Little Sandy River, southern Wyoming

Chris Shope, USGS.

ECONOMIC ASSESSMENT OF A WATER DEMAND MANAGEMENT PROGRAM IN THE WYOMING COLORADO RIVER BASIN

SUMMARY

The state of Wyoming is evaluating the feasibility of implementing a water "Demand Management" (DM) program. Under a DM program, water users in the Wyoming portion of the Colorado River Basin would be compensated for voluntarily and temporarily reducing consumptive use of water. Colorado, New Mexico, and Utah are also considering a DM program. The saved water would be used to help these states meet their obligations under the Colorado River Compact of 1922. This bulletin reports results from a study estimating the economic impacts on agricultural operations, households, and communities of a potential DM program in Wyoming, if consumptive use reductions only came from the agricultural sector.

CONTENTS

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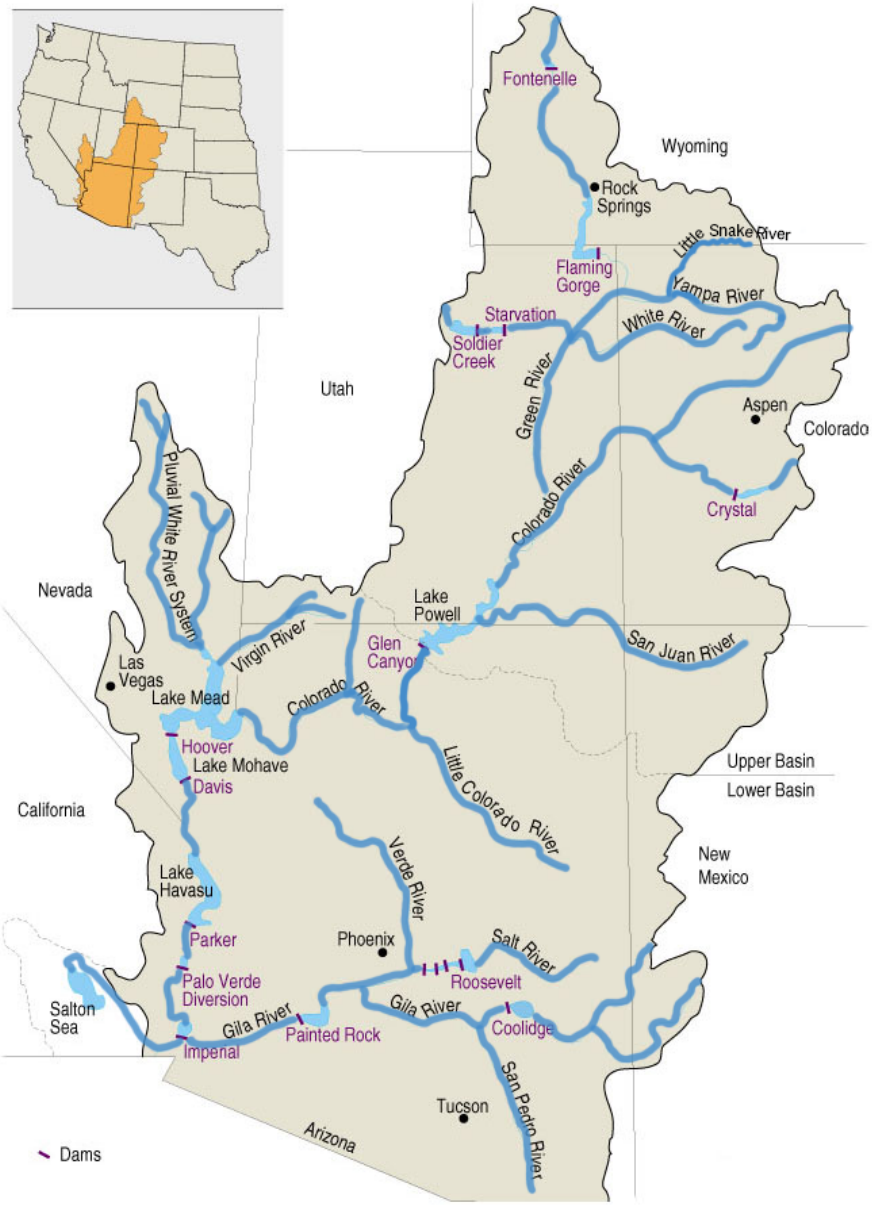

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Figure 1. The Colorado River Basin

CONSUMPTIVE WATER USE

Consumptive water use is water removed from a water resource system (for example through use by plants or evaporation) that is not returned to a stream or river. Discussions around a potential DM program refer to reductions in consumptive water use rather than diversions because the Compact measures water use in terms of consumptive use.

