Assessing the Benefits of Irrigation Modernization

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Background

In the Western U.S., the irrigation water delivery infrastructure critical to food production is still largely managed using century-old equipment and designs.

Modernization of this water conveyance infrastructure, such as piping of earthen canals, is known to improve water availability and water quality for farmers, while saving energy.

There are sparse data on irrigation infrastructure characteristics to estimate the scale of the costs and benefits associated with accelerating modernization.

This analysis estimates a variety of previously unquantified metrics related to irrigation water delivery infrastructure in the Western U.S. to support nationwide modernization planning, including the potential economic benefits from construction activities and increased water available to agriculture.


Source: https://ecbid.org/about-ecbid/

Background: Economic Value of Food Production

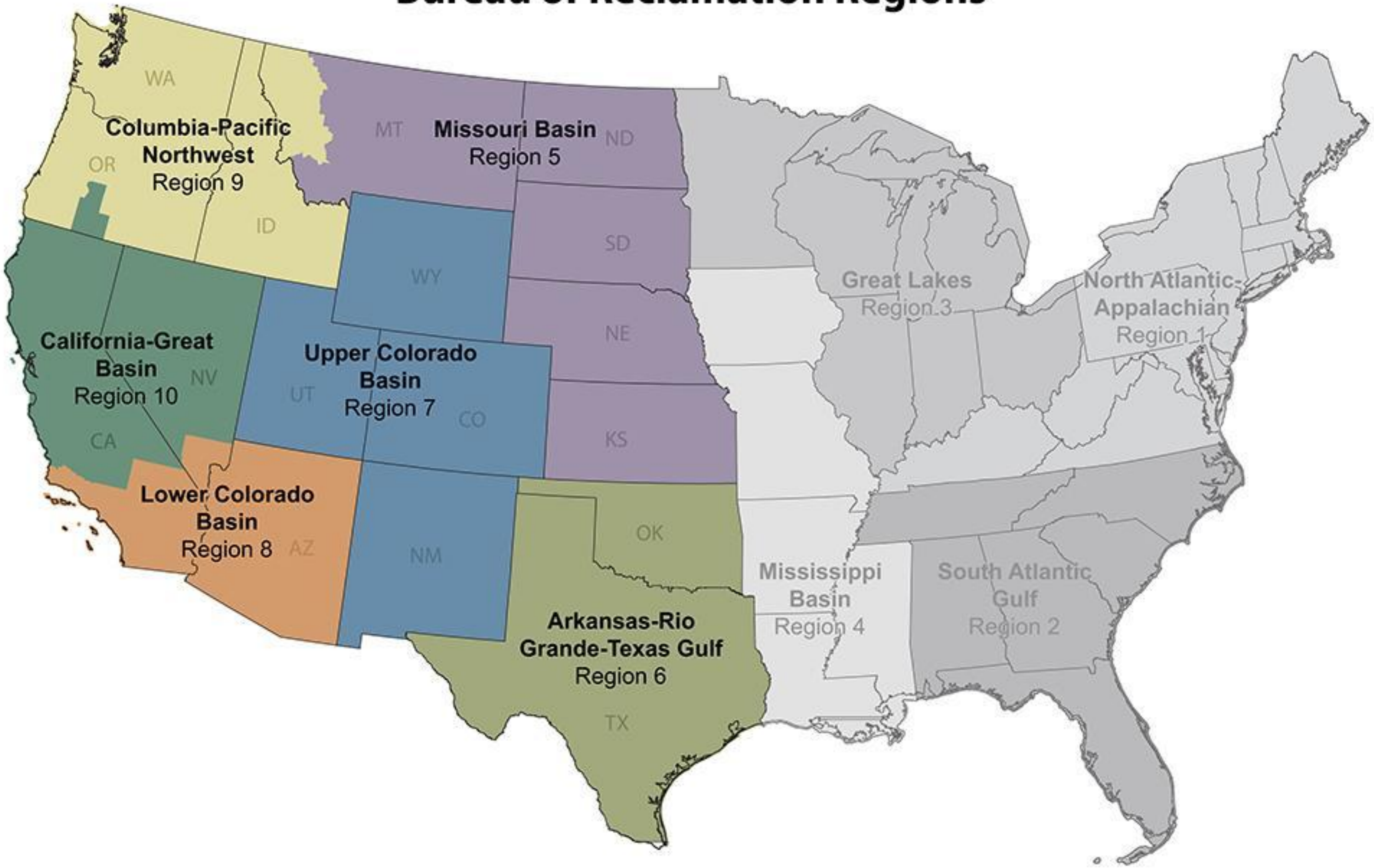
- Irrigation infrastructure is critical to food production
  - **75%** of the nation's irrigated acres concentrated in the West
  - Irrigated agriculture accounts for **half** of US crop revenues
- Farming is responsible for nearly **$203 billion in U.S. GDP and 2.6 million jobs** (USDA ERS 2024)
  - A total GDP contribution of roughly $1.5 trillion and over 22 million full and part-time jobs across agricultural and food sectors
- ~20 percent of U.S. agricultural production is for the export market, making up 7 percent of all exports (U.S. International Trade Commission 2024)
- Drought costs the U.S. over **$6 billion a year** (NIDIS n.d.)
- Irrigation modernization can reduce seepage and evaporative losses, therefore increasing the reliability of water deliveries to agricultural producers
- Improved water delivery reliability during times of drought may help reduce or avoid crop losses, potentially improving outcomes for jobs and economic productivity

