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Stream diversity and conservation in Tasmania: yet another new approach.

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SUMMARY: Tasmania might be the smallest state in Australia, but there is a surprising variety of stream types crammed into that small area. Despite the fact that over a third of the state is reserved, many stream types are not included in the current reserve system. This paper discusses an approach to improving the representation of geomorphological stream features in the reserve system. This approach will help to expand our view of conservation from the present biological focus to include the physical environment, and the protection of geodiversity, as well as biodiversity. We suggest a method to identify the geodiversity associated with streams by examining variation in stream systems on a regional basis. This will not only help to improve conservation of streams, but also provide a basis for improving stream management.

This paper describes:
- The need for a strategic approach to the conservation of streams.
- Geodiversity – what it is, why you should care about it and how you can keep track of it.
- How to get enough information to have a strategic approach - a method for identifying the geodiversity of Tasmania's streams, using GIS to define the regional context for that diversity (ie stream types and regions).

1. INTRODUCTION

In Tasmania, the Nature Conservation Branch of the Department of Primary Industries, Water and Environment is currently trying to develop a strategic approach to stream conservation. At present, when applications for developments or activities in streams come through the department for approval, they trigger a flurry of activity to assess the significance of the particular section of stream under threat, as well as the impact of the works. This situation is far from ideal, because the conservation value of any particular section of stream needs to be assessed in its catchment context, and in the context of the number and condition of all similar streams (Dixon and Duhig, 1996). This is all but impossible when these questions arise on a site by site basis, with limited time available for the assessment. What is needed is a regional assessment of the types of stream that occur in Tasmania. Part of this regional assessment should identify representative streams or stream segments that are worthy of special protection because or their good condition or their rarity within their region. Such streams can then be a focus for conservation efforts.

Defining stream regions and identifying and protecting streams representative of those regions has benefits for more than conservation. The representative streams will be valuable as templates in the design of rehabilitation works, and as benchmarks for assessing the condition of other streams in the region. Such information is necessary for prioritising stream management activities (Brierley *et al*., 1996; Rutherfurd *et al*., 1999). Identifying stream regions is also very important. The regions tell you which benchmark or template stream is an appropriate comparison to your stream. There is no point designing rehabilitation works based on a stream that has never looked the same as yours. Also, the stream regions, and the stream types within those regions, will form an ideal base for locally relevant management guidelines. For example, if you know that vegetation is particularly important to the stability of a particular type of stream, you can recommend that care be taken to prevent its removal. In this way, knowing more about our stream regions and stream types helps management of streams for both conservation and utilitarian management goals.

Figure 1. *The upper Donaldson River in north western Tasmania is one of the few rivers in the state still in natural condition on basalt. Apart from one road, the entire catchment of this river is pristine. The entire length of the river is either unreserved, or has such limited protection that forestry and mining are permitted.*

This paper describes work currently under way in Tasmania to develop this regional view of the state's streams. The focus of this project is the fluvial geomorphology, rather than biological aspects of stream ecology. There are two reasons for this. Firstly, it is acknowledged in Tasmania that landscape features are as worthy a focus of conservation as the more widely appreciated plants and animals. From this perspective, it is important to identify and protect stream geomorphology in its own right. Also, the geomorphology of streams is thought to develop largely independently of at least the stream fauna, although it is variably influenced by the flora. This means the geomorphology can generally be classified in isolation from biological systems. However, the geomorphology for a large part determines the habitat available to the biota, and the disturbance regimes influencing that habitat. Given this, a geomorphic assessment of stream types should be a useful tool in developing similar classifications based on stream and riparian biology.

2. CONSERVATION OF STREAMS IN TASMANIA: THE PRESENT SITUATION

2.1. Conservation within reserves

The reserve system in Tasmania has many strengths. Possibly the greatest, from a fluvial geomorphology point of view, is that the area covered by the World Heritage Area and adjoining parks and conservation areas is large enough to include many entire catchments. This means that all the different stream types in the catchment, from headwaters to lowland streams and estuaries, have been left undisturbed, with the possible exception of some changes in burning regimes. More important than this inclusion of different stream types is the preservation of entire catchments.

Just being in a reserve does not guarantee the good condition of a stream. A stream might already be impacted when a reserve is gazetted. Once reserved, streams are still subject to pressures from up and downstream, and within the reserve. With the notable exception of the lower Gordon River, very few management prescriptions exist for stream management within reserves. However, inside reserves there is a least some formal protection against further degradation caused by activities within the reserve boundaries.

