FARM DAMS IN THE CURDIES RIVER CATCHMENT, WESTERN VICTORIA: ITS POTENTIAL IMPACT ON WATER QUALITY

Lideweij Bakker, Jim Peterson and Shobhit Chandra

Centre for Geographic Information Systems (GIS)
School of Geography and Environmental Science, Monash University
Melbourne VIC 3800, Australia
Email: lideweij.bakker@arts.monash.edu.au

ABSTRACT

Farm dams can provide a reliable and important source of water for farmers. However, there is increasing concern about the impact that they may have on the quality and quantity of downstream water supplies.

The Heytesbury area was cleared of native vegetation shortly after the Second World War. Since then, water quality in Curdies River and its sub-catchments has fallen. Explanation is sought in reference to history of land use, climate, irrigation practice and the steady increase in the number of farm dams emplaced. Over this time period, distinctive changes in the stream regimes and nutrient load of water draining to the coastal lagoons further south have been recorded.

From an assessment of geographical variation in terrain attributes, we identified three sub-catchments of approximately equal area. We mapped the post-clearance farm dams in the Scotts Creek-Cooriemungle sub-catchment, which is thought to be responsible for 80% of the nutrient and sediment load to the Curdies River at Curdievale (Water Technology, 2008) with the highest density of farm dams. After validating the pre-requisite DEM, contributing areas were derived via deployment of the physically-based distributed multiflow modelling tool in ArcGIS for delineation of contributing areas. It is shown that 56% of this sub-catchment flows to farm dams, overflow from which can be expected in winter but only rarely in summer. Clearly the hitherto untested hypothesis that farm dam proliferation may account for summer flow losses to Curdies River needs further testing.

INTRODUCTION

Land clearances in Victoria since European settlement 150 years ago have profoundly transformed the landscape, with associated negative effects on river system health (Powell, 1967; Corangamite Catchment Authority, 2005). The gentle and slow imposition of evolving natural and aboriginal influences was radically replaced by rapid changes, which have had a significant effect on the natural processes within these ecosystems.

The Curdies River Catchment (Figure 4) provides an excellent area to study the impact of land use change on its natural environment, because the region was only recently cleared of native vegetation. The Curdies River catchment (790km^2) was predominantly covered by native vegetation until the Heytesbury Land

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Clearance in the early 1950s, which converted it into agricultural land (mainly dairying) over a very short period (Duruz, 1974; Woodgate and Black, 1988). Because of its recent clearance, rainfall and stream flow data, as well as air photos are available from this area, before and after the clearance of native vegetation, thus providing an excellent means of studying the effect of the intensification of land use on the water quality (Bibra and Riggs, 1971).

Figure 1a and 1b illustrate the land cover change in the Curdies River catchment area over the last 61 years. The Cooriemungle Creek is small stream within the Curdies River catchment. Figure 1a displays the area under predominantly forest cover with some grassland around the stream banks. Note the recent forest clearing in the North Western corner and the absence of any farm dams. In contrast, regard the land use of the same area in 2007, in Figure 1b. The whole land surface is under agriculture production aided by a prolific presence of farm dams. Hardly any remnants of the forest remain. (Source data: Corangamite Catchment Management Authority, 2005).

