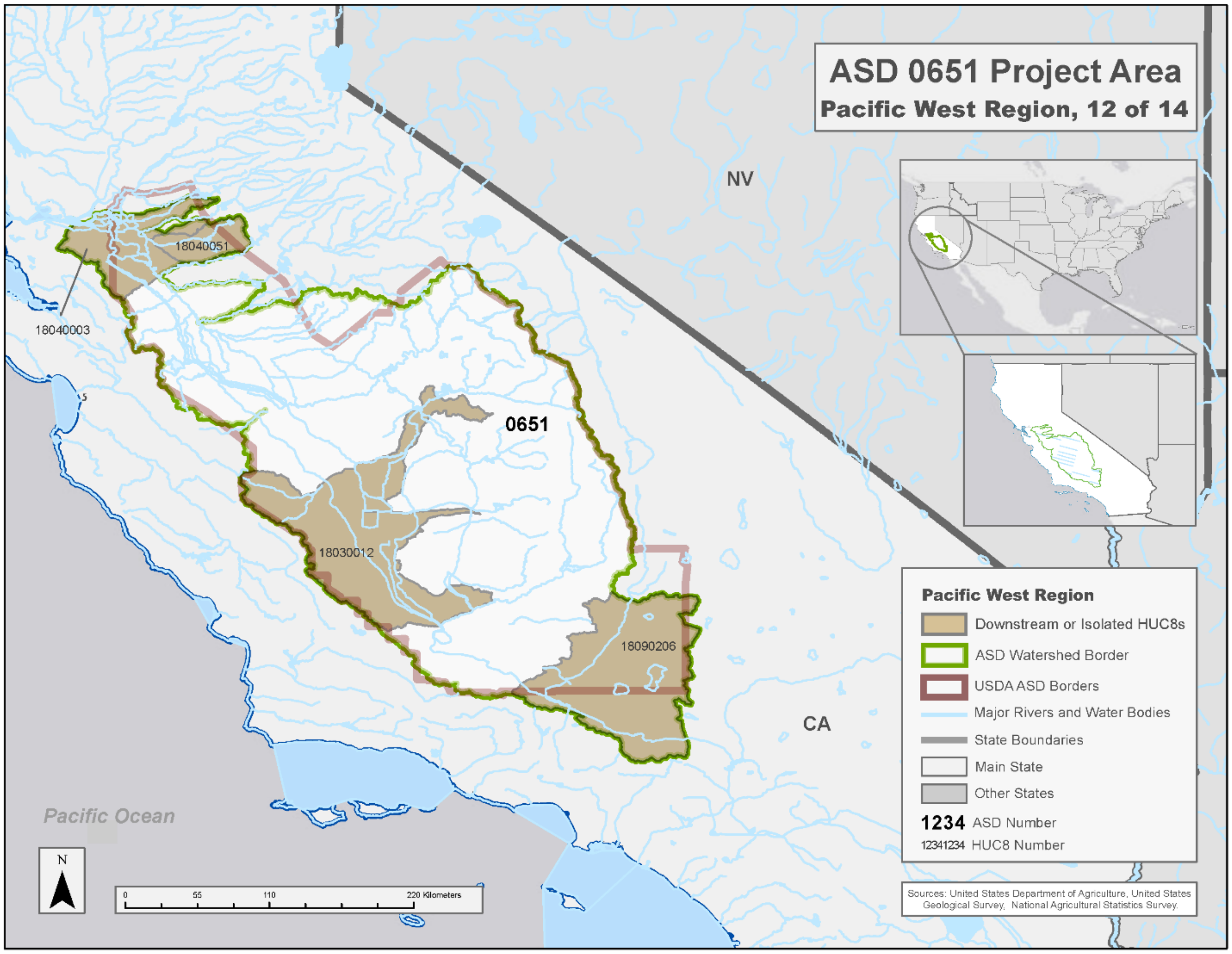

Figure C-7. ASD 0651 Watershed Borders: the borders of the ASD modified to include streamflow only for HUC8s that were mostly within its original borders.

ASD 0651 has a decrease in average available irrigation water for all scenarios except for the HSBF1 scenario. It has no significant scenarios.

Table C-7. Irrigation Water Availability Results and Analysis for ASD 0651. Units are in Mm^3/yr.

Parameter\Scenario	Historical	HSAF1	HSBF1	ISAF1	ISBF1	HSAF2	HSBF2	ISAF2	ISBF2
Average	17,269	17,127	17,421	16,710	17,006	14,825	15,084	16,230	16,517
Range	28,752	16,504	16,281	13,531	13,297	16,194	16,380	10,506	10,618
Change from Historical	----	-142	152	-559	-263	-2,444	-2,184	-1,038	-752
Slope	----	----	----	----	----	----	----	----	----
R2	----	----	----	----	----	----	----	----	----

ASD 0680

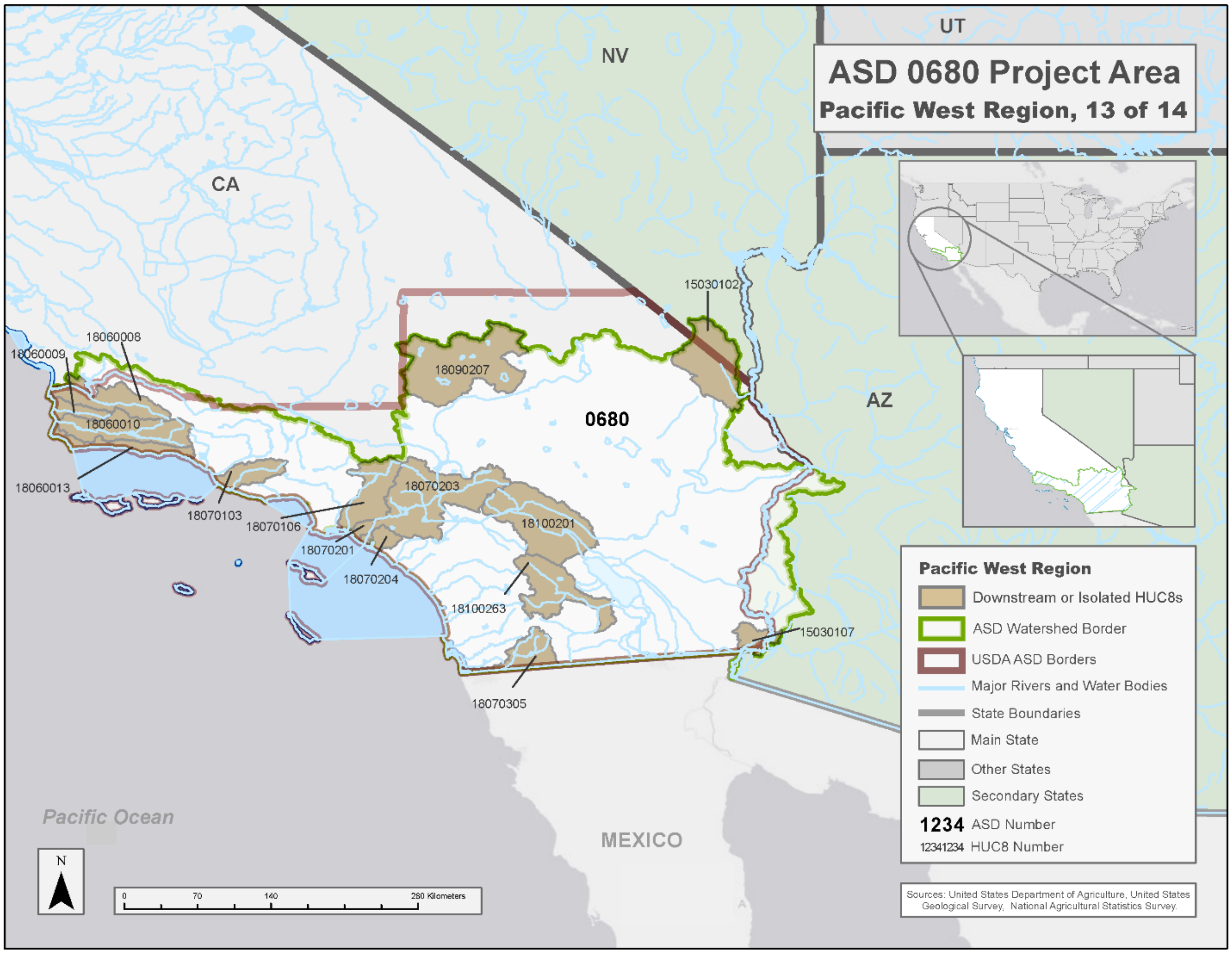

Figure C-8. ASD 0680 Watershed Borders: the borders of the ASD modified to include streamflow only for HUC8s that were mostly within its original borders.

