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Research article

A water resources simulation gaming model for the Invitational Drought Tournament

K. Wang, E.G.R. Davies*

Department of Civil and Environmental Engineering, University of Alberta, 9105 116th St, Edmonton, Alberta, Canada

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ABSTRACT

A system dynamics-based simulation gaming model, developed as a component of Agriculture and Agri-Food Canada's Invitational Drought Tournament (IDT; Hill et al., 2014), is introduced in this paper as a decision support tool for drought management at the river-basin scale. This IDT Model provides a comprehensive and integrated overview of drought conditions, and illustrates the broad effects of socio-economic drought and mitigation strategies. It is intended to provide a safe, user-friendly experimental environment with fast run-times for testing management options, and to promote collaborative decision-making and consensus building. Examples of model results from several recent IDT events demonstrate potential effects of drought and the short-to longer-term effectiveness of policies selected by IDT teams; such results have also improved teams' understanding of the complexity of water resources systems and their management trade-offs. The IDT Model structure and framework can also be reconfigured quickly for application to different river basins.

1. Introduction

Drought results from a prolonged period of abnormally dry weather that reduces water availability for human and environmental needs (Bonsal et al., 2011). It occurs in nearly every climatic zone (Mishra and Singh, 2010) and is hard to predict in terms of onset, potential duration and severity (Wilhite and Glantz, 1985). It is also challenging to manage its negative social and environmental effects that can spread over large geographical areas (Giacomelli et al., 2008; Iglesias, 2003; Mishra and Singh, 2010). These negative effects are significant: for example, Mishra and Singh (2010) detail drought damages in the United States of $40 billion in 1988, with total damages of $144 billion (or 41.2% of the total weather-related disasters) from 1980 to 2003. More recent droughts of 2009, 2011 and 2012 are estimated to have caused $5.0 billion, $12.0 and $30.0 billion, respectively, in damage to crops (NCDC, 2014). In Canada too, prolonged, large-area droughts are among the costliest natural disasters, with “major impacts on sectors such as forestry, industry, recreation, human health and society, and aquatic environments” (Bonsal et al., 2013: 501). Both drought frequency and severity are projected to increase throughout the world in the 21st century with climate change (Prudhomme et al., 2013).

Although drought has no standard definition, droughts are typically classified as meteorological, agricultural, hydrological or socio-economic (Wilhite and Glantz, 1985); further, a key characteristic is their “temporary aberration” in climate with a potential persistence of months or even years (Mishra and Singh, 2010). According to the World Meteorological Organization (WMO), “drought means a sustained, extended deficiency of precipitation”; when this deficiency occurs over an extended period, a meteorological drought can result (Wilhite and Glantz, 1985). Agricultural and hydrological droughts follow from meteorological drought and are characterized by decreased soil moisture and eventual deficiency in surface and subsurface water systems (streams, rivers, reservoirs and ground water) respectively. These three types of drought are physical phenomena. Socio-economic drought – the fourth category and the focus of this paper – incorporates aspects of meteorological, agricultural and hydrological drought, but is also associated with the supply and demand of economic goods and the effects of water scarcity on human activities (Wilhite and Glantz, 1985). According to Mishra and Singh (2010: 206), “socio-economic drought occurs when the demand for an economic good exceeds supply as a result of a weather-related shortfall in water supply”. Focusing specifically on its economic, social and

* Corresponding author.
E-mail addresses: kai7@ualberta.ca (K. Wang), evan.davies@ualberta.ca (E.G.R. Davies).

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environmental impacts, the U.S. National Drought Mitigation Centre (2013) places socio-economic drought on their scheme of drought types as the final outcome of first meteorological, then agricultural, and then hydrological drought.

Given drought's broad social and environmental impacts, drought management aims to (1) guarantee sufficient water for human needs, (2) minimize negative impacts on the condition of a river, stream, lake, aquifer or other water body and (3) minimize negative impacts on economic activities (European Commission, 2007). Traditionally, drought management activities have been initiated as a drought intensifies, abandoned after a weakening of drought conditions, and then activated again with the next drought (Abraham, 2006). This crisis-management approach, termed the "Hydro-Illogical Cycle" by Wilhite (2011), has proven ineffective because of an often-slow, expensive and poorly-coordinated response (Abraham, 2006; Wilhite et al., 2000). Therefore, drought management has begun to move from a reactive, crisis-management approach, such as response and recovery, to proactive risk management, involving early warning systems, risk and impacts assessments and drought mitigation (Sivakumar and Wilhite, 2002). However, these approaches require a better understanding of the broader impacts of drought and drought mitigation strategies (Bonsal et al., 2011), as well as public support (Stoutenborough and Vedlitz, 2014). Therefore, stakeholders from drought-affected sectors should be engaged in drought management, and successful experiences in adopting a comprehensive and active approach to drought management should be widely shared (AAFC, 2011; European Commission, 2007).