Study Overview

- Study focuses on the 17 Bureau of Reclamation States
- Assess the impact of the current rate of modernization
- Consider accelerated modernization paces (x2 and x3 current)
- The current and accelerated modernization pace scenarios are applied to various metrics*
  - Water savings from avoided seepage or evaporation
  - Energy savings
  - Changes in food production due to increased crop water availability because of water conservation achieved through irrigation infrastructure modernization
  - Economic impacts from construction activities

*Assumptions limit the absolute accuracy of our calculations but allow for reasonable estimates that enable consideration of the challenges and opportunities associated with modernizing irrigation water delivery infrastructure.

Bureau of Reclamation Regions



Irrigation Conveyance Overview

Unlined - water travels along canals of exposed dirt

Lined - canals are layered with concrete

Piped - water travels via pipeline infrastructure

Key findings that set up our economic analysis

- Across the Western United States there is an estimated **147,700 miles** of canal and pipeline infrastructure for irrigation conveyance
  - **64% unlined** (95,100 miles)
  - **27% lined** (40,200 miles)
  - **8% piped** (12,400 miles)
  - **~570 miles** of canals are newly piped or lined each year – on pace for existing canals to be completely modernized in **167 years**!
- **~38-50 million** acre-feet of water is diverted for agriculture in the West each year
  - **~10-13 million** acre-feet is lost due to seepage and evaporation
  - **~138,000** acre-feet of water is conserved annually through modernization


Source: https://ecbid.org/about-ecbid/

Key Economic Findings: Construction Impacts

- **Irrigation modernization projects create strong economic benefits.**
  - Each dollar spent on modernization **adds an additional dollar in value to the regional economy** through indirect and induced economic impacts.
- Modernizing all **95,000** miles of unlined canals could cost **~$285 billion**.
- Based on data from recent years, approximately **$1.15 billion** is spent annually on modernization projects.
  - Continuing at the present pace of modernization could cost an estimated **$22 billion** through 2050 while supporting an estimated **12,800 annual jobs.**
  - Doubling the rate of piping or lining open canals could double costs while creating an estimated **25,500 annual jobs** and adding an annual **$2.3 billion** in value to the regional economy.

Modeling: Economic Impacts of Irrigation Modernization Construction Activities

- IMPLAN (an input-output model) was used to quantify the potential impact of modernizing irrigation infrastructure on the economy in the Western U.S.
  - Construction and maintenance spending in each state was estimated using for current pace and accelerated scenarios (x2 and x3)
- Spending on irrigation modernization was modeled as an industry output event for each state
- One year of construction in each of these states was analyzed, with the assumption that subsequent years would see similar rates of construction
- IMPLAN uses regional dollar-flow data tables to calculate the direct, indirect, and induced effects and job impacts of that industry’s output change on the regional economy

Economic Impacts from Irrigation Modernization Construction Activities

Assumptions:

