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Catchment Function Analysis using Google Earth Mapping[1]

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Abstract

This paper presents a Catchment Function Analysis utilising Natural Sequence Farming and Ecosystems Management Understanding, as conceptual frameworks for system functioning, together with Google Earth, to indicate critical features of a catchment and the resulting public and private policy implications for catchment management.

Key words: catchment function analysis; catchment management; DeGrey; Google mapping.

Introduction

The importance of understanding the main components of landscapes, and the interrelationships among them, is rising with the threat of significant impacts of climate change and the persistent pressure to lift agricultural productivity while preserving or enhancing ecosystems. Adroit observation of subsystem interactions and the use of new knowledge to scale them up to relevant systems levels will be central to progress in this domain.

This paper reports such an approach. The purpose is to explain a novel process for analysing comprehensively a catchment (the DeGrey catchment in north-west Western Australia) using the Google Earth mapping tool. The catchment analysis is based on the concepts of Natural Sequence Farming of Peter Andrews (http://www.nsfarming.com/Principles/principles2.html) and the Ecosystems Management Understanding (EMU) approach of Ken Tinley and Hugh Pringle (http://www.emuproject.org.au/EMUPrinciples.htm).

Landscapes as Systems

Landscapes can be considered as natural 'systems'. Systems are made up of 'components' which interact through 'processes' that cause the system to perform 'functions'. Changing either the 'components' or the 'processes' will cause the system to function differently. Often systems appear to be very complicated and difficult to understand. But usually there are a limited number of key processes that will explain much of how a system functions.

[1] This paper is best viewed in colour. The author acknowledges the support provided by the members of the DeGrey Land Care District Committee and Rangelands NRM.

To better understand, and manage, a system it can useful to focus on the process driving the system, rather than only on its components or the outcomes of the system. This can be done by mapping out the processes of a system in what is referred to Systems Function Analysis. This approach can be applied to landscapes as 'Catchment Function Analysis'.

By analysing a catchment as a functioning system it can be determined 1) how the landscape should function, 2) where key processes have been disrupted and 3) what needs to be done to restore natural catchment function.

Landscapes are made up of many components. This includes features such as the underlying geology, soils types, hills and valleys, rivers, flood plains, plants, animals and people. Natural processes include photosynthesis and plant growth, water evaporation and condensation, energy cycles, animal grazing, nutrient cycling, rainfall and runoff, erosion and soil deposition, and soil biology. By analysing the landscape / catchment as a functioning system it can become evident where the critical points in the landscape are. At these critical points, relatively small interventions can have an impact over much larger areas. Addressing these areas ensures the greatest "bang for your buck".

Identifying and focussing on the critical points in the landscape is particularly important in the rangelands due to the vast scale of pastoral properties. It is easy to be overwhelmed by the scale of what is required on these stations. But by understanding how a station's landscape functions it is possible to strategically target the critical areas with management intervention. An approach based on managing critical catchment processes, implies relatively small investments which can improve large areas of land and yield a high return on investment. This will also avoid expenditure which will only make impacts on a small part of the property resulting in little improvement in production, profit and / or on the environment.

Catchment Function Analysis

Peter Andrews describes the Australia landscapes as functioning as a series of connected ponds. He argues that a pattern of connected 'ponds' or 'wetlands' is repeated across the landscape. One important process of these ponds is to decrease water velocity by spreading its flow evenly across a wide body of water (http://www.nsfarming.com/Principles/principles2.html). Slowing the speed of flowing water reduces its 'Kinetic' energy. Kinetic energy is the mechanical energy required for water to carry solid materials. Fast flowing water has high Kinetic energy and this causes erosion as soil is carried away. When that water is slowed it loses energy and drops its load of sediment creating new soils on alluvial fans and flood plains. The energy of any moving object is described in classical mechanics as:

$$\mathbf{E_k = 1/2MV^2}$$

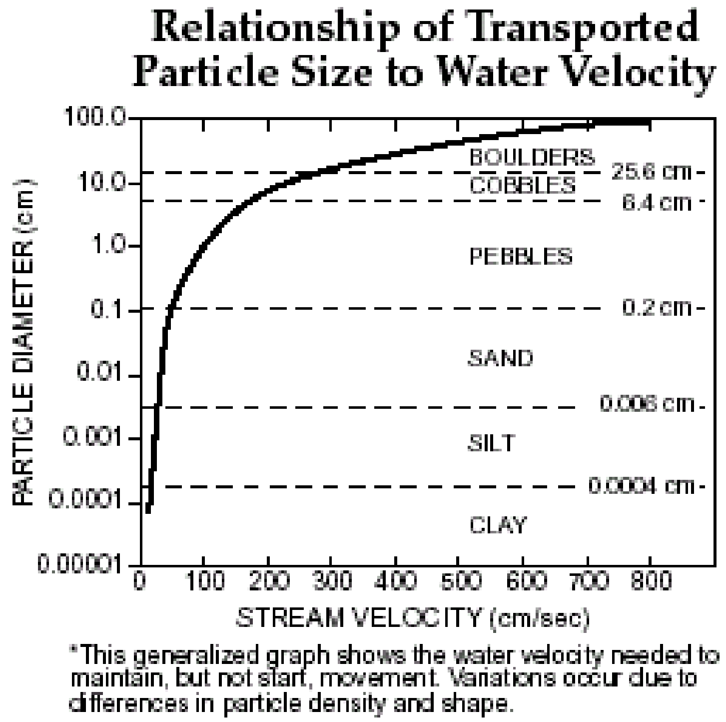
E_k = Kinetic, or mechanical energy (Joules),
M = Mass, or the volume of water (Kilograms),
V = Velocity, or the speed of flowing water (Metres per second)

The important lesson of this equation is that speed has a much bigger effect on energy than mass. Doubling the weight / volume of flowing water doubles its kinetic energy, but doubling the speed of flowing water increases its energy four fold. Similarly a small reduction of speed causes a large reduction of energy and the loading carrying ability of water. This is illustrated in Figure 1. Consequently, management should be aimed at slowing the speed that water flows through the landscape.

The speed at which water flows in a channel is determined by the slope, the uninterrupted length of that slope, and the roughness of the surface of the channel. Management cannot change the location or slope of a channel, but management can affect the roughness within the channel and the length of continuous flow.

Vegetation growing within the channel creates obstructions that water must flow around or through. This can create eddies which slows the water. In eddies, water flows back onto water, causing it to lose its speed and energy. The litter being carried by flowing water can also be trapped by larger vegetation within channels creating what are known as 'leaky weirs'. Leaky weirs, at regular intervals, reduce the length of uninterrupted slopes. They also reduce water speed and create regular ponds. Catchments with plenty of vegetation and plant litter will naturally build leaky weirs in creek lines. Trees and shrubs growing in the hills are an important source of material captured to create leaky weirs in the steep upper catchment.

Figure 1: The effect of water speed on its ability to carry soil



Source: http://en.wikipedia.org/wiki/Hjulstrom_curve
Note: 100 cm/sec = 3.6 km/hr

Another critical component of the landscape is the raised contours at the bottom of the wet lands or ponds. These ridges cause water to pond up behind them creating the wet lands. Poor management can cause erosion gullies that cut back through these critical ridges which then drain the wet lands above. This erosion through critical steps in the landscape causes 'Rangelands dehydration' (see Figure 19 below).

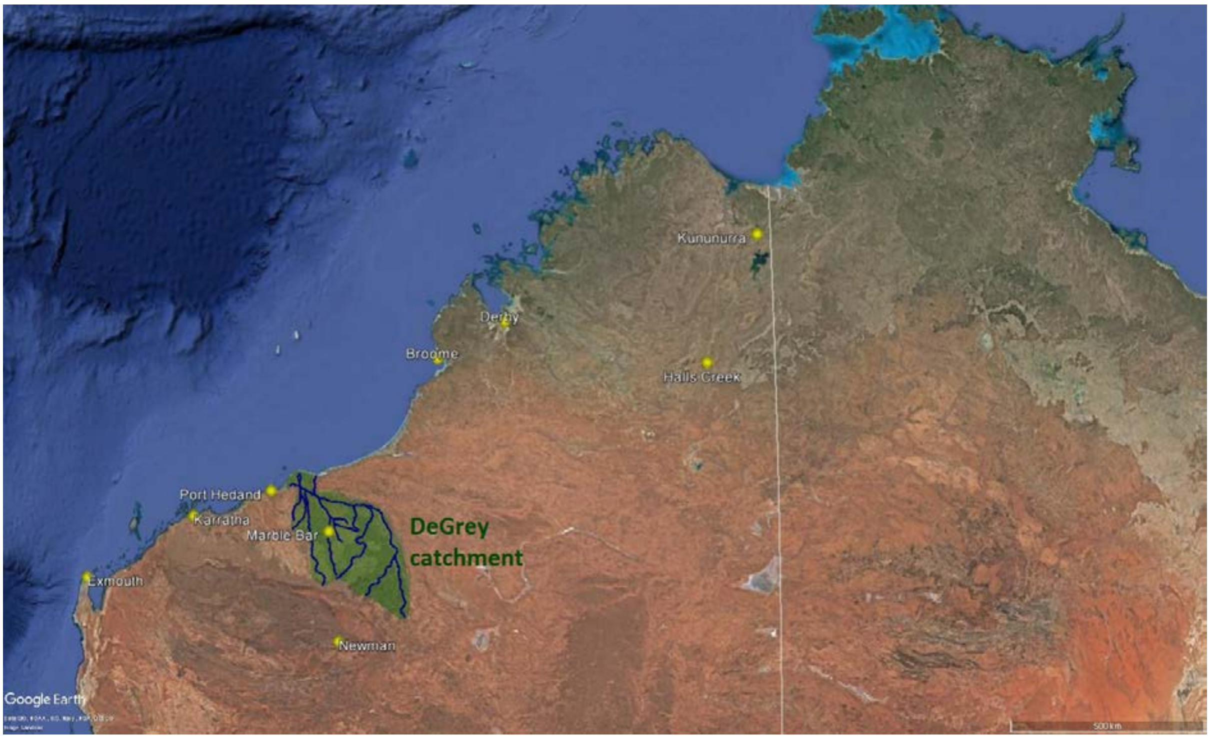
DeGrey Catchment

DeGrey location

The DeGrey catchment drains the DeGrey River and its tributaries. It is located in the North West region of Western Australia (WA) (see Figure 2). The DeGrey River flows 282 km into the Indian

Ocean. The township of Marble Bar is situated within the catchment and there are a number of cattle stations including DeGrey, Yarrie, Mulyie and Limestone.

Figure 2: Location of the DeGrey catchment in relation to the North West of Australia



DeGrey catchment function

The DeGrey catchment is drained by the DeGrey River and its tributaries including the East and West Strelley River (1 & 2), Shaw River (3), Coongan River (4), Nullagine River (5), Oakover River (6) and the Davies River(7) (Figure 3).

Functionally, the DeGrey catchment can be viewed as a series of large basins which are connected and drained by the main river channels (see Figure 4). Separating these basins are rugged ranges which have narrow gaps through which the rivers flow. These ranges are formed from 'Greenstone belts'. The basins within them are formed from 'granitic domes'. Granite weathers more quickly than the greenstone so that the granite has eroded away to form the depressed basins of today. The eastern section of Mulyie station sits within the Muccan Basin. It receives flood waters from the Oakover, Nullagine and Coongan Rivers.

Between Mulyie homestead and the North West Highway, is an area of significance for the whole catchment. This is the confluences of the DeGrey, Shaw and Strelley Rivers.

From Mt Grant to the highway there are critical flood out points in the DeGrey River. These flood outs feed water on to the main DeGrey Delta. This is the only significant delta on the west coast of Australia that has extended out into the ocean. The mouth of the DeGrey River is now ~25 km north of where the original coast line would have been. The DeGrey homestead would be close to where the original coast line would have been.