The estimated net regional economic impacts of a one-year DM program with a target volume level of 25 thousand acre-feet range from a decrease of 3.12% to 6.85% of income in the regional agricultural economy and a decrease of 0.04% to 0.10% of income in the overall regional economy, depending on how agricultural producers would change their hay and livestock operations in response to a program. This study evaluates the economic impacts of a potential DM program relative to a "business as usual" baseline rather than one of heightened risk of water curtailment or river regulation in which involuntary and uncompensated reductions in water use may be required by the state to ensure Compact obligations are met.

INTRODUCTION

Given the persistently dry hydrology the Colorado River Basin (CRB) has experienced over the past 20 years, four states in the Upper CRB (Colorado, New Mexico, Utah, and Wyoming) are considering proactive options to reduce the risk of having to administratively regulate some post-compact water users off to ensure they meet their obligations under the Colorado River Compact of 1922. One option under consideration is a Demand Management (DM) program, in which water users in the CRB portion of these four states would be compensated for voluntarily reducing their consumptive water use. These consumptive use reductions would be stored and then

released, if needed, to help meet downstream Compact obligations.

Approximately 80 percent of consumptive water use in the Wyoming portion of the CRB is in the agricultural sector, primarily for irrigation of alfalfa and native grass hay as winter feed for livestock. Thus, consumptive use reductions would likely come mostly from agriculture if a DM program were implemented. These consumptive use reductions would have an impact on the regional economy. On the one hand, using less water would reduce the amount of hay and potentially livestock produced in the region. Participating ranch operations might subsequently hire less labor to harvest hay or reduce herd sizes. On the other hand, DM program participants would spend some of the money they receive locally, which would benefit the local economy. A participant might buy a new truck or hire labor and buy supplies to fix a barn. For a small DM program, these changes would be small. For a larger DM program, they could have a noticeable effect on the regional economy.

We recently conducted a study to assess the impacts—positive and negative—of a potential DM program on agricultural operations, households, and communities in the Wyoming portion of the CRB if consumptive use reductions came from the agricultural sector. The study contains three separate components:

- **Irrigator Survey**. Interviews, focus groups, and a survey of agricultural producers with irrigation water rights in the Wyoming CRB were conducted to understand motivations for participating (or not) in a DM program.

- **Scenario Development**. Hypothetical DM program scenarios were developed, along with assumptions about what types of water users would participate and under what conditions.

- **Regional Economic Impact Estimation**. Regional economic impacts were estimated using an impact analysis model (called IMPLAN) to determine how the participation payment, reduction in hay production, and replacement hay purchases resulting from a DM program would ripple through the regional and local economy (IMPLAN, 2020).

This bulletin describes each component and associated findings.

COLORADO RIVER COMPACT OF 1922 ADDITIONAL RESOURCES

- Wyoming and the Colorado River: 2016 Report, bit.ly/Wyo-Colo-River-Report-2016

- Upper River Colorado Commission, www.ucrcommission.com

- WY-CRB DM website, bit.ly/WY-CRB-DM

DEMAND MANAGEMENT STUDY

The full study whose results are reported in this bulletin is located here: http://bit.ly/WY-DM-Study

A similar study conducted for Colorado is located here: http://bit.ly/Colo-DM-Study

AGRICULTURE AND WATER USE IN THE WYOMING COLORADO RIVER BASIN

The Colorado River Basin spans seven U.S. states before crossing into Mexico and reaching its terminus in the Gulf of California. As a whole, the Basin provides water to over 40 million people and supports economic activity valued at approximately $1.4 trillion annually (Wyoming State Engineer's Office, 2016). Wyoming's portion of the Colorado Basin covers over 17,000 square miles across the Green River and Little Snake River Basins (see Figure 1, page 2). This bulletin refers to the Green River and Little Snake Basins collectively as the Wyoming portion of the CRB (Wyoming CRB).

The Wyoming CRB is located in the counties of Carbon, Lincoln, Sublette, Sweetwater, and Uinta. Although the footprint of the Wyoming CRB is fully contained within these five counties, some parts of these five counties

Table 1. Wyoming Counties Located in the Wyoming CRB

County	County Area (square miles)	Portion of County in the WY-CRB (square miles)	%	% of the WY-CRB in each county
Carbon	7,896	2,414	31%	12%
Lincoln	4,069	1,935	48%	9%
Sublette	4,883	4,433	91%	21%
Sweetwater	10,425	10,463	100%	50%
Uinta	2,082	1,592	76%	8%
WY-CRB	29,355	20,837	71%	100%
Note: Sweetwater portion includes the Great Divide Basin.				