Many stream types in Tasmania are not represented in any formal reserve, despite the fact that just under 30% of the length of streams in the state falls within reserves. For the usual reasons, the reserved areas of Tasmania do not represent the full range of environments within the state. This statement has been made many times with respect to terrestrial ecosystems, but it is equally true for stream systems. Streams of the south west and central areas of the state are well reserved, and east coast streams are also represented in the reserve system, but elsewhere in the state reserves are fewer and smaller. The midlands, north and south east of the state are much more poorly represented in the reserve system, largely because other uses have been found for the land in those areas (ie agriculture, forestry and mining).

It is also worth noting that outside large reserves only a small proportion of streams are bounded by riparian reserves. Where these do exist, they are managed under the Crown Lands Act rather than the National Parks Act, revealing that these were often not reserved for conservation purposes, but rather to allow large yellow machinery unfettered access to the stream. There is a great need to review the status of riparian reserves to determine their conservation value and appropriate protective legislation.

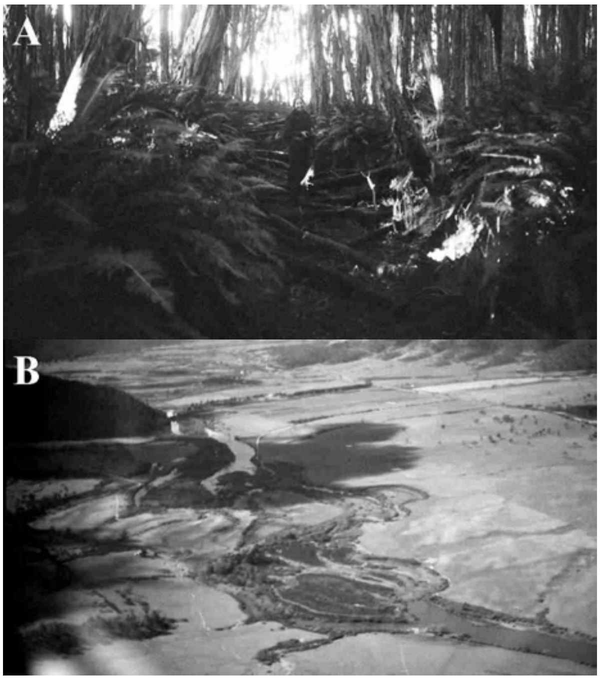

Figure 2. *Examples of unreserved stream types.*
A) The Seal River on King Island. This river runs through several swamp forests – extremely low gradient reaches with dense vegetation and underfit channels. These areas are prime targets for draining and agricultural development. Only a handful remain in natural condition. None are formally reserved.
B) A broadwater sequence on the South Esk River in north eastern Tasmania. Broadwaters are giant pools, up to 40m deep. Downstream of the pool, there is a large inset floodplain, where the river deposits sediment splays, and develops a meandering planform before entering the next broadwater. Several rivers in the region have broadwaters, but only one is not in agricultural land, and none are reserved.

2.2. Conservation outside reserves

The condition of streams outside the reserve system is highly variable. Streams in well developed agricultural areas have suffered the usual impacts of flood mitigation, water harvesting, draining, and use of the riparian zone. However, large areas of the unreserved portion of Tasmania are still fluvially in good condition. A Rivercare technical team now exists in Tasmania to provide advice on best management practice for streams outside formal reserves.

Unfortunately, much of this unreserved land is under some kind of threat. Although damage is not always imminent, there are examples from the recent past where development has moved slightly faster than conservation efforts, and valuable stream systems have been degraded. Forestry continues to move into areas of old growth forest, often replacing it with plantations that will be harvested with much greater frequency than natural regrowth. Despite the care taken to reduce impacts on streams, such activities can cause major changes to hydrology and sediment regimes, particularly in smaller streams. Areas previously only lightly grazed are being turned over to more intensive agriculture. Associated with this are activities which impact on streams, such as clearing and intensive use of riparian zones, and flood mitigation work such as channelisation and levee construction. Even greater potential to affect the natural values of our streams comes from the current push to make agricultural water supplies larger and more secure. There are many new dams proposed in Tasmania, both large and small, on and off stream.

Such developments mean a flood of work for those responsible for assessing the impacts on the natural values of our streams. Some development proposals will have little impact on the stream, while other pose a significant threat to conservation values and as such require careful assessment. There is a need for an established framework that identifies valuable streams, and gives them some measure of protection from degrading processes, that is in proportion to their value.