Figure 3: Surface water catchment and main river channels of the DeGrey River system

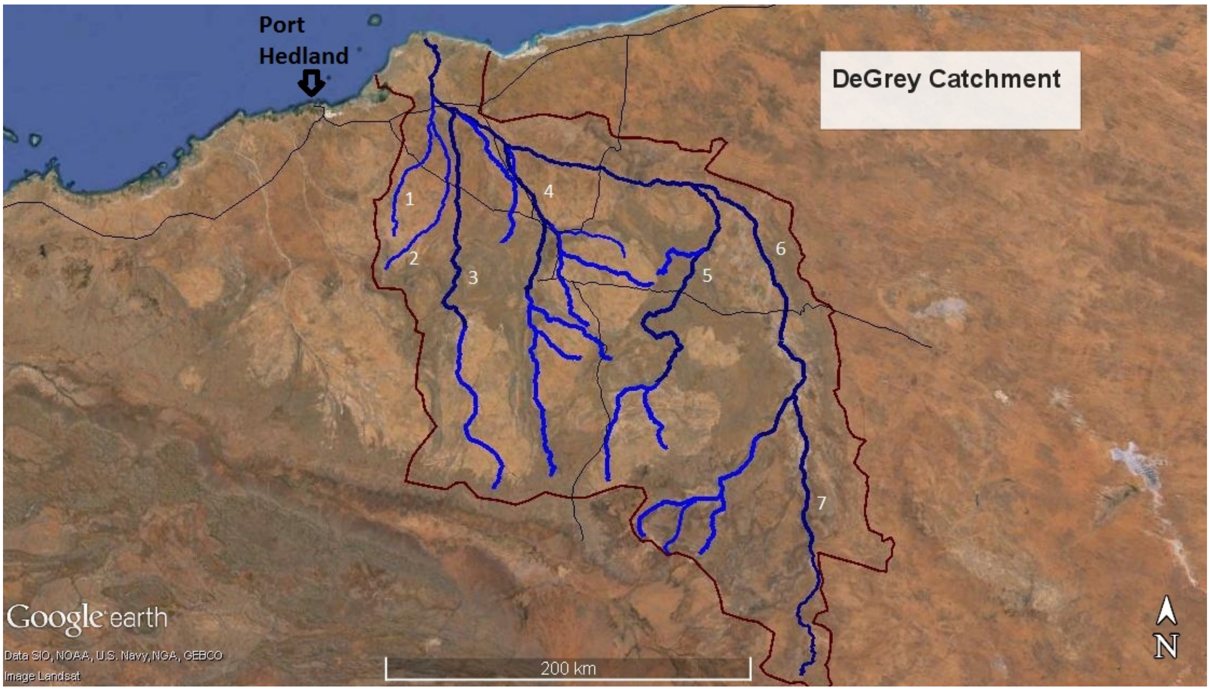
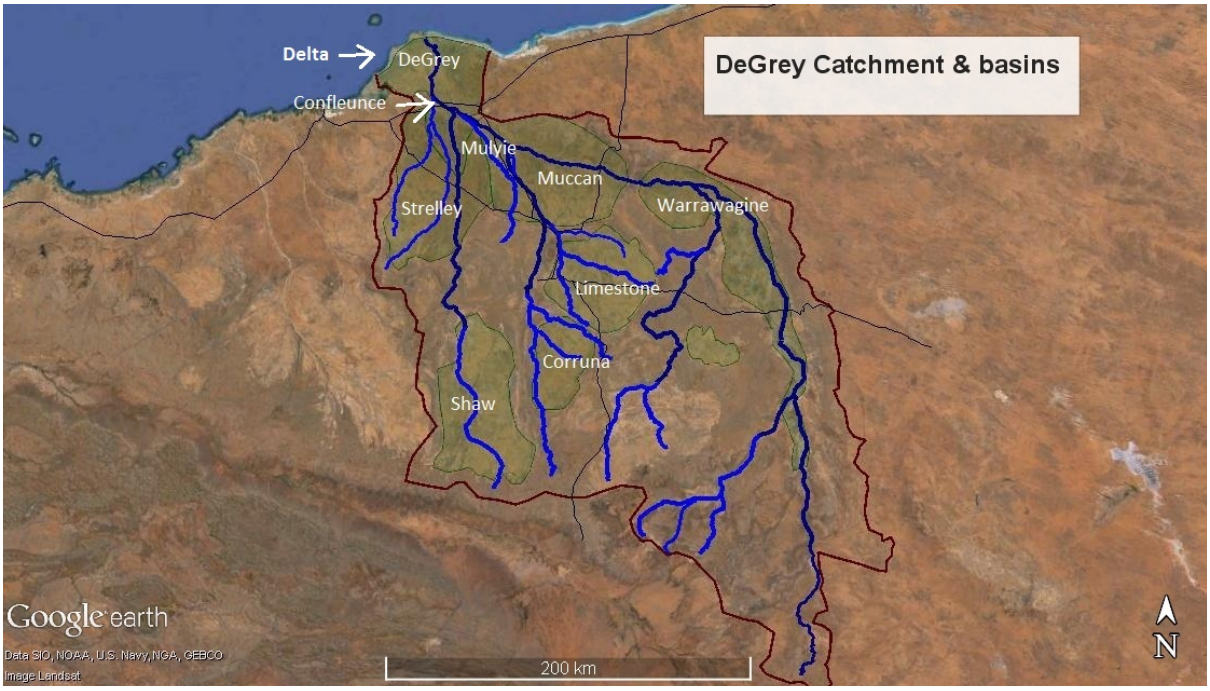


Figure 4: Basins within the DeGrey River system that are linked by the main river channels



The DeGrey River can experience major flood events due to heavy cyclonic rains. Very large floods can cause serious damage to the main river and lower flood plains. However the degree of damage depends as much, if not more, on the condition of the upslope of the catchment than it does on the condition of the catchment's lower river. If the upper catchments are too bare then runoff from numerous hill creeks combine to cause destructive water flows in the main river channels.

An extreme example of this was seen on the Chamberlain River of the Kimberley's in early 2011 (Figure 5). Most of the Chamberlain River catchment had been burnt by late season, hot fires in 3 out of the 4 previous years. Consequently, during the heavy rains of the 2010/11 summer there was no ground cover on the slopes or vegetation in the small creeks to slow the runoff. This resulted in an extremely destructive flood event tearing out the larges trees and the river bed in the main river channel.

Figure 5: Starvation Bay on the Chamberlain River a) before (November 2010) and b) after (March 2011) a destructive flood

Drainage system in the Muccan basin

The drainage patterns within the upland parts of the DeGrey catchment are controlled by the topography of the major ranges, basins and rivers. The DeGrey River runs through the central parts of Yarrie Station and the eastern end of DeGrey Station. Just inside the eastern boundary of Yarrie, flood waters spill out of the DeGrey / Oakover River creating flood plains that run to the western boundary of Yarrie and down to Mulyie homestead on DeGrey Station (Figure 6). Other smaller rivers and creeks bring water from the hills of the ranges to the north and south with some feeding through gaps in the ranges. Some of these creeks spill out on to flood plains that stretch down to the main riparian zones of the DeGrey River on the Mulyie lease.

An example of a smaller drainage system is within the Mt Edgar basin (Figure 7). Water flow here is controlled by a series of rock dykes. Some of these rock dykes have rocky ridges that are clearly visible from the ground. However in other case the rocks have broken down but the remaining clay creates steps that control the pattern of water flow. Within the Muccan Basin the water flow patterns are controlled by rock dykes in some areas (Figure 8), but in other parts by features formed by water and plants.

By mapping these drainage system and the associated wet lands, critical sites can be identified where targeted interventions to slow and spread water will have impacts over a much larger area. This detailed Catchment Function Analysis has been done using Google Earth Pro and is available in a digital form.

Canning Basin artesian drainage

The area to the north of the Muccan Basin is part of the West Canning Basin. Here there is no surface water drainage system, and water drains very slowly north through sub surface aquifers.

Figure 6: River flood plain and flood out points between Yarrie and Mulyie Stations. The broad blues lines are the flow path of flood waters that have spilled out of the main river channel. The dark blue line is the main channel of the DeGrey River, the narrow dark blue lines are the creek that cut across these flood paths and can drain water back into the river. The small blue arrows are the spill out points from the DeGrey River

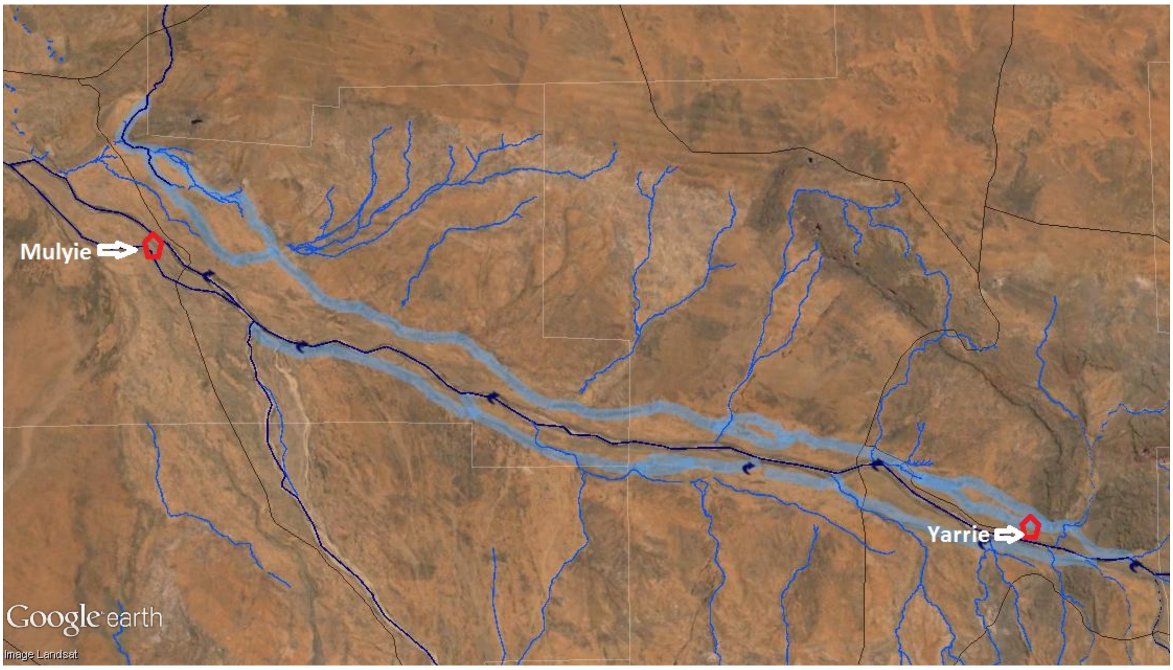


Figure 7: The drainage system (blue) and key rock dykes (red) controlling water flow within the Mt Edgar / Limestone Basin. Red lines indicate rock or clay bars that create key steps in the landscape behind which small flood plains form

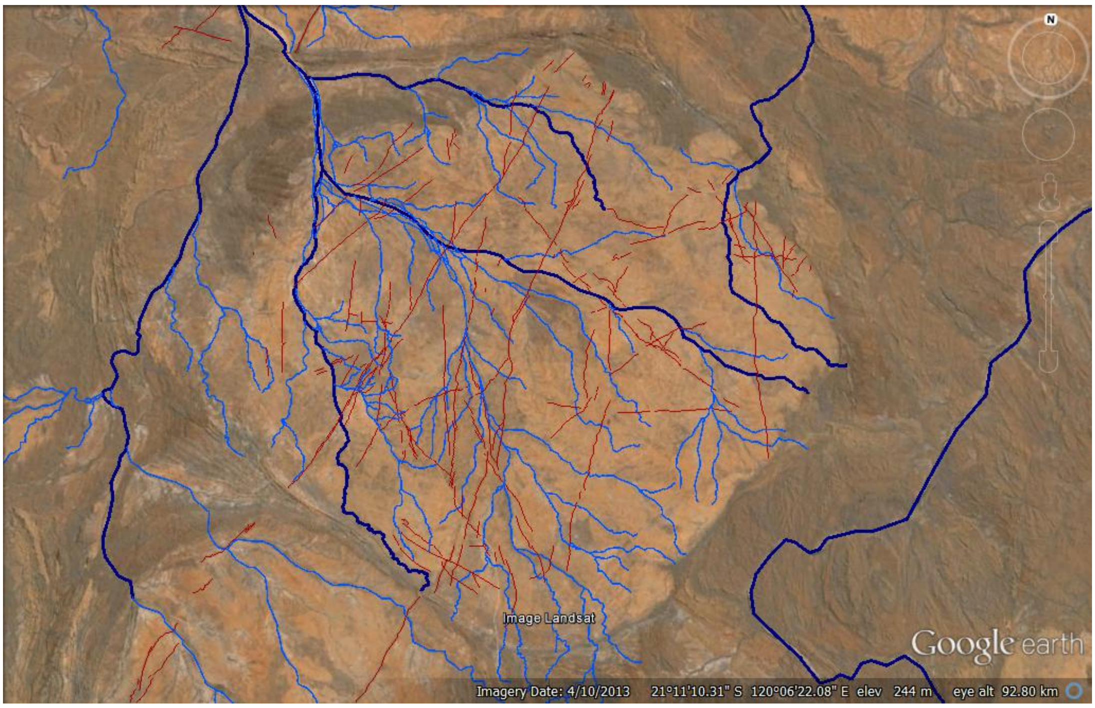
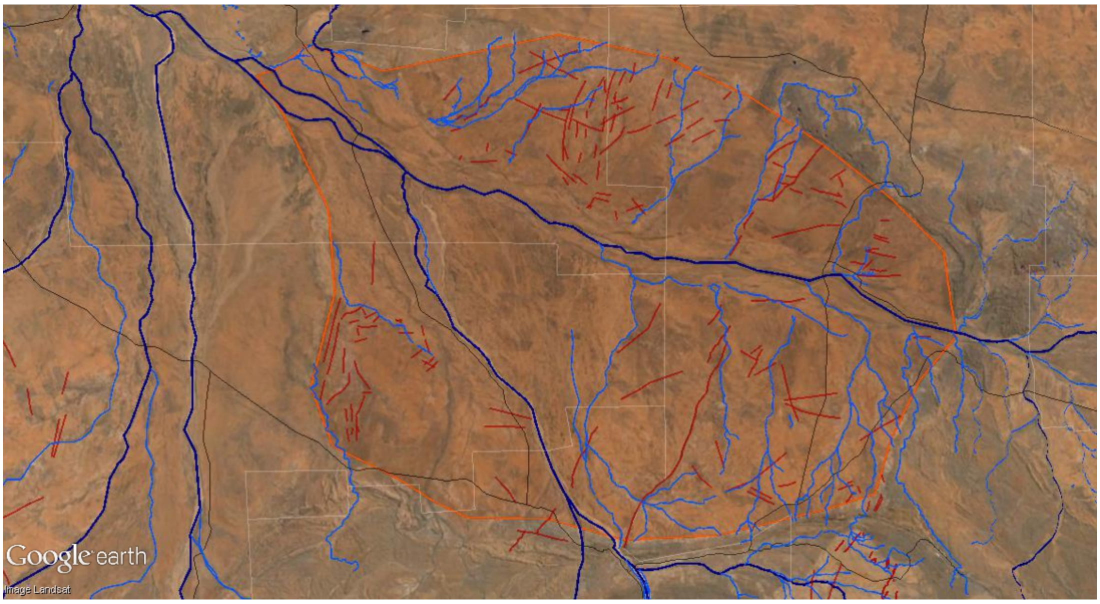