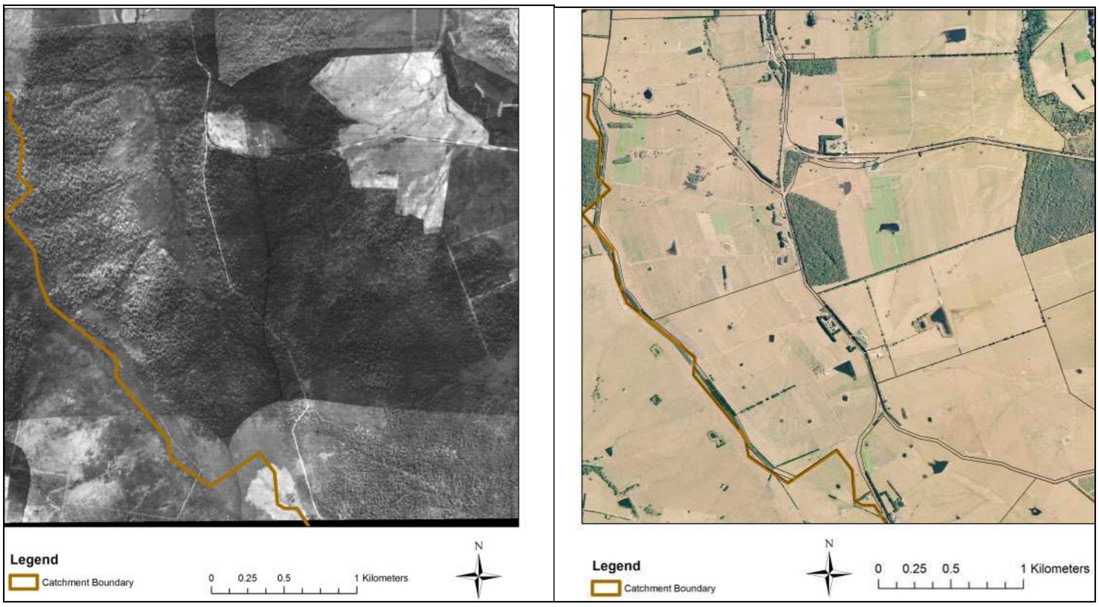

Fig. 1a: Land cover around the Cooriemungle Creek is predominantly forest cover with some grassland around the stream banks. Note the recent forest clearing in the North Western corner and the absence of any farm dams in 1946.

Fig. 1b: Land cover in the same area in 2007. The majority of the forest has been cleared and only a few forest remnants remain. Note the large number of farm dams that have appeared.

Recently, the availability of new spatial data sets has become available for adoption in decision support in environmental management. Singly, the significance of these spatial data sets is relatively limited to information assembly by simple spatial query. As Mohammadi *et al.* (2008) have recently reminded us, the real potential of these spatial data sets emerges via spatial data integration, allowing a comprehensive understanding of complex issues. It calls, among other things, upon knowledge of the science behind the various mapping themes, both in interpretation and in assessment of archival data sets in terms of fitness for use.

This case study is an example of an effective integration of various data sets (e.g. Department of Sustainability and Environment VICMAP products such as the SDI 20 meter DTM, the SDI geology, and VIC MAP Hydro, as well as the CCMA aerial mosaic). In search of an explanation for the discharge and water quality decline in runoff to the Curdies River, the following hypothesis is tested: The land use has intensified and as a result more run-off water is captured for use on the land. To test this hypothesis, we calculated the total number of farm dams and the total area of catchment runoff that is potentially trapped by these farm dams. This information was compared with trends in rainfall and stream flow data.

The Curdies River Catchment

The regional climate in the Curdies River Catchment is classified as temperate humid with a winter rainfall maximum. The annual rainfall is 800mm. Figure 2 shows the rainfall in the Curdies River Catchment for two weather stations from 1882-2005 (URL1). The relative relief in the Curdies catchment is 280m, the upper reaches being deeply incised (70-100m) into relatively unconsolidated Tertiary shallow- marine sediments. Quaternary basalts are present in the northern upper reaches of the catchment. The Tertiary sediments outcropping below ridge lines that have lost their capping of ferrugenised regolith, or, in the far north of the drainage system, remnants of thin basalt flows, are the most sensitive to erosion. As a result, deeply incised valleys with main roads built along the ridge lines are typical. No basalts are present in the Cooriemungle sub-catchment and large volumes of sediment have been removed from the upper catchment. Catchment erosion continues with active slope failure and mass movement evident on many steep slopes (Water Technology, 2008).

