Seeing rivers from the desktop: Methods for assessing geomorphic change in the Murray–Darling Basin

Tom Atkin[1], Michael Cheetham[2] and Julian Martin[1]

1 Geomorphe, Wangaratta, VIC. Email: tom@geomorphe.com.au

2 Geomorphe, Alderley, QLD. Email: Mick@geomorphe.com.au

Key points

- Desktop geomorphic analysis of LiDAR, bathymetry and imagery provides a cost-effective, spatially continuous basis for assessing channel condition and change across long river corridors that cannot be feasibly covered by field survey alone.
- Integrating multiple techniques produces a far more robust geomorphic interpretation than any single method, and supports defensible reach delineation.
- The resulting evidence base enables objective, reach-scale prioritisation of management investment and underpins clear visual communication with managers, landholders and Traditional Owner groups.

Abstract

Understanding how rivers change through time is critical for effective river management, yet assessing geomorphic condition across long river corridors remains challenging. Desktop geomorphic analysis of remote sensing data provides a cost-effective and spatially comprehensive approach to quantify river condition and change across large extents. This paper presents desktop methods applied to evaluate geomorphic condition and channel change in major river reaches within the Murray–Darling Basin, drawing on investigations of the Hume to Yarrawonga Reach of the Murray River, and the lower Mitta Mitta River.

Using remotely derived datasets and GIS-based analysis, these studies characterised channel form and geomorphic change to understand river behaviour, define geomorphic trajectory, and guide future management. Key techniques included Digital Elevation Model of Difference (DoD) analysis to detect erosion and deposition, Relative Elevation Model (REM) analysis to assess floodplain palaeofeatures, top-of-bank mapping and width-to-depth ratio analysis, longitudinal profile analysis, cross-section comparison, channel change diagrams, and remote willow mapping using multispectral aerial imagery. Applied together, these methods revealed spatial trends of channel adjustment and supported interpretation of geomorphic drivers across extensive river corridors.

The paper highlights the practical advantages of desktop geomorphic analysis. Emphasis is placed on how integrating multiple analytical techniques strengthens geomorphic interpretation, builds management confidence, and identifies priority locations for targeted field investigation and management intervention.

Keywords

Desktop Geomorphic Assessment, GIS analysis, Murray-Darling Basin, Data and evidence-based analysis

Introduction

The state of channel form, the geomorphic processes and influences driving change, and the likely future trajectory of the system need to be understood to effectively manage Australia's rivers. Traditionally, such understanding has been derived from field-based visual assessment, with supplementary targeted site-based monitoring (e.g. cross section survey, erosion pins). This approach can be costly to scale across the long management reaches and multi-channelled systems that characterise much of the Murray–Darling Basin (MDB). In addition, visual assessments rely on qualitative interpretation and site-based monitoring may be influenced by local conditions and processes and may not be representative of the broader management reach. In addition, there can be logistical challenges of accessing hundreds of kilometres of river channel in remote locations or through private land.

Advances in remote sensing technology, particularly LiDAR (Light Detection and Ranging) and high-resolution aerial imagery, together with increasingly capable GIS analysis tools, have transformed the capacity to assess river geomorphology from the desktop. Where multiple LiDAR capture epochs are available, it is now possible to quantify reach-scale channel change, including bank erosion, bed incision, and sediment deposition with spatial precision that would be impossible to achieve through field survey alone.

This paper presents and evaluates a suite of desktop analysis methods applied by Geomorphe across two major river investigations in the MDB: (1) the Hume to Yarrawonga Reach of the Murray River, (2) the lower Mitta Mitta River in north-east Victoria. Together, these projects span regulated and semi-regulated systems, gravel-bed and sand-bed environments, and reaches subject to significant anthropogenic modification, providing a broad test of the applicability and limitations of desktop assessment methods. The paper also discusses how multiple analysis techniques can be applied to gain a full picture of channel change, the current condition and likely trajectory to inform the future management of our rivers. This paper is limited to discussing a subset of the analysis techniques used in these assessments.