- 50% lining
- 35% plastic piping
- 15% steel piping

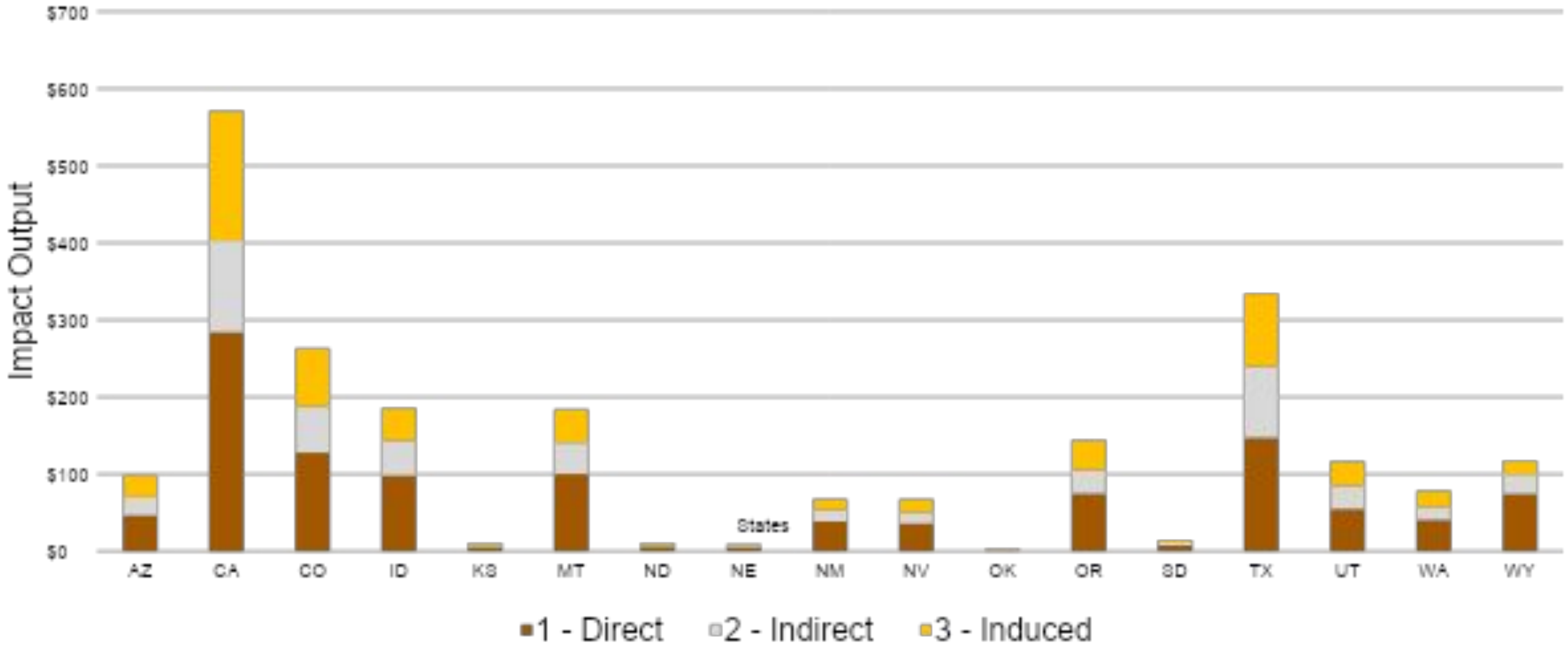
Project Type	Average cost per mile (2024 $)
Steel piping	2,453,956
Canal Lining	2,191,205
Plastic piping average	1,592,960
PVC piping	*739,485*
HDPE piping	*2,446,435*

Welding plastic pipe. Photo credit: Central Oregon Irrigation District

Economic Impacts from Irrigation Modernization Construction Activities

Current pace				
Impact	Employment (Jobs)	Labor Income (in millions)	Value Added (in millions)	Output (in millions)
Direct	7,837	$539.69	$550.92	$1,148.05
Indirect	1,782	$158.96	$245.05	$525.53
Induced	3,149	$190.53	$355.94	$604.01
Total	12,768	$889.19	$1,151.92	$2,277.61
Accelerated pace (x2)				
Impact	Employment (Jobs)	Labor Income (in millions)	Value Added (in millions)	Output (in millions)
Direct	15,673	$1,079.38	$1,101.85	$2,296.11
Indirect	3,565	$317.92	$490.10	$1,051.07
Induced	6,298	$381.06	$711.89	$1,208.03
Total	25,536	$1,778.38	$2,303.85	$4,555.22

