

TECHNICAL MEMORANDUM

SUBJECT: **Green River Basin Plan II**
Water Augmentation Opportunities

DATE: August, 17 2009

PREPARED BY: WWC Engineering

Introduction

Summary: WWC analyzed prior studies for flow augmentation in the Colorado River Basin, the Platte River Basin, and the Snake River Basin and identified various options for augmenting flows which may be applicable for the Green River Basin. All of the relevant options under current discussion are identified in the Seven States Report, so we focused our analysis on that report. Flow augmentation options may offset growth in water demands within the basin and downstream and help mitigate possible adverse affects of climate change.

A report commissioned by the Seven Colorado River Basin States entitled “Augmentation Options for the Water Supply of the Colorado River System” was generated by the Colorado River Water Consultants (CH2M Hill and Black & Veatch Consultants) in March, 2008. The report shall be referred to in this memo as the Seven States Report. The Seven States Report identified 12 basin-wide (interstate) opportunities and mentioned 3 possible localized efforts which may play roles in the long-term ability of the Colorado River basin to meet projected water demands. This technical memorandum considers the options presented in the Seven States Report, to determine their relevancy for the Green River Basin, and adds or expands upon the options deemed most relevant at an overview level. WWC targets the most likely options, lists some on-going studies and briefly visits related issues such as conservation, water quality, recreational impacts, and others.

Impractical Opportunities

Within the identified opportunities, Wyoming would not directly have an opportunity for the following, although it may support basin-wide initiatives:

- Ocean Water Desalinization - Desalinization may play a role to improve Coalbed Methane produced water.
- Import of water via ocean routes - Wyoming has no ocean routes.
- Urban water reuse and conservation - The Green River Basin does not have large urban population centers (Rock Springs-18,708, Green River-11,808, Evanston-11,507, Kemmerer-2,651, Pinedale-1,412), so reuse and conservation would likely be in the agricultural sector, although conservation and reuse efforts in communities should not be ignored. The relatively larger urban areas of Wyoming are in the Platte River Basin.
- Reservoir Evaporation Control - The Seven States study discounted the use of large-scale chemical covers on lakes Mead and Powell where significant evaporation potential exists, particularly since this has the potential of disrupting the recreational uses and causing environmental problems for the lakes. Although not specifically addressed, the use of

such methods for the Fontenelle and Flaming Gorge reservoirs would be equally problematic and less effective, given the lower evaporation potential of the reservoirs in Wyoming because of the lower ambient temperatures.

Better Opportunities

The next category of opportunities includes those that may have direct applicability for the Green River Basin, but would have to be carefully examined to determine the costs and benefits, as well as defining the precise method of application.

- **Conjunctive use of the groundwater and surface water.** The Seven States Report identified water banking as an opportunity for the Lower Basin areas where Colorado River water can be stored underground during surplus and drawn down during deficit river flows. In essence, underground storage is used as supplemental storage to balance the river flows, which could become important if the climate projections of earlier and more abrupt snow-pack runoff come into play. A benefit of this underground storage is that evaporation is minimized. A study was performed by States West Water Resources Corp. (2002), for the Wyoming Water Development Commission regarding Green River Aquifer Storage and Recovery (ASR) near the Church Reservoir. The study concluded that ASR was not feasible at this time due to unpredictable costs for pumping and possibility of cross contamination with underground minerals and salts.

Another area studied for underground storage in Wyoming is in the Cheyenne area, taking into account depletion of existing well fields. Geologic data for the Green River Basin would indicate that much of the ground water, especially the gas producing aquifers, is of inferior quality to the surface water. It may not be advantageous to subject the surface water to the mineral wealth which is generally present under much of the Green River Basin. The Wyoming Framework Water Plan lists a reduction of salt loading for the Green River as a priority, contrary to the results which may occur from underground storage options.

- **River Basin Imports.** At this time, the Wyoming Framework Water Plan conceptually addresses the possibility of interbasin transfers. There are many political and legal hurdles limiting possible interbasin transfers, however, a long-term view would keep open this option, depending on how it benefits the State overall. As shown in the 2005 Wyoming Water Framework Plan, the only two basins with no remaining available water are the Platte River Basin and the Yellowstone River. Other basins, such as the Wind-Bighorn and Platte River basins also have a larger federal presence and more regulations that provide more obstacles to possible diversions. Other basins are too far away both in terms of distance or elevation for a piping project to be feasible. As it stands, water would be more likely to be diverted from the Green River Basin rather than into, but the option of interbasin transfers still stands as a possible water augmentation opportunity.
- **Stormwater Storage.** Much of the Green River Basin consists of sparsely vegetated desert land, and the occasional rainfall events which may occur there have not been

identified as an opportunity for collection beyond the present system consisting of the two main reservoirs (Fontenelle and Flaming Gorge).

