Waterways and Gully Stabilisation in Vertosol Soils: Dry Creek, Condamine Catchment, QLD

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Key Points

- Waterways in vertisol soil landscapes have very little resistance to erosion and are extremely sensitive to changes in catchment hydrology.
- Hard engineering stream stabilisation measures are inappropriate for vertosol soils.
- Currently there is no established (proven) methodology for waterways stabilisation in vertosol soils.

Abstract

Australia has the highest diversity and distribution of cracking clays in the world. Vertosols, commonly referred to as black earths, are defined as "clay soils with shrink-swell properties that exhibit strong cracking when dry" (Isbell, 1996). The overriding problems associated with vertosols in Australia are those of erosion and waterway instability. Numerous studies into erosion and waterway stability in vertisol environments were undertaken in the 1980's, however, most focused on artificial waterways for contour farming and none found any solution to waterway stabilisation. Through community consultation, it was largely agreed upon that typical stream stabilisation measures were inappropriate for these sediments as structures were usually out-flanked or undercut.

Dry Creek flows west of the Great Dividing Range, with a small catchment covering 40 km^2. Land use on the valley floor is a combination of cropping and grazing land. Much of the agricultural land is contoured. An increase in catchment discharge, due to clearing for agriculture, and development on the floodplain, has concentrated flow, which has initiated the incision of a defined channel. The floodplains of the lower reaches of the catchment are now being intensely developed for industry. While this has led to an interest in the future behaviour of the incised streams, there is little interest, funding or even established methodology, for waterway stabilisation at this site.

With reduced political interest in waterway health in Australia, research into waterway stability in vertosol soils has all but ceased. More worryingly, those involved in research and implementation in decades past are now retired, and we are at risk of losing vast amounts of knowledge. Here we review previous research and attempts on waterway stabilisation in vertosol soils with reference to Dry Creek and vertosol soils landscapes in general.

Keywords

Waterway Stability, Gullying, Vetiver, Bank Erosion, Waterway Management

Introduction

A major development along O'Mara Road, west of Toowoomba, includes a short reach of Dry Creek. As part of the stormwater management planning for this section of the development, a geomorphic assessment of the section of Dry Creek within the development area was undertaken. This section of Dry Creek (the O'Mara Road reach) extends approximately 800 m east and west (upstream and downstream) of O'Mara Road. The development of the floodplains and channel along this section of Dry Creek involves:

- A new bridge crossing on O'Mara Road.
- Industrial development on the floodplain.
- Multiple stormwater outlets from the developed area to Dry Creek.

A geomorphic assessment of the area showed the creek to be in a heavily degraded condition, and suggested that the condition will worsen under current conditions. There are several key processes of concern in terms of channel and bank stability. These processes threaten the stability of the proposed bridge crossing, existing and future stormwater outlets and potentially the adjacent development lots. Due to the complexities associated with waterway stability in vertosol soils, a general assessment of waterway management in vertosol soils was undertaken. This assessment involved the investigation of trial sites set up and tested across the Condamine Catchment, interviews with ex-Soil Conservation Staff, and a review of literature.

Study Area Description

The Dry Creek Catchment is a headwater catchment of Oakey Creek, a tributary of the Condamine River. Dry Creek flows west of the Great Dividing Range, meets Westbrook Creek near Wellcamp, which then flows to Oakey Creek before entering the Condamine River (Figure 1). The total Dry Creek catchment is relatively small covering 40 km^2 (17 km^2 to O'Mara Road). The headwaters of Dry Creek are relatively steep and cut through the tertiary basalts of the main range. The creek then flows out onto the wide flat valley floor, on which the O'Mara Road reach is located. Land use on the valley floor is a combination of cropping and grazing land. Much of the agricultural land is contoured to reduce overland flow. Clearing land for agriculture has increased discharge along Dry Creek. Contour farming has concentrated overland flow along artificial drainage canals to Dry Creek (Sallaway, 1985).

Creek Condition

Prior to European settlement, it is likely that Dry Creek did not exist as a defined channel (i.e. before clearing of vegetation, cropping and the introduction of stock on the floodplain). As recently as 1955, the creek appears to have been a grassed discontinuous watercourse with very little surface expression. The increase in discharge, due to clearing for agriculture and development, has led to scour into the floodplain. This has initiated the incision of a defined channel. This geomorphic change is referred to as a geomorphic threshold, which once crossed (i.e. initial scour and incision), will continue to degrade until a new channel form is attained (Schumm, 1973). This reach is currently in the process of major change and has not yet reached a metastable equilibrium. Left as it is, Dry Creek is likely to continue to degrade with significant change occurring during high flow events.

