

Impact of farm dam interception on environmental flow compliance

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Key Points

- Farm dam impact on environmental flow compliance
- Management strategies can be adopted to maximise autumn and summer low flows
- Water resource models individually representing farm dams in a catchment can be developed to broaden understanding of possible management responses

Abstract

To understand the impact of farm dams on low flows in catchments and to assess potential options for mitigating their impact, there is a need to model the impact of individual farm dams distributed around a catchment. A project was undertaken in the Seven Creeks catchment that involved scenario modelling under a range of climate change scenarios to determine the most effective management strategy to maximise autumn and summer low flows, by reducing the impact of farm dams. A model of the Seven Creeks catchment, which represents the water balance for each of the 5,000 individual farm dams, was developed using a modelling platform called eWater Source. By individually representing each farm dam, management strategies such as decommissioning or bypassing farm dams were able to target key farm dams in order to improve low flow compliance. It was found that the decommissioning of farm dams with the greater volumes were able to provide the greater improvement in low flow compliance, including when impacted by climate change. Scenarios that were optimised to decommission farm dams with large contributing catchment area or volume along the same flow pathway were similarly able to improve low flows during summer and autumn.

Keywords

Farm dams, environmental flow compliance, management strategies, water resource modelling

Introduction

To understand the impact of farm dams on low flows in catchments and to assess potential options for mitigating their impact, there is a need to model the impact of individual farm dams distributed around a catchment. The Seven Creeks catchment in the Murray-Darling Basin was used as a case study to undertake scenario modelling to determine the most effective management strategy to maximise autumn and summer low flows, by reducing the impact of farm dams. The outcomes of this work provided further knowledge for consideration in management of flow stress for river systems that are impacted by farm dam interception. The impact of farm dams on the environment has been widely investigated as it poses a significant challenge for water managers. Farm dams reduce the availability of water, as they capture catchment runoff that may otherwise flow into the river (Morris et.al, 2019), but are an important and reliable source of water for stock, domestic and irrigation usage for farms (Lewis, 2002). Across Victoria, farm dams have typically reduced mean annual flows by around 4.5 ML/km² (Lowe et.al, 2005). The impact of farm dams increase at the end of autumn as the dams are usually depleted by the end of summer and have more capacity to harvest catchment runoff during autumn (Nathan et.al, 2012). Due to the significant impacts during these drier months, this paper will focus on the potential for improvement of summer and autumn flows with various management strategies.

There are a number of management strategies of farm dams available to reduce the impact of farm dams on the environment. A study undertaken by Morris et.al (2019) investigated the impact of licensing and economic instruments on the development of farm dams over time; suggesting that early licensing constraints and limits to development can prevent impacts to the environment that will reduce the likelihood of a water resource system getting stressed. This option is not explored here due to lack of licensing data availability during initial farm dam development. A management strategy that is investigated in this case study is to implement low flow bypasses to targeted dams in an attempt to increase summer flows in a catchment. The low flow bypass was previously investigated by Fowler et.al (2009) and found to approximately double the availability of flow at the catchment outlet between December and April when installed on 5% of dams in the catchment. As well, the retrofitting of low-flow bypasses minimally impacts the availability of water in the farm dam for irrigators (Fowler et.al, 2009) which makes it a more preferable option than decommissioning for water users. The second management strategy investigated in this case study is decommissioning farm dams.

Whilst there is a need for farm dam modelling to attempt to quantify its impact on the environment, there have been a number of studies undertaken to explore model uncertainty in farm dam modelling. Fowler et.al (2012) found that there is uncertainty over the uniform flow generation across a catchment, as in reality, flow does not come equally from all parts of the catchment. For the current investigation, the catchment has been split into subcatchments to try and capture this variability, however there is still a level of uncertainty. Flow uncertainty is quite large, with a standard deviation of 35% (Fowler et.al, 2012). In comparison, the uncertainty of farm dam usage is lower with a standard deviation of 0.25 (Fowler et.al, 2012). A case study in the Werribee catchment in Victoria, found that these uncertainties resulted in an 11% variance in the volume of farm dams and a 29% variance on their impact on streamflow (Lowe et.al, 2008). Whilst the outcomes of this study can be used to inform overall decision making around management strategies, the model uncertainty for the impact of individual farm dams should be considered in the future.