ASD 0680 includes some mountains and has an increase in average water availability for all but the HSAF2 and HSBF2 scenarios. It has no scenarios with a significantly different change from the Historical.

Table C-8. Irrigation Water Availability Results and Analysis for ASD 0680. Units are in Mm^3/yr.

Parameter\Scenario	Historical	HSAF1	HSBF1	ISAF1	ISBF1	HSAF2	HSBF2	ISAF2	ISBF2
Average	30,326	32,416	32,879	32,105	32,564	28,264	28,525	31,076	31,338
Range	51,434	23,854	23,771	22,011	21,824	29,459	29,640	16,358	16,610
Change from Historical	----	2,090	2,553	1,779	2,238	-2,062	-1,801	750	1,012
Slope	----	----	----	----	----	----	----	----	----
R2	----	----	----	----	----	----	----	----	----

ASD 1670

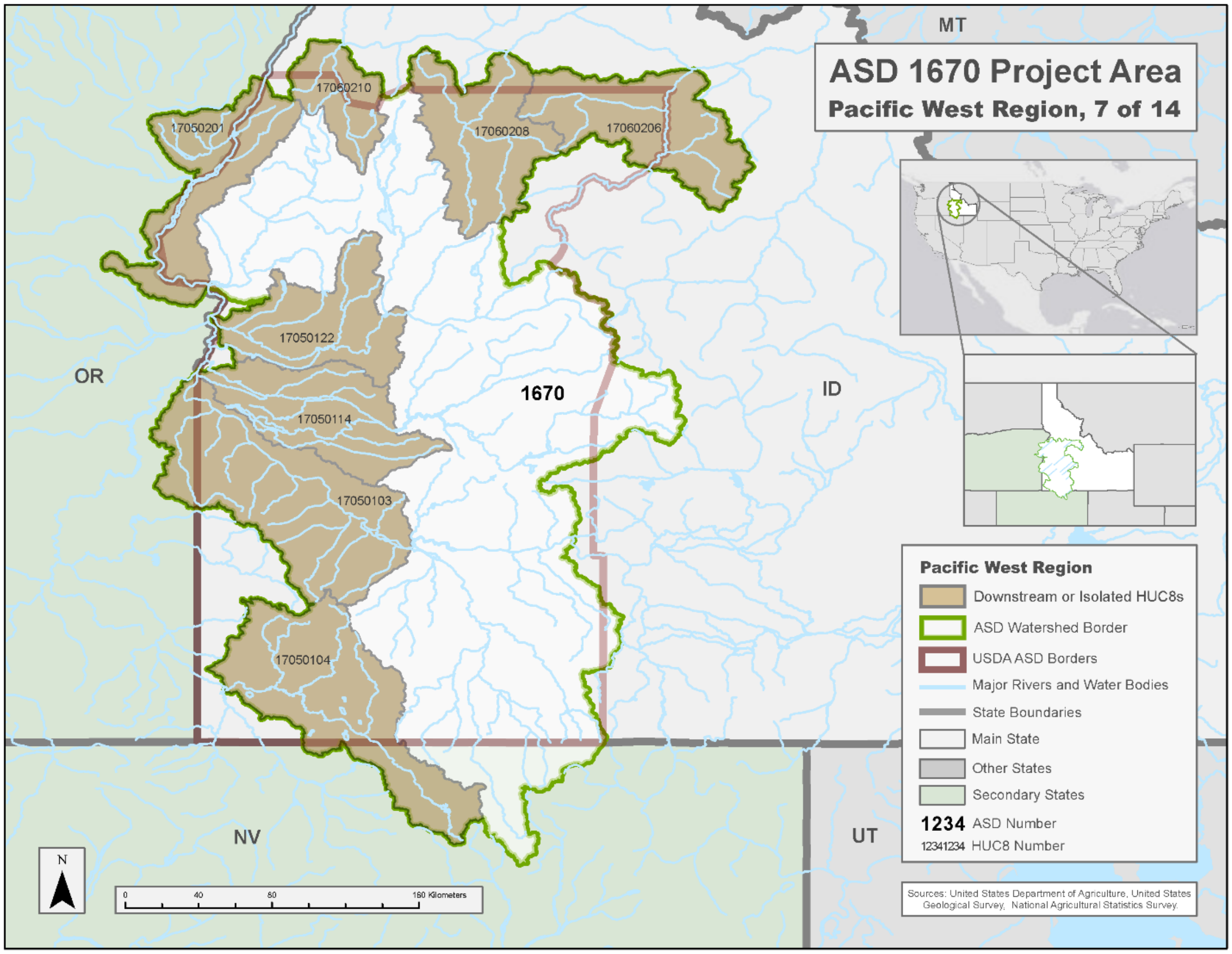

Figure C-9. ASD 1670 Watershed Borders: the borders of the ASD modified to include streamflow only for HUC8s that were mostly within its original borders.

ASD 1670 is surrounded by mountains and has positive changes in average available irrigation water for every scenario but no scenarios with a significantly different change from the Historical.

Table C-9. Irrigation Water Availability Results and Analysis for ASD 1670. Units are in Mm^3/yr.

Parameter\Scenario	Historical	HSAF1	HSBF1	ISAF1	ISBF1	HSAF2	HSBF2	ISAF2	ISBF2
Average	42,552	46,406	46,378	45,571	45,544	43,367	43,319	45,423	45,374
Range	45,231	28,673	28,678	18,756	18,770	26,626	26,637	16,402	16,401
Change from Historical	----	3,853	3,826	3,019	2,992	815	767	2,871	2,822
Slope	----	----	----	----	----	----	----	----	----
R2	----	----	----	----	----	----	----	----	----