3. GEOCONSERVATION AND TASMANIAN STREAMS

Management for the conservation of geomorphological, geological and pedological features and processes has languished somewhat in the torrent of effort being put into management of biodiversity. However, for many reasons the conservation of geodiversity is an essential component of the creation of a comprehensive and representative reserve system, and for management of natural systems off-reserve. Many of the concepts raised in this paper are discussed in some detail on the Parks & Wildlife Service Geoconservation web page (http://www.parks.tas.gov.au/geo/geohome.html).

Did you ever look at a section of stream, its waterfalls, brightly coloured pebble beds, swirl holes and sandy beaches, and think that the scene and its processes should be looked after purely because of those physical features you are seeing? A favourite stream type, for example, includes incredibly sinuous meandering reaches of the now drowned Serpentine River in SW Tasmania (Figure 3). These are perfectly legitimate thoughts – you are not abnormal! Yet the recent history of conservation management has permitted an enormous bias to develop towards assessment and management of the biotic elements of natural systems. Whilst elements of Australia's geodiversity have been reserved or protected by other means in the past, this has generally taken place in an unsystematic way.

The development of ideas behind geoconservation has many parallels with that of biological conservation in Australia. In fact some of the very earliest reserves were proclaimed to protect specific geomorphological values - good examples may be found in the numerous small cave reserves scattered through the Eastern Highlands where beautiful or spectacular geomorphological features were reserved in the late nineteenth century. A little later flora and fauna reserves were proclaimed to protect the more spectacular elements of the biotic world. Many early reserves were proclaimed using the rather broad but useful concept of 'landscape', such as our early national parks, or for wilderness values in the latter half of last century.

Figure 3. *The Serpentine River, near the original Lake Pedder. This river was an exceptional example of an anastomosing meandering river. Unfortunately, along with Lake Pedder, the entire meandering section of the Serpentine River was flooded to store water for a hydro-electric scheme.*

The biologists and politicians then decided to deconstruct the integrated landscape, looking at the conservation status of individual species and protecting habitats of rare and threatened species. The concept of biodiversity conservation presently in vogue suggests that representative examples of species or communities must be managed sustainably in order to protect the genetic diversity of life. Rather than just the spectacular species, this involves looking after things like boring little brown invertebrates and the like (Figure4). This is to be achieved both through reservation and off-reserve conservation practices.

Figure 4. *A boring little brown invertebrate, and some boring brown ground – examples of bio- and geoconservation value.*

Beyond being seen merely as essential habitat for the biological components of natural diversity, conservation of geodiversity is beginning to be recognised as a legitimate and valuable end in itself. Protection of significant geomorphological features is justified for the conservation of purely abiotic features and processes. For example Croesus Cave at Mole Creek is a biological desert (Figure 5). No primary production and negligible detrital input has meant the cave and its underground stream contains very few invertebrate species, none known to be rare or threatened. Yet it is an incredibly beautiful cave, and possibly of international scientific significance because of its sedimentary deposits and their potential for palaeoenvironmental reconstruction (P. Williams pers comm). It is also contains excellent representative examples of many subterranean landforms.

Other systems (streams being a prime example) contain elements of purely geomorphic significance, elements of biotic significance, and combinations of both. When assessing conservation significance and stream condition, and making conservation,

Figure 5. *Croesus Cave at Mole Creek – beautiful and significant despite being a biological desert. Approximately one third of the cave is located within a national park, however the remaining two thirds of the cave and the majority of the catchment are not formally reserved.*

rehabilitation and management decisions, it is important to consider first biological and geomorphological values separately, before deciding on the value of the stream as a whole. We are only beginning to assess geo-values in their own right and until these values are documented and the degree of environmental interaction with biological systems is assessed, we run the risk of unfairly biasing judgements about significance of streams (and hence many of the land management decisions which are linked to them) towards values of living communities and species.

Much preliminary work in the development of geoconservation methods has been undertaken in Tasmania over the last decade or so (Sharples 1993; Dixon 1995). Methods of classifying the elements of geodiversity (Kiernan 1995, 1996) and also defining the regional context within which the elements have formed (Houshold *et al*., 1997) are taking shape. Inventories of various elements of geodiversity (coastal, karst, glacial, etc - for examples, see Bradbury 1993; Dixon 1996; Kiernan 1995, 1996) have been compiled, often in a reconnaissance fashion. In this way, a list of both representative and special examples of geological, geomorphological and pedological features has been compiled. This information is included in the Tasmanian Geoconservation Database, which can then be used by land managers to avoid or minimise any damage to or loss of geoconservation values. The database is maintained by the Earth Science Section, Nature Conservation Branch, DPIWE.