Figure 8: The drainage system (blue) and key rock dykes (red) within the Muccan Basin (orange)



Catchment Structure and Processes

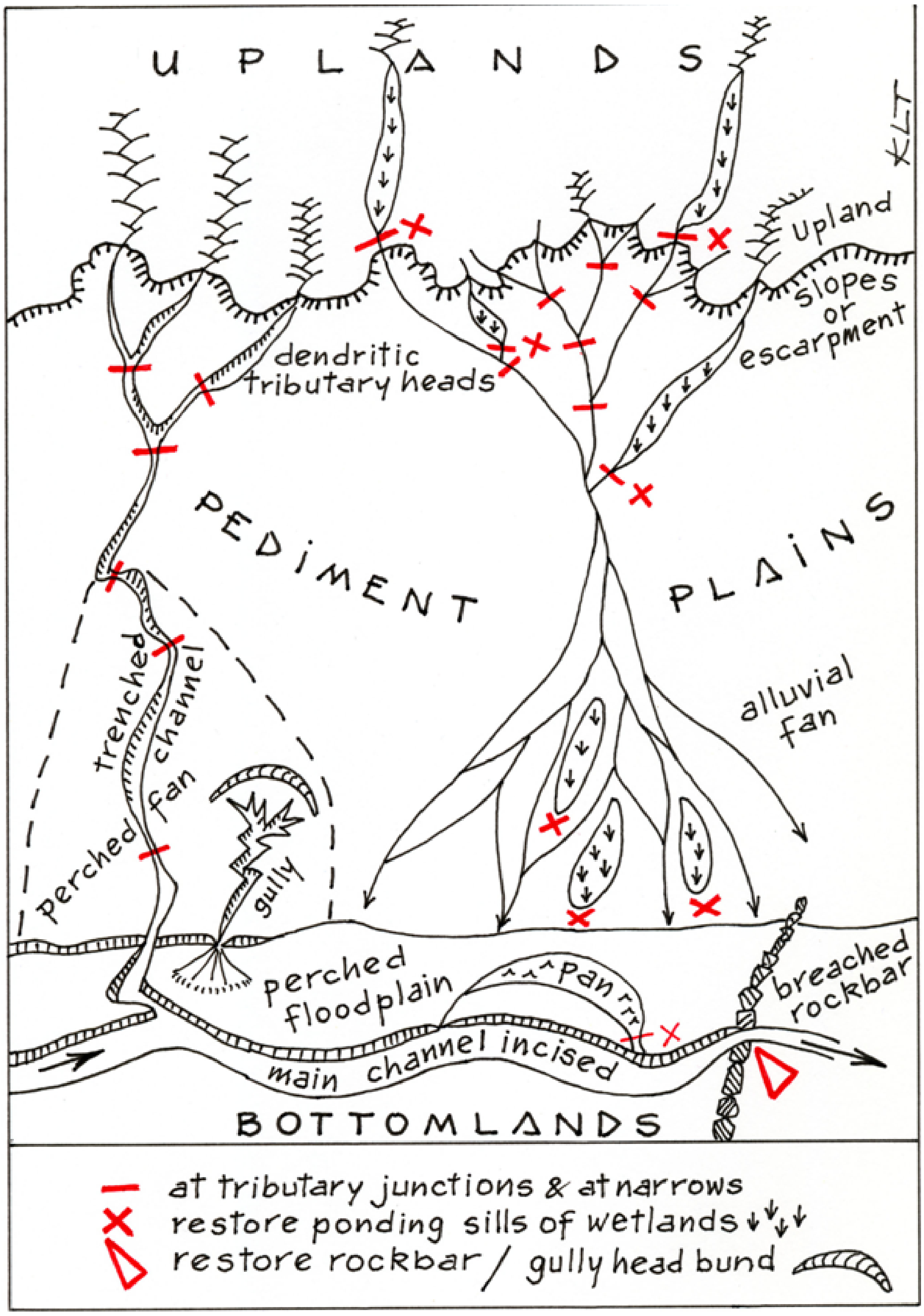
Within any catchment there is a repeating pattern of run off and flood out areas occurring at the sub catchment level. This can be seen in the DeGrey catchment. On the steep upper slopes the creeks come together and on the gentler lower slopes the water may spread out in alluvial fans and flood plains. This repeating pattern has been described schematically by Ken Tinley and Hugh Pringle in Figure 9. Specific examples of these patterns in the DeGrey catchment are also given below.

Steps and slopes in the landscape

A catchment is made up by different functional components of the landscape. How each component area functions is determined by the topography. Typically the steepest slopes are on the outer edge of the catchment. Slopes then decrease progressively towards the bottom of the catchment.
There are steps, or 'keylines', within the landscape where distinct changes in slope are noticeable. They are illustrated in Figure 10. Variable slope gradients impact the catchment's functioning. Usually the degree of slope progressively decreases towards the main river channel. However within Limestone, Yarrie Stations and the eastern section of Mulyie Station, the range between the Mt Edgar and Muccan Basins results in two repeated patterns of slope being separated by the Dooleena Gap and the Bamboo Creek gap.

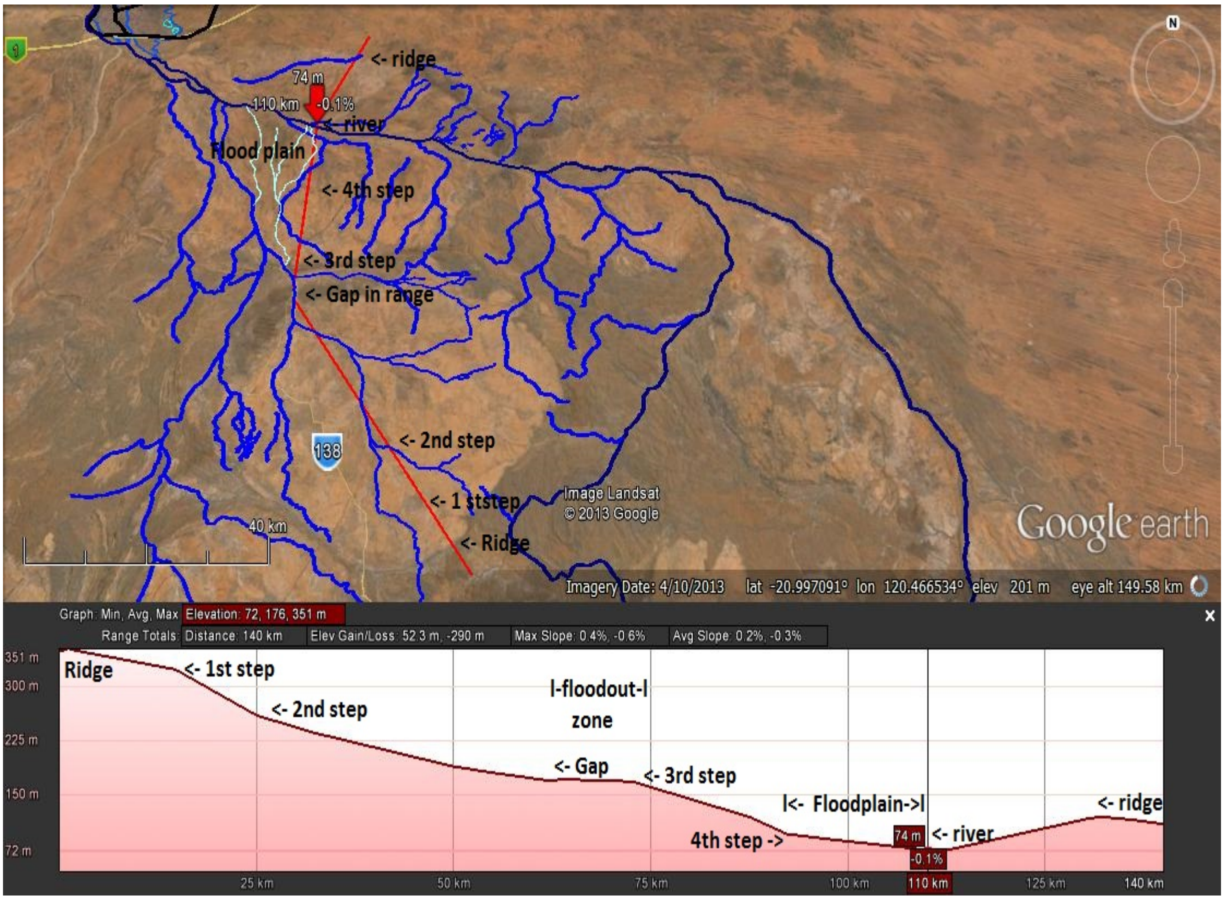
Figure 9: Schematic representation of the main Catchment Functional features with critical sites marked in red

From Ken Tinley & Hugh Pringle (2013), "Rangelands Rehydration. 1 Field Guide"
http://www.emuproject.org.au/



http://emuproject.org.au/rangelandguides/Rangeland_Rehydration_Field_Guide.pdf

Figure 10: The drainage systems of Limestone, Yarrie and Mulyie Stations separated by the Dooleena gap and an elevation transect (red line) showing the repeating pattern of major steps in the landscape separating areas with different slopes



Drainage systems in the steep hills

The steep ranges surrounding the basins can contribute significant amounts of water from smaller creek systems within the hills. Much of the rainfall comes in very heavy downpours from summer thunderstorms and cyclones. The shallow, steep soils of the ranges cannot store much rainfall so a significant proportion can run off. Retaining vegetation in these rugged ranges is vital for reducing damaging floods lower in the catchment. Spinifex helps to slow the flow rate of run off water on these hills. On very steep slopes, spinifex can also form natural ponds that function like rice paddy (Figure 11). However, for these structures to develop the spinifex needs to be protected from fire.

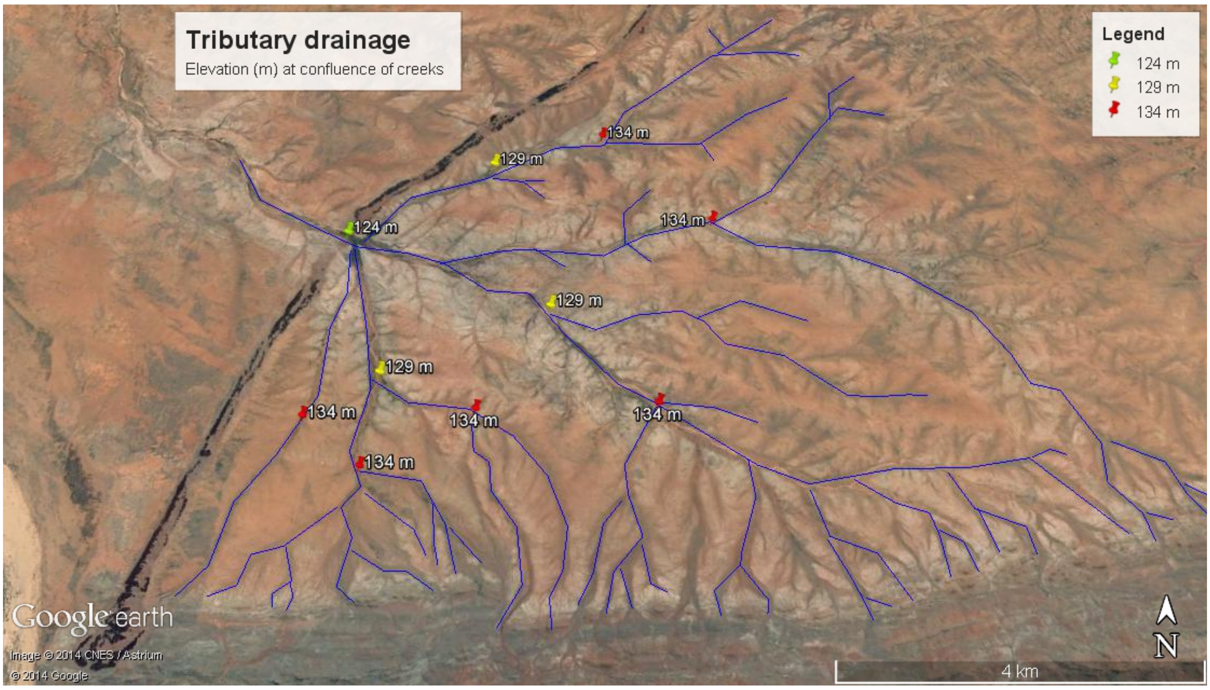
Another vital component of the hill country is the woody vegetation growing within the creek channels (Figure 12). These shrubs catch organic debris being washed off the steep hills and form 'leaky weirs' within the creek channel. This reduces the speed and energy of water flowing within the creek by reducing "the uninterrupted length of the slope" within the creek. Excessive burning exposes creeks on steep slopes to erosion.