ASD 1680

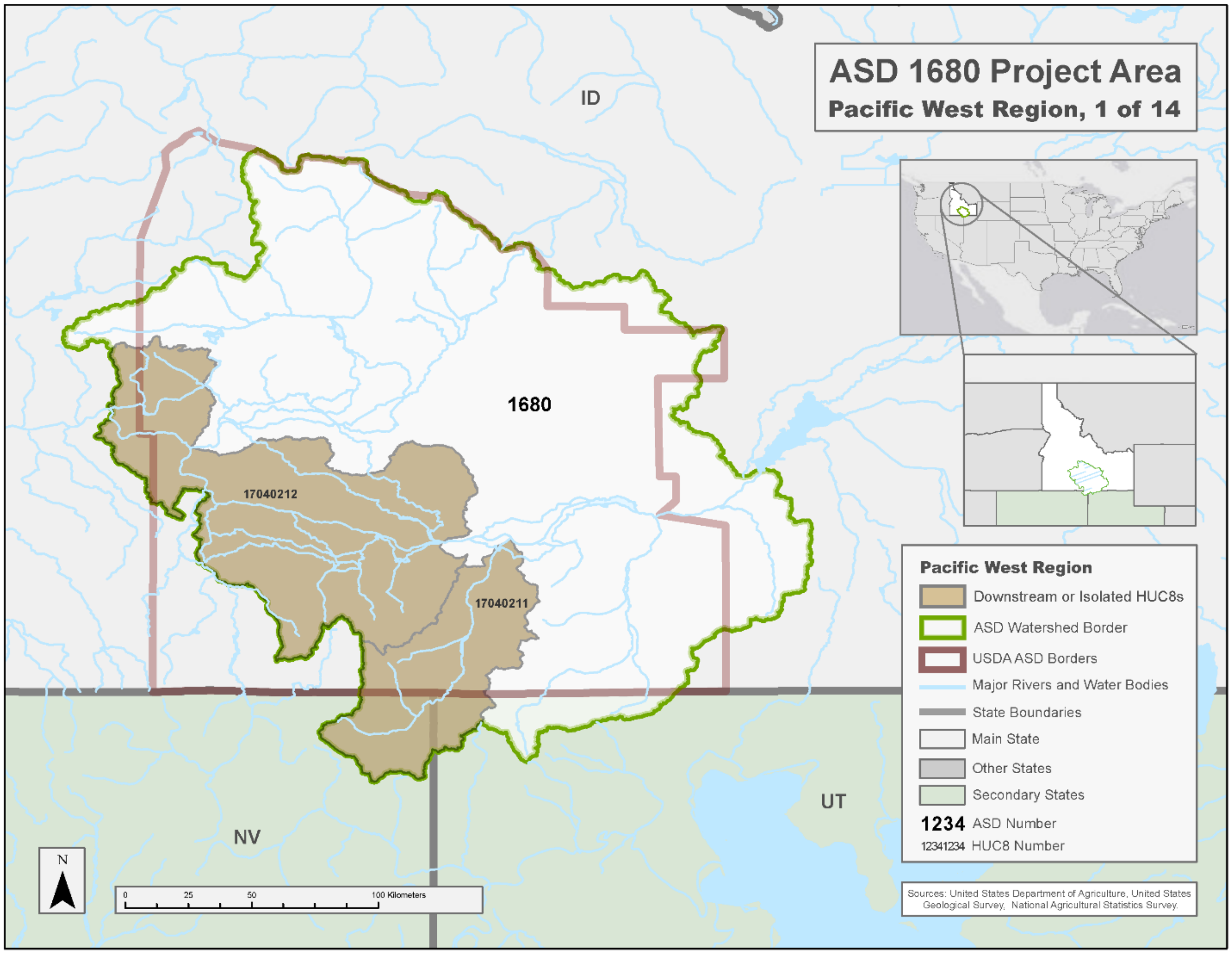

Figure C-10. ASD 1680 Watershed Borders: the borders of the ASD modified to include streamflow only for HUC8s that were mostly within its original borders.

ASD 1680 is surrounded by mountains and has positive changes in average available irrigation water for every scenario but no scenarios with a significantly different change from the Historical.

Table C-10. Irrigation Water Availability Results and Analysis for ASD 1680. Units are in Mm^3/yr.

Parameter\Scenario	Historical	HSAF1	HSBF1	ISAF1	ISBF1	HSAF2	HSBF2	ISAF2	ISBF2
Average	12,145	12,986	12,978	12,825	12,818	12,228	12,215	12,742	12,729
Range	12,358	5,790	5,793	4,805	4,806	7,191	7,196	4,991	4,997
Change from Historical	----	841	833	680	672	83	70	597	584
Slope	----	----	----	----	----	----	----	----	----
R2	----	----	----	----	----	----	----	----	----

ASD 1690

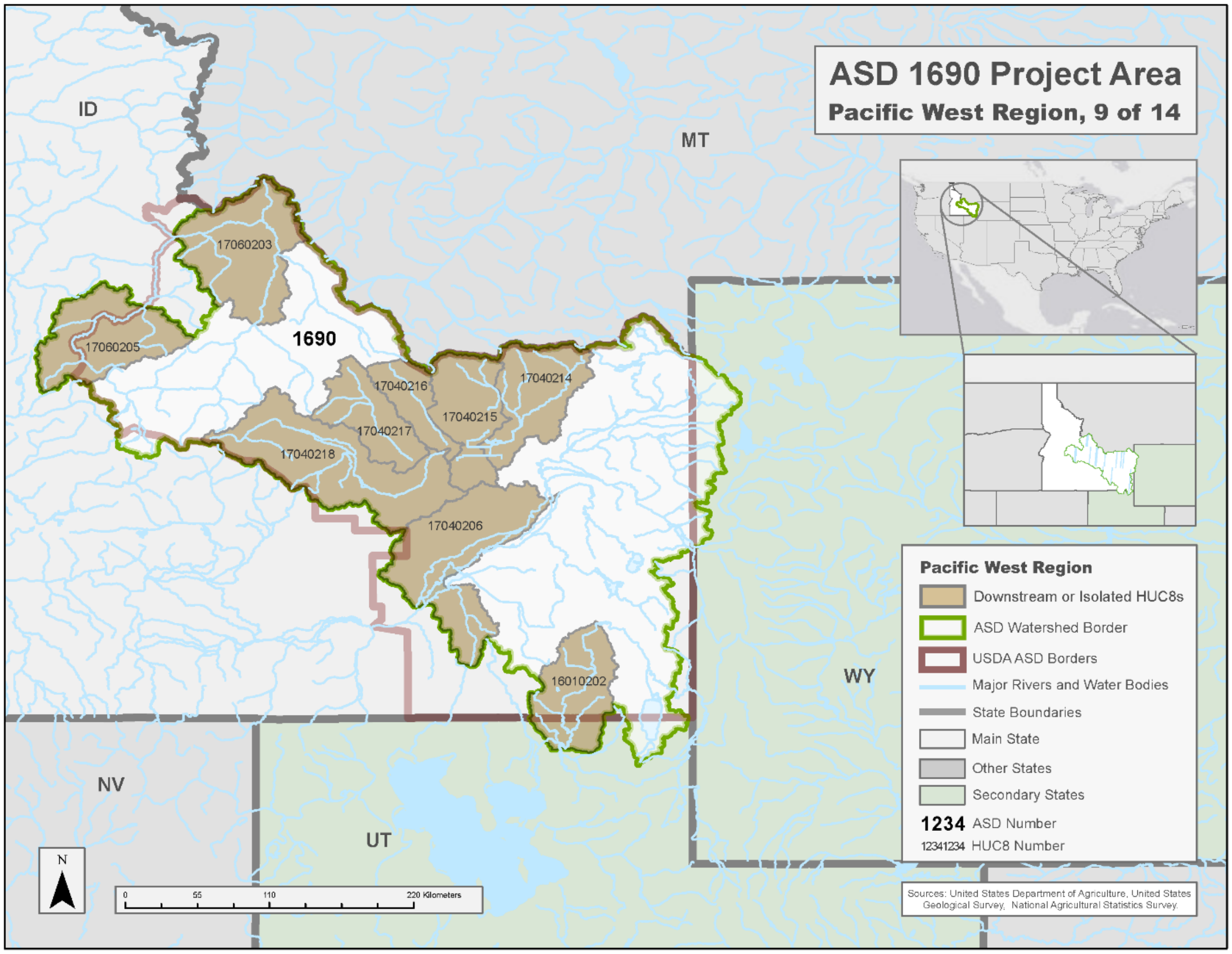

Figure C-11. ASD 1690 Watershed Borders: the borders of the ASD modified to include streamflow only for HUC8s that were mostly within its original borders.

ASD 1690 is mountainous and has positive changes in average available irrigation water for every scenario but no scenarios with a significantly different change from the Historical.

Table C-11. Irrigation Water Availability Results and Analysis for ASD 1690. Units are in Mm^3/yr.