To encourage proactive, participatory planning and adaptation for future socio-economic droughts in Canada, Agriculture and Agri-food Canada (AAFC) has recently developed a new tool, called the Invitational Drought Tournament (IDT), to support institutional drought preparedness by (1) enhancing discussions between stakeholders from different disciplines about proactive drought management, (2) improving the understanding of drought impacts on socio-economic and environmental subsystems by linking physical science (the hydrological cycle and agricultural science) with socio-economic effects and (3) assessing the effectiveness of drought mitigation strategies in reducing ecological, economic and social drought risk (Hill et al., 2014).

The Invitational Drought Tournament combines a workshop with features of a game: competition, cooperation, strategies, rules, players and referees. Essentially a "workshop with a winner", the IDT involves multi-disciplinary teams that compete over the course of a day to develop the best drought mitigation plan for reducing social, economic and environmental drought risks in both the short- and longer-term — and thereby achieve the best score. The gaming format of the IDT provides an experimental environment, based on reality, in which participants can better understand and manage the complex interactions of drought conditions, gaming decisions, and natural and socio-economic results both within teams (collaboration) and against others (competition) (Mayer and Veeneman, 2002). Further, this mixture of collaboration and competition make the IDT an enjoyable experience for the participants (Hill et al., 2014).

A number of IDT events have been held in several Canadian provinces with participants from a variety of sectors. A Calgary, Alberta, IDT in 2011 included 46 interprovincial water managers, while two Prairie IDTs in Saskatoon, Saskatchewan, in 2012 and 2013 involved graduate students from four Canadian universities. Finally, an Okanagan IDT in 2012 included a variety of water resources stakeholders, and was held in Kelowna, British Columbia (Hill et al., 2014). Each IDT has occurred in a semi-fictitious basin developed by Agriculture and Agri-food Canada (AAFC) based on real data: the Oxbow Basin for the Calgary and Saskatoon IDTs, and the Seco Creek Basin for the Okanagan IDT. Using these semi-fictitious river basins allows the IDT to (1) involve groups of participants from different river basins, (2) encourage creative decision-making, (3) reduce geopolitical sensitivities between stakeholders and (4) ensure a proper balance between realism and simplicity (Hill et al., 2014).

In terms of process (Fig. 1), participants are told at the beginning of an IDT that drought has started to create an imbalance between water supply and sectoral (municipal, industrial, recreational and agricultural) water demands; teams are not told how long the drought will last. Detailed descriptions of the basin water supply, including precipitation and reservoir storage, and anticipated sectoral water demands are then provided to the teams, and similar descriptions are provided at the beginning of each subsequent game year, with each year corresponding to a round of the game. Teams use the information provided to judge current drought conditions, assess the risks of a continued drought, and plan their actions to deal with the drought in the current game year. Teams are also given a drought mitigation budget at the start of each year — which, for realism, can vary unpredictably from one year to the next — that they allocate to a set of drought management options. These management options can focus on either a short- or long-term reduction of drought impacts, and are organized into four main categories: water management, financial management, land management and technological improvements (Table 1). At the end of each round of the game, referees score each team based on its success in drought management, as judged by the effectiveness of

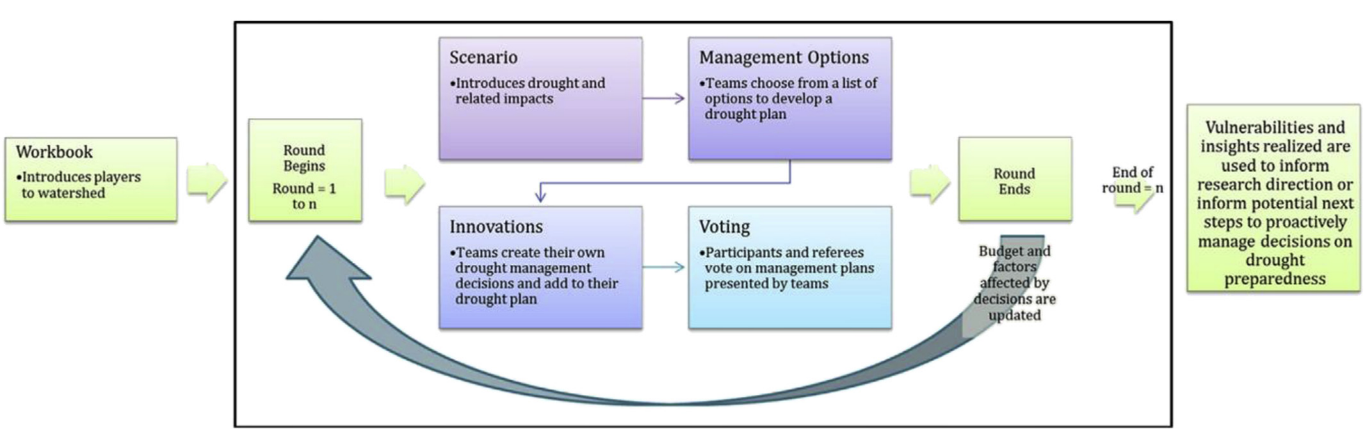

Fig. 1. IDT process (Hill et al., 2014).