Economic Impacts from Irrigation Modernization Construction Activities



Key Economic Findings: Crop Water Availability

- Modernization projects that conserve water can help to mitigate the effects of drought.
- A hypothetical example was used to contextualize the value of this conserved water: if water conserved through current irrigation modernization efforts were directed exclusively to improve alfalfa hay yields in a few representative counties in five alfalfa-producing states, production could increase in these counties by an average of **7.3 percent**.
- This added productivity could result in an increase of **1,050 annual jobs** across these counties and **$43.6 million** of added annual economic activity by 2050

Modeling: Estimated Economic Value of Crop Water Availability Impacts on Food Production

- AquaCrop, a Food and Agriculture Organization crop-water productivity (WP) model, is used to measure crop yield response to water
- Requires a set of inputs:
  - Climate, crop-type, irrigation and field management, and soil data
- Generates crop output in tons/hectare which were converted to tons/acre
- The WP metric in AquaCrop was altered to reflect changes in assumed water availability
  - The default WP metric for alfalfa is 15 g/m^2 (baseline scenario)
  - WP metric for the current, x2, and x3 scenarios were informed using the water conservation estimates

Crop	State	County
Alfalfa	Arizona	Pima
		Yuma
	California	Merced
		Tulare
	Colorado	Gunnison
		Larimer
		Mesa
	Idaho	Ada
		Canyon
	Washington	Grant
		Kittitas

Estimated Economic Value of Crop Water Availability Impacts on Food Production

Difference Between Baseline and Current Modernization Scenario, IMPLAN Analysis					
State	County	Increased Tons/Acre (Dry)	Increased Revenue (2050 dollars in millions)	Increased Number of Jobs	Total Additional Value Added (in millions)
Arizona	Pima	0.61	$ 2.14	89	$ .78
	Yuma	0.75	$ 19.76	109	$ 6.94
California	Merced	0.64	$ 25.91	174	$ 9.28
	Tulare	0.58	$ 17.83	124	$ 6.41
Colorado	Gunnison	0.23	$ 3.93	31	$ .82
	Larimer	0.29	$ 4.31	77	$ 1.18
	Mesa	0.33	$ 5.13	145	$ 1.43
Idaho	Ada	0.38	$ 2.15	32	$ .91
	Canyon	0.45	$ 9.82	53	$ 3.24
Washington	Grant	0.38	$ 28.76	120	$ 10.23
	Kittitas	0.36	$ 6.51	96	$ 2.36

Sprinkler vs. Basin

SPRINKLER						
	Baseline-Current		Baseline-2x		Current-2x	
	Employment	Value Added (in millions)	Employment	Value Added (in millions)	Employment	Value Added (in millions)
TOTAL	1050	$ 43.61	1214	$ 50.12	164	$ 6.50

BASIN						
	Baseline-Current		Baseline-2x		Current-2x	
	Employment	Value Added (in millions)	Employment	Value Added (in millions)	Employment	Value Added (in millions)
TOTAL	1015	$ 40.60	1183	$ 47.33	167	$ 6.72

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Conclusion

- Our analysis illustrates the scale of the challenges and opportunities involved in modernizing the agricultural water delivery infrastructure in the Western U.S.
- Accelerating the pace of modernization could strengthen the long-term resilience of U.S. food systems while providing significant economic, energy, water, and environmental benefits.
- Doubling the pace of current irrigation modernization activities could create an estimated $30 billion in cumulative benefits by 2050, even without accounting for the value of increased water availability, energy savings, or energy generation.