Parameter\Scenario	Historical	HSAF1	HSBF1	ISAF1	ISBF1	HSAF2	HSBF2	ISAF2	ISBF2
Average	16,640	18,524	18,514	18,461	18,451	17,020	17,001	18,222	18,202
Range	19,079	10,537	10,542	8,921	8,919	13,252	13,257	8,863	8,869
Change from Historical	----	1,884	1,875	1,821	1,812	381	361	1,582	1,563
Slope	----	----	----	----	----	----	----	----	----
R2	----	----	----	----	----	----	----	----	----

ASD 4110

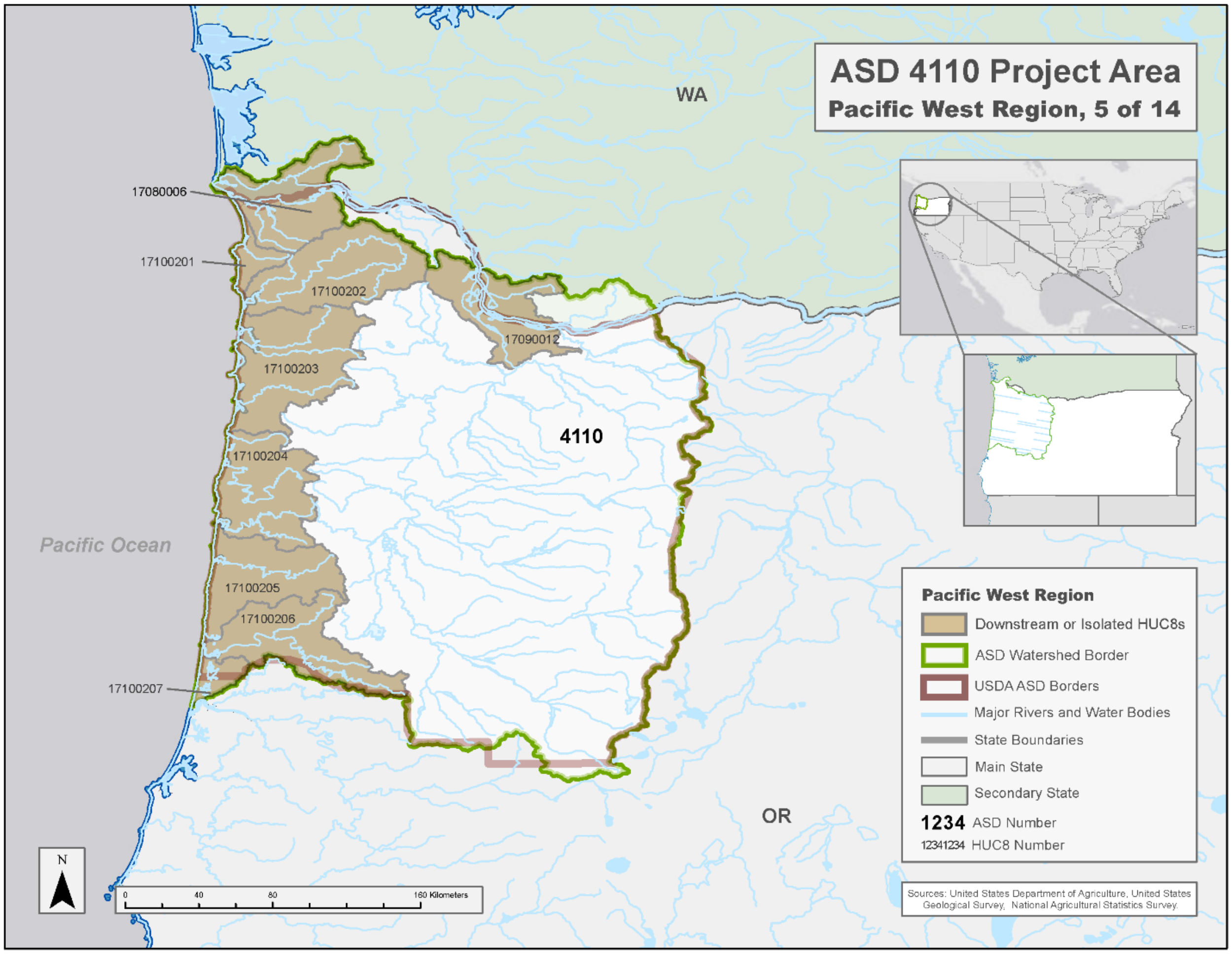

Figure C-12. ASD 4110 Watershed Borders: the borders of the ASD modified to include streamflow only for HUC8s that were mostly within its original borders.

ASD 4110 is mountainous and has positive changes in average available irrigation water for every scenario but no scenarios with a significantly different change from the Historical. This ASD also contains temperate rainforests and has by far the highest values for available irrigation water of all the ASDs used in this study.

Table C-12. Irrigation Water Availability Results and Analysis for ASD 4110. Units are in Mm^3/yr.

Parameter\Scenario	Historical	HSAF1	HSBF1	ISAF1	ISBF1	HSAF2	HSBF2	ISAF2	ISBF2
Average	254,620	277,977	278,026	273,785	273,834	266,002	266,111	272,429	272,535
Range	240,014	143,056	142,930	77,450	77,447	106,480	106,426	83,827	83,809
Change from Historical	----	23,358	23,407	19,165	19,214	11,382	11,491	17,809	17,916
Slope	----	----	----	----	----	----	----	----	----
R2	----	----	----	----	----	----	----	----	----