Study areas and management context

Hume to Yarrawonga Reach, Murray River

The Hume to Yarrawonga Reach of the Murray River extends approximately 270 km between Hume Dam and the high-water level of Lake Mulwala and is one of the most operationally significant irrigation reaches in Australia. Regulation by Hume Dam (completed 1936, enlarged 1961) and Dartmouth Dam (completed 1979) has fundamentally altered the natural flow regime, dramatically reducing the frequency and magnitude of high flows while maintaining long periods of high flows over summer. In an anabranching river system, the response to river regulation is complex, with different anabranches responding differently to the change in flow regime. However, the combination of regulated flows, riparian vegetation clearing, unrestricted stock access and dispersive/slaking soils (among other influences) have resulted in persistent bank instability. A geomorphic assessment was commissioned to characterise these changes quantitatively to support the development of an evidence-based prioritisation framework across the reach.

Lower Mitta Mitta River

The lower Mitta Mitta River extends approximately 94 km from Lake Banimboola (below Dartmouth Dam) to Lake Hume, traversing a steep, confined upper gorge and progressively widening valley floor through the lower reaches. Decades of regulation from Dartmouth Dam have significantly altered flow regimes. The river is also under pressure from stock access and native riparian vegetation is generally poor with a discontinuous single row of native trees or invasive exotic species. Current management of the reach involves the ad hoc rock armouring of the erosion hot spots with complementary fencing and revegetation and managing the spread of willows. The geomorphic assessment was commissioned to understand the current condition of the reach, the implications of erosion and sediment dynamics on water delivery and to inform the development of a prioritised management plan.

Desktop analysis methods

The desktop assessment framework used to assess the above-mentioned reaches integrates multiple spatial analysis techniques applied to remotely derived datasets. The primary data inputs are LiDAR-derived Digital Elevation Models (DEMs), sonar bathymetric survey, and multitemporal aerial imagery.

The methods described below were applied, in varying combinations, across the two study areas depending on data availability and project objectives and budgets.

Critically, the desktop analysis must be undertaken with consideration of the limitations of the applied methods and data and a critical review of the analysis results to understand and correct (if possible) potential errors and to ensure the results are interpreted correctly.

DEM of Difference (DoD) analysis

DEM of Difference analysis is one of the most robust quantitative desktop methods, providing a direct, spatially distributed measure of vertical change in elevation between two LiDAR capture epochs. The DoD is computed by subtracting an earlier DEM from a later DEM on a cell-by-cell basis, producing a raster of elevation change. Positive values indicate net deposition; negative values indicate erosion.

In the context of the rivers analysed, the DoD analysis is particularly valuable for identifying and quantifying bank erosion and retreat, aggradation of bar features, and floodplain deposition or scour. The technique can quantify volumetric change across an entire reach and provide area-weighted estimates of net erosion and deposition budgets.

A key consideration in DoD analysis is the limitations of LiDAR including the inability to penetrate water, and the influence of dense vegetation on LiDAR. Very dense riparian vegetation, particularly dense stands of willows (Salix spp.), can inflate apparent elevation, introducing noise and systematic error into the DoD output. In the Mitta Mitta investigation, areas of dense willows were identified as a source of uncertainty in the raw DoD outputs, and results were interpreted accordingly.

LiDAR processing errors associated with the water surface also introduce noise and systematic errors in the DoD (Figure 1). This is particularly of concern with older LiDAR sets where the processing of water bodies often resulted in localised artificially high areas. This noise can be processed out of the DEM by removing the water extent from the DoD. However, this can result in a loss of data along the lower bank profile. If these errors remain in the final DoD, it can make interpreting the DoD more challenging.

Figure 1 Example of a raw DoD showing errors associated with water surface and a processed DoD to reduce LiDAR error

Longitudinal profile analysis

Longitudinal profile (long-section) analysis provides an assessment of how channel slope varies along the length of the study reach. Ideally this analysis utilises bathymetric data to assess the actual bed slope, however LiDAR can be used a proxy if the bathymetric data is not available. The long-section analysis reveals the overall gradient of the channel and highlights any significant irregularities, grade discontinuities, knickpoints, or reaches of anomalous slope (Figure 2). For the Hume to Yarrawonga assessment the longitudinal profile analysis was used to assess the relative hydraulic efficiency of competing anabranches.

