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Growing community developments causing 'hazard creep' downstream of farm dams – A simple and cost-effective tool to help land planners appraise flood safety

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A B S T R A C T

Communities downstream of on-farm dams are growing as are the flood hazards and safety threats they live under. This threat exists in Australia and elsewhere due to a need for adequate integration of land-use planning and dam safety assurance policy, which is key to saving lives, public and private property and the environment downstream from dam failure. Thus, this paper considers the interrelated responsibility, cost-sharing and engineering issues associated with providing such integrated policy to mitigate dam failure threats to downstream land developments. A cost-effective flood safety engineering/planning tool is developed which involved generating complex catchment data in Australia to represent 'hydrologically homogenous' regions using best-practice water engineering methods, to in turn derive simple regionalised dam flood capability prediction relationships of acceptable accuracy. Results demonstrate the tool's successful development and potential transferability to a wide range of hydrology-variant regions and how it can link to and be applied within international best practice, integrated dam safety assurance and land planning policy. Resulting policy guidance and tool can help jurisdictions worldwide address the flood risks associated with farm dams and growing downstream land developments: by helping planners, developers, farmers and regulators account for and address the responsibility and cost sharing issues in a way that is uniform and fair for all stakeholders involved.

1. Introduction

Water storage in farm dams enables successful agricultural production which is important for both the world's food supply and the global economy. For this reason the use of farm dams has multiplied rapidly over the past century. For example, in Australia there are in excess of 735,000 private farm dams (Baillie, 2008). However, this increase has coincided with an increase in climate change induced rainfalls and floods and consequently a number of horrific dam failures worldwide which have triggered serious concerns over dam safety (Pisaniello et al., 2012).

While failures of large dams are usually more spectacular and receive much more attention, small dam failures, particularly those of privately-owned farm dams, occur far more frequently; so their total annual cost can be much greater than the rare failures of large dams. Small dam failure costs include not only economic and technical but also social impacts, usually resulting in disastrous losses (Afshar and Marino, 1990). For example, in the UK the Eigiau dam failed in 1925 resulting in the failure of a dam downstream killing 16 people (ANCOLD, 2003). In the US, a cumulative tailings dams failure in West Virginia in 1972 killed 125 people, left 4000 homeless and destroyed an entire community (Ellingwood et al., 1993); also in 1972 the small Canyon Lake dam overtopped killing 165 people (USDHS, 2011); and Lake Lawn dam, only 8 m high failed in 1982 drowning 3 people and causing US$31 million damage. In China the Shimantan and Banquia dams failed in 1975 due to the cumulative failure of 60 smaller upstream dams resulting in 230,000 deaths (Fish, 2013) and in Italy the Stava dam failed in 1985, releasing only 180 ML of tailings material, but killing 268 people (Engels, 2005). More recently, the 13 m Kaloko farm dam in Hawaii burst due to an inadequate spillway in 2006 resulting in the deaths of 7 people and widespread damage (HIDLNR, 2010); the Situ Gintung dam in Indonesia, only 10 m high failed by overtopping in 2009 killing around 100 people and causing extensive damage (The Associated Press, 2009); in Brazil in 2010, a cumulative series of private dam bursts left 50 people dead and

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an estimated 150,000 homeless (Pottinger, 2010); and in 2013, a single small dam failed in Xinjiang, China destroying 70 homes and killing one man (Fish, 2013).

The above list is only a short summary as flood damage caused by dam failures only continues to proliferate around the world (James and Hall, 1986; IR, 2008; USDHS, 2011). In 1999 a study of dam failures in the US resulting in fatalities from 1960 to 1998 found that the failure of dams less than 15 m high (typical height range of smaller dams) caused 88% of deaths (Graham, 1999). The failure of small dams, less than 6 m high, caused 2% of deaths and the failure rate of small dams is only increasing (FEMA, 1999). In the US, of the 84,000 regulated dams the average age of a dam is 60 years and population increases mean that tens of millions of citizens now live and work beneath dams (Freitag et al., 2009; Warner et al., 2011; Judi et al., 2012). In Australia, the costs of private dam failures are significant. Pisaniello et al. (2012) identified that recorded high cost dam failures are not only doubling every quarter century but that private dam failures have contributed more to this trend in the last 25 years (Fig. 1).