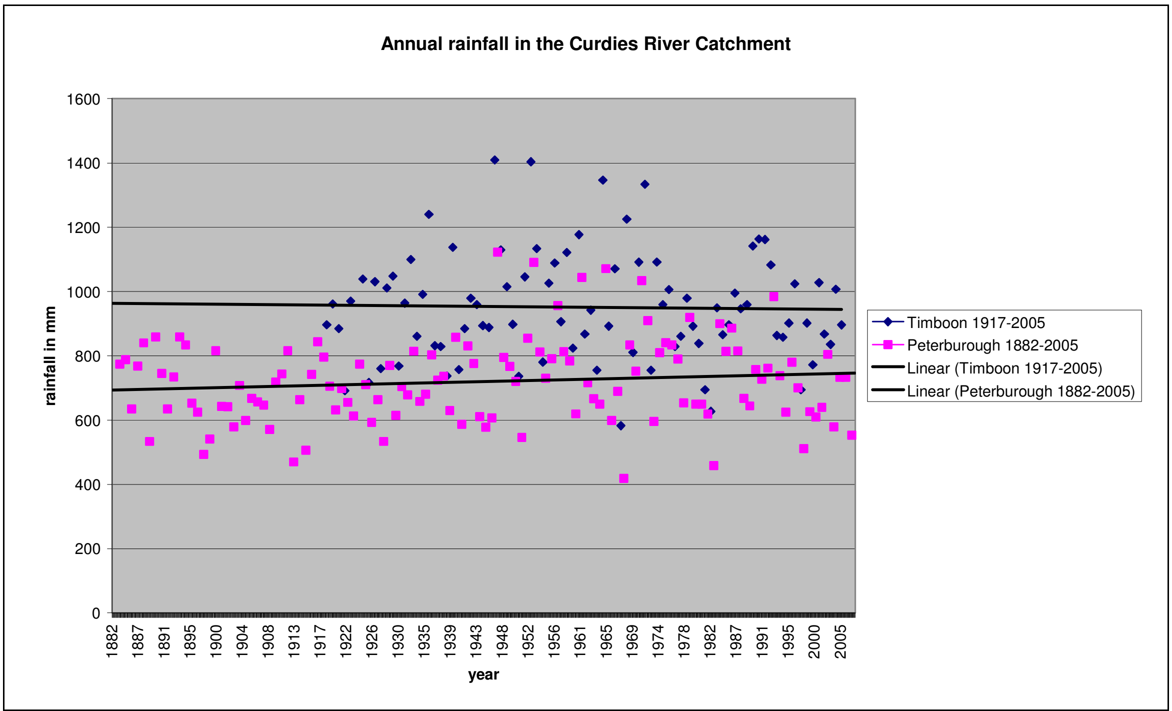

Fig. 2: Rainfall in the Curdies River Catchment for the Timboon and Peterborough weather stations from 1882-2005 (Bureau of meteorology, 2008).

METHODOLOGY

The data flow path in figure 3 illustrates the consecutive steps taken in this case study and the various data sets that were used:

1) The CCMA (Corangamite Catchment Authority) aerial mosaic. This customised mosaic was created by reprojecting Geelong imagery to MGA54. It was mosaiced in ERMapper and histograms were colour matched as best as possible to South West imagery. It was generated in Jan 2009 with images from Sept and Oct 2007, 0.35m resolution (Conroy,2009):
2) the VIC MAP Spatial Data Infrastructure 20 meter DTM (URL 2);

3) The VIC MAP Hydro 2006; 1: 25 000 vector data of the man made and hydrographical features (URL 2); and
4) The Vic Map geology; 1: 25 000 vector data of the geological features (URL 2).

The Curdies river catchment was delineated from the 20 meter DEM using hydrological modelling tools in Arc GIS. The result was verified with the blue line steam network (Vic Map Hydro).

The next step involved a geomorphological interpretation of stream networks integrated with the geological database to study regional variations which justify a division of the Curdies River catchment into three sub-catchments. The location of each is displayed in Figure 4. The Upper Curdies Catchment, which demonstrates the lowest overall drainage density, in a rectilinear drainage pattern, which is developed in Quaternary basalts and underlying softer unconsolidated Tertiary sediments. Secondly, the Scotts Creek-Cooriemungle Catchment, which is characterized by a dense network of NNW oriented valleys which are developed in unconsolidated Tertiary sediments. The third sub-catchment, the Lower Curdies Catchment, forms where the Scotts Creek flows into the Curdies River. This catchment is characterized by a steep-sided deeply incised (60-80m) valley with short streams draining into it. The Scotts Creek-Cooriemungle Catchment area has been our initial focus of attention because 80% of the nutrient and sediment load to the river at Curdievale is thought to be derived from that sub-catchment (Water Technology, 2008).

