A REVISED CRITERIA FOR RUNOFF MANAGEMENT IN SOUTH-WEST WESTERN AUSTRALIA

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Abstract
Despite emphasis on recharge and discharge, many common landscape issues are either caused or exacerbated by excess water originating from surface runoff. Many issues addressed by landholders are local, with the cause and effect occurring over relatively short landscape distances. Attention is being drawn to downstream impacts in receiving areas, both on and off farm.
Recent years have seen major changes in urban and semi-rural stormwater management. The emphasis for sustainable farming systems will increasingly become "quantity of water managed" rather than "water sent past the gate". Addressing these criteria in agricultural systems presents a major challenge for landholders and advising agencies.
Banks and surface water management structures integrated with trees and tillage practices continue to be key promoted activities in 'Landcare farming'. The ability to set and achieve realistic local (farm-scale) objectives whose benefits can contribute to landscape-scale outcomes continues to be a challenge. In Western Australia there is increasing recognition that water management scenarios must be implemented with better consideration of fundamental flow hydraulics and low impact water redistribution. There is a need to directly address runoff from smaller rainfall events in the 20-60mm threshold, in addition to the traditional need to cope with large events.

Additional Keywords: conservation earthworks, runoff, surface water management, soil and water engineering

The conservation earthworks dilemma
Despite widespread promotion, bank and soil conservation systems have often been limited to minor and ad-hoc works carried out in direct response to a local problem or production benefit over a small area. Individual banks and runoff management systems are rarely constructed to the extent recommended in extension material and soil conservation literature. Many older bank systems installed during the soil conservation periods of the 1970s and 1980s have deteriorated due to poor maintenance and in cases been removed because they are perceived to be redundant under improved tillage and pasture systems or revegetation programs. Such attitudes prevail not only in the minds of landholders, but also in the minds of many land management researchers and practitioners.

In Western Australia conservation earthworks remain essentially similar to those recommended in the primary reference publications and internationally recognised texts of the 1970's and 1980's (eg. Carder and Spencer, 1970; Bligh 1989; NSWSCS, 1992; Schwab et al, 1981 & 1985). 'Recent' developments usually arise from minor modifications to structure type, specifications and construction methods. There is an ongoing perception that surface water management is "old hat".

It would appear that in eastern Australia and internationally, the perception of banks and surface water management is not unlike that observed in WA. Rawitz and Hadas (1994), among others, identify that conservation earthworks are often perceived to be intrusive and inconvenient to broad-acre mechanised cropping where machinery efficiency and the need to minimise production overheads dominate on-ground decision-making. Where implemented, long-term conservation benefits are often secondary to immediate benefits, such as water supplies and protecting degrading soil areas, which offer 'visible' contribution to farm production.

Essential issues at farm and catchment scales
Typical watershed scale problems in the low rainfall landscapes of Western Australian include:
- sheet and rill erosion in upper and lower slopes;
- excessive water shedding in dry conditions from hardsetting clays and water repellent sands;
- saturation of upper soil profiles leading to rootzone waterlogging and local recharge-discharge (perched water table development , lateral seepage flows and discharge impacts);
- wind and water erosion of shallow topsoil exposing underlying clays, development of low yielding scalds;
- high flow velocities in upper landscape watercourse, creating erosion and sedimentation problems;
- excess water accumulation and waterlogging in receiving points and bottom of slope areas, and
- regular inundation and waterlogging of low gradient channel areas.

The four dominant soil profile groups in south-west Western Australian dryland agricultural areas include uniform coarse textured soils, permeability contrast soils, cracking clays and medium-fine textured soils. All are variously affected by tillage practices and prolonged working (Nulsen, 1992; Moore, 1998) with subsequent local impacts on infiltration and runoff. Consequential impacts such as surface sealing, compaction layers, waterlogging and profile saturation cause increased runoff volumes in both dry and wet conditions.

At paddock scales
Coles (1993) identified that runoff is generated at small paddock scales (ie. <50 Ha) from small rainfall events. Experimental site data and field observations have confirmed that infiltration excess and saturation excess processes are commonplace (once wetted) following relatively small rainfall bursts. These can lead to sheet and rilled flows over distances of hundreds of metres. Water from these scenarios is strongly influenced by small-scale morphology and has a tendency to converge onto low relief and low gradient paddock areas. It is significant that many of these rainfall events do not yield streamflows at sub-catchment scales.

The concentration of runoff to low-lying areas within the landscape results in soil profiles being impacted in a manner comparable to higher rainfalls. Impacts include waterlogging and low crop and pasture yield, that can be readily identified by the landholder. However a greater issue arises from the effect of prolonged profile saturation, fed by numerous small events and maintained by low evaporation rates, that lead to denuded pan and scald development. In landscapes with high salt concentrations repeated wetting and local shallow water table development can lead to *in situ* salinity development from passive evaporation. These areas subsequently impact upon downslope areas through increased runoff, salt export and as source areas (hydraulic gradient) for locally active sub-surface and seepage flows.