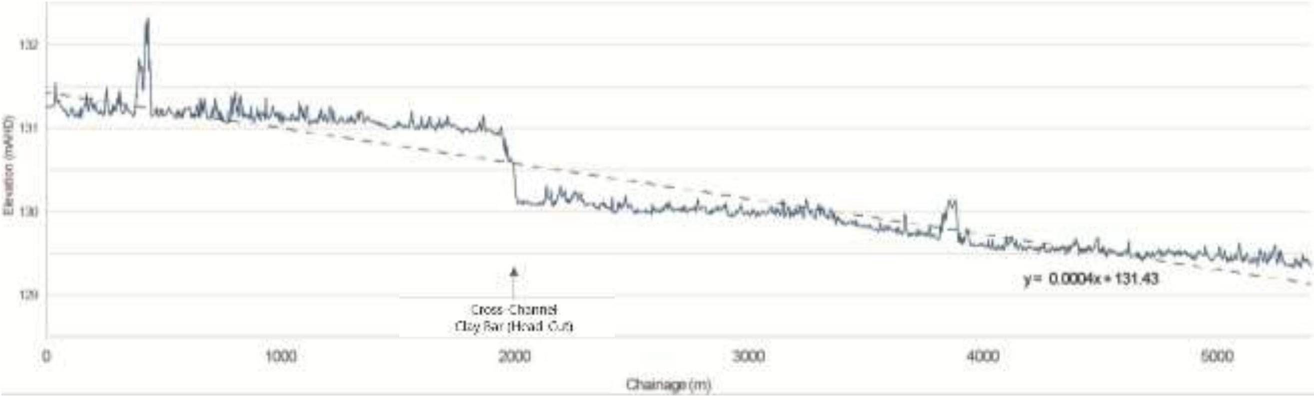

Figure 2 Longitudinal profile of Murphys Creek, a Murray River anabranch

Channel width and top-of-bank mapping

Top-of-bank (TOB) mapping involves delineating the edge of the active channel at the bankfull threshold across two or more LiDAR epochs. This allows the horizontal change in the bank profile to be quantified. For the Hume to Yarrawonga project the channel widths were sampled at 10m intervals allowing longitudinal plots of width change that reveal spatial patterns of erosion and stability. Measuring the distance to top of bank from a fixed centre line allows the change of each bank to be assessed individually rather than just the channel width.

Channel change diagrams, developed as part of the Hume to Yarrawonga investigation, present width change and dominant direction of lateral migration in a longitudinal format (Figure 3). These diagrams proved highly effective at synthesising spatial trends in channel lateral adjustment across reaches that extend for tens of kilometres, supporting geomorphic reach delineation and management prioritisation. The method was subsequently adopted for the Mitta Mitta assessment.

This analysis method relies on good quality and high-resolution LiDAR data to allow for the top of bank to be accurately mapped. Without accurately mapping the top of bank, significant error is introduced into the plots that mask actual channel change.