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Thank you

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Estimate of Irrigation Water Delivery Infrastructure Length in Western States

State	Total Length (miles)
Arizona	5,959
California	36,529
Colorado	16,438
Idaho	12,649
Kansas	702
Montana	12,893
Nebraska	598
Nevada	4,584
New Mexico	4,952
North Dakota	781
Oklahoma	213
Oregon	9,624
South Dakota	969
Texas	18,935
Utah	7,047
Washington	5,236
Wyoming	9,566
Total	147,676

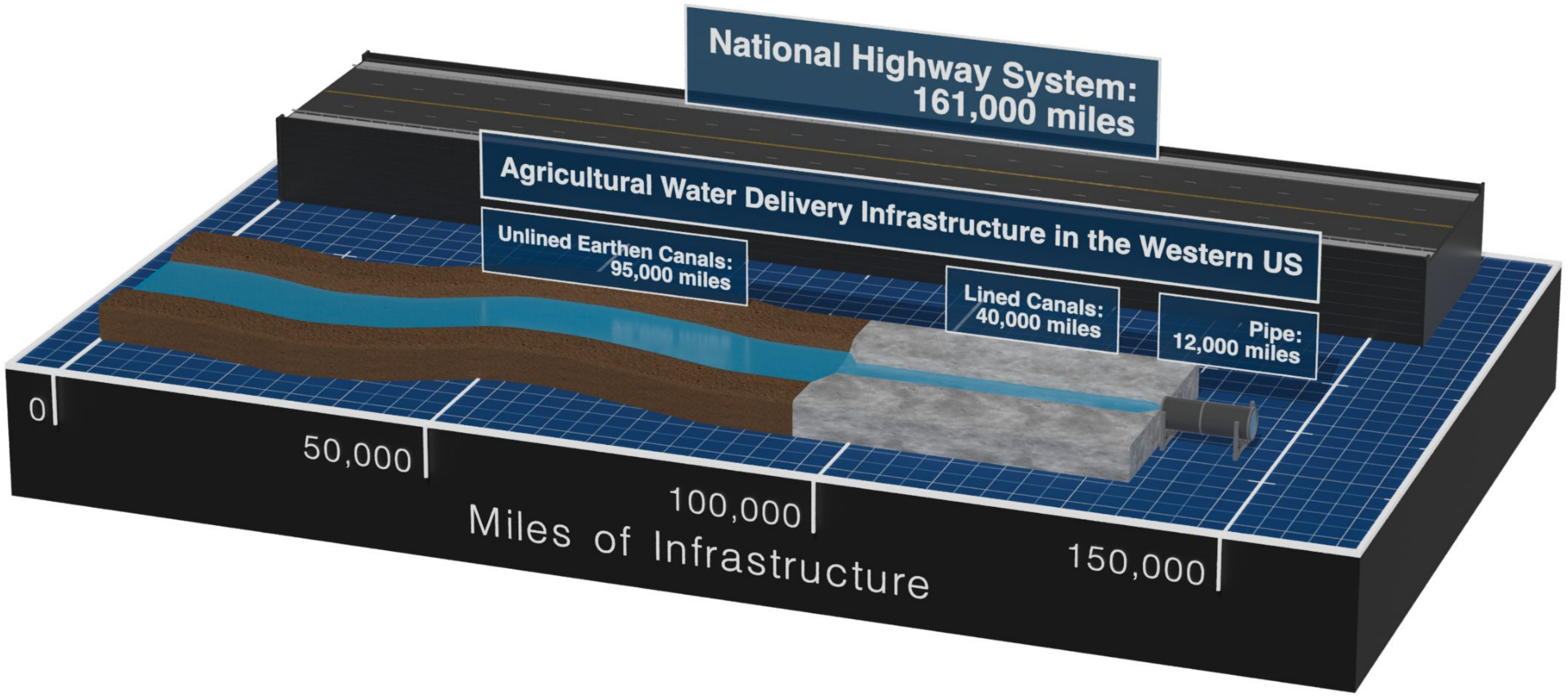
- **Estimated a total of 147,700 miles of irrigation canal and pipeline infrastructure across Western U.S.**

- Quantified using GIS software based on the USGS National Hydrography Dataset - NHDPlus High Resolution:
  1. Used the NetworkNHDFlowline and NonNetworkNHDFlowline shapefiles included in the NHDPlus HR dataset
  2. The selected lines were intersected with a state-boundary shapefile to create state level information
  3. For each state, the total miles of flow lines were summed

Estimate of Existing Lining and Piping

- Estimated using USDA NASS survey-based
- Existing literature uses USDA ERS data to estimates the averages of the amount of delivery system lining broken down by organization size (Hrozencik, et al. 2021)
- Later work provides summary results from a survey of irrigation organizations that includes percentages of piped infrastructure (Hrozencik, et al. 2022)

Lining and Piping Estimates (miles)	
Unlined	*95,100*
Lined	*40,200*
Piped	*12,400*
Total	**147,700**