Figure 11: Spinifex creating small ridges and 'paddies' on the contour at Mt Nameless, Tom Price

Figure 12: Neighbouring creek lines north of the Yarrie homestead. The photo to the left shows recent burning and resultant water erosion. The photo to the right shows no burning and creeks that are clogged with vegetation and natural litter forming 'leaky weirs' which prevent erosion

Water runs off readily from the steep slopes of the hills. Small creeks converge in to a 'tributary' drainage pattern. The point where creeks or rivers join is called a 'confluence'. Each time two creeks merge the volume of water doubles and the speed increases. Usually the steepest slopes are just below the hill tops or break away ridges. Small creeks join up here to make larger creeks. Up to four creeks may join at one point. This pattern is repeated within the area of tributary drainage creating large creeks with large water flows (Figure 13). Often the point of convergence is where there is a change of slope from a steeper slope to a shallower slope. These changes of slope where creeks meet are referred to as the earlier mentioned steps or 'key lines'. The key line point where the drainage lines meet is often a critical area for catchment function. The critical wetlands usually occur just above, or just below the key line steps.

Figure 13: Tributary drainage pattern and equivalent elevation points of creek confluences on Yarrie Station bordering with Limestone station to north east of the Coongan Gap

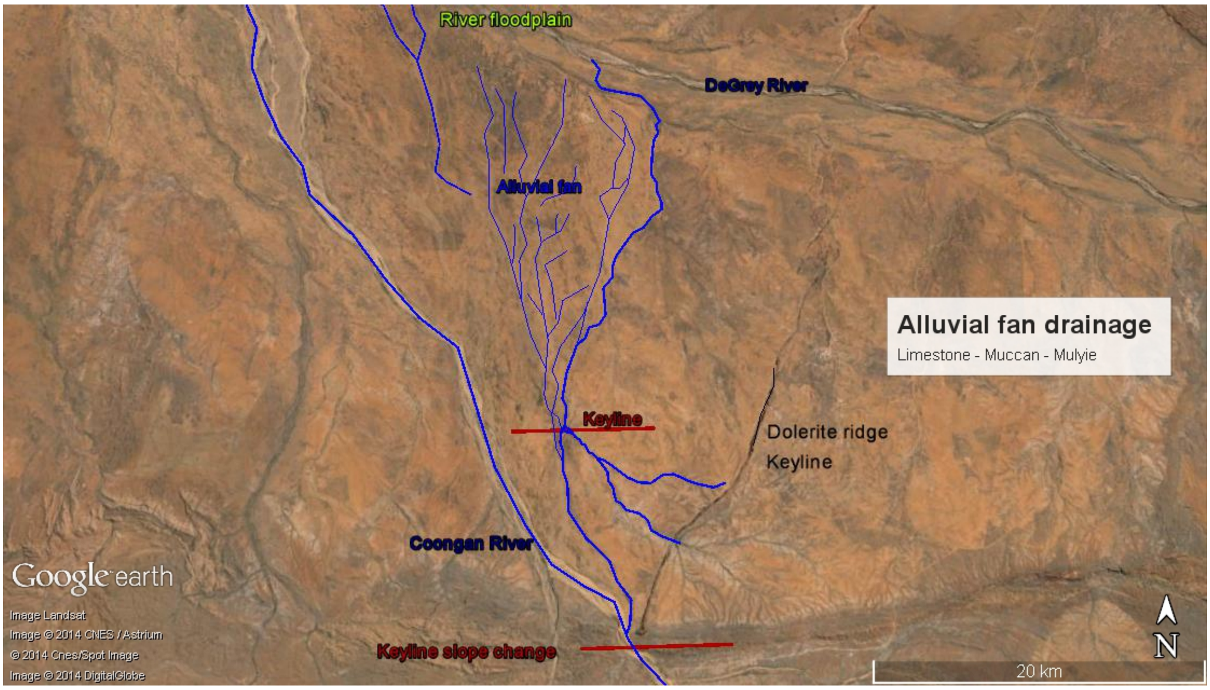


Pediments and flood plains

On the gentler slopes of the lower catchment, drainage channels can start to over flow and spill out to create alluvial fans (Figure 14). These alluvial fans have more fertile soils. Nutrients deposited there are derived from higher in the landscape. The alluvial fans also receive more water as they are "run on" areas. The alluvial fans contribute an important function for the whole catchment through the process of slowing and filtering water before it reaches the main drainage channels.

These flood plains are also vitally important to the cattle operation as they contain some of the best pastures. Proper management of the upper catchment has major implications for the productivity of the floodplain component of the landscape.

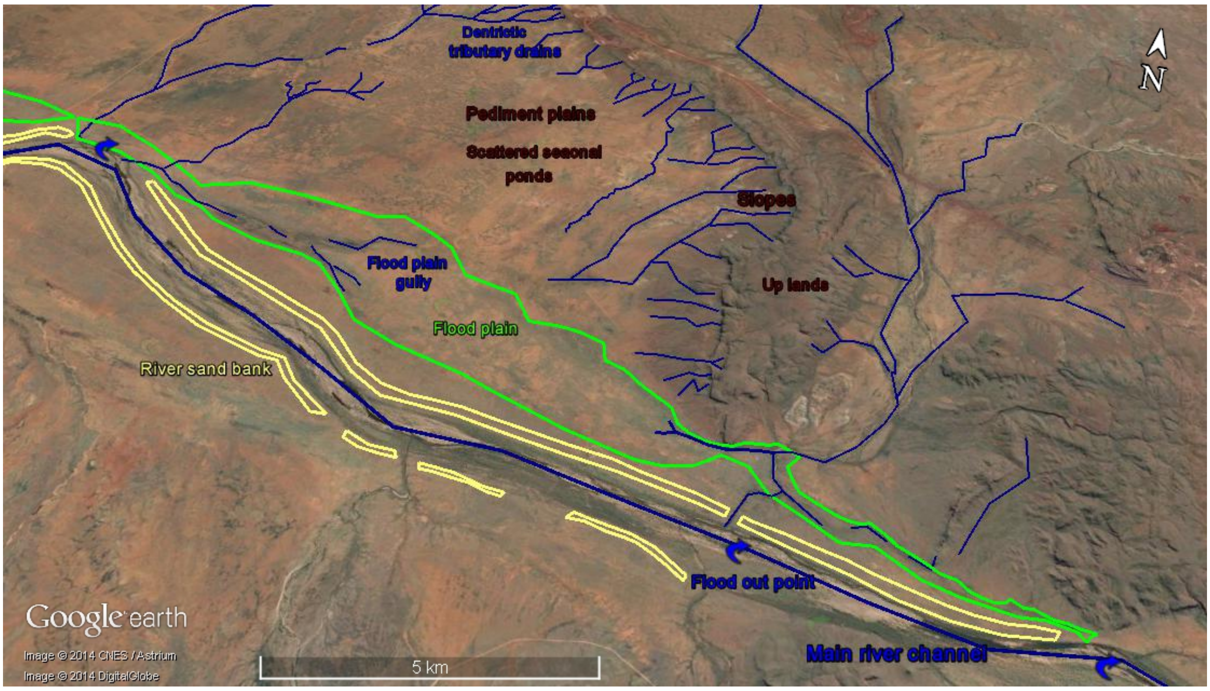
Figure 14: Alluvial fan drainage (blue lines) pattern down slope from the flood out points on 'Keyline' (red) slopes



Water within the DeGrey catchment ultimately drains into the main river channels. In major water flow events, such as cyclonic rains, these rivers also spill out to form flood plains. These flood plains are the most productive part of the catchment. They are critical for both livestock production and as nature habitats.

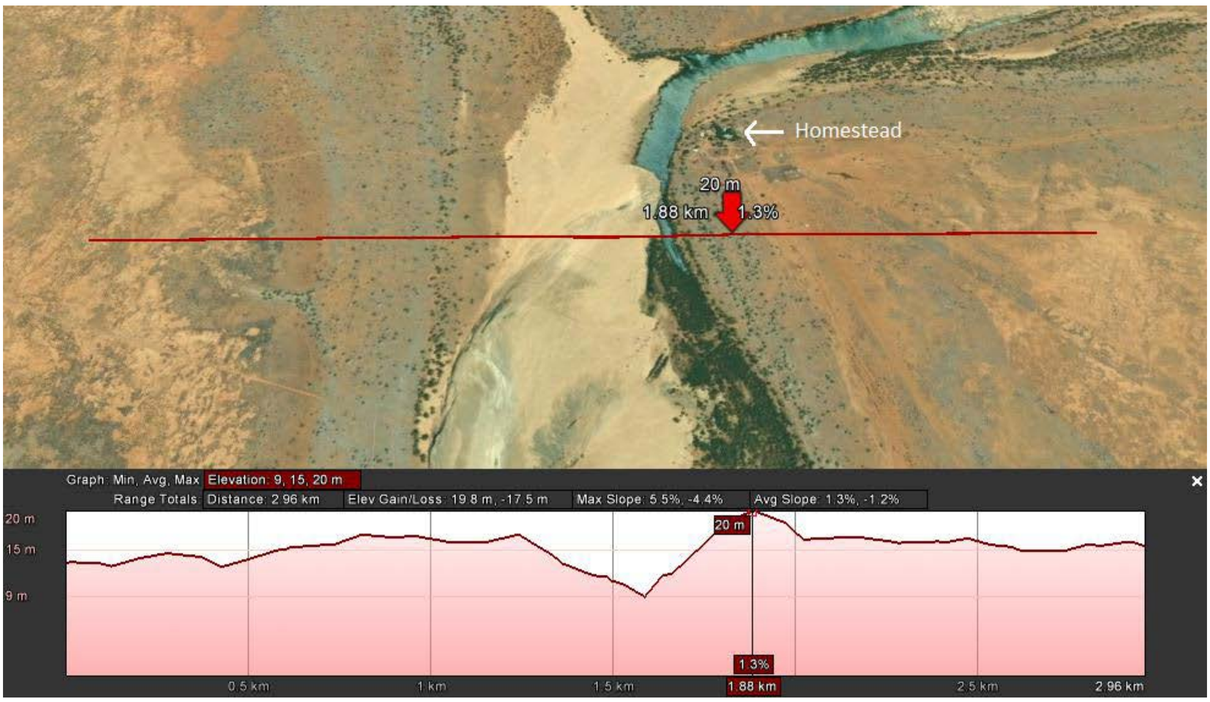
The flood plains can receive extra water from rain that falls further up in the catchment and is carried downslope in the main river channels. The water in the river is contained by sand banks on either side of the main river waterway (Figure 15). There are low points occurring in the sand bank verges at intervals along the river. These gaps are critical in that they allow the river to spill onto the flood plain during flood events. These gaps also allow water to flow in the other direction back into the river following heavy falls in the adjoining sub catchments.

Figure 15: Sand banks (yellow), flood out points (blue) and flood plain (green) on the northern side of the DeGrey River on Yarrie Station



The sand ridges along the main river paths are formed by the river. During flood events the water on the edge of the river flows at lower speed than water in the middle of the river. This reduced velocity on the edges of the river causes the water to deposit transported sedimentation, thus building the sand banks. These banks will be built up higher than the adjoining flood plain. Interestingly, all the old homesteads along the main DeGrey River channel are within 200 m of a river that can have major flood events. However, these homesteads are all on the high sand banks built by the river, and are therefore above even the biggest flood waters.