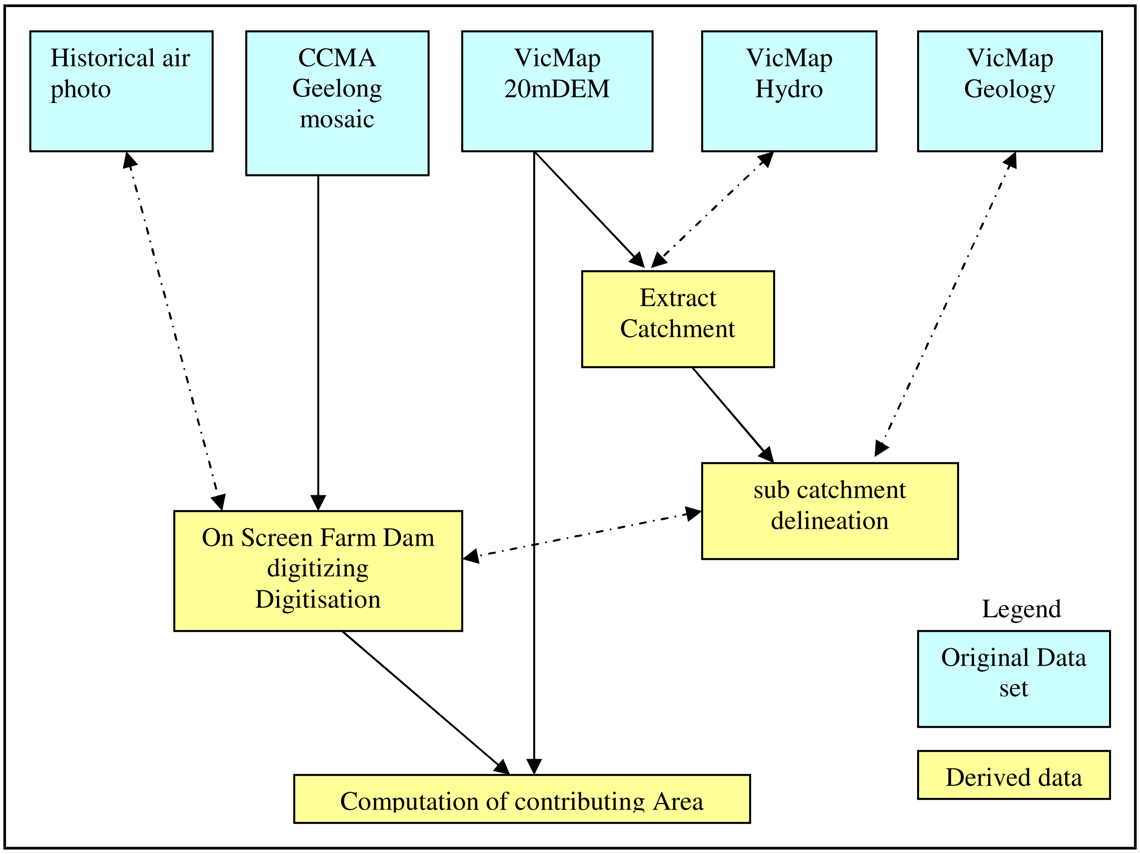

Fig. 3: Data Flow path

The next step involved the on screen identification and digitising of the location of individual farm dams on the CCMA Geelong Mosaic. Automated recognition of farm dams was unreliable due to their variation in, colour, shape, size, and boundary texture. There are very few natural looking water areas. To establish the origin of the dams (man made or natural) the location of dams of questionable origin was checked on the older aerial photographs to identify whether the water body was present in 1947. Water bodies that were present in the 1947 wilderness are excluded from the total number of farm dams reported here.

The total number of dams and the percentage of total land area covered by dams were calculated using ARC GIS. Once the total number of farm dams had been identified, their potential combined effect on the hydrology of the total catchment has been estimated using hydrological modelling. This was done by identifying areas from the catchment from which runoff contributions to the farm dams.