As a result, the Tasmanian Government now recognises the intrinsic, ecosystem and utilitarian values of geoconservation in many of its planning regulations, primarily in its reserve classification, which recognises the legitimacy of geodiversity as a reason for conserving land in all types of reserve covered by the NPW Act. The Tasmanian Nature Conservation Strategy – presently under development – includes geoconservation and protection of geodiversity as a key role.

The focus of the work described in this paper – a thematic, spatial inventory of stream landforms and processes in Tasmania - will be the first time a systematically defined inventory of geomorphic types will be assessed in their spatial context for conservation purposes. Similar to biologists we aim to establish the basis of a list of elements representing the diversity of the Tasmanian stream landscape for inclusion in a reserve system or, possibly more importantly, to provide recommendations for protection and management in an off-reserve context. The methods outlined below explain how we intend approaching the task of classifying streams in Tasmania, for setting a spatial context within which a choice of the best example may be made, and the criteria to be used to make the choice.

When a database of representative and outstanding examples of the geomorphic elements of Tasmanian streams has been compiled, this information can then be combined with sites representing significant biological systems. Rather than a simple GIS overlay, ecological links between the physical and biological components should be stressed in combining these. Only then will a comprehensive biophysical assessment of the conservation value of Tasmanian streams be possible.

4. A METHOD FOR PRODUCING AN INVENTORY OF STREAM GEODIVERSITY IN TASMANIA

This project entails use of both an essentially theoretical component and an empirical component to test it. A GIS based Environmental Domain Analysis (EDA) will be used to generate regions where similar controls on stream development have acted through time, and to predict the broad character of streams throughout the state.

This will be followed by extensive fieldwork to either confirm or refute the predictions of the EDA, and to describe the character of streams as they pass through each of the mapped regions. Once the accuracy of predictions has been assessed by checking a representative sample of streams or stream segments within each region, a decision will be made as to the likely success of extrapolating from areas which have been field checked to those which could not be checked because of time constraints. The logical continuation of this project will be to check at finer resolution the character of the streams as compared with the predictive regions, continually modifying boundaries and descriptions of stream character as more field data becomes available.

4.1. The Environmental Domain Analysis (EDA) and field testing

We have said that we will use EDA to generate stream regions where similar controls on stream development have acted through time. What are these controls, and how do we quantify them? The concept of 'system controls' was first used by Kiernan (1995) to aid in landform classification, and by Houshold *et al*. (1997), to define the regional context for landforms. The system controls on streams are those aspects of the environment that have influenced the development of those streams. The controls to be used in the EDA are:

- geology (simplified to 12 groups, that reflect the effect of geology on the landform produced, rather than the more usual description of stratigraphy),
- topography (shape parameters derived from the 25m digital elevation model (Wood, 1996)),
- climate (rainfall quantity and variation statistics),
- peat (the mapped area of peatlands), and
- process history (what areas of the state have been affected by aeolian, karst, glacial and periglacial and fluvial processes).

Ideally, vegetation would have been included as a system control where it exerts an independent control on stream morphology. However, this would have required state wide coverage of pre-European vegetation data, and this is not available.

It is important to recognise that the geomorphic processes listed above have varied through time, as climate has changed. This can be incorporated into the EDA by showing the process history at a few critical times, namely present day (0 - 6 thousand years), the height of the last glaciation (15 – 20 ky), and the maximum glaciation (> 730 ky).

The EDA will be used to produce a single map that represents the variation in the system control variables across the state. The result envisaged will be a map of Tasmania divided into many different types of domains, each of which can occur many times. This will look something like a 5000 piece jigsaw puzzle. Each type of domain will represent a distinctive landscape type, defined by similar levels of all the system controls. For example, in the south west of the state, a common type of domain will combine folded quartzite, moderate slope, reliably high rainfall, peatland and glaciation.

The advantage of the EDA is that it does not force you to define in advance the thresholds in continuous variables (eg the threshold between low and moderate rainfall is 450 mm/yr), as would a simpler overlaying technique using different GIS layers. Instead, an EDA will define areas within which the rainfall is fairly consistent. This means that a large area with rainfall between 440 and 460 mm/year will not be cut in half by an arbitrary boundary. However, some of our system controls (peat, geology and process history) are categorical variables and by definition, the thresholds between these categories must be pre defined. A description of the process used to produce an EDA from continuous variables can be found in Peters and Thackway (1998). This project is devising a method for integrating categorical and continuous variables.