ASD 4130

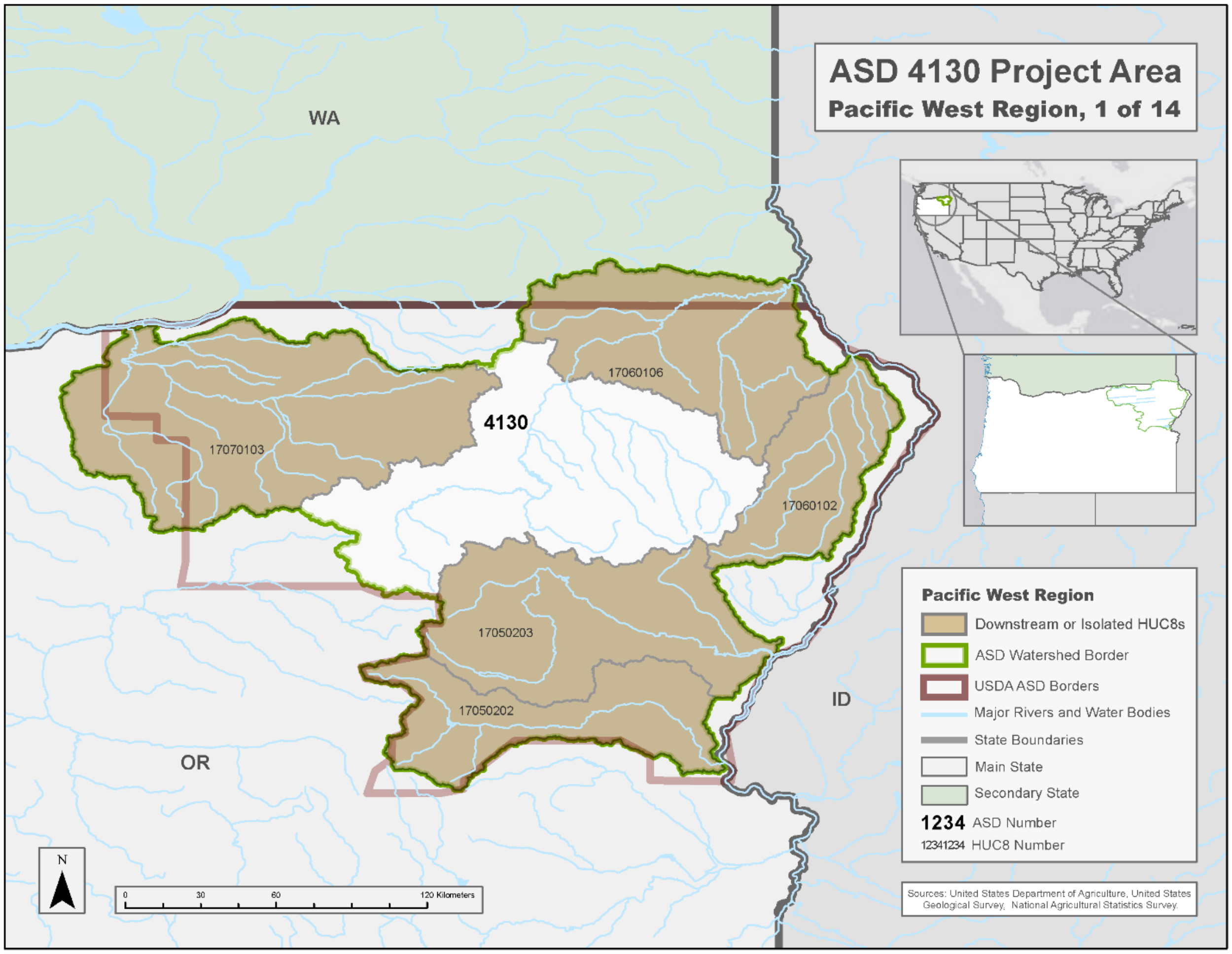

Figure C-13. ASD 4130 Watershed Borders: the borders of the ASD modified to include streamflow only for HUC8s that were mostly within its original borders.

ASD 4130 is mountainous and has positive changes in average available irrigation water for every scenario but no scenarios with a significantly different change from the Historical.

Table C-13. Irrigation Water Availability Results and Analysis for ASD 4130. Units are in Mm^3/yr.

Parameter\Scenario	Historical	HSAF1	HSBF1	ISAF1	ISBF1	HSAF2	HSBF2	ISAF2	ISBF2
Average	4,288	4,866	4,867	4,714	4,715	4,475	4,476	4,735	4,735
Range	5,151	4,156	4,155	2,172	2,172	3,094	3,093	3,150	3,150
Change from Historical	----	578	578	426	427	186	187	446	447
Slope	----	----	----	----	----	----	----	----	----
R2	----	----	----	----	----	----	----	----	----

ASD 5310

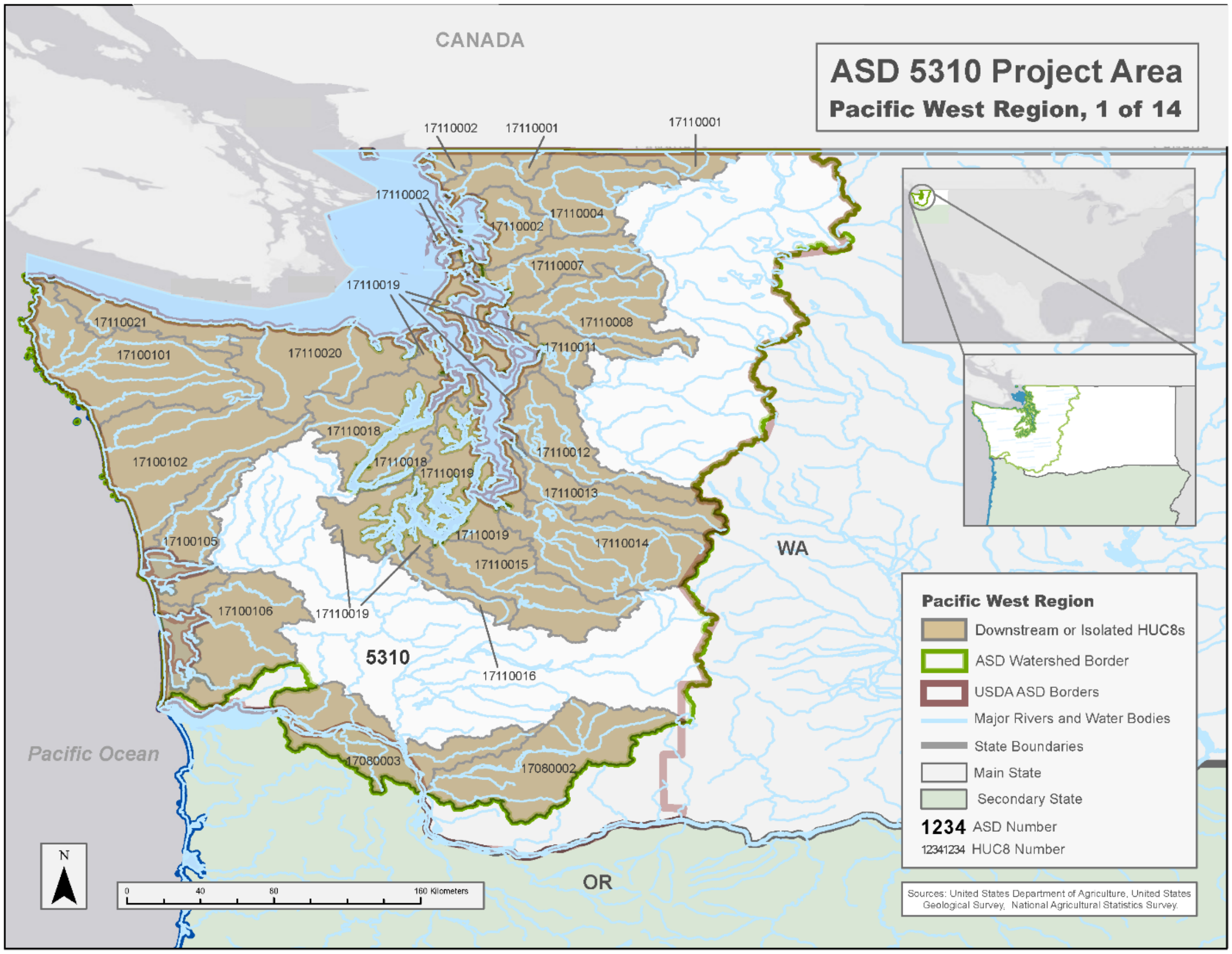

Figure C-14. ASD 5310 Watershed Borders: the borders of the ASD modified to include streamflow only for HUC8s that were mostly within its original borders.

ASD 5310 is mountainous and has positive changes in average available irrigation water for every scenario but no scenarios with a significantly different change from the Historical.

Table C-14. Irrigation Water Availability Results and Analysis for ASD 5310. Units are in Mm^3/yr.

Parameter\Scenario	Historical	HSAF1	HSBF1	ISAF1	ISBF1	HSAF2	HSBF2	ISAF2	ISBF2
Average	181,324	196,695	196,786	193,895	193,986	191,183	191,307	193,071	193,193
Range	154,741	87,822	87,750	47,236	47,292	60,822	60,825	48,439	48,435
Change from Historical	----	15,371	15,462	12,571	12,663	9,860	9,983	11,747	11,869
Slope	----	----	----	----	----	----	----	----	----
R2	----	----	----	----	----	----	----	----	----

