Colorado Climate Project

the ROCKY MOUNTAIN CLIMATE Organization

www.coloradoclimate.org

Third Draft of Possible Recommendations
Water Adaptation Policy Work Group
July 13, 2007 #2

Underscoring and strike-throughs indicate significant changes since the June 13 draft.

WA-1
Need for Leadership

Initial Drafts by Brad Udall, David Robbins, Marc Waage
Brad Udall was to edit this after July 13, but cannot before July 16;
Stephen Saunders edited somewhat.

The consensus of the scientific community is that warming caused by human emissions of greenhouse gases will have significant effects on water supplies and availability in many parts of the world, including the American West. The American Water Works Association, the primary trade group of water management professionals, has written that "global warming is a fact and water managers need to plan accordingly."

Global warming will likely affect Colorado's water supplies in several central ways, with other potential impacts described later .

- **Reduced snowpack and streamflow.** There is a consensus of model projections that warming will continue in Colorado, leading to more winter precipitation falling as rain and less as snow, lesser snowpack accumulation, earlier runoff, and more evaporation. ~~Most recent models project less or unchanged total precipitation in this region, but there is no clear consensus yet on this point.~~ Computer models are still unclear as to what changes may occur in this region with respect to the total amount and timing of precipitation. However, studies do indicate that a substantial increase in precipitation would be needed to offset the reduction in streamflow from more evaporation and ~~plant use from~~ other stream system losses caused by warmer temperatures. Most water used in Colorado comes from streamflow that originates as snowmelt.
- **More drought**. The frequency, duration, and severity of droughts are projected to increase, further reducing water supplies and making water use restrictions more likely.
- **Earlier snowmelt**. Warmer weather is expected to melt mountain snowpack earlier. An early melt potentially increases evaporative losses, reduces summer streamflow,

and disrupts established patterns of the timing of water capture and use under existing water rights.

- **Intense precipitation**. Precipitation is expected to be more concentrated or intense, potentially making the capture and storage of water more difficult. Increases in flooding are possible, with risks to lives, property, water quality, and the environment.
- **Increased water needs**. The growing season is expected to be longer and warmer. This will increase the water requirements of some plants. Irrigation of landscapes account for roughly half of the municipal water use along the urban Front Range. Increases in water use in others sectors, particularly agricultural uses with senior water rights, could reduce the supplies available to municipal providers with more junior water rights. Water use for cooling and other weather dependent uses could increase with temperatures.
- ~~**Degraded water quality.** Water quality is projected to degrade due to reduced streamflow, increases in forest fires and subsequent runoff of sediment, higher stream temperatures, and other factors. This potentially will increase maintenance and treatment costs. Sedimentation in water supply systems is expected to increase and this could decrease water storage capacity and increase maintenance costs.~~ *To be addressed later in environment section.*
- **Interstate compact calls**. Reduced streamflow and increased water use could increase the contention over interstate allocations which are based on "normal" precipitation patterns.
- ~~**Secondary impacts.** There are also a number of important secondary impacts which have the potential to affect water management, including more forest fires which can lead to increased runoff causing sedimentation of reservoirs, and forest pest outbreaks which may affect total runoff and runoff timing.~~ *To be addressed later?*

Several climate change studies have investigated possible effects on future flows of the Colorado River, the state's largest source of surface water, which is not just used on Colorado's Western Slope but also is also diverted for use in cities and farms east of the Continental Divide. ~~All studies done to date~~ They consistently project that climate changes will lead to Colorado River flows being reduced below those seen in 1905-2000. Recent projections range from a very significant reduction of up to 50% by Hoerling and Eicheid to a modest reduction of a few percentage points to11% by Christiansen and Lettenmaier. Similar studies have not yet been conducted with respect to other river systems in Colorado.

Many of these predicted impacts have already ~~been~~ begun to be observed across the West and in Colorado.

These changes are likely to have far-reaching effects in Colorado.

It will be harder to meet our water needs in the future. Phase 1 of the Colorado Water Conservation Board's Statewide Water Supply Initiative projected that even with some additional conservation measures there could be a net increase in demand of 630,000 acre-feet of water per year to meet just the municipal and industrial needs of the population projected to live in the state in 2030. This illustrates how the combined pressures of population growth and climate change will be doubly challenging.

Water engineering and management will need to change. They have generally been based on assumptions that the future will look like the past. Reservoir design, flood planning, municipal yield are but three of the critical water management areas where good engineering practice has dictated the use of historical hydrology in planning. As the globe warms, past assumptions about municipal yield, supply, demand, flood control and other water management issues based on historical hydrology will become less valid.

Newly edited as of July 13 by Joel Smith: Agriculture consumes a significant majority of the water used in Colorado, so if climate change produces a more restricted water supply over the long term it will have a commensurately greater impact on agricultural ~~production~~ water consumption than consumption by other consumers of water in the state. ~~If water supplies become scarcer, the amount of land in irrigated agriculture inevitably will be reduced.~~ In the event of shortages, there will be transfers of water from agricultural uses to other uses, such as for municipal and industrial purposes.

