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Decision-centric adaptation appraisal for water management across Colorado's Continental Divide

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ABSTRACT

A multi-step decision support process was developed and applied to the physically and legally complex case of water diversions from the Upper Colorado River across the Continental Divide to serve cities and farms along Colorado's Front Range. We illustrate our approach by simulating the performance of an existing drought-response measure, the Shoshone Call Relaxation Agreement (SCRA) [the adaptation measure], using the Water Evaluation and Planning (WEAP) tool [the hydrologic cycle and water systems model]; and the Statistical DownScaling Model (SDSM-DC) [the stochastic climate scenario generator]. Scenarios relevant to the decision community were analyzed and results indicate that this drought management measure would provide only a small storage benefit in offsetting the impacts of a shift to a warmer and drier future climate coupled with related environmental changes. The analysis demonstrates the importance of engaging water managers in the development of credible and computationally efficient decision support tools that accurately capture the physical, legal and contractual dimensions of their climate risk management problems.

Introduction

There is a growing recognition that planning for adaptation to climate change must proceed despite the limited predictability of hydro-climatic changes on temporal and spatial scales relevant for water resource planning (WUCA, 2010; Miller, 2010;Yates and Miller, 2011; Deser et al., 2012a,b). There are irreducible uncertainties in multi-decadal regional climate projections (Kundzewicz and Stakhiv, 2010; Pielke and Wilby, 2012) with internal climate system variability playing the dominant role in driving that uncertainty, especially for precipitation projections over the next half century (Hawkins and Sutton, 2010; Deser et al., 2012a,b). In addition, recognized limitations of regional climate downscaling further impair the utility of climate model output for decision-making (Salzmann and Mearns, 2012).

The conventional "top down" approach to providing advice for adaptation planning is poorly suited to the task. That approach involves downscaling future climate scenarios, generating input data for impact models, evaluating the consequences relative to present climate, and finally considering adaptation responses. Typically, large uncertainties attached to climate model scenarios accrue into even larger uncertainties in downscaled regional climate change scenarios and impacts.

Planners are then left with an intractable range of possibilities, and may habitually resort to "low regret" decisions (World Bank Independent Evaluation Group, 2012). These are measures that are believed to yield benefits regardless of the climate

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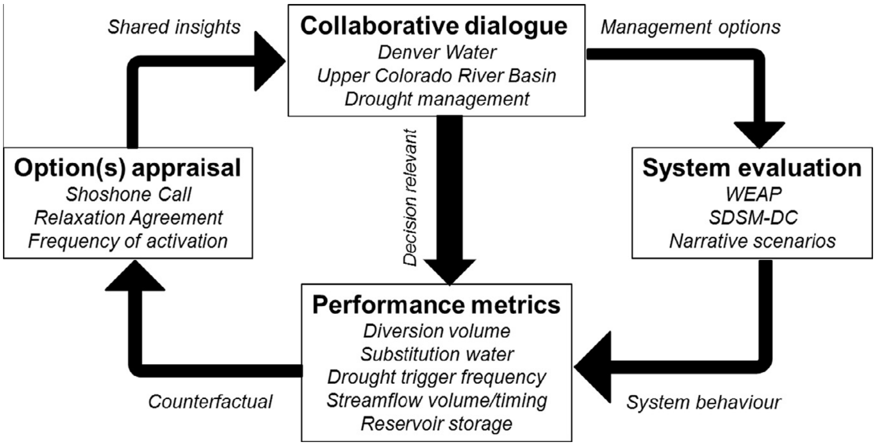

Fig. 1. The adaptation option appraisal process (illustrated using attributes of the Upper Colorado River Basin shown in italics).

outlook. Although that may be a safe strategy, a more pro-active planning approach may yield better results. Water management professionals increasingly comprehend the value of a systematic risk-management approach to adaptation planning that focuses on identifying and reducing vulnerabilities to a plausible range of climate scenarios, while maintaining the flexibility to respond to evolving conditions (WUCA, 2010; Lempert et al., 2006).

A useful approach for such planning is to turn the traditional top-down framework upside down and place greater emphasis on identifying and appraising adaptation choices from the outset (Wilby and Dessai, 2010). In this configuration, the scenario is used much later in the process to evaluate the performance or "stress test" adaptation decisions. As such, the scenario does not need to be explicitly tied to a given climate model or ensemble. For example, plausible futures can be generated stochastically (Steinschneider and Brown, 2013; Nazemi et al., 2013) and then used to test the sensitivity of the system, ideally to reveal non-linear or threshold behaviors to the climate-forcing (as in Brown et al., 2011; Brown and Wilby, 2012; Lopez et al., 2009; Prudhomme et al., 2010; Stakhiv, 2011; Whitehead et al., 2006). This paper demonstrates how downscaling and water systems models can be used in ways that focus the effort on evaluating adaptation measures despite large uncertainty about future climatic and non-climatic stressors.

Our collaborative decision support process comprises four elements (Fig. 1): (i) identifying management practice(s) or adaptation option(s) to be evaluated; (ii) modelling the water supply through physical representation of the hydrologic cycle; (iii) modelling the water collection and distribution systems in the context of the hydrologic cycle and the legal water rights; and (iv) stress-testing the system using narratives of future climatic and non-climatic conditions to explore the performance of the adaptation option(s) in supporting overall water supply.

We illustrate our approach by simulating the performance of an existing drought-response measure, the Shoshone Call Relaxation Agreement (SCRA[1]) [the adaptation measure], using the Water Evaluation and Planning (WEAP) tool [the hydrologic cycle and water systems model]; and the Statistical DownScaling Model (SDSM-DC) [the stochastic scenario generator]. This analysis involves downscaling multi-basin, multi-elevation daily temperature and precipitation scenarios for the Upper Colorado River Basin (UCRB). These scenarios are used alongside broader narratives of future conditions in the basin that could affect security of water supplies and to evaluate the benefits of steps taken to manage these risks. Our main aim is to highlight the potential benefits and portability of the process using water resource and river flow obligations in the Upper Colorado as an exemplar.

The following section provides further details of the study area and water system, including a synopsis of the pertinent water rights. Sections 3 and 4 outline the WEAP and SDSM models respectively. WEAP is used as the laboratory for appraising the SCRA under specified climatic and non-climatic narratives; SDSM is used to generate daily weather inputs to stress test the Upper Colorado hydrology and water management systems as simulated by WEAP. Section 5 provides an overview of our chosen narratives for basin wide stressors on the water supply system. Section 6 reports the findings of the analysis using metrics of water system performance with and without the SCRA, while Section 7 summarizes the study by drawing out key findings, considers the transferability of the process to other water systems, and identifies opportunities for further research.

Study area and characteristics

Droughts are a recurrent feature of Colorado's climate (McKee et al., 2000) and there is consensus amongst climate models that future air temperatures will rise, implying earlier and shorter snow melt seasons (Rasmussen et al., 2014; Miller and

[1] The Shoshone Call Relaxation Agreement (SCRA, 2006) is an agreement between Denver and Xcel Energy, the owner of the Shoshone hydroelectric power plant, allowing an early start to storage operations during drought years. The agreement has been endorsed by Western Slope water interests because they may benefit from increased drought-year water storage in the UCRB reservoirs.