Table 2. 2019 Consumptive Use by Sector

Use Sector	Green River Basin		Little Snake River Basin		Wyoming CRB		LSRB as % of WY-CRB:
	AF	% of GRB	AF	% of LSRB	AF	% of WY-CRB	
Agriculture	422,532	81%	30,593	65%	453,125	80%	7%
Municipal and Industrial	62,372	12%	282	1%	62,654	11%	<1%
Reservoir Evaporation	25,148	5%	1852	4%	27,000	5%	7%
Trans-Basin Diversions	1,515	0%	14,500	31%	16,015	2.82%	91%
Total	519,748		47,227		566,975	100%	8%
Source: WSEO.							

Table 3. Average Irrigated Acreage and Consumptive Use by Crop and County (2018)

	Irrigated Land				Crop Consumptive Use		
	Alfalfa Pivot	Grass Pivot	Grass Flood	Total	Alfalfa	Grass	Total
County	acres	acres	acres	acres	AF/acre	AF/acre	AF
Carbon	401	3,498	12,242	16,140	1.98	1.79	28,960
Lincoln	919	2,703	20,228	23,850	1.81	1.66	39,835
Sublette	6,327	16,859	143,922	167,108	1.52	1.50	251,141
Sweetwater	11,996	3,087	12,927	28,010	1.94	1.76	51,438
Uinta	8,733	21,002	51,650	81,385	2.18	2.05	167,615
WY CRB	28,376	47,149	240,969	316,494	1.91	1.68	538,989
Source: WSEO WY 2019 Consumptive Use Report.							

are not located within the Wyoming CRB. Table 1, page 4, (middle columns) indicates the area of each county (in square miles) and the percentage of each county in the Wyoming CRB. Economic data needed to estimate regional economic impacts is collected and reported at the county level, so impacts are reported for this five-county area rather than just for the precise footprint of the Wyoming CRB. The final column of Table 1 indicates the percentage of the Wyoming CRB contained within each county.

Agriculture accounts for most consumptive use in the Wyoming CRB (see Table 2, page 4). In 2019, agriculture accounted for an estimated 453,125 of the total 566,975 acre-feet of consumptive use in the Wyoming CRB, or 80 percent. Municipal and industrial uses accounted for roughly 11 percent and reservoir evaporation for 5 percent of 2019 consumptive use.

Table 2 also breaks down Wyoming CRB consumptive use between the Green River Basin (GRB) and Little Snake River Basin (LSRB). Overall, the Little Snake

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Battle Creek, Little Snake River Valley

River Basin accounts for 8 percent of consumptive water use in the Wyoming CRB and 7 percent of its agricultural water use. The two largest trans-basin diversions are from the Green River Basin to the Bear River Basin and from the Little Snake River Basin is to the City of Cheyenne.

The agricultural sector has the most variable consumptive use, ranging over the 2011–2019 period from a high of over 530,000 acre-feet in 2011 to below 370,000 acre-feet in 2013. During this same period, the other major consumptive use sectors had little annual variability. Annual variability in the agricultural sector is largely driven by water supply during the irrigation season linked to snowpack and water storage conditions.

Livestock production is the largest part of Wyoming's agricultural economy, generating over 60 percent of the value of production. In the Upper CRB, the estimate jumps to over 78 percent of the region's agricultural economy. While this study is not directly focused on livestock, much of the agricultural land in the Wyoming CRB is tied to livestock production. Virtually all irrigated acres in the Wyoming CRB are alfalfa hay and grass hay, primarily used as feed for livestock production. Table 3, page 4, indicates acreage levels for these two crops and distinguishes between flood-irrigated and pivot-irrigated grass hay. Averages are based on irrigated acreage during the years 2011 through 2019.

Wyoming and other CRB states implemented the System Conservation Pilot Program (SCPP) from 2015 through 2018. The SCPP was a temporary, voluntary, and compensated water conservation pilot program. The purpose of the SCPP was to assess the likelihood of water users participating in a program designed to voluntarily and temporarily reduce their consumptive water use. Producers who participated in the SCPP implemented partial-season irrigation reductions (irrigate early in season then shut off water). An estimated 24,181 AF of CU savings were produced in Wyoming from 23 projects over the four years of the SCPP. In the final year of the program, volume-weighted average price in Wyoming was $150/AF. Participating

producer impressions and experiences with the SCPP is an important starting point for this study.