Figure 16: Cross section elevation (m) showing the river bed, sand banks and flood plains near the DeGrey Homestead. The homestead is perched on the 20m elevation point

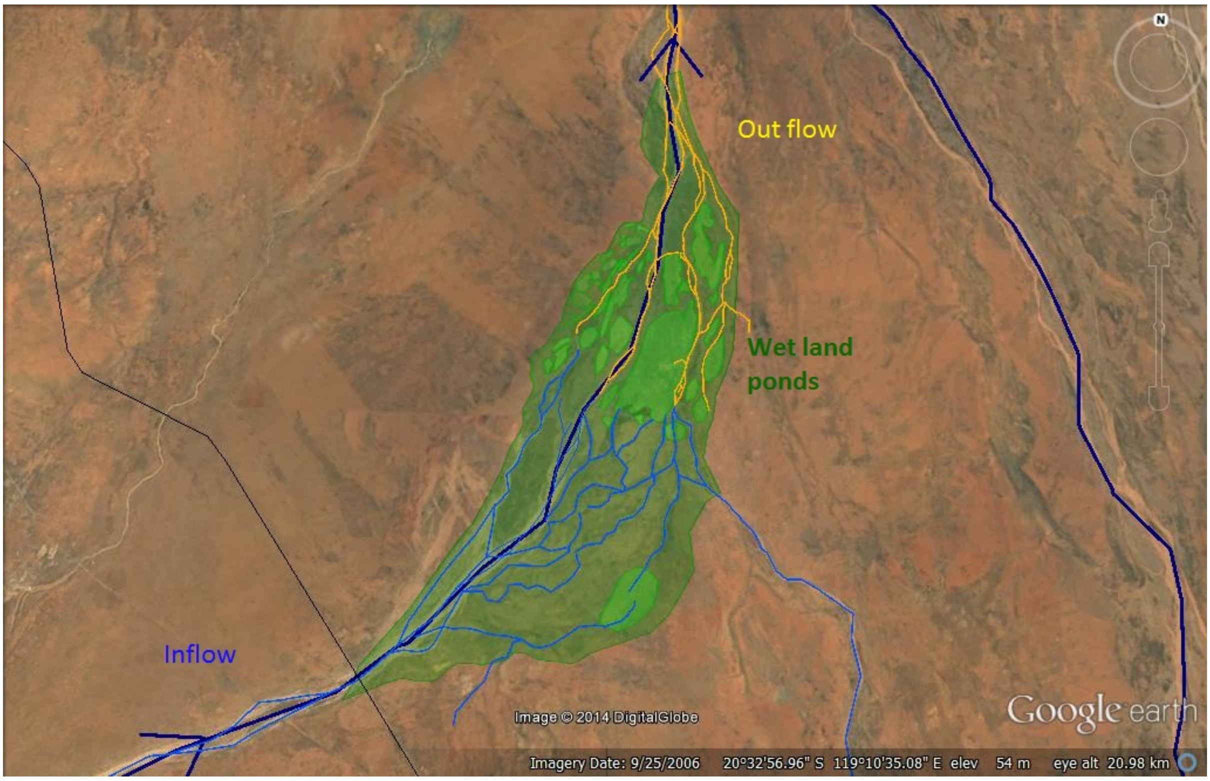


Critical wetlands

Another critical component of the lower reaches of the catchment are the wet lands which act to decrease water flow rates, and as filters, within the larger river networks (Figure 17). These wet lands are found on the gently sloping pediments that sit above the true flood plains of the main river channels. Flood waters flow into these wet lands and are dispersed through a series of ponds. However many of these flood plains presently have erosion drainage channels running lengthwise through them (Figure 19) reducing their effectiveness as a buffer to floods.

It should be a priority to restore the functionality of these critical wet lands by encouraging natural revegetation to clog up the drainage channels. In some cases, earth works to plug the drainage channels may be warranted in critical flood plains. This will slow the flow of water, storing it in the landscape and provide a longer lasting store of water for pasture production and habitats.

Figure 17: Critical Wet lands on the Strelley River north of the Marble Bar Road

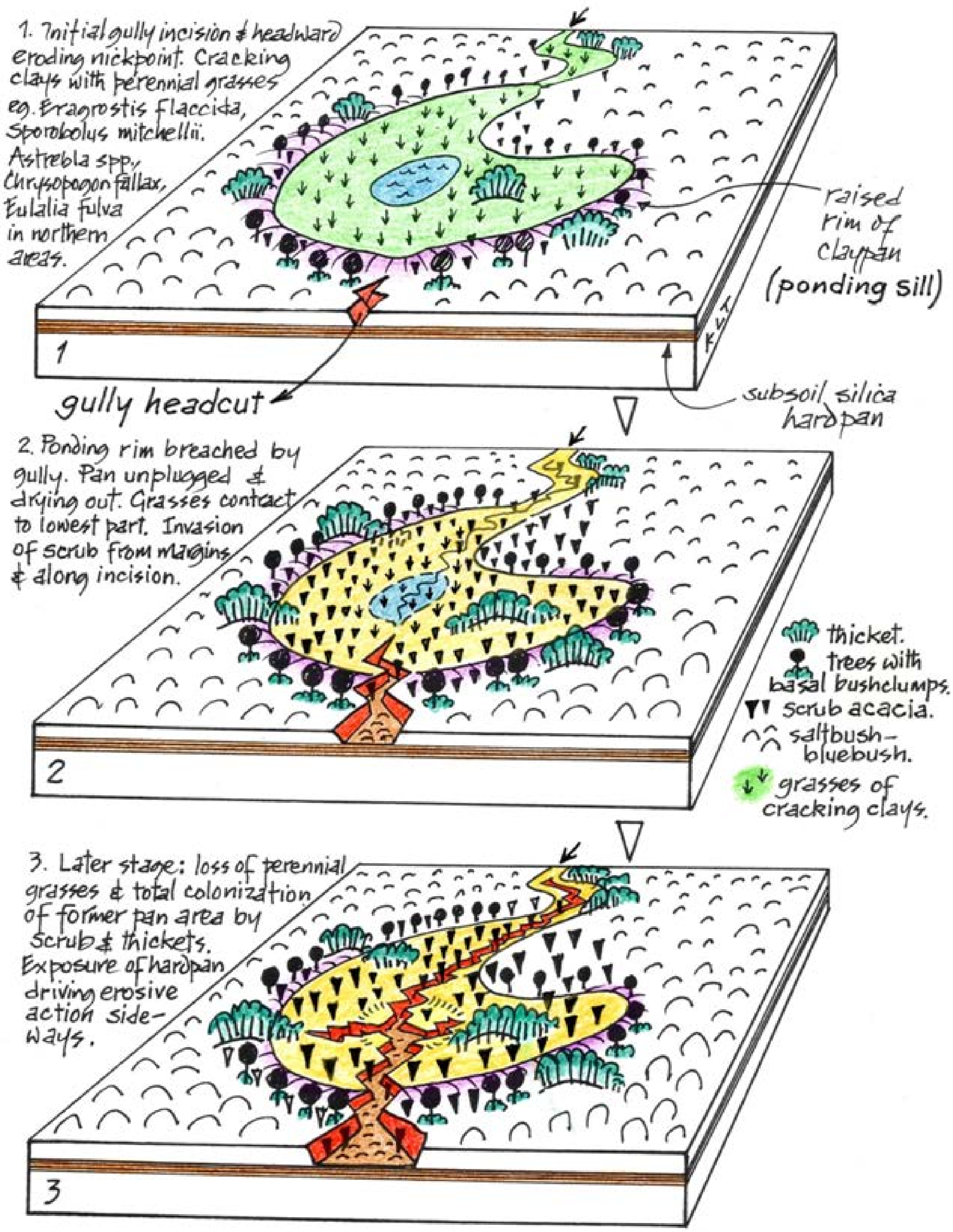


Often the function of these wet lands is lost due to erosion gullies cutting back into the natural ponds from downstream (Figure 18). Some critical active erosion gully heads have been identified on Mulyie and DeGrey Station that justify earth works to save wetlands from being drained and dehydrated.

Figure 18: An example of active gully erosion heads threatening to join up and drain wetlands near Limestone Homestead

Healthy wets lands tend to be dominated by grasses. However in flood plains that have been drained by erosion, woody shrubs will begin to invade. This woody 'weed' encroachment is a sign of dehydrating wet lands. However, this shrub invasion is also the first step in the natural healing processes. Once the eroding creeks are clogged up by 'woody weeds', they will start to fill in again restoring the raised rim, or step, at the bottom of the wet lands. Once the wet lands start functioning again causing flooding for part of the year, the woody shrubs will decline and be replaced by productive grasses.

Figure 19: The process of active gully erosion destroying the natural function of a wetland
(from Ken Tinley and Hugh Pringle (2013), "Rangelands Rehydration. 1 Field Guide"
http://www.emuproject.org.au/)



Braided drainage patterns

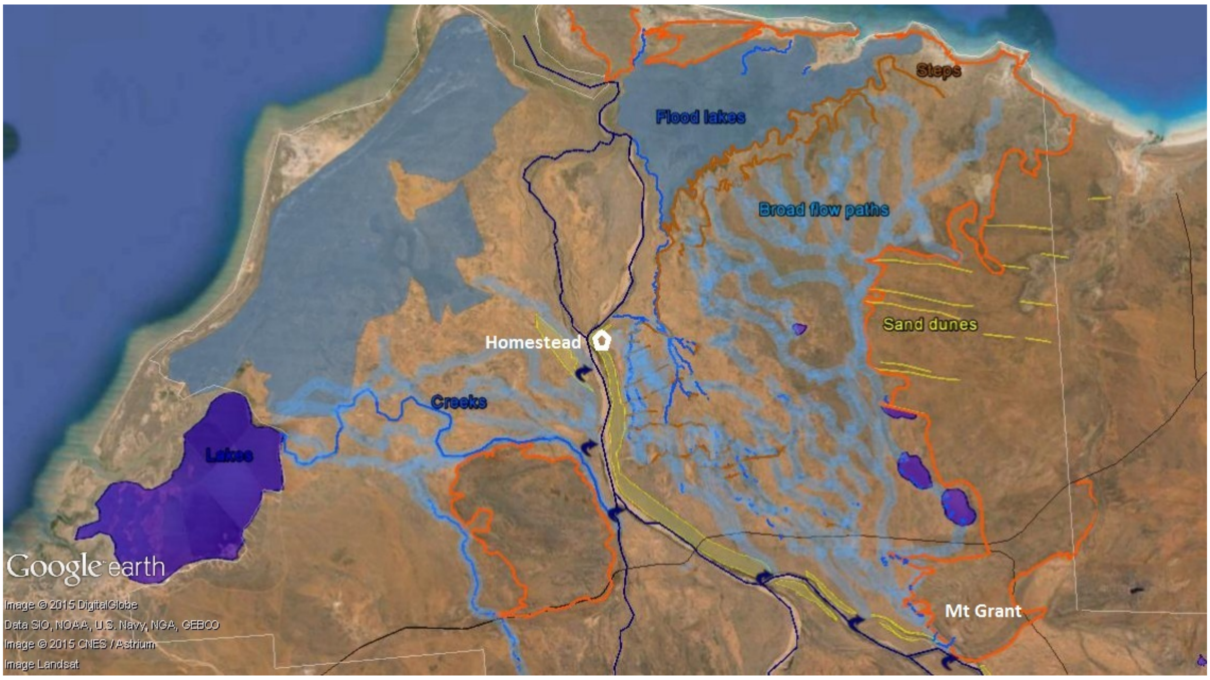
On very flat land fluvial fans can form braided drainage patterns. Within this landscape pattern, river channels split and subsequently rejoin resulting in flood waters flowing down multiple paths (Figure 20). This system of linkages between channels means the velocity and Kinetic energy of the water in all channels are reduced. Any disruptions which reduce the number of effective channels will increase the destructive power of flood waters.

Figure 20: A braided drainage pattern in the DeGrey River near Mulyie Homestead. Note the transition from one main channel branching out to multiple channels, resulting in reduced water velocity

Coastal delta

The northern most section of the DeGrey catchments is a large coastal delta (Figure 21). There is an outlet from the DeGrey river 55km upstream from the mouth of the river. Here flood water can spill out of the river at the base of Mt Grant. There are also a number of other spill out points downstream from this. The Strelley and Shaw Rivers can also contribute water to the flood plains between Mt Grant and the DeGrey Bridge.

Figure 21: Functional components of the DeGrey delta including the DeGrey River (dark blue lines), flood pout points from river (dark blue arrows), incised creeks (light blue lines), broad water flow paths without incised creeks (light blue broad lines), sand dunes (yellow lines), river sand banks (yellow areas), seasonal lakes (purple areas), coastal flood lakes (blue areas), steps on the flood plain (brown lines), the boundary of the flood plain (orange line) and roads (black lines)

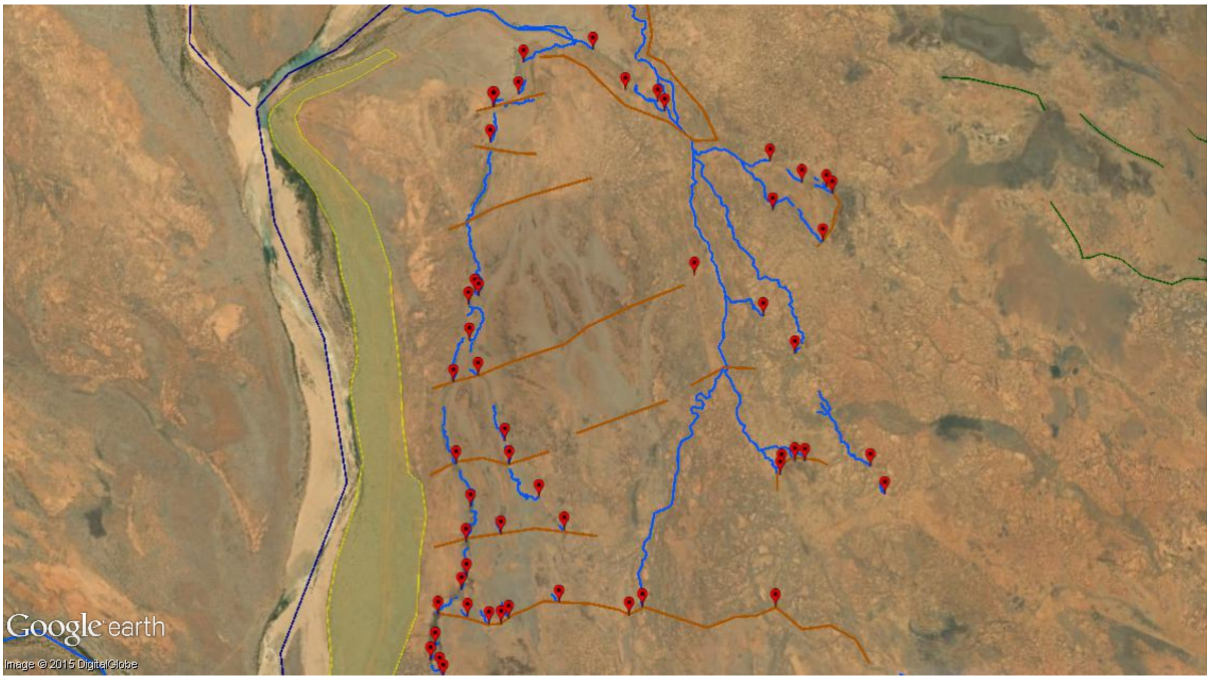


Within the delta there are distinct zones that function differently. As the mechanism for water flow and control differ, the processes that disrupt healthy catchment function, and the strategies to correct the dysfunction, also vary from zone to zone.