The hypothesis of this current study is that removing or bypassing farm dams with the greatest volume and contributing area (or key farm dams), a large proportion of intercepted water can be recovered. As well, this paper will test whether the selection of management decisions will be sensitive to, and remain relevant under projected climate change.

Methodology

A farm dam model of the Seven Creeks catchment (~5,000 farm dams) was developed using a software called eWater Source. The farm dams are spatially distributed in the model and fully configured to represent the filling, spilling and extraction of each farm dam. The configuration of the farm dam model inputs adopts a similar approach to Fowler et.al (2016). The model was verified at available streamflow gauges distributed throughout the catchment to demonstrate that it was appropriate for modelling farm dam impacts on flows. As shown in Figure 1, the verification of modelled outflow of the farm dam model compares satisfactorily, particularly for the key low flow component, against gauged flows at the outlet of the catchment. This gave confidence to the modelling of flows and farm dams in the system to be able to undertake further scenario modelling.

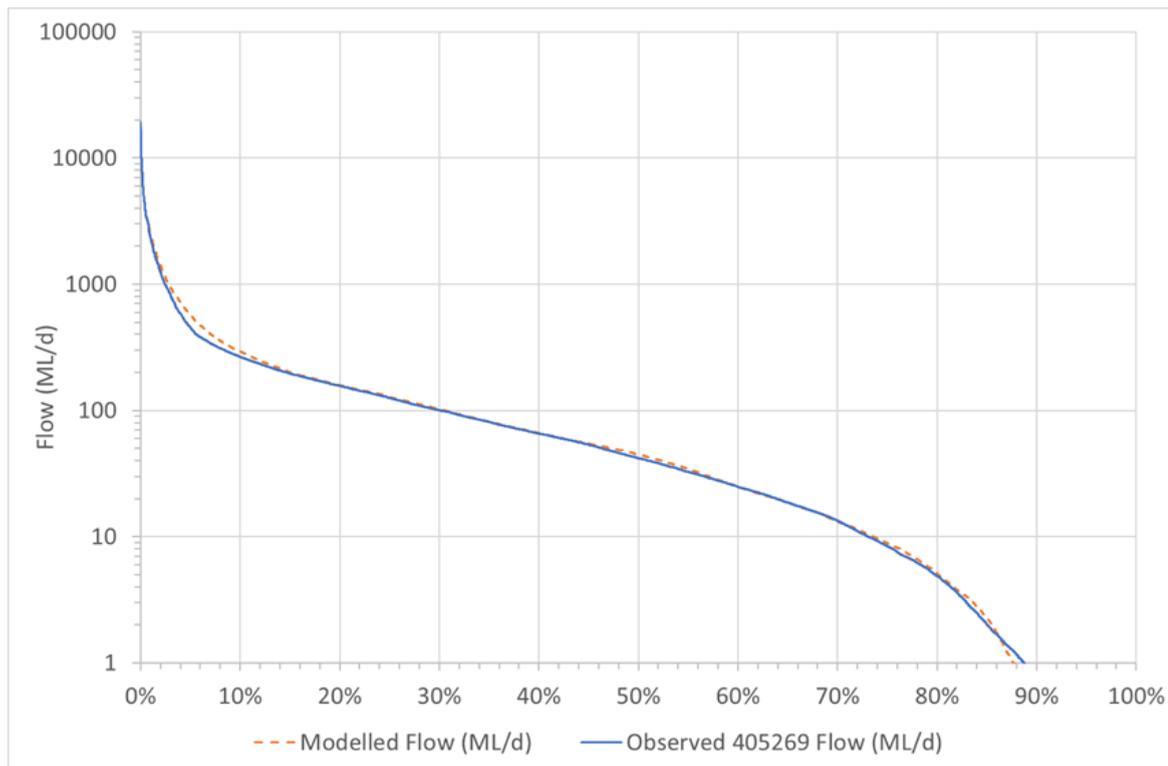


Figure 1. Verification of modelled and gauged flow at the outflow of the Seven Creeks model with farm dams individually represented

The base case water resource model was then used for scenario modelling to determine the best management option to improve low flows. Two types of management options were investigated: decommissioning farm dams; and implementing low flow bypasses on farm dams. A bypass allows low flows through the farm dam while still allowing the dam to harvest higher flows, whereas decommissioning entirely removes a farm dam. For the low flow bypass assumption, it was assumed that every farm dam has a low flow bypass installed such that up to an additional 20 ML/d (or natural flow) is achieved at the streamflow gauge. To do this, the bypasses are calculated using the following equation:

$$\text{Farm dam bypass (ML)} = \frac{\text{Farm dam upstream catchment area}}{\text{Total farm dam impacted area upstream of Euroa}} \times 20 \text{ ML/d}$$

This resulted in a bypass size of 0.13 ML/d/km² or 0.015 L/s/ha of upstream farm dam catchment area for each farm dam in the catchment. This bypass sized was applied to all subsequent management scenarios.