FINDINGS

1. Irrigator Survey

We implemented a survey of agricultural producers with irrigation water rights in the Wyoming CRB as part of this study.

System Conservation Pilot Program Participant Experiences. Because producer experiences with the SCPP is important to understanding how any future DM program would need to be structured to be of interest to producers, we asked 22 ranch operations that participated in the SCPP for at least one year about their experience with the SCPP. Fourteen producers responded, for a response rate of 64 percent.

Overall, survey respondents were satisfied with the SCPP (Table 4, page 7). They generally reported that their household and county were both about the same or better off as a result of the program and the county would be about the same or better off with an expanded version of the program in the future. SCPP participants noted the financial benefits of participation as a positive feature of the program. They also reported the SCPP brought the community together and helped people to realize the value of the region's natural resource base. When asked about negative impacts of the SCPP, some participants reported early drying up of hay fields with negative yield impacts in the following year and concerns about long-term impacts of participation on water rights.

In addition to asking SCPP participants about their experiences and impressions of the SCPP, we also asked many producers in the Wyoming CRB—both SCPP participants and non-participants—about their ranch operations, irrigation water management, and demographics. The purpose of these questions was to give a sense of how ranch operations, crop mix, yields, irrigation management, and perceptions vary across the region. This survey was received by 474 agricultural producers with irrigation water rights in the Wyoming CRB in December 2019. A total of 147 producers responded to the survey, for an overall response rate of 31 percent.

Producer Perceptions of Ecological and Neighbor Impacts from Practice Implementation. Of concern to many interviewed producers, focus group participants, and survey respondents, was how changes in the quantity and timing of return flows might affect ecological conditions and downstream neighbors in the region. The most prevalent impacts reported by producers were losses or reductions in grass composition or species diversity, wetland presence, and return flows (Table 5).

Also of concern to many interviewed producers and focus group participants was the possibility that participation in a DM program might affect timing and availability of water for other producers. Producers were asked how likely they were to consider how their irrigation decisions affected their neighbors, and how their neighbors' decisions affected them. Table 6, page 8, shows producers perceive themselves to be

SURVEY QUESTIONS

Overall, what type of impact has program participation had on your operation? See Table 4.

There are potential agronomic and ecological tradeoffs associated with implementing these practices. Do you think there would be agronomic impacts, ecological impacts, or hydrologic impacts from implementing these practices on your ranch? See Table 5.

When you make decisions about how, when, and how much you irrigate, do you consider how these decisions affect your neighbors (e.g., return flows, their ability to irrigate)? Do your neighbors' decisions about how, when, and how much they irrigate affect your water availability (e.g., return flows, your ability to irrigate)? See Table 6.

If there was a voluntary program available to compensate producers for a reduction in irrigation would you be interested in any of the following demand management practices? See Table 7.

quite hydrologically connected and interdependent; well over half of respondents indicated Likely, Very likely, or Always to both questions. Hydrologic studies modeling water flows would be useful to help quantify the impacts in different locations. These producer perceptions nonetheless demonstrate the general consensus in the region that producer decisions about water affect others.

Producer Interest in Various Demand Management Practices. Producers were also asked what practices they might be interested in, if there was a voluntary program available to compensate producers. The practice that generated the most interest was investments that reduce water use by enhancing delivery systems (Table 7, page 8). Also, relatively popular, was the partial-season practice (irrigate early in season then shut off water), a version of which was implemented in the System Conservation Pilot Program discussed below. Only 10 percent of respondents indicated interest in no irrigation on some fields for an entire season.

In spite of low producer interest, no irrigation on some fields for an entire season is the practice we include in the study. Consumptive use reductions for no irrigation are currently much easier to track and quantify in a DM program framework than partial-season reductions or irrigation investments. In fact, the data needed to accurately incorporate the partial-season irrigation reduction practice into the study does not currently exist. This study highlights the need for improved scientific data on within-season crop consumptive use, to improve the feasibility of including a broader selection of management practices in any future DM program.

2. Scenario Development

Many of the details about what a DM program would look like have not yet been determined by Wyoming and the other states considering a DM program. This section lays out what a DM program might look like, for the purpose of considering economic impacts. Any DM program the Upper Basin states decide to implement might be structured similarly to the hypothetical program described here or it might look quite different.