The current condition of the O'Mara Road reach of Dry Creek is very poor. Dry Creek in its present form exists as an incised and over-widened stream. The creek at this location is highly unstable. The creek has adjusted laterally in the recent past and has incised and widened significantly over the last four years. Numerous (five) head-cuts were identified in the study area and it is expected that most are highly active (rapidly retreating). This is a process of channel deepening, which will lead to continued channel widening. Changes in bed grade and riverbanks are expected under low flow conditions; however, the bed and bank have the potential for significant alteration under bank full and overbank flows. Key detrimental processes occurring within the reach are:

- Increased discharge (in response to changes in land use).
- Head-cut migration upstream (channel deepening in response to increased discharge) (Figure 1 &2).
- Bank collapse and channel widening (in response to channel deepening) (Figure 3).
- Gullying into Dry Creek floodplain at the confluence of a lateral overland flow path (also head-cut development in response to Dry Creek channel deepening) (Figure 3).
- Scour downstream of infrastructure (gabion mattresses, road crossings).

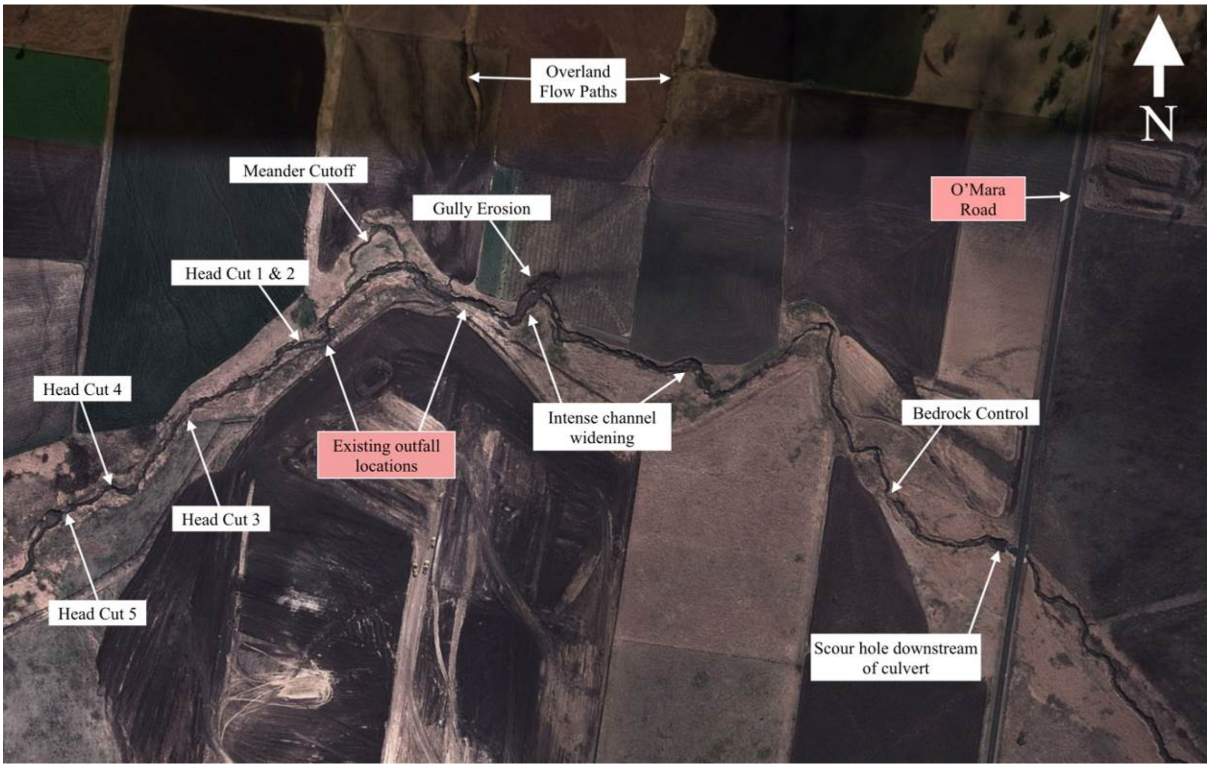

Figure 1. Aerial Photograph of study reach downstream of O'Mara Road showing the location of key areas of concern (2013 Google Earth, © 2013 DigitalGlobe).