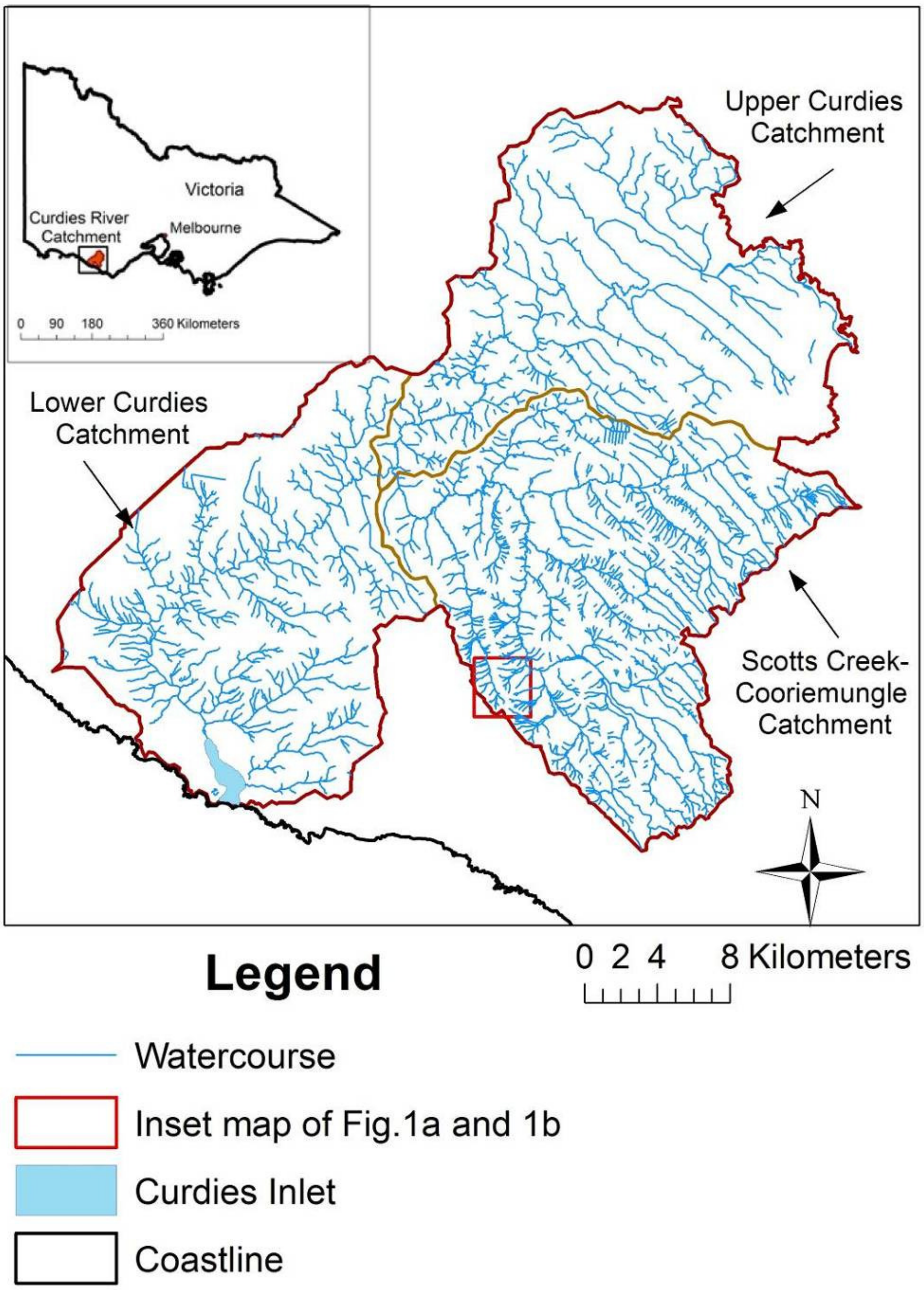

Fig. 4: Stream net work and the location of sub-catchment boundaries within the Curdies River Catchment.

RESULTS

There are 2200 water pondages ranging in size from $58m^2$ to $27{,}000m^2$. The mean size is $4{,}100m^2$ and the median size is $734m^2$, indicating that most farm dams are very small. The total area covered by dams is $2.8km^2$, which is less than 1% of the total Scotts Creek-Coorriemungle Catchment area ($345km^2$).

The morphology of most water bodies indicate they are man made, with each dam clearly visible on the CCMA Geelong mosaic. The majority of the dams are small (<800 m^2), square or rectangular water-holding bodies located on farms in no relation to any stream ("turkey-nest dams"). The rest are mainly formed by damming of existing waterways. There size can vary, but the majority is still small (around $10.000m^2$). These dams have a more profound impact on the regional hydrology because they directly influence the stream flow. The farm dam distribution is illustrated in Figures 5a and 5b. Figure 5a shows the whole Scotts Creek Cooriemungle sub-catchment and Figure 5b shows a small area around the Cooriemungle Creek. The area exhibits a high density homogeneous pattern of farm dam distribution, where multiple farm dams are often present on one farm.