Newly edited as of July 13 by Joel Smith: The combination of changes in water availability and of the legal regimes governing water uses may affect both individual water users and the state as a whole. Changes in runoff timing could affect whether holders of water rights will have water supplies when they need it. For example, water could well be more available earlier in the spring and less available in late spring and summer. State or regional water shortages may trigger the application of interstate compact requirements that could lead to additional water restrictions in Colorado.
All in all, the likely effects on water supplies represent what may well be Colorado's greatest vulnerability to climate change.

Recommendation

1. Federal, state and local public officials in Colorado who have general responsibility for the health, safety and welfare of the citizens of the state, or a particular responsibility for meeting the consumptive and non-consumptive water needs of Coloradans, should exercise leadership in addressing the identified causes of, and adapting to, the impacts of climate change upon water supplies. Even if greenhouse gas emissions are reduced, scientists believe that our climate is likely to change enough to significantly impact current flow regimes. These effects could pose substantial risks to the economic, social and environmental well-being of the state. Accordingly, our public officials should give the highest priority to identifying and implementing actions designed to respond, in a responsible and coordinated manner, to the potential adverse effects of climate change on our water resources and the full range of beneficial uses associated therewith. Key public officials to whom this recommendation apply include our elected representatives to

Congress, the Governor and other officials in the executive branch of state government, members of the Colorado General Assembly, elected and appointed officials in local governments, water providers, and officials in public colleges, universities, and research institutions.

WA-2
Consideration of Climate Change in Water Decisions

Initial Drafts by Brad Udall and Marc Waage

Recommendations

1. All Colorado water managers should investigate the vulnerabilities to climate change of the water supply systems they manage and determine how they will continue to meet future water needs in light of those vulnerabilities. In planning changes in future water supply systems and operating current ones, water providers should no longer assume the future will necessarily be like the past. Most water supply planning in Colorado is based on the past hydrology of some recent period ~~of 30 to 50 [?] years~~. New plans should consider both the substantial variations in regional climate now understood to have occurred in the more distant past and potential climate changes and their effects. Colorado water managers should also:

    A. Assess the vulnerability of their supplies and systems to climate change effects.

    B. Identify and preserve adaptation options.

    C. Apply risk management and adaptive management.

    D. Explore phased approaches to adjust with climate changes.

    E. Consider increasing water system reliability, diversity and flexibility.

    F. Use "no-regrets" planning of actions that would produce benefits even if the climate does not change as now projected.

    G. Create and participate in regional efforts to model and analyze the impacts of climate change.

2. Water suppliers should carefully consider the appropriate roles under a changed climate of:

    A. Reuse. *An addition about non-tributary reuse to be made.* A reduction in the water available for first use within a municipal system could also reduce water available for reuse including use in water recycling systems, river exchanges and augmentation plans. Municipal water rights that were transferred from very senior agricultural rights may not see a reduction in water available for the first use and reuses. Some municipal water rights cannot be reused. Suppliers should analyze their system vulnerability.

B. **Conservation.** See recommendation WA-7, below.

C. **Storage.** *An addition about evaporative losses to be made.* The value of new or enlarged storage in reducing the impacts of climate change on municipal water supplies is being debated in the west. Some believe that reduced streamflow would mean there would no longer be additional water available for storage in new or enlarged reservoirs. Others believe new storage could play a role along with other measures to smooth out what could become an even more variable supply. In particular, new or enlarged storage could be important to capture the water from more intense precipitation events.

3. The state government should provide assistance to water providers without the resources needed to consider the effects of climate change on the water supply systems they manage to help them do so.

References

AWWA - Climate Change Primer for Water Providers (2006) and Climate Change Webcast (2007) Stratus Consulting- Climate Change Report for Denver Water. (2006) National Research Council – Colorado River Study (2007) Southwest Hydrology – Inconvenient Hydrology (2007) Water Utility Climate Change Conference, San Francisco (2007) [Need to add exact cites]

WA-3
Colorado River Water Availability

Initial Draft by Eric Kuhn

The 2007 version of the Colorado Water Conservation Board (CWCB) annual project authorization bill (SB-2007-122) directed the CWCB to evaluate how much remaining Colorado River water the State of Colorado has to develop. Section 15 of that law states:

> "(1) In addition to any other appropriation, there is hereby appropriated, out of any moneys in the Colorado water conservation board construction fund not otherwise appropriated, to the department of natural resources, for allocation to the Colorado water conservation board, for the fiscal year beginning July 1, 2007, the sum of five hundred thousand dollars ($500,000), or so much thereof

as may be necessary, for the board to evaluate water availability in the Colorado river basin and its tributaries. The board shall work in full consultation with, and with the active involvement of, the basin roundtables. The study shall consider current and potential future in-basin consumptive and nonconsumptive needs. The board, in consultation with the basin roundtables, shall recommend whether additional study or phases of study should be undertaken."

This is an essential public policy question. Under 2005 legislation, (HB-2005-1177) the State of Colorado is engaged in a broad public effort to take a comprehensive evaluation of Colorado's future water needs and identify solutions to meet the identified needs. Through the HB-1177 process and the companion Statewide Water Supply Initiative (SWSI) process, a number of new projects have been proposed in the future. These projects range in size from small local projects to improve water use efficiency to large multi-state, multi-billion dollar projects that would convey water as far away as Flaming Gorge Reservoir to the Colorado Front Range.