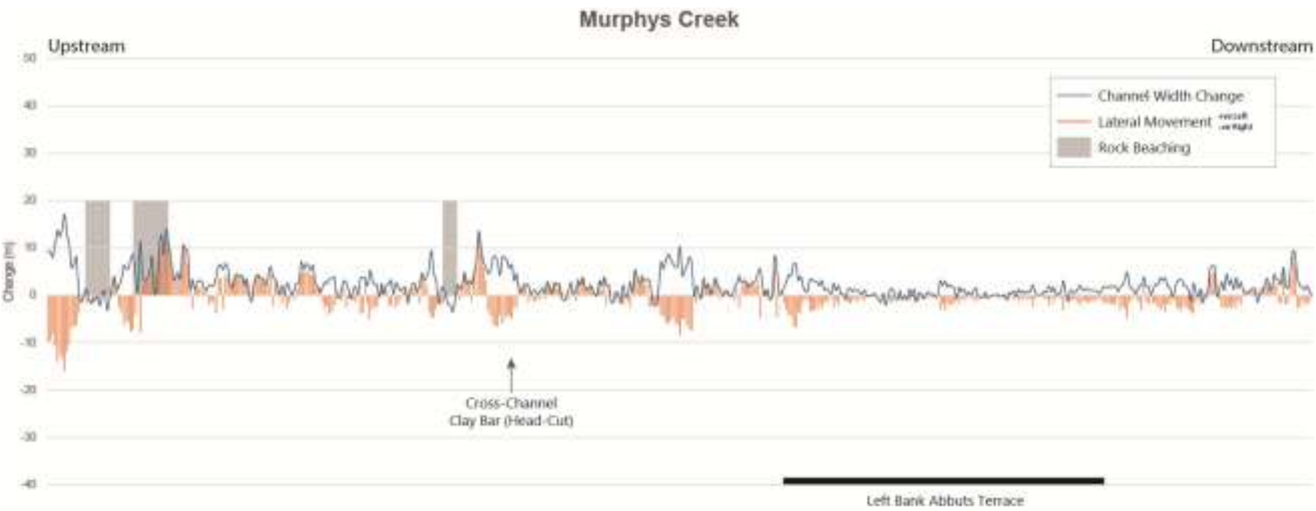

Figure 3 Example channel change diagram of Murphys Creek (a Murray River anabranch) showing lateral channel change

Width-to-depth Ratio analysis

The width-to-depth (W:D) ratio is a fundamental measure of channel cross-sectional geometry, describing the proportional relationship between bankfull width and mean channel depth. In the Rosgen (1994, 1996) stream classification framework, W:D ratio is a primary discriminator of channel type and entrenchment, with lower values indicating narrow, deep channels typical of confined or incised reaches and higher values indicating wide, shallow channels characteristic of less confined alluvial systems with greater lateral adjustment potential.

To accurately assess the width-to-depth ratio, bathymetric survey and accurate top of bank mapping are required. The need for bathymetric survey can be a limitation in applying this technique as good quality bathymetric survey can be costly.

For the Mitta Mitta investigation, the W:D analysis was undertaken using a single long section bathymetry survey. While this is better than nothing, it must be acknowledged that this survey did not necessarily pick up the thalweg. Therefore, the W:D ratio is likely to be overestimated, however the relative W:D is still valuable and can help identify trends.

Relative Elevation Model (REM) analysis

A Relative Elevation Model (REM) (Figure 4) is constructed by subtracting a reference surface, the bed level or water surface elevation of the main channel, from LiDAR elevation data. This effectively removes the longitudinal slope trend and represents terrain height above or below the local river level. The resulting model highlights floodplain features such as palaeochannels, relict anabranch pathways, natural levees, meander scroll features, potential avulsion or breakout paths and the valley margin that may be difficult to identify on standard LiDAR due to the dominant downstream gradient trend.