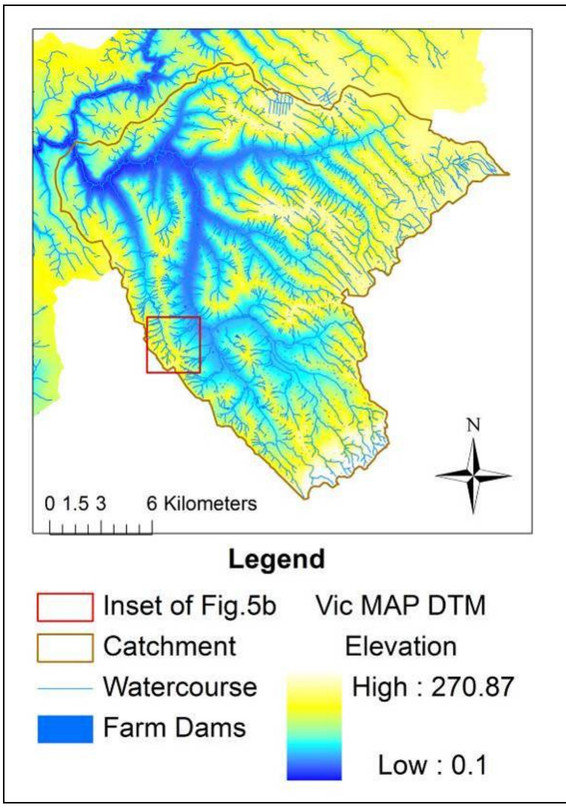

Fig. 5a: The farm dam distribution in the Scotts Creek Cooriemungle sub-catchment. The whole sub-catchment exhibits a high density homogeneous pattern.

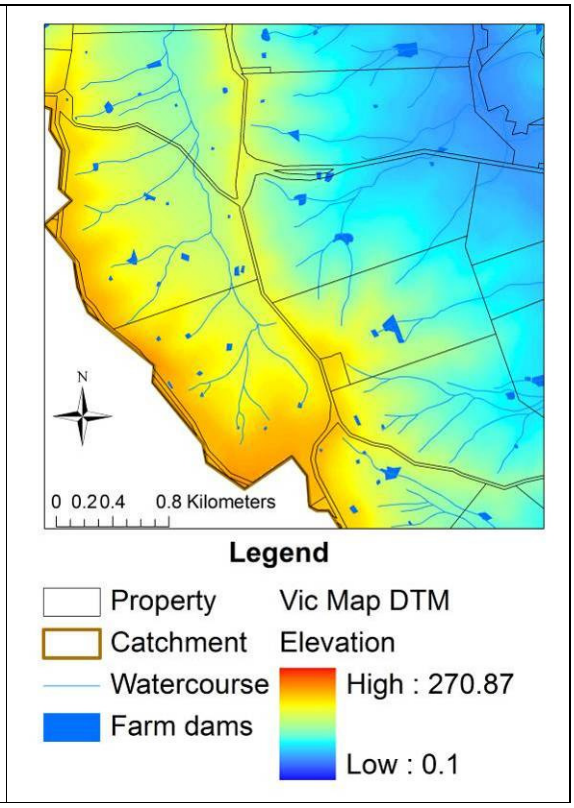

Fig. 5b: A detail of the sub-catchment illustrating that each tenement has multiple farm dams. (Primary data source: VicMap Cadastral (2006)

The contributing area is the area from which runoff contributions to these dams and is illustrated in Figures 6a and 6b. Collectively, this area is $225km^2$ (56%) which means that the hydrology in more than half the total land area is potentially affected by these man-made farm dams. The homogeneous distribution of the farm dams ensures that nearly all run off originating in the headwaters of the Scotts Creek Cooriemungle sub-catchment has the potential to be retained in a farm dam.