Best Opportunities

The last category of opportunities consists of the most likely or productive areas for further study for their applicability in the Green River Basin.

- **Vegetation Management.** The Seven States Report identified control of Saltcedar (Tamarisk) as a high priority. Wyoming is currently involved with a joint effort on Tamarisk Removal which is in a study, evaluation, and planning stage. This effort is being spearheaded by the Metropolitan Water District (Los Angeles), and wide scale action may still be several years away. According to John Shields at the State Engineer's office, the Tamarisk infestation in the Green River Basin does not appear to be as dense as downstream areas, and there is hope for alternative control methods such as Chinese Beetles.

The following were not mentioned in the Seven States Report, but may merit additional study. There may be opportunities related to crop adjustments such as using more drought tolerant agricultural crops and better irrigation controls and delivery means within the basin. A large portion of the basin is controlled by the Bureau of Land Management, and to a lesser extent the United States Forest Service, and leased for grazing lands. Range Management studies have shown that one result of overgrazing has been the transition of perennial streams to intermittent streams. (John Lamman, USFS Laramie District Office, range specialist). A reduction in vegetative cover (due to overgrazing, for example) would result in more direct run-off with a consequent increase in sediment load and adjustment in runoff timing. An increase in vegetation, including replacement of beetle-kill trees in the forested areas, may slow the run-off but improve the water quality, especially long-term. The impacts of beetle-killed trees on area hydrology are projected in several studies conducted on the Platte River in Wyoming and the Yampa River in Colorado, and these studies suggest that it will most likely take more than twenty-five years for forests to naturally recover from these hydrological impacts, leaving ample time and opportunity for forest management (Uunila *et al*, 2006 and Troendle *et al*, 2003).

Mr. Dave Gloss, (US Forestry Service, hydrologist, Saratoga, WY) indicated that water yield studies on forested areas performed previously by the Colorado Water Institute (CSU) found there are balances between runoff and forest cover and water quality. Current and long-term management emphasis of the Forest service is for forest enhancements, while water yield issues may be only secondary.

- **Power Plant Modification.** Power Plant modification can reduce consumptive use. The two large power plants in the Green River Basin, (Bridger and Naughton) both use an evaporative cooling mechanism with a combined annual consumptive use estimated in the Seven States Report at 33,230 acre feet per year. The Seven States Report further suggests that most of this consumptive use could be eliminated if the plants were to

retrofit to an air-cooled system. The costs of such a modification (\$1,000 to \$4,000 per acre-foot recovered) do not look promising at the present time, but the opportunity certainly does exist.

- **Desalinization.** Desalinization of brackish water, especially Wyoming coal bed methane (CBM) production water, could augment the usability of waste water. At present, most CBM water in the basin is re-injected into the aquifers to avoid disposal problems since the water is generally brackish. Assuming the cost of desalinization would be similar to that reported by the desalinization project in Yuma, AZ, a base cost of about \$700 to \$2,000 per acre foot would be expected, depending largely on the cost of electricity. In addition, there are water conveyance and collection problems because the CBM wells are dispersed throughout the basin. Currently, some ideas for this option are under study, but any solution based on this option would likely be applied first in the Powder River Basin because of the greater density of CBM wells located in this basin closer together.
- **Weather Modification.** Weather modification specifically targets cloud seeding to increase snow pack at the upper reaches of the basin. The Green River side of the Wyoming Range and Wind River Mountains would be the areas to be targeted with this solution. Current studies are on-going in the Snowy Range and Sierra Madre mountains in south central Wyoming and the Wind Rivers. Other studies have initially indicated an increase in yield of perhaps 10% for snow run-off, although the percentage of true snow-pack yield for the Green River in Wyoming is perhaps less than the contribution of snow-packs in Colorado and Utah. The estimated cost for this opportunity given in the report was just \$20 to \$30 per acre foot, although the science is still under scrutiny. Water quality for this source would likely be equal to the present surface water quality. Because of the importance of the weather modification efforts, Mr. Barry Lawrence of the Wyoming Water Development Commission has contributed a stand-alone technical memo detailing the goals and status of these efforts. The memo is attached.
- **Storage Reservoirs.** An additional augmentation opportunity which was mentioned in the Seven States Report, but not specifically addressed, was building additional storage reservoirs with possible permitted uses including agriculture, municipal, recreational, stock, and environmental. Water storage qualifies as an augmentation opportunity not necessarily because it produces more water, but because it holds existing water supplies for controlled releases timed throughout the year effectively augmenting water supplies in times that naturally would see much lower flows. The Seven States Report indicated that this opportunity is being pursued by each state entity rather than jointly. In the case of the Green River Basin, the Wyoming Water Development Commission is certainly interested in any possible storage opportunities. The WWDC has recently supported the construction of the High Savery Dam and the Greybull Basin Dam. Other opportunities are also under study and are outlined in the Bibliography Technical Memorandum. Finally, the Governor of Wyoming supported the creation of the WWDC Dams and Reservoirs division with an emphasis specifically to identify and take advantage of any further storage opportunities, statewide.