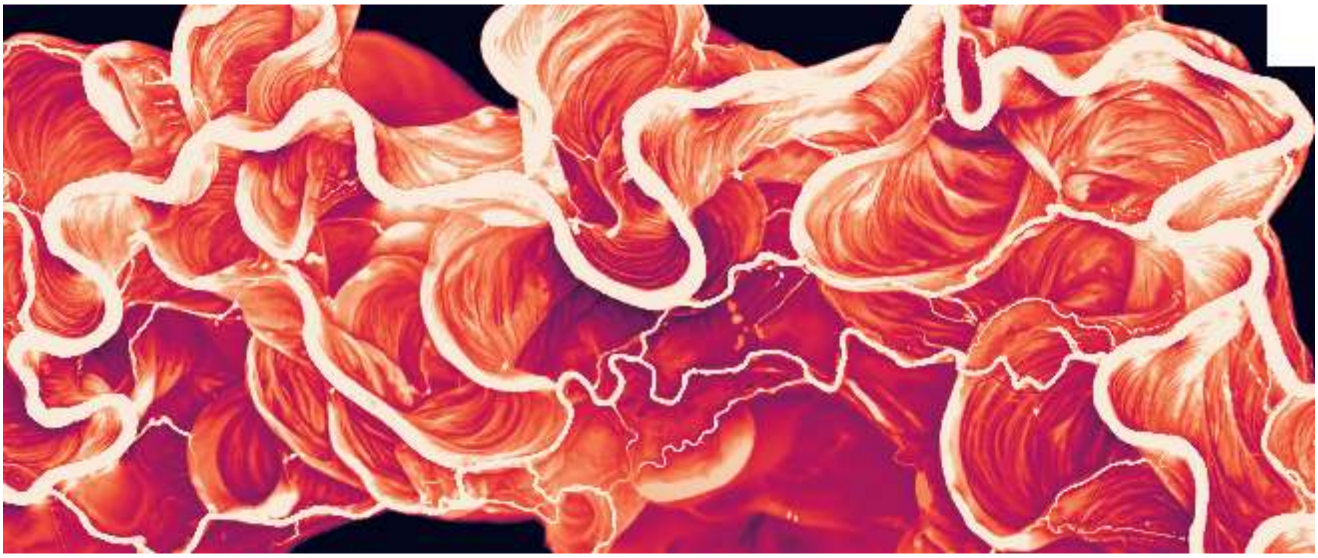

Figure 4 Example Relative Elevation Model showing detailed floodplain morphology (Murray River at Howlong)

Remote willow mapping using multispectral imagery

Invasive willows are a major management concern across many reaches of the MDB, contributing to altered bank morphology, increased roughness, and interference with geomorphic survey data. Quantifying the spatial distribution and extent of willows is essential for targeting management efforts and monitoring the efficacy of management.

A remote mapping trial was undertaken as part of the Hume to Yarrawonga assessment using a combination of aerial imagery and LiDAR to delineate willows. The trial area covered a representative area selected for the diversity of vegetation classes present, including dense stands of willows, individual willows, native vegetation, cleared farmland, and mixed willow–native communities. The trial identified that:

- The willow mapping identified most willows, however missed some small willows that were located under the canopy of mature River Red Gums. This is a limitation of using aerial imagery to map willows.
- The analysis identified some exotic tree species (e.g. Box elder) as well as willows. It is likely that these species represent a relatively small amount of the detected 'willows'. These species are also invasive so there is some value in including them in the assessment.
- The analysis did not identify native vegetation (notably River Red Gums and Blackwood) as willows.

The willow mapping approach has been used to map willow distribution on the Mitta Mitta River to inform the management priorities (Figure 5).

Figure 5 Example of the willow mapping undertaken on the Mitta Mitta River, with the red polygons the mapped willows

Integrating methods: Reach delineation and geomorphic characterisation

The value of the desktop analysis approach is maximised when multiple methods are applied in combination, with each technique contributing a different dimension of evidence to the overall geomorphic picture. No single method provides sufficient information in isolation to support confident reach-scale geomorphic characterisation or management prioritisation. The standard integration approach used for these investigations followed a similar approach, described below.

First, a data review and high-level visual assessment of the raw data (e.g. LiDAR, aerial imagery) establishes the reach-scale geomorphic context of the system and an understanding of data availability and limitations which inform the selection of analysis techniques and methods.

Second, the GIS assessments are undertaken and analysed at a reach scale with the intent of identifying reach-scale trends, processes and influences (Figure 6). This allows the project reach to be delineated into management reaches (or sub reaches). The long-section analysis and REM can be particularly helpful to identify reach scale trends and assist with management reach delineation. The ultimate reach delineation needs to consider the primary geomorphic drivers and management context. For example, Hume to Yarrawonga reach was delineated into sub reaches with consideration of the anabranch networks while the Mitta Mitta River was separated into sub reaches with consideration of the valley width, longitudinal slope and reach scale review of the channel change metrics (i.e. DoD and top of bank mapping).