A Hypothetical DM Program. If the dry hydrology the CRB has experienced for the past 20 years persists, Upper Basin states may face a higher risk of curtailment. The purpose of a DM program would be to reduce the risk of curtailment. One way to think about how

Table 4. Impact of SCPP on Ranch Operation

Question: Overall, what type of impact has program participation had on your operation?		
Response	**#**	**%**
Positive impact	8	57%
Negative impact		0%
Both positive and negative	2	14%
No impact	2	14%
Missing response	2	14%
Total responses	14	

Table 5. Potential Impacts on Ranch from Demand Management Participation

Question: There are potential agronomic and ecological tradeoffs associated with implementing these practices. Do you think there would be agronomic impacts, ecological impacts, or hydrologic impacts from implementing these practices on your ranch?			
Impact	**Losses or reductions**	**No change**	**Gains**
Grass composition or species diversity	51%	23%	5%
Wetland presence	49%	24%	7%
Return flows	40%	26%	12%
Bird presence	37%	38%	5%
Big game presence	32%	41%	7%
Invasive species coverage (e.g., cheat grass)	24%	25%	30%
Fish presence	17%	53%	9%
Stream bank erosion	10%	53%	11%
Water turbidity	10%	50%	9%
Other	4%	4%	2%

Note: Percentage of respondents who indicate losses, no change, or gains sum to less than 100% for each impact because some respondents skipped the question.

Table 6. Potential Neighbor Impacts

Questions: When you make decisions about how, when, and how much you irrigate, do you consider how these decisions affect your neighbors (e.g., return flows, their ability to irrigate)? Do your neighbors' decisions about how, when, and how much they irrigate affect your water availability (e.g., return flows, your ability to irrigate)?				
	Do your own irrigation decisions affect neighbors?		**Do your neighbors' decisions affect your water availability?**	
Response	#	%	#	%
Not at all	28	19%	31	21%
Not very likely	20	14%	18	12%
Likely	33	22%	25	17%
Very likely	26	18%	27	18%
Always	31	21%	38	26%
No response	9	6%	8	5%
Total Respondents	147		147	

Table 7. Producer Interest in Various Demand Management Practices

Question: If there was a voluntary program available to compensate producers for a reduction in irrigation would you be interested in any of the following demand management practices?			
Practice	**Yes**	**No**	**% Yes**
Investments that reduce water use by enhancing delivery systems	85	22	58%
Split season (do not turn water back on after last cutting)	57	56	39%
Everyone on a tributary (or irrigation district) agrees to implement specified management practices (e.g., above programs)	47	58	32%
Everyone on a tributary (or irrigation district) agrees to save a certain amount of water (no specification of management practices)	37	62	25%
Forego the use of any stored water	17	79	12%
Earlier harvest than normal (and then turn off water)	15	87	10%
No irrigation on some fields for the whole year	15	90	10%
No irrigation on the same fields for multiple years	7	95	5%
Number of respondents			147

Table 8. Demand Management Scenarios

Scenario	**Initial Target Volume**	**Replacement in Years 5, 7, and 9**	**Total CU Reductions in Ten Years**
1	25 KAF	0	25 KAF
2	50 KAF	10 KAF	80 KAF
3	75 KAF	20 KAF	135 KAF

large a DM program would be is to think about what curtailment might look like in Wyoming.

The WY State Engineer's Office roughly estimates Wyoming's maximum exposure to curtailment would be approximately 70–80 thousand acre-feet (KAF); and more realistically, Wyoming's exposure could be 30–50 KAF, depending on water year conditions and historical consumptive use. We model a 10-year DM program of three different sizes, each with an initial target volume level to be achieved in the first three years and possible replacement of water used or evaporated in years five, seven, and nine (Table 8). These three initial target volumes were chosen to give an indication of potential regional economic impacts across a broad range of possible DM program sizes.

Producer Participation. The first step to estimating potential regional economic impacts of a hypothetical DM program is to understand an agricultural producer's decision of whether to participate. These firm-level decisions are aggregated to the regional level to estimate regional economic impacts.

We envision a typical DM program participant is an agricultural producer with a moderately-sized cattle herd who would enroll grass hay acres for one year by not irrigating for the full season. The producer might decide to do one of three things in response to the resulting loss in hay production. First, they might simply reduce hay production without making any other changes to their operations. This could mean they absorb the loss of hay production into their operation by stretching their other hay resources a bit further or they reduce hay exports from the region. Second, they might use a portion of the compensation they receive from the DM program to purchase replacement hay. Third, they might reduce their cattle herd size in proportion to the lost hay production.