Once water floods out of the main river channel, it runs through broad flow paths that generally do not contain incised waterways. These paths can be hundreds of meters wide. Water velocity reduces as it spreads out across these flow paths. This low velocity means a reduction in destructive power of flood events and allows sediments in the flood water to settle out building fertile soils.

The zone just to the east of the DeGrey Homestead has a slightly greater slope. Here small creeks have formed that are actively eroding back up slope (Figure 22). By mapping the erosion heads in these creeks, and the points where flow paths split, it is possible to identify subtle steps formed by slightly raised ridges. When intact and functioning properly, these contours would help to slow and spread out flood waters. The management priority for this area is to stop the erosion heads and the rehabilitate the natural ridges. The Bettinis' have commenced implementing this type of earth works in this region.

Figure 22: Active erosion heads (red dots), creeks (blue lines), landscape steps (light brown lines) and river sand banks (yellow areas) to the east of the DeGrey Station homestead



On the eastern edge of the DeGrey Delta, flood waters flow through broad flow paths. Within this zone are ridges formed by the process of flood waters building wooded vegetation rises that are on perfectly level contours.

This area is very flat and during flood events water spreads out to form large ponds. Litter, including seeds and dung, are deposited on the edge of these ponds. Once the water levels drop, this mixture of organic material and seed is deposited on the natural contour. The acacia seeds germinate and form strips of dense woody vegetation. In subsequent floods these woody groves trap more trash and soil which builds up the raised ridge. These woody ridges become important structures for slowing and spreading flood waters (Figures 23, 24 and 25).

Figure 23: Eastern DeGrey delta water flow paths (light blue) and woody vegetation contours (green)

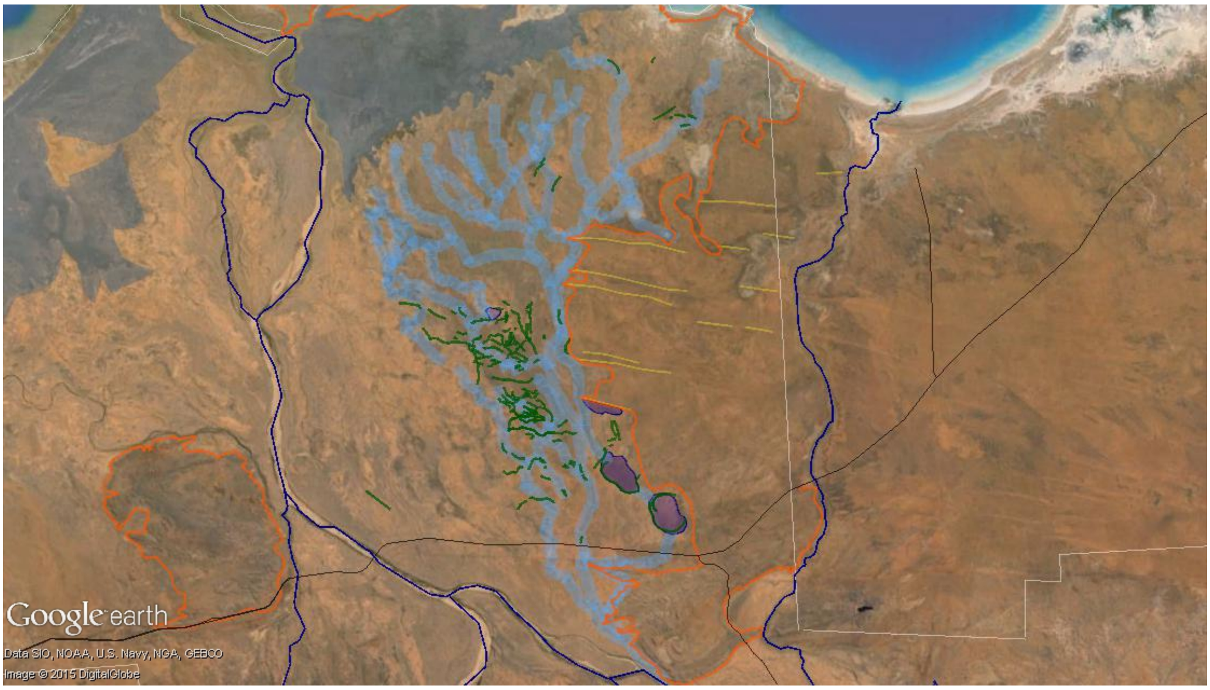


Figure 24: Acacia groves forming woody contours across the landscape on the eastern part of the DeGrey delta

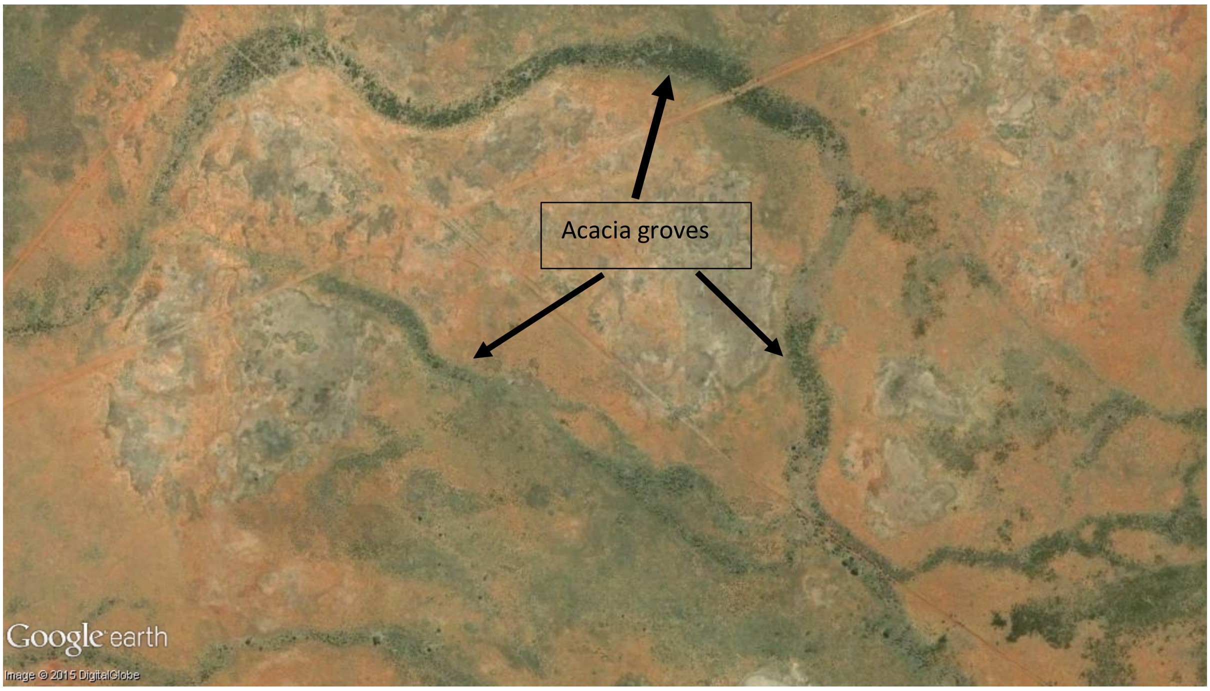
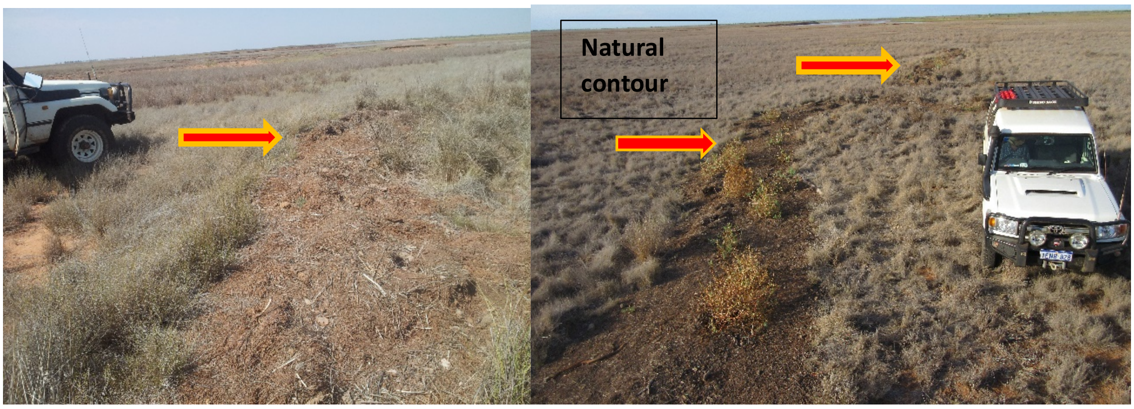


Figure 25: Organic litter deposited by flood waters on the contour on the DeGrey coastal flood plain from Cyclone Rusty



In the central part of the DeGrey flood plain east of the river there is a zone where no distinct flow paths are discernible (Figure 26, pink areas). This zone has duplex sand over clay soils. Decades ago over grazing by sheep resulted in small, deep hollows of erosion. These depressions are separated by sand ridges covered with spinifex (Figure 27). There is no distinct flow path, except for a few creeks cutting back into the zone. Grazing strategies that encourage plant cover will be the main management option to regenerate this area.

Figure 26: Zone of diffuse drainage (pink area) and nearby incised creeks (light blue lines)