Estimated Annual Miles of Lining and Piping

State	Combined, pro-rated annual piping and lining (miles)	Total modernized miles in 2050		
		Current Pace	2X Current Pace	3X Current Pace
Arizona	23	598	1,196	1,794
California	141	3,666	7,332	10,997
Colorado	63.4	1,650	3,299	4,949
Idaho	48.8	1,269	2,539	3,808
Kansas	2.8	70	141	211
Montana	49.8	1,294	2,588	3,882
Nebraska	2.4	60	120	180
Nevada	17.6	460	920	1,380
New Mexico	19.2	497	994	1,491
North Dakota	3	78	157	235
Oklahoma	0.8	21	43	64
Oregon	37.2	966	1,932	2,897
South Dakota	3.8	97	195	292
Texas	73	1,900	3,801	5,701
Utah	27.2	707	1,414	2,122
Washington	20.2	525	1,051	1,576
Wyoming	37	960	1,920	2,880
Total miles	**570**	**14,820**	**29,640**	**44,460**

Limited data suggests ~570 miles of canal are lined and piped each year (~285 miles each)

Analysis included data from:

- WaterSMART Water and Energy Efficiency Grant (WEEG) from 2015 through 2023
- Farmers Conservation Alliance (FCA) representing completed and scheduled piping projects for the state of Oregon between 2017 and 2026

Estimated Water Conservation Potential Associated with Lining or Piping Open Canals

Data suggests ~138,000 acre-feet of water are conserved each year based on the current pace of modernization.

Water conservation potential calculations rely on **3 inputs** calculated for each state:

1. Estimated **% of conveyance loss** at high and low levels
2. **Conservation achieved annually** at current and accelerated (x2 and x3) scenarios
3. **Water availability** for irrigation using high, medium, and low ranges

- Self-reported data from USDA ERS reveals 19% average (13 - 25% range) conveyance loss by state (Potter 2023)
  - Assumed low-end estimate → a high-end estimate assumed to be 10% greater
- DOI performance reports were used to obtain data for annual water conservation in acre-feet from 2012 to 2021 (U.S. Department of Interior n.d.)
- $Total\ acre-feet\ diverted = \frac{acre-feet\ applied}{\ldots} x\ 100$

Water Conservation Potential Associated with Lining or Piping Open Canals

State	Current estimated conveyance loss, high-loss scenario	Estimated total diversion, acre-feet	Estimated current conveyance losses, acre-feet	Pro-rated estimated current conservation achieved annually, acre-feet
Arizona	24%	3,522,245	845,339	13,177
California	23%	11,984,636	2,756,466	45,425
Colorado	26%	2,090,384	543,500	7,614
Idaho	30%	4,437,074	1,331,122	15,289
Kansas	35%	60,298	21,104	193
Montana	26%	1,988,789	517,085	7,244
Nebraska	35%	770,725	269,754	2,466
Nevada	23%	438,360	100,823	1,662
New Mexico	24%	860,809	206,594	3,220
North Dakota	35%	113,640	39,774	364
Oklahoma	35%	85,994	30,098	275
Oregon	30%	2,312,246	693,674	7,967
South Dakota	35%	194,618	68,116	623
Texas	35%	1,733,011	606,554	5,545
Utah	24%	1,936,089	464,661	7,243
Washington	30%	3,099,067	929,720	10,678
Wyoming	26%	2,474,773	643,441	9,015
	Total	**38,102,759**	**10,067,826**	**138,000**

Water Conservation Potential Associated with Lining or Piping Open Canals

	High Loss (millions of acre-feet)			Low Loss (millions of acre-feet)		
Values	Average Year	Drought Year	Wet Year	Average Year	Drought Year	Wet Year
Sum of Estimated total diversion	42.19	38.10	50.19	37.14	33.53	44.22
Sum of Water applied	31.10	28.03	37.27	31.10	28.03	37.27
Sum of Starting conveyance loss volume	11.09	10.06	12.91	6.04	5.49	6.94
Sum of Total conservation achieved by 2050 at current conservation rate	3.58	3.58	3.58	3.58	3.58	3.58
Sum of 3X Accelerated Conservation	10.76	10.76	10.76	10.76	10.76	10.76
Sum of Water available in 2050 under current conservation rate	34.68	31.62	40.86	34.68	31.62	40.86
Sum of Water available in 2050 under 3X Accelerated Conservation	41.13	37.49	48.04	37.14	33.53	44.13