Discussion and Recommendations

The Green River Basin has surplus water when viewed from a basin wide perspective. Flow availability work reported in the body of the Green River Basin Plan II provides estimated amounts of available water supply at specific locations in the basin. This is unlike the situation in several other Wyoming basins, such as the North Platte, and in the Colorado River Basin below Wyoming, where shortages are chronic and widespread. This is not to say that the State should not think about augmentation or not evaluate augmentation when it seems reasonable. We suggest the State's consider actions such as:

- Continue to monitor the flow augmentation studies and efforts of others, particularly the lower Colorado basin work. With time, water demand and the economics of augmentation may eventually demonstrate that enhancing flows in river basins has a favorable cost benefit ratio. Since Wyoming's situation is unique and dynamic, the opportunities and economics for flow augmentation may differ from those found in other locations, thus the state should continue to evaluate and develop flow augmentation as one important piece of the water resource puzzle aside from what other states are doing.
- In the case of cloud seeding, Wyoming is currently well underway on evaluating this augmentation method. We recommend that the state continue to fund this effort and to answer the questions that the project originally set out to answer. Scientists will be evaluating the effectiveness of the cloud seeding program as one technology to augment wintertime snowpack. Both physical and statistical methods will be used to quantify any such increases. Ancillary studies are evaluating what such incremental increases mean for increased flows in the basin. Based on the findings of the pilot study, the state of Wyoming will need to determine whether cloud-seeding is a viable, cost-effective long term strategy for augmenting flows in the respective basins and whether the program should be funded operationally.

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Individuals Consulted:

US Forest Service: John Lamman, Range Management specialist, Laramie, WY District Office.

US Forest Service: Dave Gloss, Hydrologist, Saratoga, WY District Office.

WY State Engineer's Office: John Shields, Interstate Streams Engineer, regarding tamarisk removal efforts.

Wyoming Water Development Office: Barry Lawrence, regarding snow pack augmentation studies.

Appendix

Green River Basin Plan II—Water Augmentation Opportunities
Weather Modification Technical Memorandum

Technical Memorandum

SUBJECT: Green R Basin Plan II – Water Augmentation Opportunities
RE: Weather Modification

DATE: April 8, 2009

PREPARED BY: B. Lawrence

- **Weather Modification.** “Weather modification” or “cloud seeding” activities have been widely conducted in the western U.S. over the years as methods to increase winter snowpack, enhance rainfall, disperse fog and suppress hail. In 2001, the National Oceanic and Atmospheric Administration (NOAA) documented 66 projects being conducted in the western U.S. The practice of cloud seeding to increase snowpack is utilized by many western states as a means of improving soil moisture, recharging aquifers, and increasing spring runoff, thereby improving water supplies for municipalities, industry, irrigation, recreational activities, etc. The American Meteorological Society, in its *Policy Statement on Planned and Inadvertent Weather Modification* (1998), noted that present statistical evidence suggests seasonal snowfall increases of about 10 percent have been achieved in well-conducted winter orographic programs. It should be noted that this technology is not a “drought” busting tool; works best in normal to near-normal weather conditions; and should be viewed as a long-term water management strategy for increasing water supplies.

Cloud seeding improves a cloud’s ability to produce precipitation by adding tiny particles called ice nuclei (which water needs to freeze) to a cloud. These nuclei help the cloud produce precipitation by acting on supercooled liquid water (SLW), the raw material from which precipitation is formed. These artificial ice nuclei promote freezing of SLW at warmer temperatures than it would naturally, accelerating the precipitation process and making more efficient use of the water in the cloud (North American Interstate Weather Modification Council, 2009). Both aerial and ground-based methods exist for the transport of the artificial ice nuclei, with the later method being the most commonly used, through the deployment and operation of ground-based generators. These generators often times burn a seeding solution mixture of silver iodide and acetone.