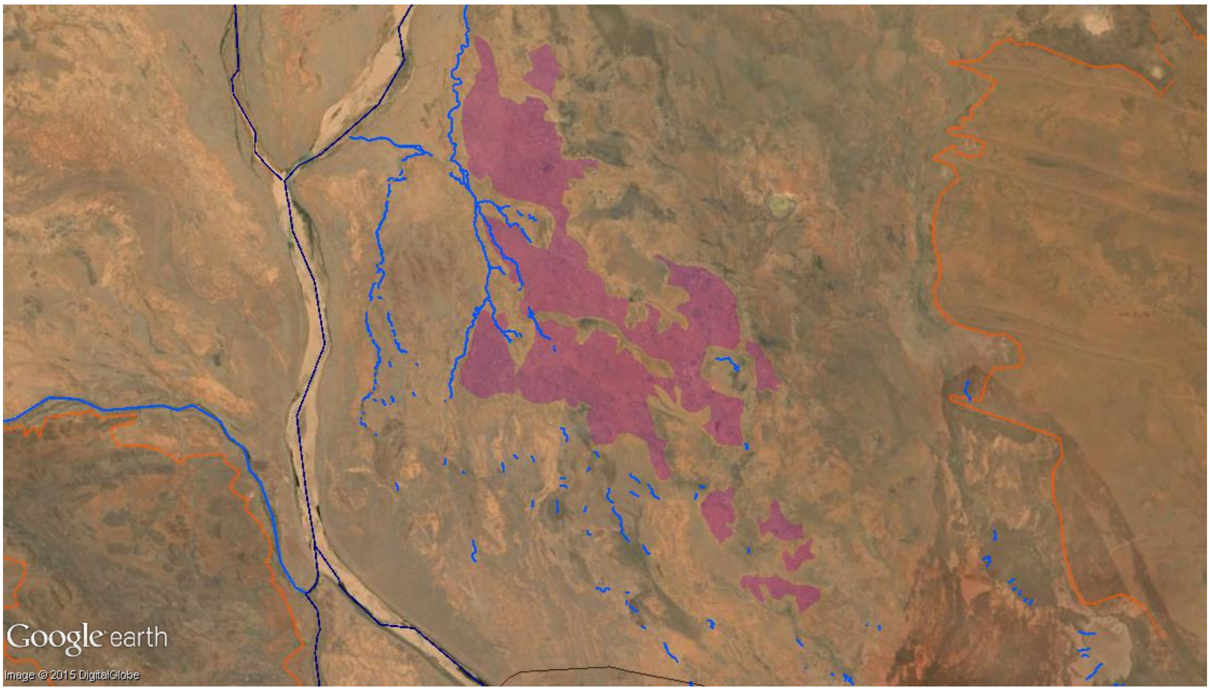
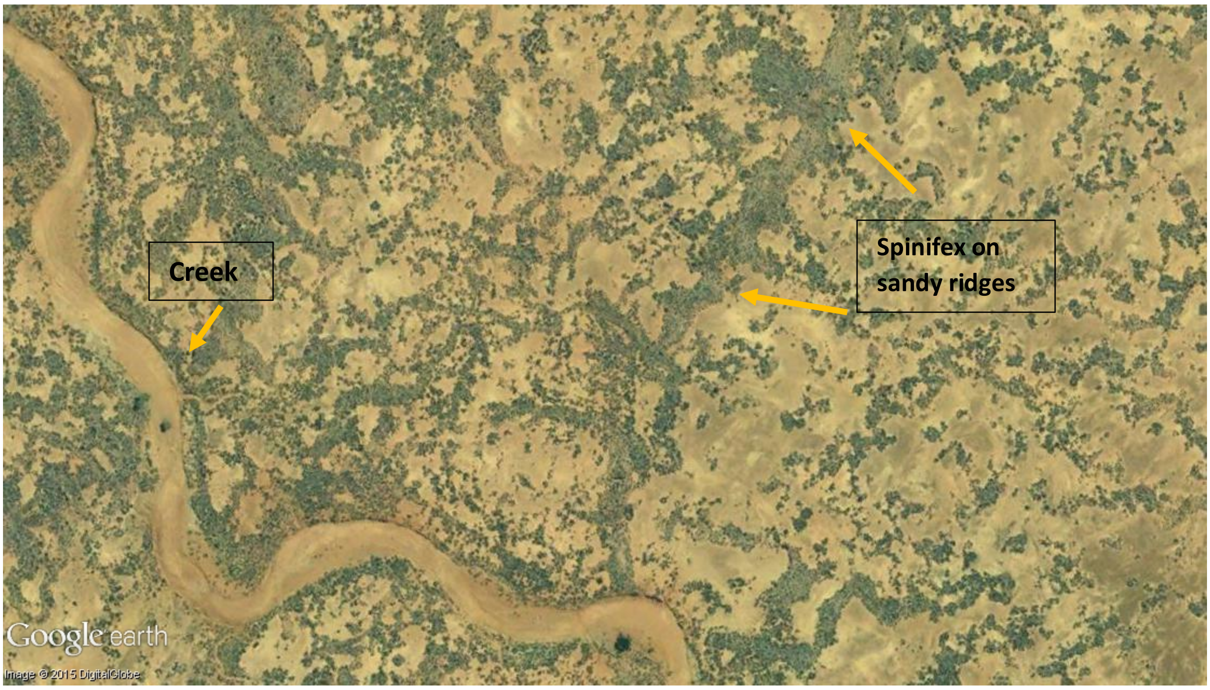


Figure 27: Spinifex on sandy ridges between eroded hollows on the zone of diffuse drainage, with a creek cutting through the zone



BHP Billiton rail line cuts off the flood plain flows

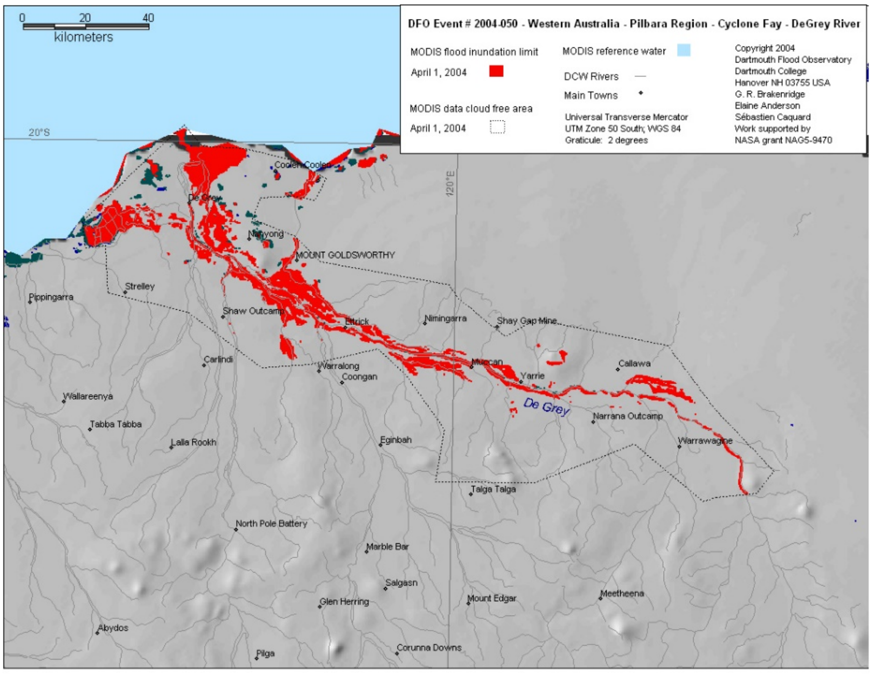
In large floods, massive volumes of water can spill out of the DeGrey River between Mt Grant and the DeGrey Bridge (Figure 28). This flood water flows north up until the BHP Billiton rail line. The rail line was built up several meters and acts as a dam wall. Flood water is then diverted sideways (west) back into the main river channel. This causes major erosion near the rail bridge. In the very large Cyclone Rusty flood of 2013, the rail line eventually burst in several places allowing the water to follow the natural flow paths across the delta. In small floods the rail line contributes to starving much of the delta of flood water. Modifications to the road and rail line are needed restore natural functions of the flood plain.

Figure 28: Water flowing on to the flood plan after the BHP Billiton rail failed from Cyclone Rusty flood waters

Major floods

Severe cyclones, such as George (2007) (Figure 30) and Rusty (2013) (Figure 29), caused major flooding of the lower DeGrey. Satellite imagery of the floods can help to map out how the flood plain works (also Figures 31 and 32). This imagery helps to identify critical flood out points and flow paths. The DeGrey pastoralists will be testing out earth works that might allow water to spill onto the flood plain more regularly. One of these key flood outs points is at the foot of Mt Grant.

Figure 29: DeGrey flood waters from Cyclone Rusty on 4 March 2014



http://www.dartmouth.edu/~floods/images/2004050DeGrey.jpg

Figure 30: Cyclone George flood waters on 6 March 2007

http://earthobservatory.nasa.gov/IOTD/view.php?id=80564

Figure 31 and 32: Before and after satellite images of Cyclone George flood waters, March 2007

March 13, 2007

March 6, 2007

http://earthobservatory.nasa.gov/IOTD/view.php?id=7500&eocn=ge_feed&eoci=gallery

Banks to divert some water out of the main river channel

Members of the DeGrey LCDC plan to construct small sand banks within the river beds to draft some water through the flood out points (Figure 34). Peter Andrews will assist in the construction of these banks. The aim is not to dam the river, rather to encourage part of the river flow to spill out through natural low points along the river' sand banks. If water was to spill out of the Talga River at the gap (Figure 33) it would then flow across 40 km of flood plain until draining into the main DeGrey River. If successful, this process would rehydrate an area of 15,000 ha. Similarly the spill out on the eastern Yarrie (Figure 33) boundary would rehydrate up 10,000 ha. Flood out at Mt Grant on (Figure 35) DeGrey Station would rehydrate 51,000 ha of the coastal delta (Figure 36).

Figure 33: Site where the bank spills water out of the Talga River (blue arrow) at the Gorge Range gap. A proposed small bank (brown line) within the river bed might help to spill more water onto the flood plain downstream

Figure 34: Flood out points (blue arrows) on the Talga River and DeGrey River and the areas downstream which would receive extra water (green areas)

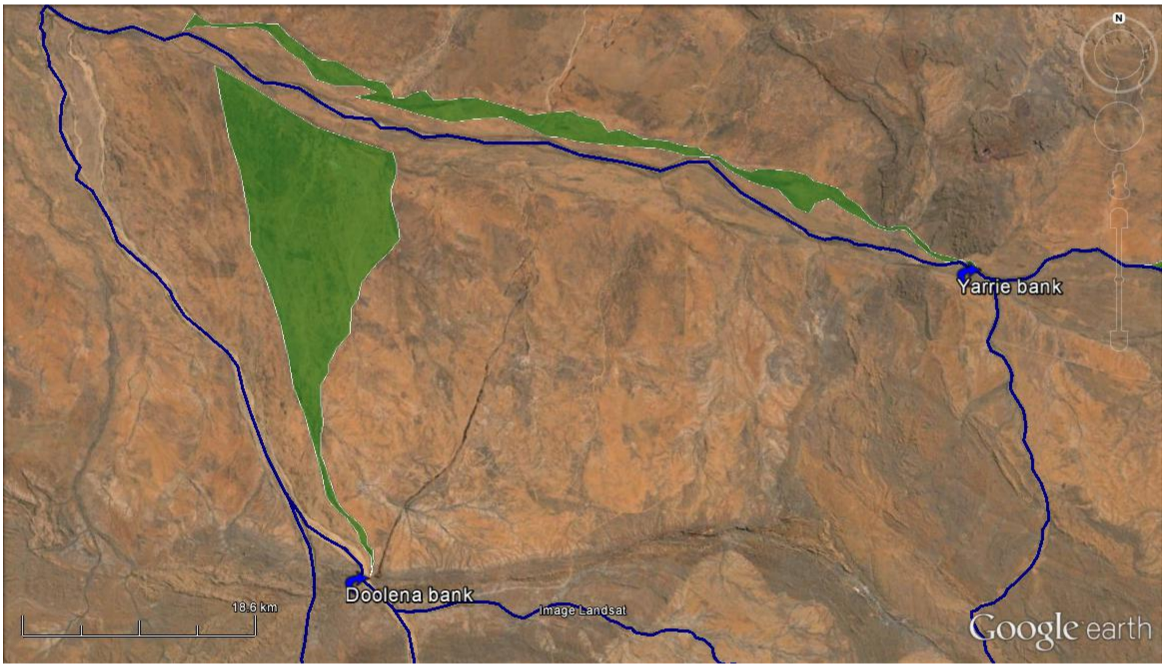


Figure 35: Water diversion bank (brown line) and the start of the DeGrey delta flood plain (green area) from the DeGrey River below Mt Grant

Figure 36: Area (green area) potentially rehydrated by the flood out point below Mt Grant

Catchment Function and the Cattle Enterprise

The DeGrey catchment can be viewed and interpreted from a pastoral / livestock perspective as well as a natural / biodiversity ecosystem.

The early pastoralists needed three vital components to run their stock. These were land with good pasture production, permanent watering holes and natural barriers to prevent stock from straying off their land. The original station boundaries were largely set on these requirements.

In the early days of pastoralism there were very few fences to prevent livestock from wandering. Station boundaries were often set on landscape features. The rugged ranges of the region acted as natural barriers to stock. Part of the Limestone – Yarrie boundary runs along the Gorge Range. This narrow, but steep range limits the movement of stock from one station to the other. Similarly the ranges to the south and west of Limestone homestead restrict the movement of stock.

Sheep and cattle need to drink regularly, at least once a day during the hotter parts of the year. Deep pools and springs along the main river channels provided reliable water holes to get stock through the long dry season. During the summer wet season stock could spread out as there were small creeks and pools back into the ranges.

The supply of natural pastures is not spread evenly over the DeGrey catchment. The best and most valuable grazing is found in the floodplains associated with major drainage channels. The best of these are in the river riparian zone, the flood out country from the main tributaries and the coastal delta. Useful feed also grows on the riparian zone along the smaller creeks in the ranges, particularly during the wet season.

The steep rugged hills of the ranges are predominantly covered with hard spinifex of little grazing value. However these craggy ranges are important components of the whole system. Their runoff water feeds the large floodplains along the rivers and the DeGrey delta.

During the summer wet season stock can graze back into the ranges. However, in the past stock would have to move back to the main rivers as the dry season progressed. This led to over grazing, erosion and disruption to the natural drainage system along the water courses. Most of this damage was done in the first half of the 20th century. Despite the 'softer' grazing of cattle in recent times much of the degradation of land along the main rivers has yet to recover. Improved stock infrastructure and grazing management will be crucial tools for repairing this historical land damage.

Fire and its Impacts on Catchment Function

The DeGrey region has a long hot dry season making the country susceptible to regular burning. The frequency of burning is influenced by the land systems and landscape. Satellite monitoring of fires (http://www.firenorth.org.au/nafi3/) shows three categories of country with different burning patterns within the DeGrey catchment (Figure 37-39):

1. The main river systems and associated flood plains that are rarely burnt. This category includes the low lying country along the DeGrey River, the main tributaries and the coastal delta. This country carries the highest stocking rates so that the fuel load is significantly reduced from grazing by the later dry season.
2. The spinifex plains of the basins are burnt on a modest frequency of usually between every 7 to 12 years.
3. The rocky ranges are burnt very frequently, typically with less than 6 years between fires, and some of it every 3 years. Burning this country regularly creates a major problem in that there is not enough ground cover and creek vegetation to slow, and reduce, water runoff.