Management strategies were then explored by targeting farm dams within the catchment in order to improve summer and autumn low flow availability. This involved decommissioning or bypassing 5% of the total number of farm dams in the catchment. 5% of farm dams was chosen as an arbitrary value for the purpose of this study. The farm dams were chosen either by volume, by upstream catchment area, or using a combination of both. Results indicated that the ‘by volume’ selection method returned more summer flows than the ‘by catchment area’ selection method. Further scenarios tested an ‘optimised’, manually selected set of farm dams, comprised of a combination of farm dams of large volume, large upstream catchment area and their location in relation to other farm dams on the same flow pathway. This scenario gave similar results to the ‘by volume’ scenario.

Climate change modelling was also undertaken to test whether the selection of management decisions will remain relevant under projected climate change, or the decision is sensitive to it. The climate change assumptions utilized the 2016 Guidelines for Assessing the Impact of Climate Change on Water Supplies in Victoria (DELWP, 2016). These scenarios include the baseline and step climate change scenarios. The climate

change scenario results will be able to better inform the impact of each management option in improving low flows as the flows in Seven Creeks reduces due to a drier climate. Baseline climate is defined in the Victorian Guidelines for Assessing the Impact of Climate Change on Water Supplies in Victoria (DELWP, 2016) as being represented by post 1975 conditions. To create a long-term baseline series, data prior to 1975 is adjusted by decile scaling. For this project, seasonal scaling was used with the warm season being from November to March and the cool season from April to October. The step climate change scenario is represented by post 1997 (Millennium Drought) climate conditions. To create a long-term step climate series, data prior to 1997 was adjusted by seasonal decile scaling. Climate change adjustments are applied to rainfall, evaporation and natural flows, which are used as inputs to the farm dam model for climate change modelling

Results

The results from the scenario models for the two management strategies were compared to the availability of water in the catchment due to the current distribution of farm dams. Two additional scenarios were also run, which whilst unrealistic, were able to show the catchment wide impact of farm dams on average annual and summer flow. These scenarios were to decommission all farm dams or install low flow bypasses on all farm dams in the study catchment. The results are summarized in Table 1, showing that the management strategy of decommissioning the top 5% of farm dams selected by volume were able to achieve the greatest increase in summer flow. This is supported by Nathan et.al (2012) that observed that the larger the total volume of farm dams in the catchment, the greater their impact.

Table 1. Summary of management scenario modelling results when compared to the base case

| Scenario | % increase in mean annual flow | % increase in mean summer flow |
|---|---------------------------------------|---------------------------------------|
| Decommissioning all farm dams | 2.8% | 9.0% |
| Bypassing all farm dams | 0.3% | 4.1% |
| Decommissioning top 5% of farm dams selected by catchment area | 0.4% | 1.5% |
| Bypassing top 5% of farm dams selected by catchment area | 0.0% | 0.7% |
| Decommissioning top 5% of farm dams selected by volume | 1.2% | 2.4% |
| Bypassing top 5% of farm dams selected by volume | 0.1% | 1.2% |

The impact of farm dam interception in the Seven Creeks catchment on environmental flow compliance was also assessed. The modelled flows produced from various management strategies were compared to the environmental flow recommendations for Reach 2 of the Seven Creeks catchment (SKM, 2006). Overall, all the management scenarios (either decommissioning or bypassing farm dams) were able to improve on environmental flow compliance of the summer low flow recommendations by 4-5% when compared to the base case. Consistent with the results shown in Table 1, the greatest improvement able to be achieved was for the scenario where the top 5% of dams by volume were decommissioned. This can be seen in Figure 2 where management strategies applied to the top 5% of farm dams by volume were able to achieve more summer low flow compliance in the catchment during drought years. The same comparison was made for all years over the model run period, as shown in Figure 3. Whilst the decommissioning of the top 5% of farm dams was similarly able to produce the most improvement in environmental flow compliance; the change was improvement was smaller than what was achieved during drought years.