ASD 5390

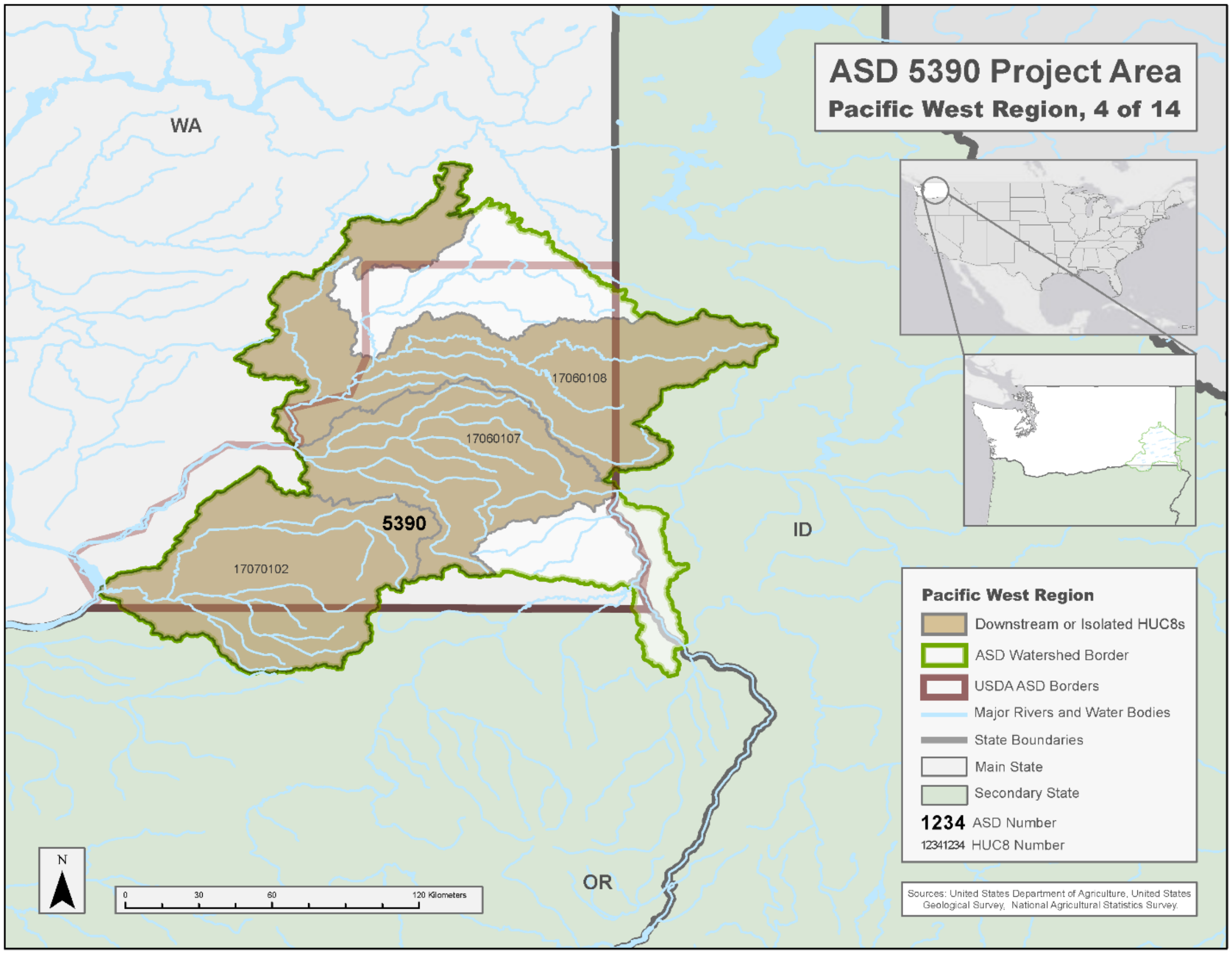

Figure C-15. ASD 5390 Watershed Borders: the borders of the ASD modified to include streamflow only for HUC8s that were mostly within its original borders.

ASD 5390 is mountainous and has positive changes in average available irrigation water for every scenario but no scenarios with a significantly different change from the Historical.

Table C-15. Irrigation Water Availability Results and Analysis for ASD 5390. Units are in Mm^3/yr.

Parameter\Scenario	Historical	HSAF1	HSBF1	ISAF1	ISBF1	HSAF2	HSBF2	ISAF2	ISBF2
Average	43,454	47,154	47,136	46,424	46,407	44,007	43,976	46,161	46,130
Range	46,440	28,824	28,821	18,242	18,256	24,278	24,285	21,461	21,458
Change from Historical	----	3,699	3,682	2,970	2,952	553	522	2,707	2,675
Slope	----	----	----	----	----	----	----	----	----
R2	----	----	----	----	----	----	----	----	----

C.4. Plains

ASD 0880

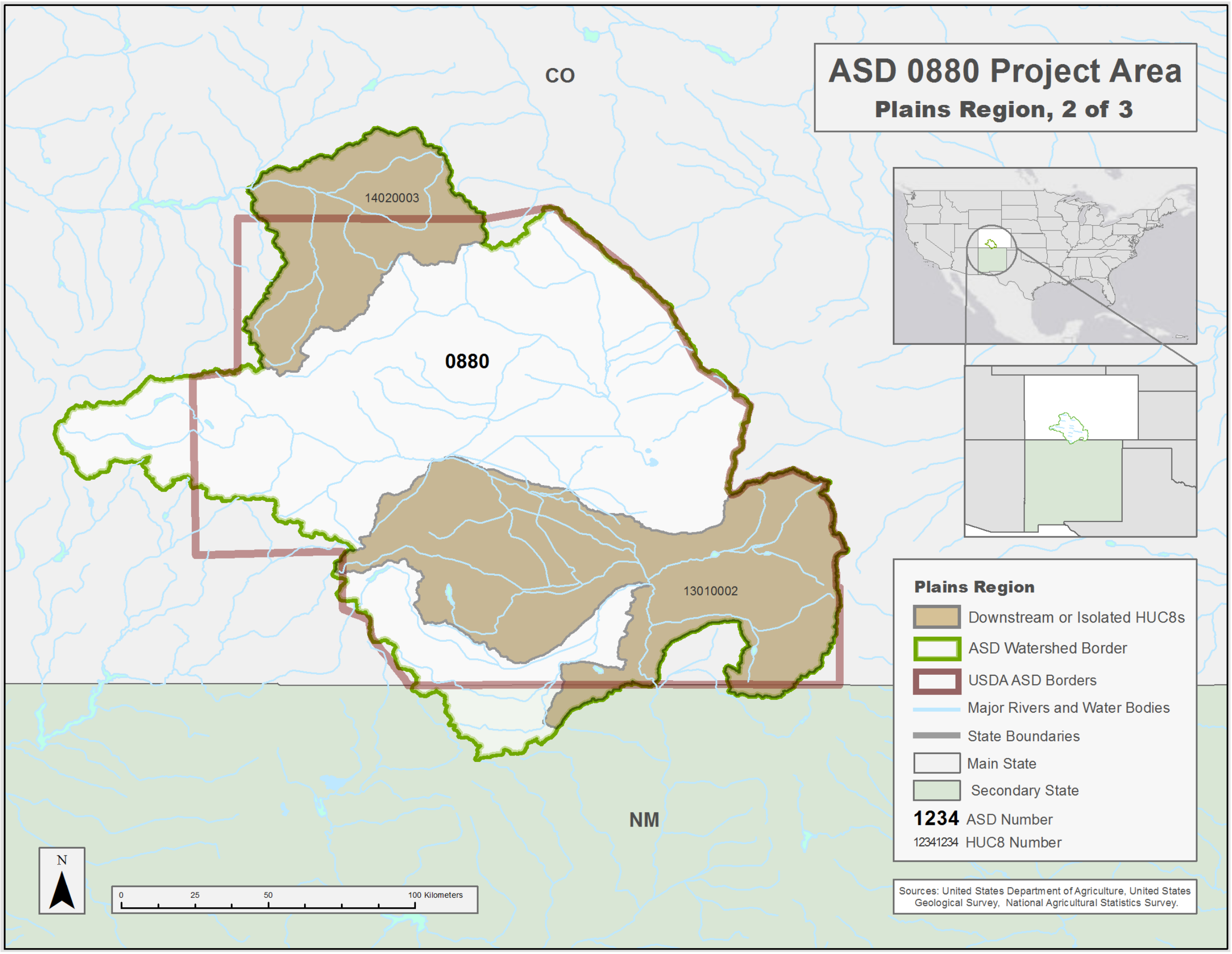

Figure C-16. ASD 0880 Watershed Borders: the borders of the ASD modified to include streamflow only for HUC8s that were mostly within its original borders.