This hypothetical producer would potentially participate for one year, or maybe three out of five years, so that their participation in the program is clearly temporary and not putting the producer in danger of abandonment of their water right. The requirement that participation be temporary makes it less likely a producer would reduce herd size in response to the DM program, but the program may be attractive to a producer who was already considering a change in their cattle operations.

CURTAILMENT

Under curtailment, Upper Basin states may be required to regulate some water rights with a post-1922 Compact priority date to reduce consumptive water use in proportion to their historical consumptive use. Wyoming would meet this obligation by regulating off water rights in the Wyoming portion of the CRB in reverse priority (starting with the most junior and working backwards by priority date) until its obligation was met.

ABANDONMENT.

Under Wyoming water law, any water right not put to its permitted beneficial use during the previous five years could be forfeited through an abandonment procedure. Thus participating in a potential DM program for fewer than five successive years should not result in a forfeiture of the water right.

The study assumes producers will enroll flood-irrigated grass hay acres rather than pivot-irrigated alfalfa or native grass hay acres. This financial determination is made based on per-acre consumptive use estimates, crop yields, hay prices, and production costs for these crops at various locations across the region. Focus group conversations and producer interviews affirm producers would be more likely to enroll flood-irrigated grass hay acres than grass or alfalfa hay under pivot, primarily due to the higher yields they receive under pivot.

The practice modeled is no irrigation for the full season. This was not a popular practice with producers (Table 5, page 7). The full-season no-irrigation practice is used in the study even though it is not popular because consumptive use reductions from this practice are much easier to track and quantify than partial-season irrigation reductions, making it a more viable practice for a DM program.

ADDITIONAL RESEARCH

Even after water is shut off, a crop is still consumptively using water being stored in the soil. In a DM program, a producer would not get "credit" for consumptive use reductions until the point at which all the water applied before the shut-off date had been used by the crop or evaporated. More research is needed to help determine how crop, soil type, and land location (bench or bottomland) affect the soil moisture profile after water has been shut off in high-elevation mountain valleys. Once this research has been done, the more popular partial-season irrigation reduction practice could be modeled.

YIELD IMPACTS

Few scientific studies exist on the yield impacts associated with foregoing irrigation on native grass hay for an entire season. These yield impacts are based on field trials conducted by Dr. Joe Brummer in Colorado for alfalfa and native grass hay, some at high elevations. A recent study of regional economic impacts of a potential DM program in Colorado relied on the same estimates (BBC Consulting, 2020). Study results are sensitive to this yield impact assumption.

For more information: Agronomic Responses to Partial and Full Season Fallowing of Alfalfa and Grass Hayfields. Update 2015 & 2016. Power Point presentations. Dr. Joe Brummer. Colorado State University.

The study assumes a decrease in yields of 70 percent in the year acres are enrolled and a decrease of 50 percent in the following year (during which full irrigation occurs as usual). Negative yield impacts in the enrollment year and the following year may be higher or lower than these levels in any given year, depending on specific field characteristics and water available to enrolled fields through sub-irrigation and precipitation.

A DM program would be voluntary, so the payment participants receive for enrolling acres would need to be sufficiently high to compensate them for the costs of participating. Producers might choose to purchase hay to replace lost hay production, or they might need a 50 percent premium over their net operating income (revenue minus agricultural operating expenses associated with producing a crop) to be induced to participate. Participation payment is assumed to be $230/AF based on these calculations. These payments also potentially have positive impacts on the community, to the extent that participants spend their payments in the local economy.

Table 9, page 10, presents acreage and consumptive use reductions for a one-year 25 KAF program (Scenario 1) under these assumptions. (Also shown is the percentage of each crop's acreage removed from production over the course of the ten-year study period). However, if a DM program were large, more practices and different payment levels might need to be implemented to achieve the target reductions. The

Table 9. Acreage Enrollment for Scenario 1 (25 KAF in One Year)

	Grass Flood (Acres)	% of County's Irrigated Acres	Consumptive Use Reductions (AF)	% of the Region's CU Reduction	Consumptive Use for Grass Hay (AF/acre)
Carbon	712	4.41%	1,275	5%	1.79
Lincoln	1,132	4.74%	1,884	8%	1.66
Sublette	8,788	5.26%	13,200	53%	1.50
Sweetwater	1,256	4.48%	2,213	9%	1.76
Uinta	3,143	3.86%	6,429	26%	2.05
Wyoming CRB	15,031	4.75%	25,000	100%	1.68

study relies on annual consumptive use estimates made by the Wyoming State Engineer's Office (WSEO) for each WSEO district (Table 9, final column). Yields are generally positively correlated with consumptive use. Because producers are more likely to enroll their less productive fields in a DM program, fields with lower consumptive use might tend to be the ones enrolled in a DM program. The positive correlation between yields and consumptive use combined with the likelihood that low-productivity fields might tend to be enrolled in a DM program suggest more acres may need to be enrolled than indicated in Table 9.