Weather modification activities in Wyoming date back to the early 1950’s with a variety of projects being permitted by the Wyoming State Engineer’s Office for such purposes as rainfall enhancement, winter snowpack augmentation, etc. The longest running operational program in the State of Wyoming is Eden Valley Irrigation District’s winter cloud seeding program which utilizes ground-based generators to target the southern Wind River Range (Big Sandy Opening). This program was established with the assistance of the University of Wyoming whose atmospheric scientists provided a turnkey system for the District to operate in the mid 1970’s. The program continues to operate today, with the District believing that they are achieving an 11-13% increase in snowpack due to seeding operations.

In response to numerous inquiries received by the State to investigate this technology as a means of augmenting water supplies, the 2004 Wyoming State Legislature funded a state sponsored weather modification feasibility study for the Medicine Bow/Sierra Madre (MB/SM) and Wind River (WR) Ranges which evaluated the feasibility of conducting cloud seeding programs in each of the two project areas for winter snowpack augmentation. Included in the project was a determination of the experimental and control regimes to be employed (blueprint) for a proposed 5-year pilot program based on the climatology and hydrology of each target area. The study identified methods, equipment, siting issues, permits required, operational criteria, monitoring regimes, evaluation methodology, water resource benefits, and a cost/benefit analysis.

Based on those recommendations, the 2005 Wyoming State Legislature funded implementation of a 5-year weather modification pilot program to assess the viability of conducting weather modification activities as a means to augment flows in the Green, Wind-Bighorn and Platte River Basins. The program is unique in that nearly one quarter of the project budget is being used to support a strong scientific independent evaluation. The National Center for Atmospheric Research (NCAR) out of Boulder, Colorado is conducting this evaluation. It was noted that physical and statistical evaluation components of the program would be essential in establishing that the cloud seeding methodology is scientifically proven and is an integral part of the 5-year pilot program.

The National Environmental Policy Act (NEPA) analyses required for deployment of the ground-based generators targeting the Medicine Bow/Sierra Madre Ranges (MB/SM) was completed during 2006 with a categorical exclusion determination being issued by the Medicine Bow National Forest. Annual permits for ground-based seeding operations over this target area have also been issued by the Wyoming State Engineer's Office. Sixteen ground-based generators have been deployed on the western flanks of the Medicine Bow/Sierra Madre Ranges (eight targeting each range) and are available for seeding operations when specific case calling criteria are met. Operations in the MB/SM Ranges are randomized and adhere to a strict experimental design set forth by NCAR.

Applications for the special use permits necessary for the deployment of ground-based generators to be sited on federal lands and targeting the Bridger-Teton and Shoshone National Forests (for the Wind River Range) were withdrawn March 2007 due to increased costs and lengthened timelines associated with receiving federal clearance for the project. Eight ground-based generators targeting the central and southern Wind River Range have since been deployed on state and private lands and are available for seeding as conditions warrant. Basing in such a manner is typical for other states' programs. Two additional ground-based generators have also been deployed along the northern end of the target area as made possible by supplemental funding received from Lower Colorado River Basin entities in an effort to make the system "whole". Annual permits for ground-based seeding operations over this target area have also been issued by the Wyoming State Engineer's Office.

Seeding operations over both target areas commences November 15th each year of the study and runs through April 15th. Silver sampling measurements have, and will continue

to be taken by the Desert Research Institute, in each of the target areas. Additional climatological monitoring devices have been deployed across the target areas, and include high resolution precipitation gages, weather stations, radiometers, and ice nuclei counters. Also, instrumented weather balloons are being launched during the operational season. Project meteorologists and field technicians remain deployed near the target areas during operations. The study is now concentrating on acquiring enough seeding events under the randomized program to achieve statistical significance in the confirmatory part of the experiment. Numerous additional physical measurements are also being taken which will aide the exploratory portion of the project as well. Finally, additional coordinated research efforts (externally funded) between the States' operations contractor, scientists at the National Center for Atmospheric Research, and the UW Department of Atmospheric Science are ongoing. Recent promising ancillary research includes efforts by UW researchers using the UW King Air aircraft and Wyoming Cloud Radar to detect microphysical changes in cloud structure due to seeding operations over the Medicine Bow Range.

Based on the results of the weather modification pilot study which will have assessed the technology and its effectiveness at increasing snowpack in the target areas, it will then be up to the policy makers to determine whether cloud seeding represents a viable strategy for augmenting flows, and whether the State should continue to pursue this technology, thus converting this research-based program to one of operations. Additional target areas could also be considered at that time, including the Salt and Wyoming Ranges, where another WWDC weather modification feasibility study was recently completed. The results of that study indicated that significant benefits could be achieved in both the Snake-Salt and Green River Basins by targeting those double barrier mountain ranges through cloud seeding operations.

References

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