Determining now much Colorado River water is available to Colorado under various federal statutes, state statutes, interstate compacts and international treaties (commonly referred to as the "Law of the River") is going to be a complicated and difficult endeavor. The issue is complicated by the potential impacts of climate change. For decades, Colorado water officials have assumed that the State of Colorado could develop at least 3.0 million acre feet per year. However, this conclusion is based on the basic assumption that in the future, the Colorado River flows will be similar to the most recent past (1905-2000). Scientific studies, however, project that Colorado River flows will actually be reduced as a consequence of climate change.

Recommendation

1. To ensure that the new Colorado River water supply study is complete, relevant, widely accepted, and useful for future decision-making, the state government should ensure that the potential effects of climate change are considered in the study.

WA-4
Interstate Compacts

Initial Draft by David Robbins

Interstate compacts to which Colorado is a party apportion among our state and other states the right to make beneficial consumptive use of interstate rivers and related water supplies. Several compacts, including the Republican River Compact and the Rio Grande Compact, contain mechanisms to adjust Colorado's apportionment based on climatic conditions. Others, such as the Colorado River Compact, contain requirements for delivery to downstream states of at least specified minimum amounts of water, causing Colorado to bear a greater share of any significant shortage. In the case of the Colorado River, therefore, the operation of the compact can serve to increase Colorado's vulnerability to climate change-driven water shortages.

Although it is a popular topic of discussion, the idea of renegotiating interstate compacts is not particularly realistic or appealing. All of the signatory states to compacts in the western United States are suffering from varying degrees of water shortage and will be adversely affected by water shortages brought about by climatic change. Each signatory state would have a similar goal in any compact negotiation, namely to acquire a greater share of the available supply for its citizens.

Recommendations

1. Colorado should not assume that interstate compacts can or will be renegotiated to reduce the effects that climate change may have on the amount of water available for use in the state. Planning based upon assumed changes in compacts would likely lead to nothing but frustration and disappointment.
2. ~~The state government should evaluate with respect to each major river basin the combined effect in that basin of the possible effects of climate change on water supplies and the operation of the interstate compact applying to that basin.~~
3. The state government should develop for each major river basin where one does not now exist a mechanism to deal with potential compact calls should they occur for any reason.

WA-5 ~~5A~~
Climate Monitoring Data

Revised Draft as of July 13 by Ben Harding

Understanding and adapting to the effects of climate change on water supplies will require good information on what changes are occurring, with respect to such key elements as temperatures, precipitation, snowpack, the timing of snowmelt, and streamflows. The data collection systems that currently exist to gather this information were not designed to track changes in climate, and so may be incomplete to meet today's needs. Also, many of the programs for collecting and disseminating these data have deteriorated or have been diverted over the last quarter-century, with the result that many long-term climate and streamflow records have been interrupted.

Recommendations

1. A task force appointed by the state government, with participation by invited federal agencies and research organizations, should assess the data and data systems that are needed to enable water suppliers and others in Colorado to understand and adapt to the possible effects of climate change on water supplies in the state, and identify gaps in current data and data systems.

2. The state government and water users should support additional data collection with an emphasis on preserving and extending long-term records.

3. Colorado's representatives in Congress, our state and local governments, and water providers should support re-definition of agency priorities and, where necessary, increases in federal funding for collection of key data related to the potential effects of climate change on the state's water supplies.

4. *To come: expansion of CWCB's current drought vulnerability assessments* **(Will Veva write this or should I?)**

WA-6 ~~5B~~
Vulnerability Assessments ~~Regional Modeling and Data~~

Revised draft as of July 13 by Ben Harding

There was conversation at the last meeting about revising this to also address:

1. *Sharing of data, modeling, etc., among those engaged in considering the vulnerability to climate change of the state as a whole, river basins, and/or local water supplies.*
2. *Coverage of all river basins or other units of the state by vulnerability assessments.*
3. *Assistance to smaller entities without adequate resources to assess the vulnerability of their water supplies to climate change.*

Climate change will impact water supply by changing the amount and timing of streamflows and the amount and timing of water requirements for agricultural, industrial and municipal uses. A water user requires estimates of future water use to plan its own system and operations, but also to understand how competing water rights will affect its water supply.

The nature of future water supply conditions can be estimated based on projections of future climate conditions from climate models but such estimates require that the models' output be translated into projected streamflows and water requirements at relevant locations. Because current climate models use large grids (with a typical grid cell covering one-fourth of Colorado), model results must be mapped to a finer level of detail prior to translation to streamflows.

Several scientific studies have made projections of the possible effects of climate change on water supplies in the Colorado River basin, but these studies are at scales too large for local water supply planning. The state's other river basins have not been studied even at large scales. Some larger water providers have conducted studies to begin to estimate the potential impact of climate change on their systems.

Making estimates of future water supply conditions presents a number of technical challenges:

- **Scale/Translation.** For the reasonable future, climate model data will be available at scales that are far too large for planning and decision making by water users. Until climate projections become available in appropriate scales, planners will require some method of mapping large scale climate projections to scales appropriate for planning purposes. Planners also require that climate projections be translated into streamflows. Many techniques are currently available to re-map and translate climate projections, and new techniques are becoming available.