What is now required is some way of spatially aggregating upwards of 50 different domains to produce a manageable number of stream regions that reflects the variation in streams to be seen on the ground. What we hope to find is that streams tend to run through a typical sequence of domains, and it will be this characteristic sequence that defines the final regions. For example, the streams on the central east coast share a repeating pattern. The headwaters are on dolerite, sometimes on top of a dolerite plateau, sometimes on an escarpment. Those streams that start on the plateau soon run over an escarpment. At the base of the escarpment, the streams run through huge, largely fossilised alluvial fans, then onto a floodplain where they develop a meandering planform, and so to the coast. Each of these stream segments should correspond to a domain in the EDA. The stream region will be made up of all the streams that follow a similar pattern. The key to defining regions is to identify and describe these patterns.

This regionalisation will have the following interesting features:

- A region can occur in more than one area. If the streams draining the Western Tiers are similar to those draining the Eastern Tiers, then those two areas will form one region, even though the Macquarie and South Esk Rivers that run between the two areas will fall into quite a different region.
- A stream can run from one region into another. In other words, region boundaries will not necessarily follow catchment boundaries.
- The stream type does not have to remain the same throughout each domain. The final regionalisation will be hierarchical, allowing the identification of variation in stream type at a much finer scale. For example, a domain might cover the whole floodplain segment of a stream. However, within that floodplain segment, there will be a distinct sequence of stream types, from alluvial fan through to meandering floodplain stream. This scale of variation will need to be identified during the field work phase of the project

It is vitally important to firmly connect this desktop GIS exercise with the real wet and muddy world. Thus a large component of this project will be field work to test the boundaries and internal consistency of the regions derived from the EDA. This field work will also describe the stream types within each region, and attempt to identify those streams or reaches that are good condition, and thus are contenders for benchmark status. A potentially useful method for collecting empirical data for this classification is a geomorphic characterisation approach like that described by Brierley *et al.* (1996).

At some stage a decision will be made about whether enough data is available to make an informed decision about which streams or sections of streams form the best representative sample of the range of types identified, and following identification, an assessment of the best method available to conserve them. To make such decisions, we need to be confident that we know what types of stream occur, what region they occur in, and what the range of condition is for streams in that region.

From this information, we can then work out which streams in a region are the highest priority for conservation, following the prioritisation principles described in Rutherfurd *et al.* (1999). Conservation priority will depend on the condition of the stream, and the rarity of streams of that type in good condition. Basically, any stream in good condition is a high priority for conservation, because it is so much easier to preserve a good stream, than to repair a degraded stream (Rutherfurd *et al*., 1999). But, where there is only one example of that stream type in good condition, that stream would be a higher conservation priority than an example of a very common stream type.

Where there are no examples of a given stream type in good condition, it may be worthwhile taking one of the least degraded reaches and attempting to rehabilitate it (Rutherfurd *et al*., 1999). Such a reach would have potential for high conservation value, even though it is presently in average condition.

The ideal way to present the results of this work is as an Atlas of the Streams of Tasmania. This format will allow lots of maps and photographs. For each region, we aim to produce:

- a region map, showing the landscape segments identified by the EDA;
- a description of the typical stream segment sequences through the region;
- a map of stream condition in the region;
- a description and map of general conservation value, and identifying specific streams that require some form of protection to maintain their high conservation value, and
- management advice for different sorts of stream.

CONCLUSION

This basic approach to classifying streams should be appropriate anywhere in Australia. It may be that some system controls would need to be added or excluded in different areas. For example, while the history of periglacial processes are probably important throughout south eastern Australia, it is not relevant in other areas of the country. Extending the classification to different states would allow a comparison of stream type to be made across state boundaries. More importantly, stream regions are unlikely to coincide conveniently with state boundaries. When assessing the condition and conservation status of a stream, it is important to consider the whole region over which that stream type occurs, even if that does involve looking interstate.

So, why not give regionalising your stream geomorphology a go! It will give you a measure of the geodiversity present in the streams of your state, and help you muster arguments for looking after that diversity. It will help you develop an understanding of why different stream systems behave in different ways, which should be invaluable for improving stream management techniques. It will hopefully form a good base for understanding differences in stream ecosystems, which should also help with their conservation. Best of all, the focus on identifying pre-European stream types means you can direct more of your field work away from the standard degraded stream system, and into your states or territory's most beautiful areas!

5.ACKNOWLEDGEMENTS

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