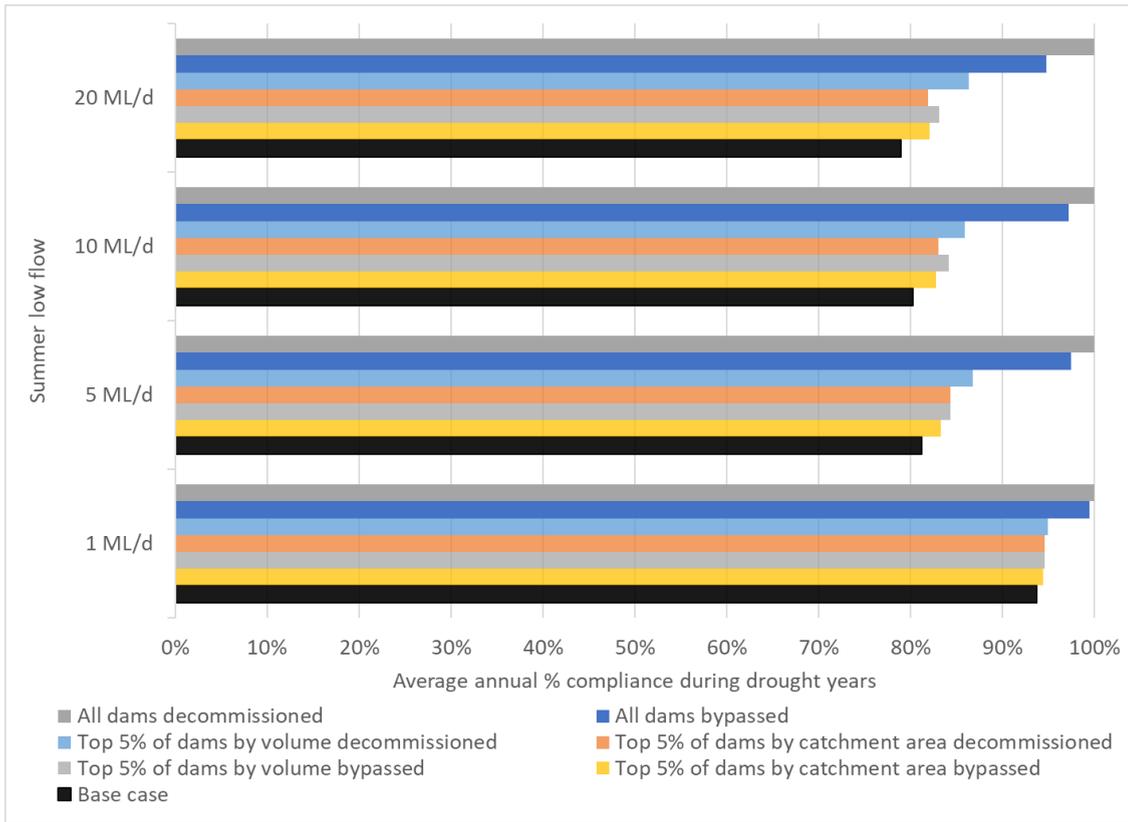


Figure 2. Improvement in summer low flow average annual compliance during drought years due to farm dam management strategies