Some fires in the region are naturally lit due to lighting strike, however many are deliberately lit. Stations do strategic burning every year to create fire breaks, freshen up spinifex and to create a mosaic of vegetation conditions. Often the burning is done during the wet season resulting in a slow, cool burn from which vegetation recovers quickly.

Unfortunately there are fires started by other people. Limestone Station has a particularly bad problem with miners and prospectors lighting fires to reduce the spinifex cover simply to make it easier for them to walk around. These fires are mostly started in the middle, or later in the year, resulting in very hot fires.

The highest frequency of these fires is in the ranges where most of the gold is found. Unfortunately, protecting this steep country from fire is critical to maintain the cover needed to retain water higher in the landscape. The creek lines in the hills should be clogged up with woody vegetation for them to function effectively in slowing water. Regrettably there are now very few creek lines in the hills with any woody vegetation.

DeGrey Station has also had problems with people lighting fires when travelling to and from the coast on station tracks. These fires not only destroyed valuable feed but also threatened station infrastructure, stock and people. One commonly used track was on the highway opposite the Warralong Road. In May 2014 the Bettini's decided to close the public access tracks to the coast as a consequence of deliberately lit fires. The Bettini's would like to develop a management plan in collaboration with the Town Of Port Hedland and the State Government to reopen access to the coast in a controlled and manageable fashion.

Figure 37: Number of years since last burnt showing the least fires along the river systems and the most in the rugged ranges (from http://www.firenorth.org.au/nafi3/)

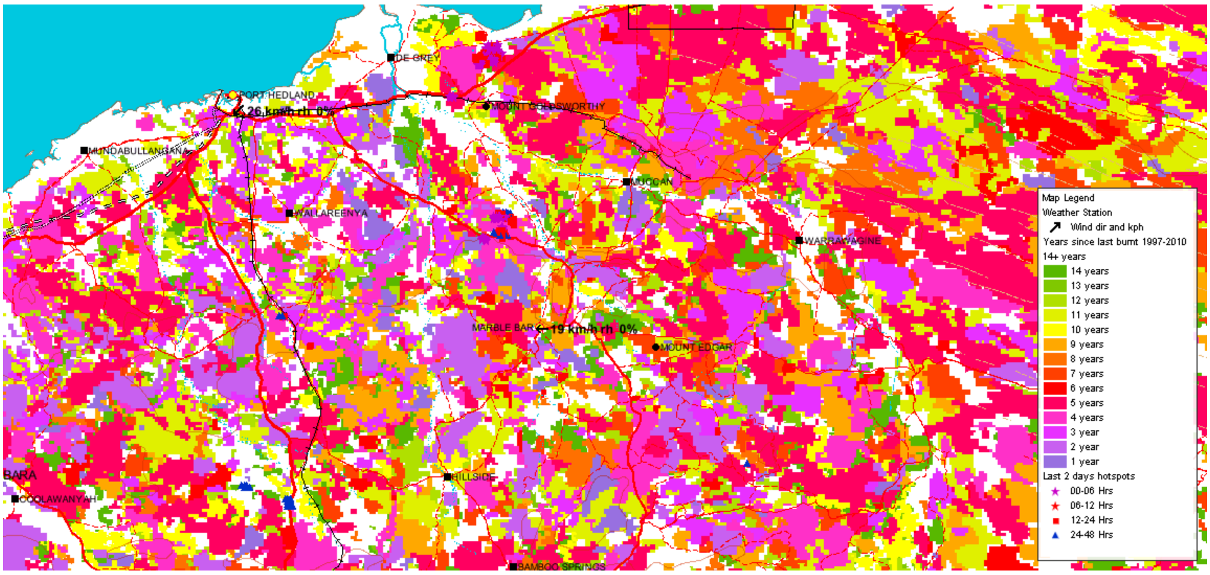


Figure 38: Number of times burnt between 1997 and 2010 showing that the major rivers and their flood plains are rarely burnt

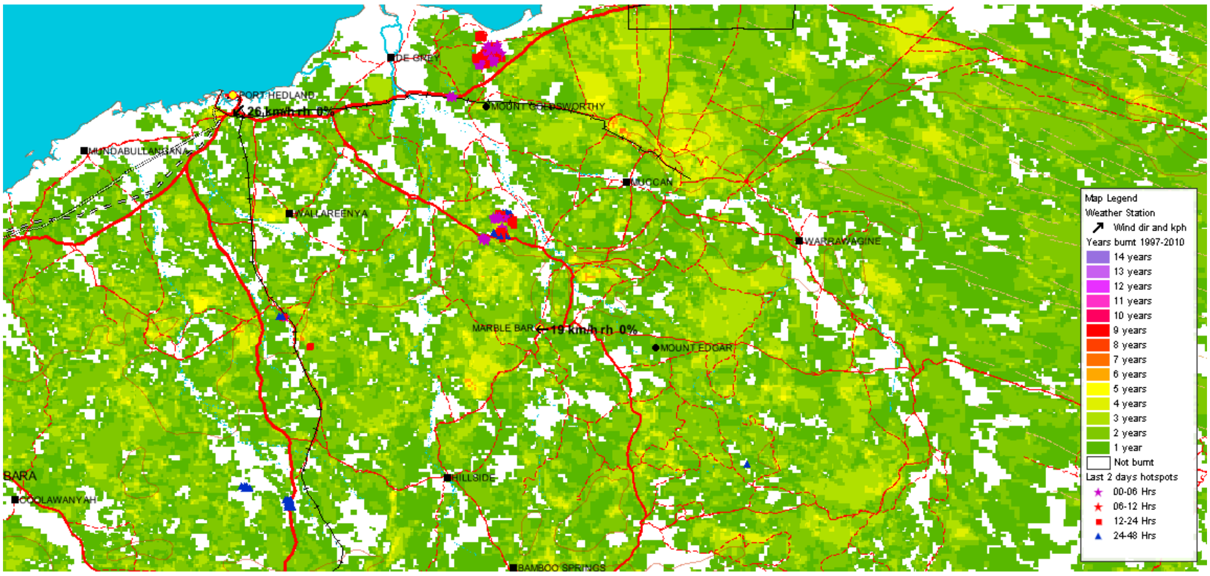
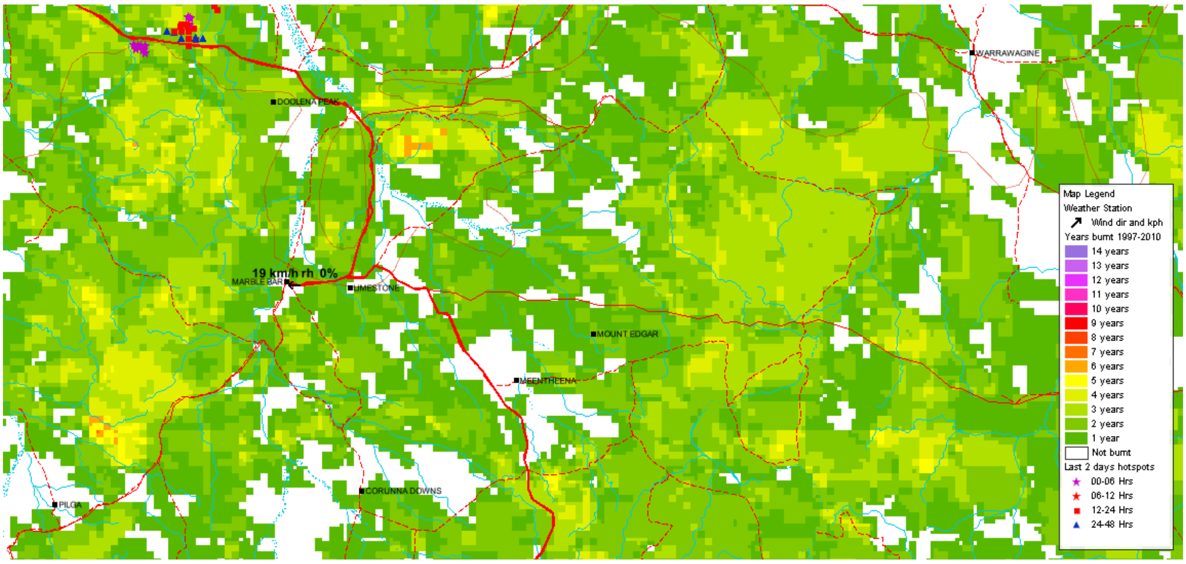


Figure 39: Number of times burnt between 1997 and 2010 showing the most frequent burning is in the circle of ranges surrounding the Mt Edgar Basin on Limestone station



A key strategy to improve the catchment function will be to implement an effective, and targeted, fire management plan (Figure 40). A detailed fire management plan should be developed in conjunction with other land holders in the catchment and with the support from specialists.

Keeping fire off the steep slopes and their creeks lines should be the highest priority. To achieve this will require 1) some targeted fire break burning, 2) a public awareness campaign on the damaging nature of fires, and 3) assistance from authorities to convict some arsonists.

On the spinifex plains, mosaic burning should continue with an emphasis on 1) having regular fire breaks, and 2) keeping fire out of the critical wet lands in the drainage lines.

Currently, the rivers and their flood plains usually won't burn as the fuel load is kept down by grazing. However if more intensive rotational grazing systems are introduced, then the risk of fire on sections of the river may increase due to less grazing intensity. Fire management would need to be built in to the grazing plan for this zone.

Figure 40: Fire management zones for lower DeGrey catchment

Overview

As is common with systems analysis, the validity and usefulness of a system-wide purview and analysis, compared to partial approaches, is almost painfully apparent. The implications for policy, across private enterprise and the public sector, are likewise clear. Perhaps most importantly, the approach, enabled here by two major recent innovations, provides new, valid insights into interdependencies among physical components of landscape at a relevant scale for management response. In the process, meaningful responses can be identified and properly evaluated, in physical outcome and economic terms, exposing truly optimal action.

Glossary

Kinetic energy

- ‘Kinetic energy’ is ‘mechanical energy’. It is the energy that an object, body of water or body of air possesses due to its motion. It is defined as the work needed to accelerate a body of a given mass from rest to its stated velocity. Having gained this energy during its acceleration, the body maintains this kinetic energy unless its speed changes. The same amount of work is done by the body in decelerating from its current speed to a state of rest.

Catchment

- a ‘catchment’ is the area of land from where rainfall runs off and then converges to a single point at a lower elevation, usually the exit of the basin, and where the water channel then joins another waterbody, such as a river, lake, reservoir, estuary, wetland, sea, or ocean.

Topography

- the three-dimensional shapes and features of the land surface. It includes features such as hills, valleys, ridges and drainage lines.

Confluence

- a ‘confluence’ is the meeting point of two or more bodies of water. It refers either to the point where a tributary joins a larger river or where drainage lines of similar size meet.

Landscape steps

- Landscapes are not made up of one continuous slope from the top of the catchment to the bottom. Rather there are a series of gentler slopes that are separated by sharper declines or ‘steps’. Steps are often natural ridges that follow a contour.

Keyline

- The ‘keylines’ in landscapes are the points at which there is a change in the slope of the land from quite steep to much flatter. This is usually associated with a change in the pattern of drainage.

Contours ridges

- ‘Contours ridges’ are rises that run at close to a consent elevation across slopes in the landscape. Often these rises may be very subtle but water will pond behind them. Contour ridges function to direct water flows across the landscape, either into or out of a drainage line.

Leaky weirs

- ‘Leaky weirs’ are formed by plant litter collecting at specific sites within a water drainage channel. Dead branches, logs or whole trees catch together to form a barrier in the drainage line. These weirs have many holes that allow water to flow through, but at a much reduced speed. Water will pond up above these leaky weirs when there is a stream flow. When shrubs grow within a drainage line they often become the anchors for catching litter to form leaky weirs.

Riparian zone

- ‘Riparian zones’ are the interface between drier land and a river or stream. Generally it is the area of land along a water course that will be covered by water in a small flood event.

Alluvial fans

- ‘Alluvial fans’ are fan- or cone-shaped areas of sediment soils that were deposited from a creek. Alluvial fans are typically start where a creek line with a steeper slope emerges out onto a flatter plain.

Pediment

- ‘Pediments’ are raised areas of flatter land above the riparian zone of a river. They are characterised by meandering water courses or indistinct, diffuse, water flow paths.

Rock dykes

- ‘Rock dykes’ were formed in ancient geological times when old rocks cracked allowing molten minerals to seep in forming ‘dykes’ of another rock type. Often these dykes are dolerite inclusions into older granites. As the dolerite weathers more slowly these rock dykes are left to form ridges or rises in the landscape. Typically rock dykes are in fairly straight lines with many lining up parallel to each other within a region. In some cases no rock is visible at the surface of a dyke, rather the clays from the decayed dykes form raised contours that are visible from above as straight lines.

Wet lands

- 'Wet lands' areas of land where water ponds resulting in better plant growth. The extra plant growth then helps to slow and filter water flowing through these ponds. These wet lands ponds are formed behind steps in the landscape.

Run off areas

- 'Run off' areas are those with steeper slopes where water readily runs off the surface following rain rather than soaking into the soil.

Run on areas

- 'Run on' areas are those where water spreads out from a drainage line and settles allowing additional water to soak into the soil.