- **Water rights response.** Almost all water supply models in Colorado rely on historical records of water rights yields, calls, or both. Climate-change induced changes in streamflows and water use will affect the yield of individual water rights and the pattern of calls. Historical water rights yields and calls can no longer be depended on to represent future conditions.

- **Uncertainty.** Projections of future climate contain much uncertainty, arising from projections of future policy and economic responses (which are necessary to estimate future greenhouse gas concentrations), and from simulations of future climate responses. Further uncertainty is introduced by re-mapping and translation methods.

Collecting the data and constructing and running the models necessary to project future streamflows is a substantial effort. Many smaller municipalities and most individual agricultural users will not have the resources to make these assessments. Further, virtually every productive watershed in the State is shared by many water users, so if water users make independent assessments, the result will be much duplication of effort.

Recommendations

1. The state government, water providers, and others should cooperate in:

   A. Developing information from climate models on the possible effects of climate change on water supplies in each of the state's major river basins. The state government should not impose common planning assumptions on water providers, or indirectly determine common assumptions by embedding them in information on models and data supplied to water providers.

   B. Developing common practical tools and databases for re-mapping and translation of climate model outputs. These tools should allow for the flexibility, on the part of water providers, to choose from a variety of approaches to assessing climate change effects.

   C. Setting up and maintaining a clearinghouse of up-to-date climate projection data.

D. Supporting cooperative efforts among providers to make basin-wide assessments of water rights yields and call patterns in support of the individual water supply modeling of water providers.

WA-7
Water Conservation

[submitted by Bart Miller, Andy Colosimo and Marc Waage[1], June 2007]

Decreasing river flows and lake and reservoir levels that are the expected by-product of climate change provide great incentives to step-up water conservation throughout Colorado.

Role of State. While the bulk of conservation work needs to be carried out by individual water providers and water users throughout Colorado, state agencies can play an important role by providing funding and technical assistance and helping shape regional and state-wide education and message development.

Planning. Recent additions to state law require more frequent conservation planning and conservation goal-setting by water suppliers. Substantial state funding is available in the form of planning and implementation grants from the Colorado Water Conservation Board.

Water Supplier Dilemma. Water conservation is favored by many water suppliers as a cost-effective means to decrease the need for new water development. The risk of a drying climate poses a new dilemma for water suppliers. Do the suppliers use the water saved from conservation to: (1) supply new population growth, (2) reserve some or all of the saving to protect against shrinking supplies; or (3) set aside some savings for environmental purposes such as improving river habitat. If the supplier uses the savings exclusively to supply growth in their service area, water efficiency is increased but more people become dependent on the same supply of water. If that supply shrinks, the additional savings needed to provide for the essential human uses in that supplier's service area might affect landscapes and businesses within the service area. Water suppliers need to recognize that the choices are very case-specific and should carefully consider the risks and potential tradeoffs.

Recommendations:

1. Many ~~cities~~ water providers across the state have demand management programs but, in many areas, improvements can still be made as ~~cities~~ they refine their conservation programs and savings goals. *[Is this a separate recommendation, or should it be dropped or moved?]*

[1] This version is Bart's best effort to merge prior drafts with elements that both Marc and Andy like.

2. Water providers are strongly encouraged to should implement and maintain strong and diversified water conservation programs. These programs should consider measures that are cost-effective for both the utility and customers and that accomplish significant water savings. Conservation programs should address all customer segments, particularly those that demand the greatest volume of water or place the greatest burden on the water system in terms of peak use. Regulatory and voluntary measures are necessary and each should be evaluated and utilized to address different aspects of both indoor and outdoor water use. Water providers should reserve some of the savings from water conservation for future supplies in time of shortages instead of allowing all savings to shift to consumption by other users.

3. Water providers should evaluate the actual impacts of conservation on system yields and reliability through model runs and reasonable assumptions about technological and behavior savings that may be expected from customers before and after the implementation of conservation measures. Mechanisms must be devised and applied to effectively and accurately monitor and report program savings in order to evaluate this impact.

4. Specific recommendations for demand-side programs and measures include: *["A or B should …"?]*

   A. Rate structures that reward conservation and provide incentive to avoid water waste.
   B. Rebate programs that encourage customers (both residential and business) to install high efficiency water fixtures (e.g., toilets and clothes washers).
   C. City ordinances and utility programs that encourage efficient irrigation.
   D. Business and residential audits that identify property-specific water issues and educate the customer on how to curb demand.
   E. Education programs that deliver a consistent conservation message to all.
   F. Water loss reduction programs that decrease treatment costs and plant capacity needs.
   G. Using non-potable water supplies for landscape or other appropriate water use whenever possible and metering this use, just as is done for treated water.

5. Industrial water users are encouraged to conserve and reuse water.

6. As municipal landscapes' irrigation accounts for roughly half of total annual municipal water use, it deserves special attention. ["A or B should"?] Successful outdoor programs include:

   A. Incentives and requirements to amend the soil before planting new landscapes.
   B. Encouraging Xeriscape—to boost the prevalence of water-saving landscapes. For new development, consider limiting the amount of turf as a percentage of total landscaped area. For existing development consider turf removal incentives for both residential

and commercial customers. Landscape changes may lower owner's maintenance costs.