ASD 5310 is located in the Rocky Mountains and is quite mountainous. It has positive changes in average available irrigation water for all but the HS F2 scenarios, but it has no scenarios with a significantly different change from the Historical.

Table C-16. Irrigation Water Availability Results and Analysis for ASD 0880. Units are in Mm^3/yr.

Parameter\Scenario	Historical	HSAF1	HSBF1	ISAF1	ISBF1	HSAF2	HSBF2	ISAF2	ISBF2
Average	3,042	3,285	3,285	3,358	3,358	2,966	2,967	3,192	3,194
Range	3,379	2,237	2,237	1,814	1,814	2,656	2,654	1,598	1,598
Change from Historical	----	244	244	317	317	-76	-74	151	152
Slope	----	----	----	----	----	----	----	----	----
R2	----	----	----	----	----	----	----	----	----

ASD 4897

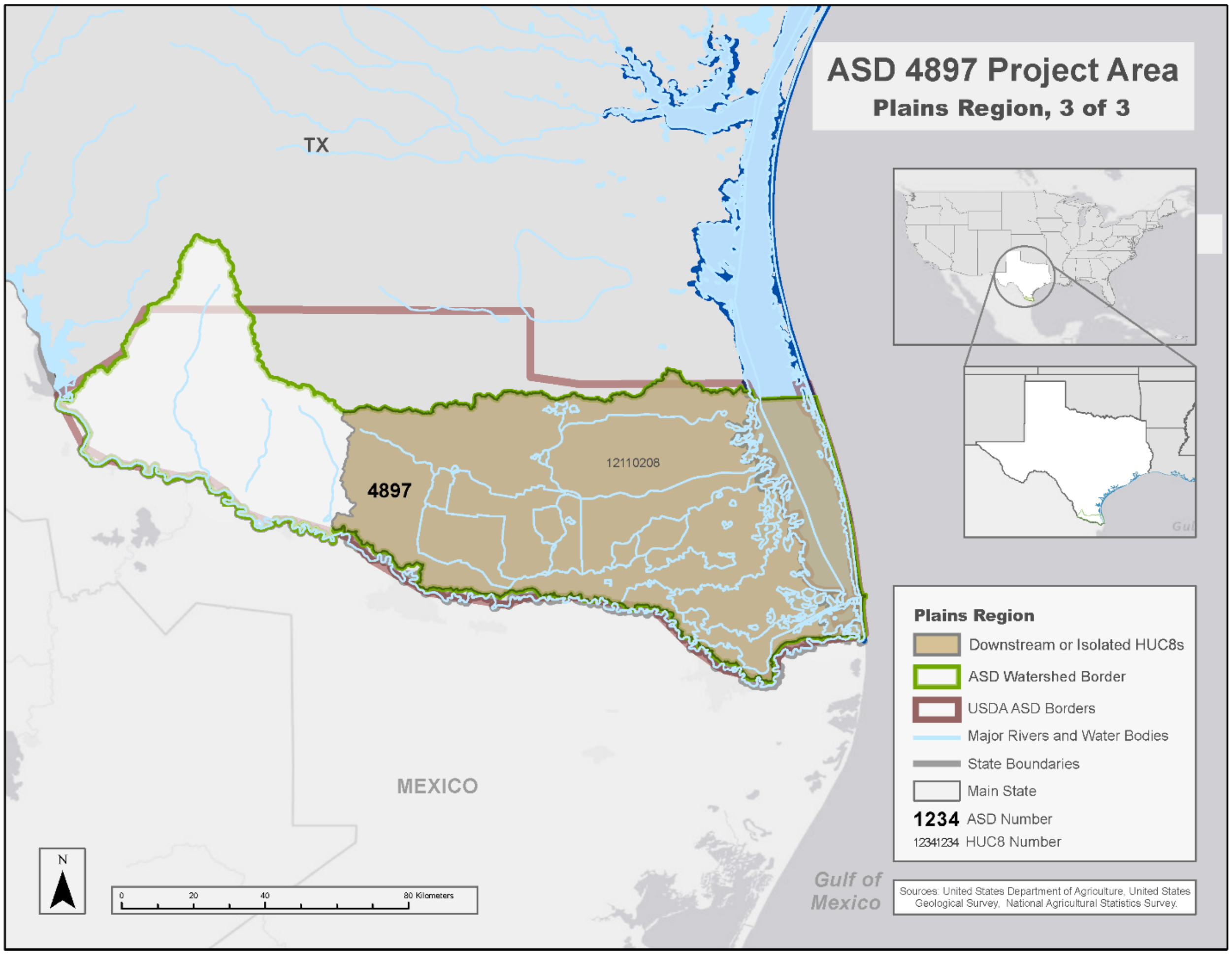

Figure C-17. ASD 4897 Watershed Borders: the borders of the ASD modified to include streamflow only for HUC8s that were mostly within its original borders.

ASD 4897 has an increase from the Historical scenario in average available irrigation water for the IS F1 scenarios, and a decrease for all others. It has no significant scenarios.

Table C-17. Irrigation Water Availability Results and Analysis for ASD 4897. Units are in Mm^3/yr.

Parameter\Scenario	Historical	HSAF1	HSBF1	ISAF1	ISBF1	HSAF2	HSBF2	ISAF2	ISBF2
Average	7,857	7,719	7,741	7,998	8,020	7,635	7,656	7,533	7,556
Range	8,073	6,672	6,629	6,175	6,172	7,099	7,087	5,739	5,741
Change from Historical	----	-138	-116	140	163	-222	-201	-324	-302
Slope	----	----	----	----	----	----	----	----	----
R2	----	----	----	----	----	----	----	----	----