The two key issues for the reach are high discharge and bed-level lowering (channel incision). These are the key processes leading to channel widening and gully formation. Channel widening and gully formation will affect the bridge crossing, existing and future stormwater outlets and, potentially, the development lots. In general, after a head-cut forms, it will continue to migrate upstream until it reaches either the head of the catchment or a solid barrier (rock bar, road crossing) (Figure 2). That is, discharge reduction in the creek may reduce the speed of head-cut migration; however, without physical intervention within the creek, the head-cut will continue to migrate and the creek will continue to deepen and widen.

Due to the exceedance of a threshold of incision, rehabilitation of the creek to its original condition is not likely feasible or possible. The best outcome would be to:

- Minimise future impact on the creek from further development.
- Create a new sustainable condition that is "stable" under the new flow conditions.

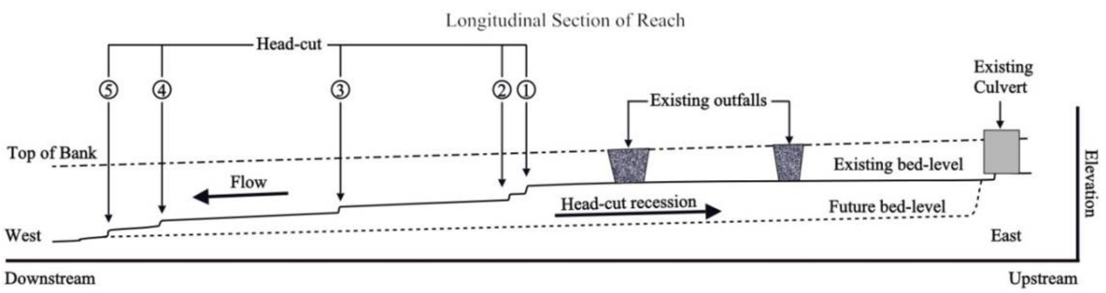

Figure 2. Conceptual model of head cut migration towards existing infrastructure aligned with the current bed level (not to scale).

Figure 3. Gully erosion and channel widening between 2009 and 2011 (2013 Google Earth, © 2013 DigitalGlobe).

Previous Research

Numerous studies into erosion and waterway stability in vertisol environments were undertaken in the 1980's, most notably Sallaway (1985) and Truong (1983) both commissioned by the then Queensland Department of Primary Industries. The term "waterways", in these reports refers to overland artificial flow paths in to which water from contours is directed. Very little attention was paid to the stream to which these "waterways" drained.

Truong (1983) investigated "waterway" instability in several regions across Queensland including North Queensland, Capricornia, Burnett, Near North Coast, Near South West, Moreton and the Darling Downs. All regions were found to experience severe gullying into the floodplain and, in most cases, this was attributed to a lack of vegetation, difficulties in vegetation establishment, and/or poor maintenance. As such, the investigation drew on other research into the grass types suitable for stability in various regions undertaken in the 1960's and 70's. Truong (1983) summarised several issues and several means of stabilisation, all associated with maintenance and vegetation. He also proposed that planting lines of kikuyu across the flow path was detrimental in that accumulated sediment formed a grade change capable of initiating incision. This is contrary to the findings of the Condamine Alliance (2013) and Sallaway (1985).

Sallaway (1985) focused on the central highlands and compared cropping with grazing land along with contoured vs. in-contoured farming land. He found that the instabilities in "waterways" were often associated with cropping rather than grazing and that contoured cropping land was slightly worse than un-contoured. He found that perched and constructed waterways do very poorly and attributed this to the disturbance of the soil.

Sallaway (1985) states that "without a detailed understanding of the geomorphology of these catchments, and a detailed survey of the geometry of each individual catchment a guaranteed stable design could not be given" for stabilisation of waterways in these landscapes. He recognised that many of the waterways are in a state of dynamic equilibrium. Sallaway (1985) cites (Schumm, 1977) and discusses catchment/waterway system stability in terms of threshold exceedance and complex response. These thresholds are dependent on slope, sediment supply, sediment type and flow conditions and the sensitivity of the floodplain during large-scale rainfall events (Schumm, 1973; Lewin and Macklin, 2003).