C. Increasing efficiency by changing watering habits (decreasing the numbers of watering days per week and lowering the amount of time per sprinkler zone).
D. Irrigation improvements, including rains sensors (that turn off sprinkler systems during rain) and more efficient sprinkler head placement and water pressure.

7. Because Colorado's new residents have not yet arrived, there can and should be a special focus on new development to decrease the future water-use footprint. ["A or B should"?] This involves encouraging residential and commercial developers and builders to use state-of-the-art conservation practices.

References:

American WaterWorks Association, "*Water Resources Planning (M50), Second Edition*," *2007*.

Colorado Foundation for Water Education, "Citizen's Guide to Colorado Water Conservation," 2004.

Metro Mayors Caucus and Colorado WaterWise Council, "Best Management Practices for Water Conservation and Stewardship," 2005; found at www.coloradowaterwise.org

Pacific Institute, "Waste Not, Want Not: the Potential for Urban Water Conservation in California," 2003.

WA-8
Agriculture

To be restored. David Robbins's original draft follows .David to edit?

Agriculture consumes a significant majority of the water resources apportioned to the State by interstate compact. Consequently, if climate change produces a more restricted water supply over the long term it will have a commensurately greater impact on agricultural production in the State. Because of the close relationship between agricultural production and water consumption it will be necessary to develop strategies which trade some measure of increased productivity for a known amount of actual conservation.

However, it is unreasonable to assume that increased conservation practices and efficiencies in agriculture will result in a long-term quantity of "saved" water. If the "saved" or conserved water is in turn applied to consumptive purposes. The cold hard facts are that as water supplies become more scarce, the amount of land in irrigated agriculture will have to be reduced and if water conservation is viewed as a source of supply for municipalities the amount of irrigated agriculture will have to be reduced even more. In the event of shortages, there will be a movement of water use from lower intensity uses to higher intensity uses, such as municipal supplies.

WA-9
Energy and Water
REVISED DRAFT AS OF 7/13/07

Merged draft by Brad Udall, Andy Colosimo, and Bart Miller

Water and Energy are inextricably linked. Drinking water requires energy for water treatment, distribution, heating, and waste water treatment. Energy production requires water for cooling of thermal plants or water for generating hydropower. The strong connection between water and energy provides opportunities to reduce greenhouse gases and reduce water supply vulnerabilities by conserving water and by examining increasing hydropower generation. On the other hand, both energy production and water supplies may be impacted by reductions in water availability.

Thermal power production—principally to cool steam at fossil fuel plants—requires large amounts of water. In 2000, fossil fuel plants in Colorado withdrew 20 billion gallons (just over 61,000 acre-feet), consuming 500 gallons per megawatt-hour generated. Increased source water temperatures may require additional water diversions for the same cooling effect. But for those thermal generation plants which utilize dry cooling systems, water consumption would not be impacted.

Proposed new sources of energy including ethanol and oil shale production also have large water requirements. New demands should be evaluated in terms of relative production efficiencies and in the case of oil shale development potential impacts to junior users of the Colorado River. Ethanol production with corn grown in Colorado requires approximately 1000 gallons of water per gallon of ethanol produced, if you include water used to grow the corn. Oil shale production uses roughly 200 gallons of water for each barrel of oil, such that a full production scenario for Colorado of 1 millon barrels of oil daily is projected to require somewhere between 180-270 million gallons/day (200,000-300,000 AF/year) for retorting the shale and related power needs.

Many new proposed water supply projects in Colorado involve moving water over significant distances because of the scarcity of undeveloped water near population centers. Unallocated water is usually far downstream or even across mountain ranges from the anticipated point of use. In these cases Colorado's geography may impose potentially significant pumping requirements, with the potential for significant increased greenhouse gas emissions.

Hydropower can provide energy without consuming water and without generating carbon. However, some hydropower facilities have resulted in adverse environmental effects—including blocked fish passage, decrease in sediment transport, and water quality impacts. New hydropower as an energy solution to climate change requires a close examination of environmental impacts. Possibilities include improving the efficiency of existing plants or examining whether existing water storage and conveyance facilities may have hydropower additions with little or no negative environmental impacts.

Colorado's geography provides for a unique synergy between water providers and energy generation through the use of hydroelectric power. Communities, especially front-range water providers, may have ideal attributes for development of small hydroelectric projects at existing facilities – significant volumes of water flowing from higher elevations to water treatment facilities at lower elevations. But climate change or drought conditions could pose challenges to hydropower generation located in snowmelt dominated basins as water supplies decrease.

Recommendations

1. Cooling technologies should be evaluated on all new electricity generating facilities. Closed-loop recycling and dry-cooling use much less water than once-through cooling. Wind and solar generating facilities use no water, and should continue to be promoted, however, recognizing its limitations for base load generation..

2. The link between water conservation, energy conservation and carbon dioxide must be made visible and educational programs developed to encourage both energy and water conservation.