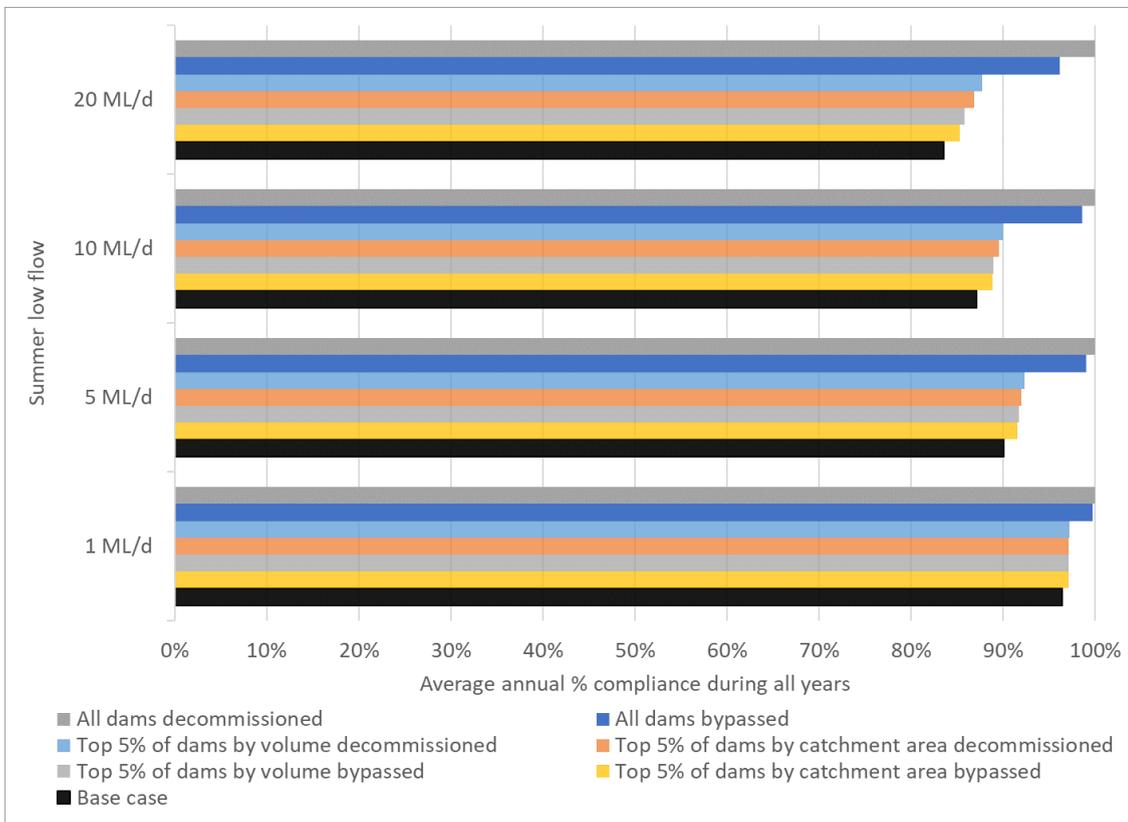


Figure 3. Improvement in summer low flow average annual compliance during drought years due to farm dam management strategies

It was found that while climate change had a large impact on the magnitude of flows in Seven Creeks, it did not have a differential impact on the effectiveness of the management scenarios and the impact of climate change on flows was consistent across all management scenarios. The impact of climate change on stream flow is more significant than the impact of farm dams, which impacted up to 3% of flows over the entire year and 9% of flows during the summer. Climate change also reduced environmental flow compliance. However, the management options were able to provide up to 4% of additional compliance with the 20 ML/d of summer low flow for the post-1997 climate change scenario.

Conclusions

A project was undertaken in the northern Victorian catchment of Seven Creeks to determine the impact of farm dams on summer and autumn low flows. As part of this work, a water resource model was developed that individually represented each farm dam. This model was verified at available streamflow gauges and used to model various management strategy scenarios, such as decommissioning a dam or installing a low flow bypass. It was that the greater improvement to environmental flow compliance occurred when the top 5% of farm dams ranked by volume were decommissioned. This was favored over decommissioning farm dams by catchment area; as for some of the farm dams with the greatest catchment areas, they had only a small storage volume and the majority of the water was spilling and not intercepted by the farm dam. As well, it was found that while climate change had a large impact on the magnitude of flows, it did not have a differential impact on the effectiveness of the management scenarios. Whilst further modelling is required across a broad range of catchments with various farm dam distributions is required to fully understand the impact of farm dam interception on environmental flow compliance, this case study showed that it is possible to build a water resource model to individually represent each farm dam. As well, this model can be used to target various farm dams to determine the impact on environmental flow compliance and low flow availability. This is an important tool to develop a business case for farm dam management strategies prior to stakeholder and community consultation.

Recommendations

It should be acknowledged that this study has been undertaken on a catchment level to determine the benefit of farm dam management options on a larger scale. The feasibility of applying the management options on individual dams has not been considered and it is recommended that prior to the adoption of a management option, further investigations on a more local scale are undertaken. This includes further investigation on the social implications of applying the management options. As well, the farm dam model developed for this project is able to show the overall impact of farm dams within the catchment, however the model uncertainty for the impact of individual farm dams (also explored in Fowler et.al, 2012) should be considered in future.

Acknowledgments

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