At sub-catchment scales
Clearing has increased runoff occurrence in the south-west agricultural region of W.A. Areas with higher winter rainfalls and low evaporation experience prolonged soil wetness; leading to periodic upper profile saturation, seasonal seepage fed flows and saturated stream areas. In lower rainfall areas (ie. < 400mm), and during dry periods, wetted conditions exist for shorter periods and runoff tends to become episodic rather than seasonal. Gauging data and field observations show that runoff generated in upper catchment areas does not necessarily translate to flows beyond tributary streams. Excess water accumulation is associated with low gradient flats, riparian features such as small lakes and swamps and poorly defined channels. Water accumulation is locally exacerbated by flow impediments such as roads and farm tracks.

Various datasets for the south-west wheatbelt demonstrate that streamflow regularly occurs in agricultural catchments from rainfall events as small as 20-40mm. Anecdotal evidence and limited data suggest that thresholds for uncleared catchments are much higher, typically requiring larger rainfall events of 60mm and higher. For example, Bligh (1983) identified significant rainfall events as 95mm and 85mm for two uncleared wheatbelt catchments versus 25-50mm for comparable cleared catchments.

Rainfall analysis has shown that events in the 30-60mm range frequently occur on an annual (often multiple) basis whereas rainfall events 60-90mm occur less frequently (1-in-3 to 1-in-5 for most areas). Rainfall events of around 90-120mm typically represent events with 1-in-10 return periods. On this basis it is evident that the initial receiving points in agricultural areas are experiencing frequencies of runoff delivery well above that to which natural riparian systems had adapted.

Recent investigations (Farmer et al, 2002; Cattlin et al, 2002; Farmer et al, 2003; Cattlin et al, 2004) have demonstrated that the redistribution of runoff at sub-catchment scales is a major cause of degradation in lower landscape areas. While salinity derived from valley scale rising water tables might present the longer-term risk, short-medium term secondary salinity and riparian degradation is often more likely to be associated with erosion, sedimentation, inundation and waterlogging. Degradation is localised and coincides with changes in the regularity and volumes of surface water delivered from steeper upper landscape areas (shedding landscapes) to low gradient, high storage capacity main valley and tributary areas (receiving landscapes).

The excess water management quandary
Management options must engage in reducing accumulation potential. At the same time, soil and water conservation earthworks and excess water management systems should maintain or improve land use capability and reduce the risks of dryland farming. To maximize benefits to the farmer, tillage and cropping/pasture practices

must ensure adequate water retention while excess surface water is collected and removed using banks, tramlining, keyline systems and shallow surface drainage.

Enhanced soil infiltration and surface retention is only viable if the water can be effectively used within the root zone. Beyond this level it simply results in excessive profile moisture and ultimately recharge. McFarlane et al (1987) showed that when held for extended periods, ponded runoff becomes head driven vertical recharge that subsequently interacts with salt rich deep clay profiles; i.e. simple embankment works that pond water without leakage management can actually result in a negative impact. This limits the scope for low cost detention structures such as level banks, absorption banks, small gully dams and detention levees that have been widely used in other areas.

Trees and revegetation continue to be promoted as optimal water users. However in many low rainfall situations revegetation is water deficient in summer and unable to maximise water use during low evaporation winter months when excess soil-water is abundant. In commercial tree cropping the reduction of growing stresses through reduced winter waterlogging and increased summer water availability is needed to ensure optimal biomass accumulation. Stress minimisation is also important for revegetation and perennials in poor quality soils under adverse site conditions. Unless growth rates achieve the biomass densities required to effect flow retardation and water retention then the expected benefits simply do not eventuate.

Traditional excess water management in agricultural landscapes is fundamentally driven by the need to effectively collect and convey water to the nearest natural channel (Figure 1). Once in the watercourses excess water essentially ceases to be a farm planning issue. A conflict occurs at sub-catchment scales, since many landscape and riparian management objectives require a net reduction in upper landscape discharge in order to address degradation issues in valley landscapes.