3. New water projects and activities must explicitly consider greenhouse gas emissions. The State should provide guidance on limiting such emissions and should encourage alternatives that minimize them.

4. Additional small hydropower opportunities should be evaluated, recognizing the costs, risks, and environmental impacts associated with additional units.

References:

U.S. Department of Energy, Energy Demands on Water Resources, Report to Congress on the Interdependency of Energy and Water (2006).

Energy Information Association (EIA) 2000, Form 767, Steam-Electric Operation and Design Report, Schedule V, Cooling System Information, Section A, Annual Operations.

Bartis, J.T., et al., Oil Shale Development in the United States: Prospects and Policy Issues. RAND Corporation. Santa Monica, CA (2005).

Clark, J. R. Nuclear energy proposed for production of shale oil. Oil and Gas Journal, vol 104(26) (2006), at 18-20.

New merged draft by Brad Udall and Andy Colosimo

Water and energy are inextricably linked. Drinking water requires energy for water treatment, distribution, heating, and waste water treatment. Energy production requires water for cooling of thermal plants and for hydropower. The strong connection between water and energy provides opportunities to reduce greenhouse gases and reduce water supply vulnerabilities by conserving water and by increasing hydropower generation. On the other hand, both energy production and water supplies might be impacted by reductions in water availability.

Hydropower is a proven technology. By improving the efficiency of existing plants or taking advantage of existing water storage and conveyance facilities, additional generation can be provided with little or no negative environmental impacts.

Colorado's geography provides for a unique synergy between water providers and energy generation through the use of hydroelectric power. Communities, especially Front Range water providers, have ideal attributes for development of small hydroelectric projects – significant volumes of water flowing from higher elevations to water treatment facilities at lower elevations.

Successful small hydropower projects require adequate flow rate and water pressure, reasonable physical access for construction and maintenance, access to transmission lines and ability to secure a FERC license or exemption.

Climate change or drought conditions could pose challenges to hydropower generation located in snowmelt-dominated basins through decreases in water supplies.

Thermal power production is highly dependent on water for cooling use. However, higher water temperatures would result in small incremental increases in water consumption. For those thermal generation plants which utilize dry cooling systems, water consumption would not be impacted. [*Last sentence may be unnecessary, Andy says – delete it?]*

Many new proposed water supply projects in Colorado involve moving water over significant distances because of the scarcity of undeveloped water near population centers. Unallocated water is usually far downstream or even across mountain ranges from the anticipated point of use. In these cases Colorado's geography may impose potentially significant pumping requirements, with the potential for increased greenhouse gas emissions.

Recommendations

1. Additional hydropower opportunities should be evaluated and encouraged while recognizing the costs and risks associated with additional units.

2. Cooling technologies should be evaluated on all new electricity generating facilities.

3. The link between water conservation, energy conservation and carbon dioxide must made visible.

4. New water projects must explicitly consider greenhouse gas emissions.

WA-10
Information Exchanges

Revised draft as of July 13 by Ben Harding

Climate change presents complex policy, planning and operational issues to water users, water managers and appointed and elected officials. Planning for adaptation requires an understanding of the potential impacts of climate change, of the probabilities that particular impacts will occur and of the range of potential technical and policy responses to those impacts. While there is no shortage of information about climate change, much of that information exists at two extremes: academic journal articles, research reports and policy analyses; or articles in the popular press (not to mention the entertainment industry). It is difficult and inefficient for water resource managers to use the academic resources, but the reliability of the information in the popular press is doubtful.

Likewise, the sophistication of water-dependant organizations in Colorado covers a very wide range. Large organizations, such as large utilities or large water conservancy districts, have their own technical staff, while a small town or a small mutual ditch might have only a part-time manager or maintenance person.

For these reasons it will be difficult to convey information about climate change to the broad spectrum of water users throughout the state. But, on the other hand, Colorado is blessed with exceptional technical, research and educational resources in the fields of climate, water resources and policy.

Recommendations

1. Support the development of at least one publication (or set of related publications), using either traditional or electronic media, that addresses an audience of water resources professionals, managers and policy makers. Such a publication should translate research products to useful practice- and policy-oriented information. In order to be authoritative, such a publication will need some degree of peer review.

2. Support efforts, by state universities, state and federal agencies, and other organizations, to:
    - Provide practice-oriented information about climate change;
    - Host information exchanges among water management organizations, at both the policy and technical level, where they can trade experiences, successes and failures;
    - Conduct research oriented toward practical issues of water resources management and policy in the face of climate change; and
    - Provide opportunities for training and education in specific, practice-oriented topics related to climate change.

3. Encourage and facilitate cooperative working relationships among water-provider organizations in order to facilitate joint adaptive responses.

4. Develop training and education opportunities for elected officials.

5. *To come: recommendations with respect to Water Availability Task Force and Western Water Assessment* **(I think this is covered in 2 without getting too specific. These recommendations should be more durable than the lifetime of a state or federal reorganization.)**

WA-11
Recreation and Tourism

Initial Draft by Bart Miller, Chris Crosby

Climate change's effects on Colorado's snow and water resources are likely to have a wide range of impacts on the opportunities for recreation and tourism in the state and the industries that support them. These impacts threaten to decrease the intrinsic and economic value of resources that currently bring enjoyment to millions of residents and add billions of dollars to the State's economy.