3. Regional Economic Impacts

Based on the hypothetical DM program scenarios and producer participation profile, we estimate regional economic impacts using a regional impact analysis model constructed for Carbon, Lincoln, Sublette, Sweetwater, and Uinta counties and for the broader regional functional economy of the Wyoming CRB.

We measure four types of economic impacts in the study:

- **Private Enrollee Impacts**: Net benefit to ranchers of enrolling acres. This is the participation payment of $230/AF less any replacement hay purchases. The program is voluntary, so producers would only participate if these impacts are positive and sufficiently cover income losses and risk.

STUDY BASELINE

Results are presented against a base case of average water years with no curtailment. A future with higher curtailment risk may be a more realistic base case moving forward. The negative economic impacts of curtailment could potentially be larger than the negative economic impacts associated with a DM program. The purpose of a DM program would be to reduce or remove entirely the risk of curtailment. Thus weighing the costs and benefits of a DM program involves an estimate of the benefits to the region associated with reducing or removing entirely the risk of curtailment.

WYOMING'S AGRICULTURAL ECONOMY

The agricultural economy of southwestern Wyoming includes livestock, crop production, and agricultural support services. The percentage impact of a 25 KAF DM program is larger for option 3 than 1 and 2 because changes in the livestock sector have a relatively large impact on the agricultural economy. The overall regional economy includes other sectors of the economy in addition to agriculture: construction, government, manufacturing, mining, and services.

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Battle Creek, Little Snake River Valley

- **Direct Impacts**: Transactions between DM program participants and others in the local economy. Examples: DM program participant buys a new truck; hires less help for harvest.

- **Indirect Impacts**: Firm-to-firm transactions in the economy. Examples: truck dealership pays its accountant; custom harvest company has less business.

- **Induced Impacts**: Changes in household spending by enrollees and other households affected by the program. Examples: the accountant's household buys more groceries; custom harvest company employees reduce household expenditures.

We measure results in two ways:

- **Value-Added Income**: The income or wealth portion of industry output (includes employee compensation, proprietary income, other depreciation payments, property income, and indirect business taxes).

- **Employment**: The number of jobs (both full-time and part-time) throughout the economy that derive, directly and indirectly, from the change in activity.

Hay Sector Results. Table 10, page 12, presents results only for Scenario 1 (in which 25 KAF in consumptive use reductions are achieved) for the sake of simplicity. The full study presents results for all three scenarios. In option 1, all DM participants are assumed to respond to the reduced hay production that results from enrolling acres in the DM program by reducing hay exports out of the region. In option 2, all DM participants are assumed to respond by purchasing hay to replace their lost production. No changes are made to livestock operations in the region under either of these options.

The top row of Table 10 indicates the participation benefits experienced directly by DM program participants. For option 1, this is the full $5.75 million in gross participation payment ($230/AF multiplied by the consumptive water use reduction of 25 KAF). For option 2, this is the gross participation payment less replacement hay purchases, for a total of $1.82 million.

The net regional economic impacts for options 1 and 2 are all negative at a participation payment level of $230/AF. They range from a decrease of $2.17 million to $3.38 million in lost income and 95 to 111 in lost jobs. Net impacts are more negative for option 2 than for option 1 because program participants in option 2 spend a large portion of their participation payment on replacement hay instead of re-spending it locally. Note, it would be comparing apples and oranges to sum the positive participation benefits and the net regional economic impacts because the two are measuring different types of things. The participation benefit is the primary benefit received by DM program participants. The net regional economic impacts are experienced by the overall economy and calculated based on estimates of how much of the participation payment remains local.