C.5. Southeast

ASD 1250

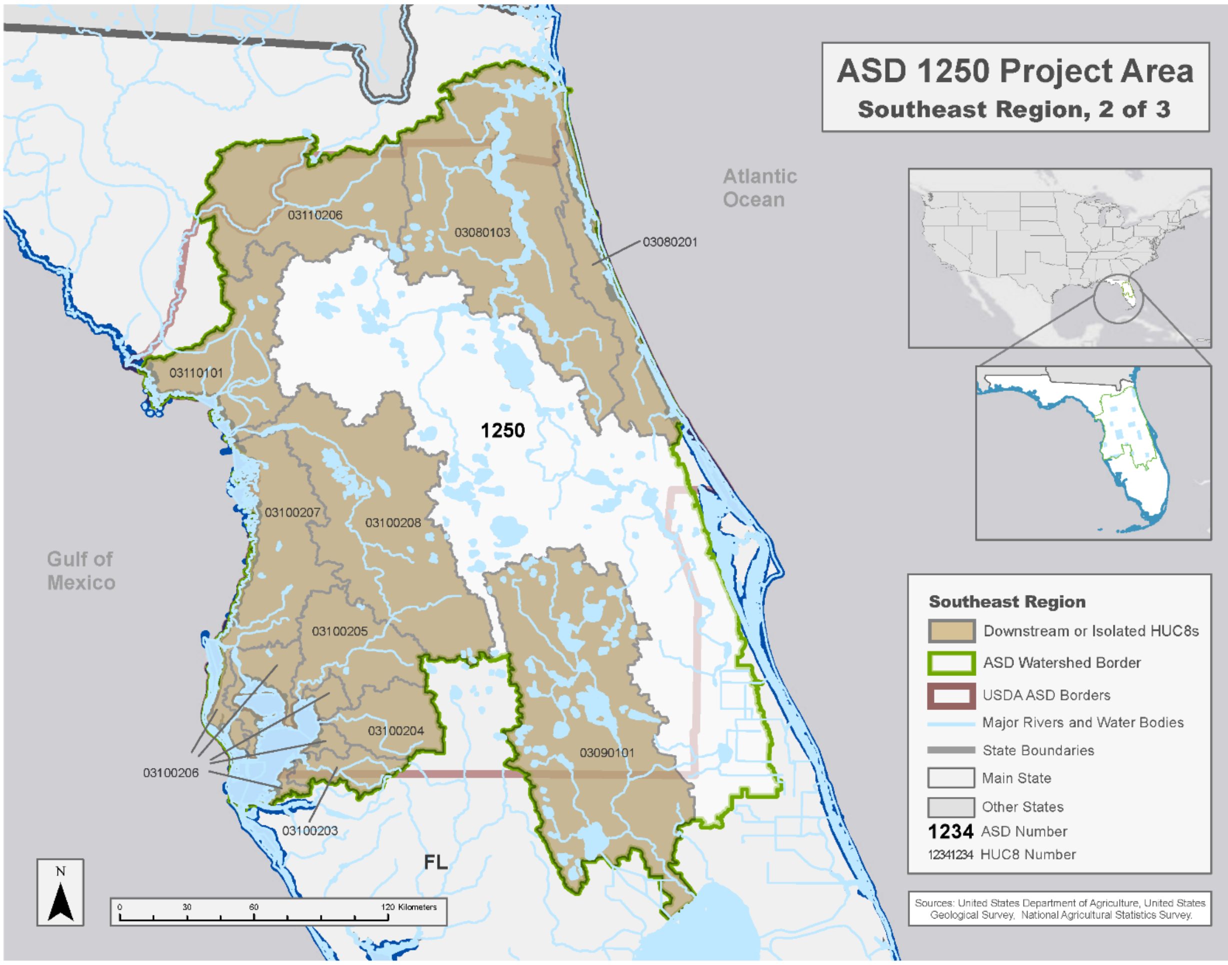

Figure C-18. ASD 1250 Watershed Borders: the borders of the ASD modified to include streamflow only for HUC8s that were mostly within its original borders.

ASD 1250 is located on the Florida peninsula and has an increase in average available irrigation water for the near future scenarios and a decrease for the far future. It has no significant scenarios.

Table C-18. Irrigation Water Availability Results and Analysis for ASD 1250. Units are in Mm^3/yr.

Parameter\Scenario	Historical	HSAF1	HSBF1	ISAF1	ISBF1	HSAF2	HSBF2	ISAF2	ISBF2
Average	19,398	19,594	19,538	20,172	20,117	17,336	17,247	19,026	18,937
Range	19,106	15,566	15,596	19,474	19,528	15,957	15,960	20,006	19,987
Change from Historical	----	196	141	775	719	-2,061	-2,151	-372	-461
Slope	----	----	----	----	----	----	----	----	----
R2	----	----	----	----	----	----	----	----	----

ASD 1370

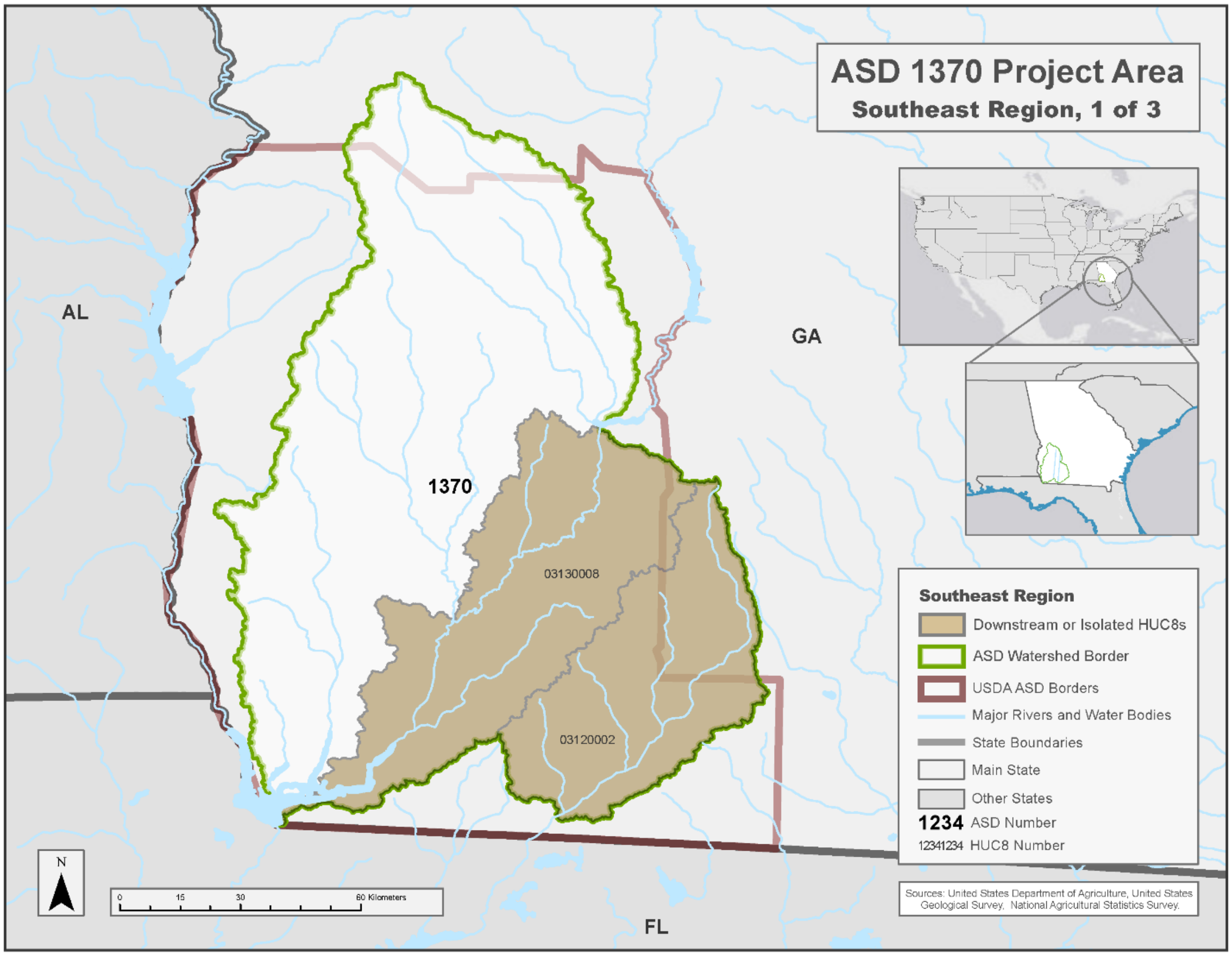

Figure C-19. ASD 1370 Watershed Borders: the borders of the ASD modified to include streamflow only for HUC8s that were mostly within its original borders.

ASD 1370 has an increase in average available irrigation water for the HS F1 scenarios, a decrease for all others, and no significant scenarios.

Table C-19. Irrigation Water Availability Results and Analysis for ASD 1370. Units are in Mm^3/yr. Results for the statistically significant scenarios are in bold.

Parameter\Scenario	Historical	HSAF1	HSBF1	ISAF1	ISBF1	HSAF2	HSBF2	ISAF2	ISBF2
Average	9,038	9,167	9,159	8,710	8,702	8,416	8,406	8,675	8,665
Range	11,015	6,096	6,095	7,026	7,025	6,585	6,585	7,502	7,501
Change from Historical	----	129	121	-327	-335	-622	-632	-363	-373
Slope	----	----	----	----	----	----	----	----	----
R2	----	----	----	----	----	----	----	----	----