Several recreational and tourism impacts include:

- **Fishing**. Warmer trout streams will eliminate or reduce trout populations in many river reaches. Lower flows will make trout more susceptible to disease, winter kill, and angling pressure. Angling and related activities are estimated to bring hundreds of millions of dollars annually to Colorado's economy.

- **Skiing**. Less snow and warmer temperatures means shorter ski seasons and fewer days of champagne powder. Increased snow-making will reduce stream flows farther, potentially affecting angling and increasing pollutant concentrations that are harmful to aquatic life.

- **Rafting and Boating**. Less runoff will shorten the prime spring runoff and affect river running (rafting was estimated to have $135 million in economic benefit in 2006). Many lakes and reservoirs are likely to have decreased levels, affecting marinas and exposing sand and dirt to wind, snow, and erosion.

- **Hunting.** Fewer wetlands will leave fewer nesting ponds for ducks and geese and few hunting spots in the fall. Vegetation changes may affect elk and deer food supply at different elevations.

- **Camping, Hiking, and Biking.** More forest fires will mean more forest closures and campfire restrictions. The aesthetic value of streams will decrease as flows drop.

Recommendations

1. State and federal agencies should undertake studies to evaluate possible impacts of climate change on recreation and tourism in Colorado~~, and the environment~~. Responsible state agencies include the Division of Wildlife (DOW), Colorado State Parks, Water Quality Control Division, Air Pollution Commission, as well as the state legislature [legislature? – Stephen . Responsible federal agencies include the Forest Service, Bureau of Land Management, Fish and Wildlife Service, Corps of Engineers, Department of Agriculture, and Environmental Protection Agency. [Federal studies specific to Colorado? -- Stephen]

2. The potential impact of climate change on the ~~value of~~ outdoor recreation and tourism ~~the environment~~ underscores how essential it is for natural resource management agencies to set the example in decreasing greenhouse gas emissions while at the same time preparing for impacts on Colorado's valuable waterways. Federal, State, and local management agencies should increase funding for programs that lower greenhouse gases. For example, Rocky Mountain National Park can help decrease car user miles (and congestion) by increasing bus schedules, especially during the busy summer season.

   OR, an alternative suggested by Stephen: Government agencies and businesses managing and providing outdoor recreation and tourism opportunities and services should take visible actions to reduce their emissions of climate change and to adapt to the effects of climate change, and educate the public on the risks of climate change and actions that can be taken to reduce it and respond to it.

3. The Colorado Water Conservation Board should evaluate its instream flow program for any changes needed in its administration to reflect the effects of climate change on the purposes for which the program was established.

4. **[All new]** The state government should investigate habitat protection and enhancement needs for terrestrial and aquatic species particularly vulnerable to climate change.

References

Todd Pickton and Linda Sikorowski, "The Economic Impacts of Hunting, Fishing, and Widlife Watching in Colorado"; found at http://wildlife.state.co.us/About/Reports/EconomicImpacts/

Colorado River Outfitters Association, "Commercial River Use in Colorado: 2006 Year End Report"; found at http://www.croa.org/media.htm

WA-12
Water Quality ~~and the Environment~~

Initial Draft by Mark Pifher

See new separate draft WA-13 by Joel Smith and Bart Miller on other environmental issues

Climate change can have significant impacts on the water quality of our rivers and lakes and the associated aquatic ecosystems. Climate driven increases in water temperature, seasonal decreases in flow, and changes in the intensity and duration of precipitation events can all influence water quality standards and designated beneficial uses. Potential impacts include:

- Increased pollutant runoff from more frequent and severe rainfall events.
- Periodic drought related low flows below aquatic life needs.
- Loss of anticipated dilution flows.
- Channel reconfiguration and sediment transport through flooding.
- Reduced dissolved oxygen levels in waterbodies.
- A loss of, or change in, biodiversity.
- An increase in forest fires and accompanying run-off concerns.
- [Moved from WA-11] Threatened and endangered species, including four fish species native to the Colorado River and its main tributaries, will face additional pressure due to changes in stream flows, increases in water temperature, and degradation of other habitat elements.

Climate induced hydrologic modifications may similarly affect the implementation of water quality regulatory programs, such as compliance with wet weather mandates. (combined sewer overflow (CSO) and stormwater BMP's); the establishment of permit effluent limitations based on "low flow" averages; and the listing of waterbodies as impaired under Section 303(d) of the Clean Water Act (TMDL program) due to increased pollutant loadings, elevated temperature or the mere loss of flows. Water resource allocation decisions designed to adapt to changes in water availability will also hold implications for water quality. For example, there may be a tendency to expand reuse programs, necessitating additional protective reuse regulations, or to adopt enhanced treatment techniques, such as reverse osmosis, with attendant brine disposal concerns.

Recommendation

1. Additional data gathering and research on water quality impacts related to climate change, along with a re-examination of certain regulatory programs under both the Clean Water Act and the Safe Drinking Water Act, are warranted. EPA and certain states have commenced an examination of these issues and their efforts should be utilized in the development of a response strategy.