Table 10. Net Regional Economic Impact Estimates of a 25 KAF DM Program

	Option 1: Reduce Hay Exports		**Option 2: Purchase Replacement Hay**		**Option 3: Reduce Herd Size**	
Participant Benefits ($)	5,750,000		1,181,988		5,750,000	
Net Regional Economic Impacts						
	Value-Added ($)	**Jobs**	**Value-Added ($)**	**Jobs**	**Value-Added ($)**	**Jobs**
Direct	-1,671,954	-81	-2,599,785	-95	-3,847,142	-129
Indirect	-272,785	-9	-424,164	-11	-573,066	-12
Induced	-227,898	-4	-354,367	-5	-347,834	-5
Total	-2,172,638	-95	-3,378,316	-111	-4,768,043	-146

James W. Kay

Upper Green River

Livestock operation impacts. We also analyze potential impacts to the livestock sector that might result from a DM program. A DM program could affect livestock production if DM participants reduce herd size in response to their decreased hay production. Net regional economic impacts on the Wyoming CRB economy when livestock operations are affected are estimated to be $4.77 million in lost income and 146 in lost jobs for a 25 KAF DM program.

Impacts in Context. It is useful to place these impacts into the context of the regional economy. The net impact to the agricultural economy of a 25 KAF DM program would be -3.12 percent under option 1 (all participants reduce hay exports), -4.86 percent under option 2 (all participants purchase replacement hay), and -6.85 percent under option 3 (all participants reduce herd size) in response to reduced hay production. The impact to the overall regional economy would be -0.04 percent for option 1, -0.07 percent for option 2, and -0.10 percent for option 3. This analysis has assumed enrolled acres would be distributed evenly across the Wyoming CRB. These impacts could fall more heavily on some communities than others, depending on the location of enrolled acres.

STUDY ASSUMPTIONS AND LIMITATIONS

We estimated regional economic impacts based on the best information available. Better information on three things would be particularly useful.

Yield impacts. Results are sensitive to assumptions about how irrigation reductions would affect hay yields in the enrollment year and the following year. Better scientific data on the relationship between yields and irrigation reductions would increase the certainty around these results.

Mid-season Consumptive Use Data. Partial-season irrigation reductions (much preferred by survey

respondents to full-season irrigation reductions) could not be modeled for lack of reliable mid-season consumptive use estimates.

Ecological impacts. We do not consider the ecological impacts of changes in quantity and timing of flows that would result from implementation of a DM program. Subsurface irrigation is important in these systems and could be harmed by adoption of a large DM program, depending on which acres producers voluntarily enrolled. Not included in this study for lack of scientific data are estimates of how much longer recharge would take in areas where producers voluntarily enrolled acres, or how much this recharge would be worth economically, to crop production through subsurface irrigation or to recreation/tourism through wildlife habitat. Also not included for the same reason is a quantification of any additional angler benefits that might occur from increased stream flows associated with not diverting water. The impact analysis modeling framework we use in this study has two limitations that should also be noted:

The impact analysis framework assumes well-functioning and connected markets, so that imported labor and inputs are replaced without short-run changes in price or wages. This is a reasonable assumption for small economies that are integrated into larger well-functioning markets.

Impacts (positive and negative) are overstated if producers and community members can adjust to reduced hay production in ways not directly captured in the impact analysis framework. Impact models assume job losses are permanent and employees leave the region. In reality there could be smaller job losses for employees kept on the payroll for other tasks or opportunities.

Three additional points should be noted:

- Livestock impact estimates would be improved with a better understanding of ranch-level management of year-to-year variability in hay yields and livestock prices and multi-year decision-making on herd culling and management.
- Evaporation and conveyance losses that might reduce credited consumptive use savings are not included.
- Any producer's participation is assumed to be temporary, so their water rights would not be in danger of abandonment.

SUMMARY AND DISCUSSION

Net regional economic impacts of a 25 KAF program (with reductions occurring in a single year) range from $2.17 to $4.77 million in lost income and 95 to 146 in lost jobs, depending on how producers change their hay and livestock operations in response to the program. This range represents 3.12 percent to 6.85 percent of income in the regional agricultural economy and 0.04 percent to 0.10 percent of income in the overall regional economy. Where in this range the impacts of a DM program of this size would fall depends on how many DM participants would implement each of these three strategies in response to decreased hay production.

Results are presented against a base case of average water years with no curtailment. A future with higher curtailment risk may be a more realistic base case in any subsequent regional economic impact analysis of a DM program. Further, the negative economic impacts to the overall economy from curtailment could potentially be larger than from any DM program. This is because curtailment would directly affect the municipal and industrial sectors of the economy in addition to agriculture. The purpose of a DM program would be to reduce or remove entirely the risk of curtailment. Thus, weighing the costs and benefits of a DM program involves an estimate of the benefits to the region associated with reducing or removing entirely the risk of curtailment.

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