Interviews were conducted with people who were intimately involved in soil conservation research in the 1980's and 1990's. Discussions with ex-Soil Conservation staff revealed the degree of complexity in stabilising gullies or waterways in Vertosol soils. It was largely agreed upon that solid in-stream structures (rock or concrete) were inappropriate for these sediments as the structures were usually out-flanked or undercut. Vegetation cover was the preferential treatment with a degree of earthworks and had been the only treatment to work. This is what lead to the research focus on vegetation types (particularly grasses) in the mid 1980's and 90's. Vetiver Grass (sterile vetiver cultivars) was agreed to be one of the best plants for stabilisation due to its ability to grow quickly in many environments and its deep roots (up to 5 m)(vetiver grass is an introduced species). Lomandra has also worked well in the past and both Lomandra and Vetiver are often complimented with Kikuyu.

Case studies and stabilisation design trials were carried out over two years (2012-2013) within the Condamine Catchment. These trials involved attempts at gully stabilisation on properties in Greenmount, Allora and Ramsay. At all sites, gullies had developed in artificial waterways, which drained water from farming contours. The trial solutions to gully progression involved the design and installation of a rock chutes complemented by differing combinations of Ag pipe installation, geofabric underlay, and vertically placed marine ply or rubber sheeting upslope or beneath the rock chute. Vegetation (either Lomandra of Vetiver) complimented all but one site. Where sites have experienced substantial flow, all have failed to a degree. This was due to either poor design of the rock chutes, a lack of vegetation, or a combination of the two.

Example of Successful Stabilisation

Fourteen Mile Creek is a tributary of the north branch of the Condamine River. The Creek use to cross Pittsworth-Norwin Road just before it intersection with Wallingford Road but was diverted to run along the northern side of Pittsworth-Norwin Road. Like Dry Creek, Fourteen Mile Creek has experienced sever incision and widening; however, this incision is halted by a series of road crossings (weirs, drop structures etc.). Figure 5 shows the upstream and most effective structure on Fourteen Mile Creek.

Figure 5. Drop structure at Wallingford Road.

Figure 5 show the drop structure located at the Wallingford Road crossing and the difference in bed elevation up and downstream of the structure. The downstream bed level is estimated at between 4 and 5 m lower than that of upstream. This highlights the degree to which incision in these soils can occur. However, incision at this location appears to have ceased, most likely due to the dramatic decrease in channel slope and thus the erosive force of the water. Widening appears to have also stopped and this reach appears to be relatively stable now although it is not known how long this structure has been in place.

Summary & Conclusions

The underlying issue at Dry Creek is high discharge and bed-level lowering (channel incision). These are the key processes leading to channel widening and gully formation. For Dry Creek, this will affect the bridge crossing, stormwater outlets and, potentially, the development itself. Whereas discharge can be reduced, the head cuts will continue to erode even at low flow because the threshold of initial incision has been crossed. The ideal solution for the reach is to:

- Install detention basins upstream of the O'Mara Road reach to reduce discharge.
- Halt incision into the bed through the installation of grade control structures (e.g. rock chutes).
- Batter and revegetate the banks and leave a majority of the floodplain intact.
- Place the development boundary outside the natural extent of the 100-year ARI flood.

The trial sites examined as part of this assessment had failed largely due to lack of, or poor maintenance of ground cover vegetation. Where the rock structures had failed, it is considered that rock types was an issue and not the design of the structure itself. However, the literature review and interviews with ex-soil conservation staff revealed a consensus that hard engineering (in stream rock or concrete structures such as rock chutes) are ineffective and that they are almost always outflanked or undercut. The key recommendations that came from the literature review and interviews with ex-soil conservation staff, included:

- Surface vegetation cover is crucial.
- Maintenance of ground cover is crucial.
- Bank outlets should not enter a confined flow.
- Slowing and spreading of flow is desirable.
- Vetiver Grass and Lomandra and effective at stabilising gullies.

Waterways in vertisol soil landscapes are highly sensitive to changes in catchment hydrology. The research conducted as part of this review suggests that once incision has occurred, there is little we can do to stop it. The effectiveness of the Wallingford Road drop structure is promising, as it suggests that there is a slope, at which incision slows significantly in these soils. That slope, however, is estimated at close to zero and this drop structure is a very large and costly in-stream grade control measure. Perhaps this will be a good deterrent for developing these landscapes. If further development of vertisol soil landscapes is to be pursued, a great deal of research is required to establish an effective methodology for stabilising waterways.

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