References

EPA Website on Climate Change: http://www.epa.gov/climatechange/

Memorandum from Benjamin Grumbles, EPA Assistant Administrator for Water, to office Directors on Climate Change and the National Water Program, dated March 2, 2007.

Climate Change Science Program Synthesis and Assessment Product 4.4, Preliminary Review of Adaption Options for Climate Sensitive Eco-Systems and Resources (EPA et. al., to be completed December, 2007)

WA-13
Other Environmental Issues

WA-13
River Ecology
New Draft by Joel Smith, and Bart Miller

There is a clear scientific consensus that climate change will have broad negative implications to aquatic ecosystems. Numerous peer-reviewed studies have predicted broad declines in many fish populations. Fish that need cold water are among those at particular risk because of accelerated warming of water temperatures. Low flow conditions during much of the year could also pose risks to fish populations. Trout fishery populations in many rivers and streams—worth over $1 billion annually for tourism in Colorado—may substantially decline.

Most remaining Colorado River cutthroat trout populations—already below adequate habitat thresholds in 5 of the state’s 8 major river basins—are restricted to small, headwater streams. These ecological strongholds will feel the brunt of climate change impacts due to declining snowpack, drought, wildfire, and development of proposed water supply projects.

In addition, threatened and endangered species, including four warm-water fishes at risk of extinction in the Colorado River and its main tributaries, will face additional pressure due to additional loss of peak and base flows, and degradation of other habitat elements.

Because it is more biologically sound and cost-effective to protect existing population strongholds than attempt to restore them once they have been disturbed, it is prudent for consumptive water users to choose strategies for new water projects and activities that avoid or minimize further impairment of native and wild fishery habitats.

Recommendations

1. **Protect remaining core habitat areas and genetic and life history diversity.** Remaining trout strongholds as well as watersheds that produce reliable supplies of cold water should be protected from additional disturbances. Watersheds that currently support large and robust populations of native fisheries should be protected from new water withdrawals, inundation or barriers.

   Higher levels of genetic diversity enable populations to better adapt to future environmental change. In most situations, one set of stocks will be favored and produce abundant offspring for a period of time (or be subject to increased threat and decline due to wildlife or targeted drought), and when conditions shift, a different group of populations will be favored (or decline). In addition, life history diversity can protect fish populations. Where many populations are restricted to single tributaries, restoring migratory populations expands habitat options, produces bigger fish, and allows remaining individuals more opportunities to find suitable habitats as stream conditions and flows change.

2. **Increase size and extent of existing populations.** Currently, many populations of native trout in the West have been pushed into upper elevation streams as non-native species have been introduced downstream. At least 5 miles of continuous high quality habitat are necessary to ensure the likelihood that each trout population will persist for many generations. Climate change will squeeze them from upstream as snowpack diminishes and precipitation patterns change. The options for these fish are to expand into remaining downstream habitat or perish. For downstream expansion to be possible, non-native fishes must be removed and habitats restored.

3. **Minimize outside stressors.** The impacts of climate change will bring additional stress to stream systems and watersheds that already have been pushed to their ecological limits. We should identify and remove or mitigate existing sources of stress, such as sediment sources like roads, barriers to passage like dams and culverts, degraded riparian area due to grazing, inefficient diversion structures, and the like. Healthy watersheds will be better able to withstand the stress of climate-imposed impacts and rebound from disturbances.

4. **Manage at watershed scales to reconnect stream systems.** Many existing stream systems have been disconnected by construction of dams, water diversions, and other dewatering processes. Such actions isolate fish populations and introduce barriers to migration which would allow adaptation to climate change. We should identify and reconnect streams in those areas that are most likely to provide for long-term fishery survival. In some cases, this may be as easy as replacing poorly designed culverts with small bridges that allow upstream and downstream movement of fish and spawning gravels.

5. **Monitor, evaluate and employ adaptive management.** Because ecosystems are complex and climate change impacts are difficult to predict with certainty, it is important to adequately fund monitoring programs and maintain the ability to modify our management approach in the face of changing conditions and new information.

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Groundwater
Initial Draft by David Robbins

The tributary groundwater supplies in the State will respond to the effects of climate change in a manner very similar to that of the surface stream systems to which they are connected. As the surface stream flows diminish their ability to replenish groundwater systems declines commensurately; as surface irrigation supplies diminish the ability of those irrigation systems to recharge the groundwater declines; and as "conservation" and improved efficiency in agricultural irrigation practices increase in response to climate change there is a resulting loss in return flows to the groundwater systems.

Nontributary groundwater systems, such as the Denver Basin, are relatively immune to the effects of climate change. On the other hand, they are effectively non-replenishing from natural sources and as tributary systems are affected by climate change, the temptation to continue to rely upon them and mine the water within them will increase hastening their ultimate elimination as viable source of water supply.

Recommendations

1. Colorado should reduce the use of groundwater for irrigation supplies in groundwater-dependent basins including the South Platte, the Republican, the Arkansas and the Rio Grande until recharges match discharges from pumping, natural losses and the obligations to neighboring states under our compacts.

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Colorado Water Institute
To come from Susan Avery