Estimated Energy Use and Savings Potential

- **~12,000 GWh of electricity used annually to pump off-farm surface water**
  - **Piping projects that create gravity pressurization could *conservatively* save 5,800-17,400 MWh of electricity annually, reducing costs and burden on the grid**.
- Followed methodology from “The energy footprint of U.S. irrigation: A first estimate from open data” was used, with some minor exceptions noted below (Sowby and Dicataldo 2022)
- Uses **state average electricity rate data** instead of national electricity rate data
- 3 scenarios were created:
  1. Current pace
  2. x2 modernization
  3. x3 modernization
- Estimates were made using 3 ranges for the 3 modernization pace scenarios described above: 25, 50, and 75 percent energy savings per mile, for every mile piped

Geographic area	Large Organizations	Medium Organizations	Small Organizations
Eastern Rockies	9,213	880	507
High Plains	5,258	502	290
Northwestern	6,516	622	359
Pacific	9,738	930	536
Southwestern	4,254	406	234
	Total Estimated Lined Miles		**40,244**

Geographic area	Estimated number of miles of fully piped infrastructure in small organizations	Estimated miles of piping in an average system after accounting for fully piped systems
Eastern Rockies	1,460	1,794
High Plains	833	1,024
Northwestern	1,033	1,269
Pacific	1,543	1,896
Southwestern	674	828
	Total Estimated Piped Miles	**12,355**

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State	Baseline (g/m^2)	Current (g/m^2)	2x (g/m^2)	3x (g/m^2)
Arizona	15	16.13	16.25	16.25
California	15	16.13	16.23	16.23
Colorado	15	16.13	16.26	16.28
Idaho	15	16.13	16.26	16.36
Washington	15	16.13	16.26	16.36

Estimated Economic Value of Crop Water Availability Impacts on Food Production

SPRINKLER						
	Baseline-Current		Baseline-2x		Current-2x	
County	Employment	Value Added (in millions)	Employment	Value Added (in millions)	Employment	Value Added (in millions)
Pima	89	$ .78	106	$ .92	16	$ .14
Yuma	109	$ 6.94	129	$ 8.21	20	$ 1.27
Merced	174	$ 9.28	190	$ 10.12	16	$ .84
Tulare	124	$ 6.41	135	$ 6.99	11	$ .58
Gunnison	31	$ .82	36	$ .97	6	$ .14
Larimer	77	$ 1.18	91	$ 1.39	14	$ .21
Mesa	145	$ 1.43	172	$ 1.70	27	$ .26
Ada	32	$ .91	38	$ 1.07	6	$ .16
Canyon	53	$ 3.24	62	$ 3.83	10	$ .58
Grant	120	$ 10.23	142	$ 12.08	22	$ 1.85
Kittitas	96	$ 2.36	113	$ 2.79	18	$ .43
TOTAL	1050	$ 43.61	1214	$ 50.12	164	$ 6.50

Estimated Economic Value of Crop Water Availability Impacts on Food Production

BASIN						
	Baseline-Current		Baseline-2x		Current-2x	
County	Employment	Value Added (in millions)	Employment	Value Added (in millions)	Employment	Value Added (in millions)
Pima	89	$ .78	106	$ .92	16	$ .14
Yuma	108	$ 6.86	128	$ 8.13	20	$ 1.27
Merced	231	$ 12.30	247	$ 13.14	16	$ .84
Tulare	124	$ 6.41	135	$ 6.99	11	$ .58
Gunnison	30	$ .81	36	$ .96	6	$ .14
Larimer	77	$ 1.18	91	$ 1.39	14	$ .21
Mesa	145	$ 1.43	172	$ 1.70	27	$ .26
Ada	2	$ .04	9	$ .24	7	$ .19
Canyon	53	$ 3.27	62	$ 3.86	10	$ .58
Grant	60	$ 5.12	84	$ 7.16	24	$ 2.04
Kittitas	96	$ 2.36	113	$ 2.79	18	$ .43
TOTAL	1015	$ 40.60	1183	$ 47.33	167	$ 6.72