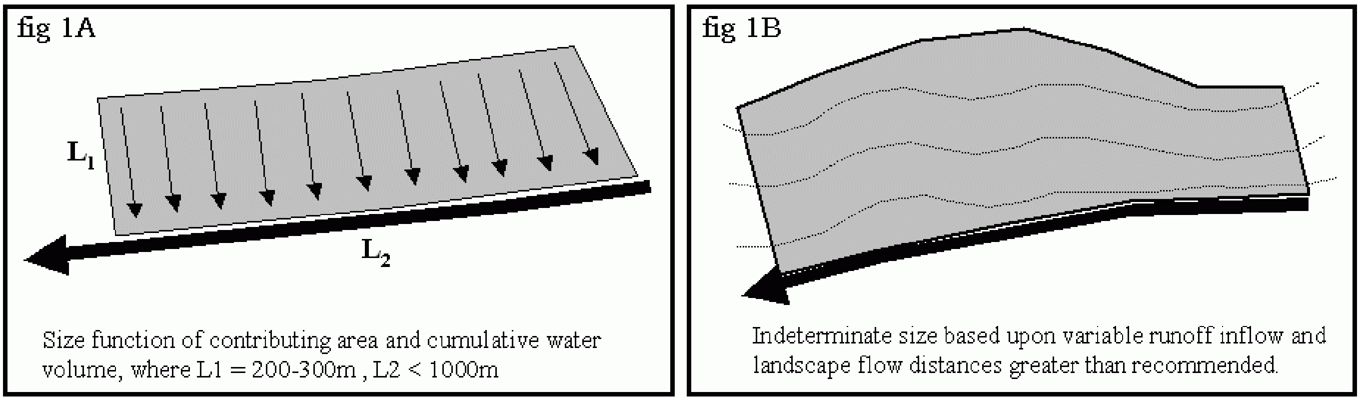

Figure 1. Schematic bank layouts (left) often differ from design requirement for a collection and conveyance structure in a working hillslope under varying treatments (right).

Establishing realistic objectives

The fundamental components of a surface water management system are engineering structures designed to deal with the collection, conveyance, detention and disposal of excess water resulting from rainfall events. Current practice is that these systems should cope with runoff events with a 10 to 20 year return period (ie. correlates to rainfall events of 90 to 130mm). The challenge is presented of adapting conservation earthworks to the requirements and expectations of integrated water management systems.

Structures not being constructed to design standards and poor maintenance are major problems encountered with many existing bank systems. Reduced size (ie. channel capacity) and increased bank spacings are commonly used to achieve lower installation costs or minimise productive land 'lost'. In many instances such outcomes stem from a perception that structures installed to recommended specifications are excessive. Limited capacity and poor placement reduces water management benefits and increases the risk of exceedence during large events. Poorly implemented works are often cited as the basis for 'substantiating' that surface water management did not work.

There is a need to utilise works that result in minimum intrusion into farm activities (applies mainly to cropping and movement of stock) and offer additional benefits to the farm business. Water harvesting and reclamation works are two examples of derived benefits; good quality water is required for farm operations and reclamation can return 'non-arable land' to productivity. On productive slopes it is unlikely that recommended earthworks illustrated in Figure 1A will be adopted, leaving the situation illustrated in Figure 1B. As flow distances increase the design requirement for collection and conveyance structures must increase to cope with the additional volume and velocity of water to be managed. It is inherently more difficult to safely manage runoff from larger areas using simple earth structures. From a soil conservation perspective long flow distances are extremely undesirable.

Benefits result from landholders adopting alternate management strategies such as strip cropping, minimum tillage, stubble retention and controlled grazing. These can assist to moderate overland flows prior to collection. However there remains the risk that vegetation cover may not be adequate all year or that large intense rainfall will exceed the limited hydraulic benefits of these treatments.

Broad-based banks offer the dual benefit of a broad channel base and shallow backslopes that can be utilised for cropping or perennials (eg. Stanton, 2003a, Stanton, 2003b). As the cross-section is generally larger than conventional soil conservation banks there is greater capacity available to cope with larger runoff events. The combination of broad, shallow cross-section and plant stubble or grass offers hydraulic benefits that can retard flow velocities and assist in flow attenuation. Sufficient grade is required to ensure that excess water can achieve a safe flow if waterlogging is to be avoided. For small events the broad channel and vegetation provides opportunity to promote transmission loss without the risk of excessive profile wetting (degree of loss being determined by soil moisture state). Banks associated with dams can incorporate a broad compacted half-road (roaded bank) to promote water harvesting and discharge into the storage structure.

Experience suggests that a combination of improved waterways, numerous small works within and above degradation areas, and broad based banks over cropping areas will approach the capacity needed to contain smaller runoff events with minimal interruption to farm activities. Coupling banks with large dam storages of (ie. > 10,000 kL) increases the opportunity to detain runoff and provide water supply benefits to the farm business.

Conclusions

Analysis of rainfall events and runoff thresholds for south-west Western Australia suggests that significant benefit can arise from managing post-clearing runoff associated with small rainfall events. Soil conservation earthworks selected and implemented in accordance with recognised principles and local objectives will continue to provide one of the most effective means of managing runoff and minimising soil loss from paddocks. In the absence of upslope retention, excess water reaching valley floors can realistically only be detained in sacrificial areas (ie. lakes and wetlands) or collected and conveyed downstream. Large events are inherently difficult to mange in most landscapes and hence the constructed works are limited to the attenuation of peak flow rather than the containment of runoff volumes generated.

The implementation and planning problem faced by land mangers at catchment scales is the capacity to invoke a variety of integrated solutions on individual farms that contribute to catchment management outcomes and are acceptable to the landholder. Previous experience suggests that 'landholder acceptable' works will generally fall below the default specifications determined from event modelling. Purpose designed conservation works such as broad based banks and water harvesting systems make it possible to provide options that are beneficial to both on and off farm activities. These structures can be implemented to have minimal affect on farming operations, yet still offer adequate levels of protection and water management on susceptible hillslopes. Increased acceptance and adoption of these methods will assist in the management of excess water in the upper landscape, and ultimately provide the critical link to whole-of-catchment outcomes.

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