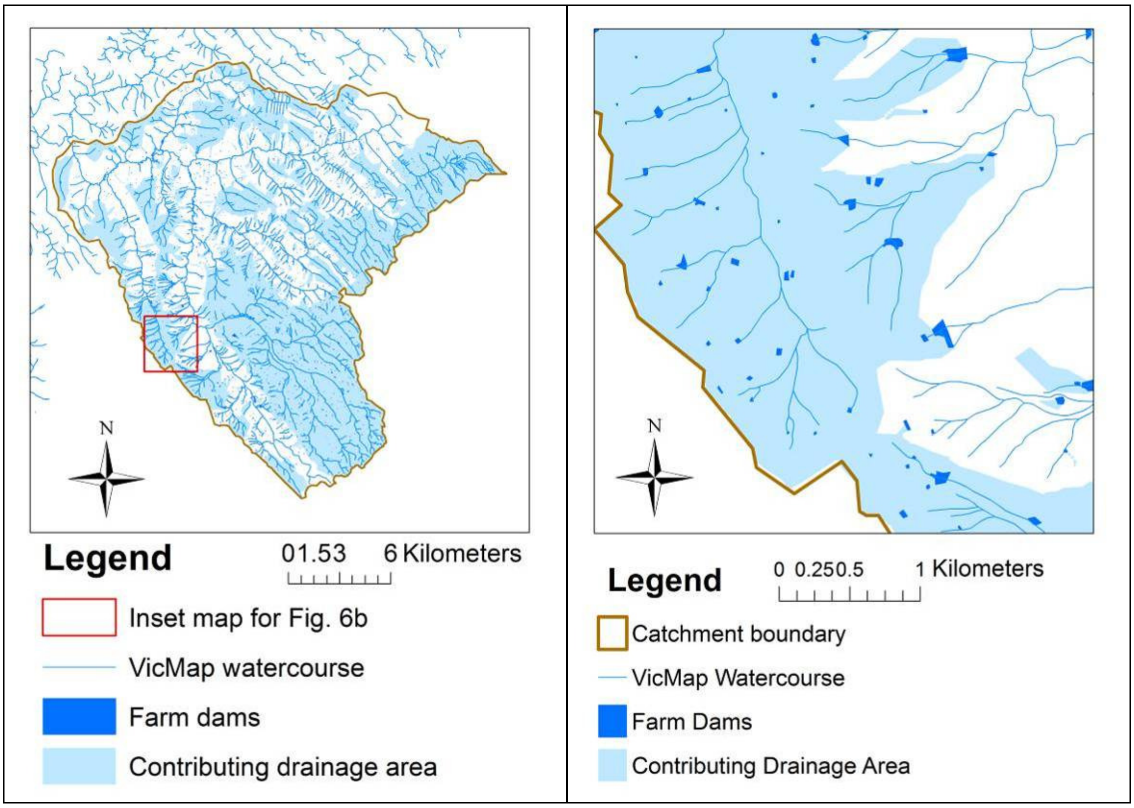

Fig. 6a and 6b: The contributing area from which runoff contributions to farm dams. Collectively, this area is 225km^2 (56%) which means that the hydrology in more than half the total land area is potentially affected by these man-made farm dams.

DISCUSSION

The relationship between rainfall and stream flow data in the Curdies River catchment has been studied in great detail by Peel *et al*, (2000) and Barton and Sherwood (2004). Both studies have found that annual observed flows are closely correlated to the modelled natural flows (Figure 7a), the latter of which is a function of the rainfall pattern Peel *et al*, (2000). However, annual rainfall has not reduced over time (Figure 2). At first sight, this would imply that farm dam proliferation has not had any adverse effects on the hydrology in the Curdies River Catchment. However, there is a seasonal rhythm to the variation between the actual flows and the expected natural flows in the Curdies drainage basin. Observed month by month, the summer flows are actually up to 80% less than the expected natural flows (Figure 7b, from Barton and Sherwood, 2004). Because the volume of water in the summer flows is so much smaller than the winter flow, this 80% variation is hardly detectable when only the annual total flows are considered.

This extreme low summer flow and associated ecological summer stress is also mentioned as the main contributing factor that the Curdies River scores a "poor water quality" a score of 15 out of 50, in the final ICS scores of 2008. (Department of Sustainability and Environment, 2005). Low flow periods are a natural feature of Australian river systems, and are generally regarded as a period of high stress for aquatic biota. An increasing frequency of low summer flows reduces the availability of in-stream habitat, which can lead to long term reduction in the viability of aquatic communities. Incidentally, in 1999, when low summer flow was not yet used as a criterion for river health, the Curdies River Catchment ICS score was of 9 out of 10 "good".

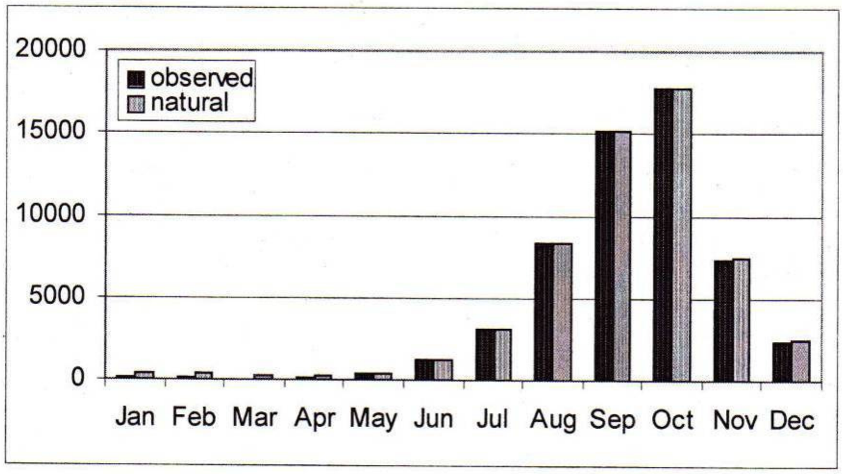

Fig. 7a:Monthly observed flows (ML/Month) for the Curdies Estuary in 1999 compared to the modelled natural flows. From Barton and Sherwood (2004).