The above history from abroad and trend from Australia shows that without appropriate design, construction, maintenance, surveillance and upgrading (when necessary), inadequately managed small dams pose significant individual and cumulative risks that can cause considerable human, property, and environmental costs to growing communities in a rapidly changing climate of increasing rainfalls and floods (Warner et al., 2011; EA, 2014). These costs include tangible costs of emergency response, community disruption, loss of local income, loss of the use of the dam, but also those costs that are harder to measure, including loss of life, psychological stress, burden on local facilities and loss of local heritage (Ellingwood et al., 1993). Hence, ensuring adequate management of these structures that takes into account population growth and also climate factors is critical (Sheer, 2009). The most urgent circumstance/scenario that is largely ignored or inadequately accounted for by land use and safety assurance policy makers is that of new community land developments downstream of existing private dams and the increased hazard and dam safety management that this brings: addressing this scenario and the associated responsibility, cost-sharing and engineering issues is the key focus of this paper. Coupled with this focus is a response to calls for cost-effective tools that can better account for and support minimisation of dam failure flood risk in the land planning process (Sheer, 2009; Warner et al., 2011). To this end a cost-effective flood safety engineering tool is developed to help planners and regulators address the responsibility and cost sharing issues in a way that is uniform and fair for all stakeholders involved.

2. Land planning and safety assurance policies associated with private dams: research context and scope

There are many factors in dam design that have changed over time, including population distributions, infrastructure patterns, meteorological information, engineering methods and design standards, together with the condition of the dams, raising serious doubts about dam adequacy. The safety assurance policy and land use planning issues will first be considered below in the Australian context.

2.1. Research context: Australian private dams standards and policies

Despite research and overseas experience demonstrating that the individual and cumulative impact of inadequately managed private dams can pose catastrophic risk to downstream communities (see Pisaniello et al., 2012), the majority of these dams remain unregulated for safety in most Australian states. Uniform private dam safety policy nationally has not been forthcoming (Pisaniello, 2011). Land use policy for risk has also not prevailed - deficiencies remain around Australia in regulating the significant amount of dam development in catchments and inadequate integrated floodplain management (Smith and Handmer, 1984). What endures is the dam owner responsibility that exists under common law to manage dams according to current standards (Pisaniello, 2011; Pisaniello and McKay, 2007). In Australia, these standards are set by the Australian National Committee on Large Dams (ANCOLD, 2000, 2003, 2012). Under these guidelines the standard of care expected by the dam owner depends largely on

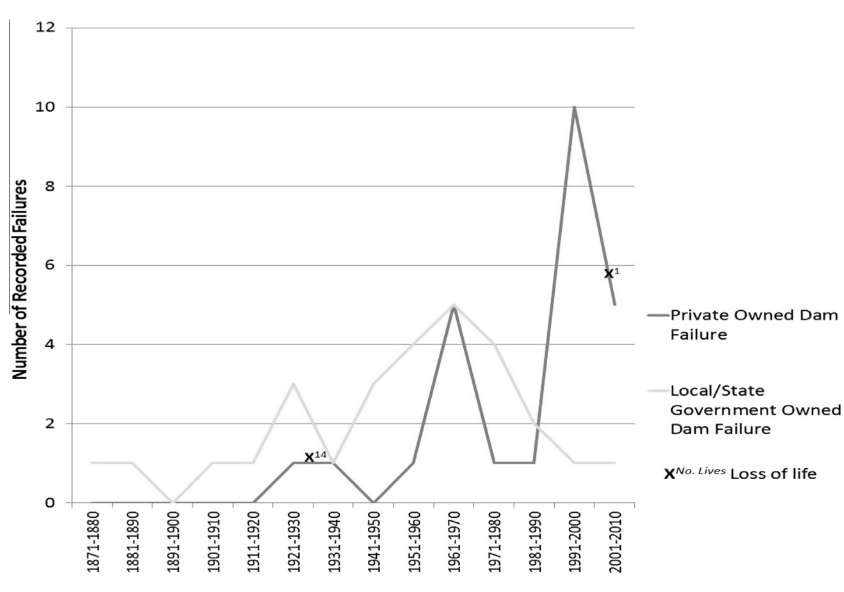

Fig. 1. Recorded[a] Dam Failures[b] in Australia (after Pisaniello et al., 2012). Notes: [a]The table refers to recorded failures only – data is not systematic as failures are seldom publicised and recorded. [b]"Failure" refers to a lack of performance as originally intended, which has resulted in a loss of life and/or substantial costs for rectification (i.e. more than US$1,000,000) and/or damage to the environment (Pisaniello, 1997).

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