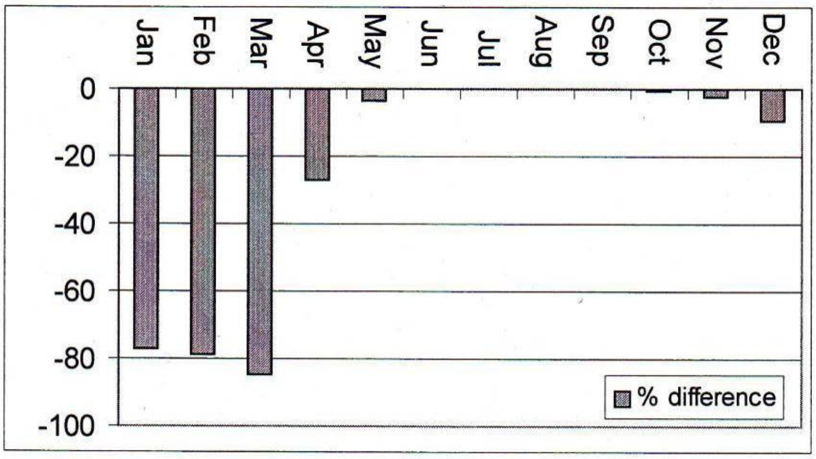

Fig. 7b: Percent difference of monthly observed flows (ML/Month) for the Curdies Estuary in 1999 compared to the modelled natural flows. From Barton and Sherwood (2004).

Barton and Sherwood (2004) do not elaborate on the possible causes of these highly reduced summer flows, but the presence of farm dams are likely to have a negative effect on summer flows. During summer, when water scarcity problems are more acute and water in farm dams is used to irrigate, any precipitation that occurs is likely to be contained within the dams. Whereas in winter when there is a relative abundance of rainfall, overflow over the spillways can be expected. With 56% of the surface area of the Scotts Creek Cooriemungle sub-catchment flowing into farm dams, their combined effect has the potential to be highly detriment to the already low summer flows of the Curdies River.

The reduction in water quality of the Curdies River has the potential to have a damaging effect on the hitherto relatively undisturbed natural habitat of Curdies Inlet, which still hosts many rare species of birds, fish and vegetation (Victorian Government Department of Primary Industries, 2005; Water technology, 2008). A second disadvantage associated with low summer flows is toxic algal bloom (Department of Sustainability and Environment, 2005). Indeed, toxic algal blooms were reported in

Curdies Estuary in March 1991, April 1998, March 2001and July 2003 (Water technology, 2008). A third issue related to low flows during the summer months is the closure of the estuary by the formation of a sand bar. To prevent flooding of the surrounding dwellings, a closed bar needs to opened artificially before high flow volumes return in winter (Barton and Sherwood, 2004; Water technology, 2008).

CONCLUSION AND FURTHER WORK

The proliferation of farm dams the Curdies River Catchment is likely to be one of the main causes of low summer flow stress which is experienced in the Curdies River System. Even though the total area of dams in the Scotts-Cooriemungle sub-catchment is less than 1%, a much larger 56% of this sub-catchment drains in a farm dam, ensuring that more than half the surface flows generated in the Scotts-Cooriemungle sub-catchment can potentially be retained in a farm dam. Overflow from farm dams can be expected in winter but most precipitation is likely to be contained in summer, when water is scarce. Currently, these low summer flows are the most threatening factor to the health of the Curdies River System (Index of Stream Condition: URL3, 2008).

Clearly the hitherto untested hypothesis that farm dam proliferation may account for flow losses into Curdies inlet appears viable enough to justify further testing. Such a test would involve extending the work reported here to the other two sub-catchments. There is much scope for detailed assessment: the dams can be classified (in-stream pondage, "turkey-nest ponds, diary effluent ponds). Further investigations into seasonal flow rates up- and downstream of in-stream pondage would allow quantification of summer water loss through farm dams. Water quality issues can be done through the identification of septic tanks (Allen and Peterson, 1998) and diary effluent ponds to assess the relative significance of point-source and non-point-source pollution.

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BRIEF BIOGRAPHY OF PRESENTER

Dr Lideweij Bakker originates from the Netherlands where she completed her MSc (1993) at Wageningen University in Soil Science and Paedology. During her PhD (1997) she focused on landform evolution in Ignimbrite landscapes, using terrain GIS based terrain analysis, at Waikato University, New Zealand. She is now affiliated as an adjunct research associate to the Centre of Geographic Information Systems at Monash University. Her research focuses on integration of readily available spatial data sets for sustainability and environmental purposes.

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