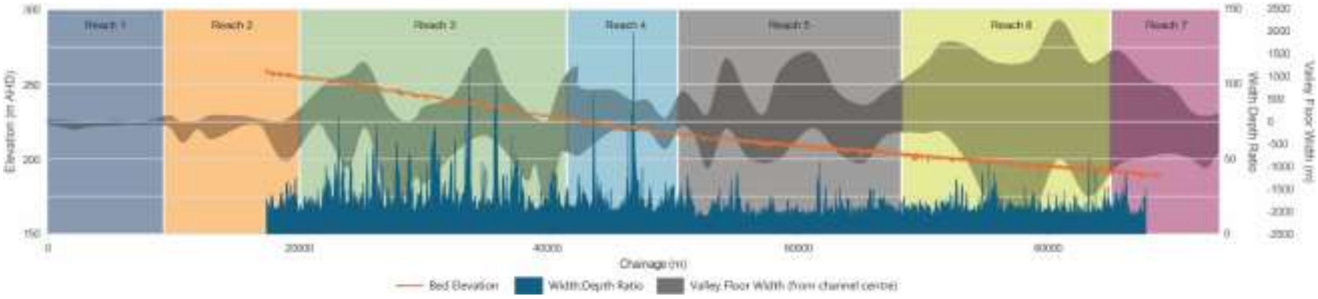

Figure 6 Example of the reach scale analysis output used to help identify trends and management reaches

Third, the desktop analysis is reviewed and interpreted at the management (or sub) reach scale to understand the river form and the degree and spatial distribution of channel change at reach scale to identify reach and site scale processes, trajectories and management implications. Integrated graphical outputs that summarise the findings are central to this interpretive step, drawing together the individual analyses into a single view of channel behaviour at the sub-reach scale.

Channel change diagrams integrated with longitudinal profile and width to depth ratios (Figure 7) are an example of an integrative output that distils information from multiple methods into a single, sub reach-scale visualisation. These diagrams can plot multiple analysis outputs (e.g. plot longitudinal trends in channel width change, dominant direction of lateral migration, bed level elevation, and W:D ratio) simultaneously in a format readable by both technical and non-technical audiences. These diagrams can be further overlaid with additional information such as erosion hot spots, erosion mitigation works, presence of willows or critical infrastructure. The diagrams proved to be a valuable output of the investigation, enabling spatial prioritisation decisions to be made with confidence across a 270 km reach.

Figure 7 An example of a channel change diagram from the Mitta Mitta project integrated with long section and width to depth ratio

Integration with field based assessments

Desktop analysis, however sophisticated, cannot fully substitute for field investigation. Channel processes, bank materials, in-channel features (bedforms, woody debris, infrastructure), and the condition of riparian vegetation are all best assessed in the field. The appropriate role of desktop analysis is to guide and target field effort by identifying the reaches and locations where field investigation will add the greatest value and to provide the spatially continuous, quantitative backdrop against which field observations are interpreted. The integration of desktop and field stages, with the desktop informing and being ground-truthed by the field-based assessments, is the central principle of the assessment framework applied across both investigations.

Management benefits

Applied in combination, the desktop methods provide an objective, data-based interpretation of channel change and the primary drivers of that change (e.g. flow regulation, soil characteristics, vegetation clearing). This evidence-based understanding of process and trajectory is fundamental for developing targeted objectives and process-driven investment, rather than reactive, site-by-site responses to isolated symptoms. It also extends naturally to reach-scale prioritisation and the identification of priority intervention sites to direct management effort to the reaches and individual sites where intervention will deliver the greatest return, across long river corridors that are not feasibly covered by field survey alone.

The inherently graphic nature of the outputs (maps, channel change diagrams, charts) supports clear communication with technical and non-technical audiences alike, including river managers, landholders and Traditional Owner groups. On the Hume to Yarrawonga project, channel change and geomorphic trajectory across a complex anabranching system were communicated to the project steering group using these outputs, with feedback indicating the assessment and resulting management framework were both clear and practical. Because the methods are objective and quantifiable, they are also repeatable: the same techniques can be re-applied at later LiDAR epochs to monitor project reaches and evaluate the effectiveness of management interventions, providing an evidence base for adaptive management.

Conclusions

Desktop geomorphic analysis using remotely derived datasets represents a cost-effective, spatially comprehensive, and scientifically defensible approach to characterising river condition and change at the reach scale. When multiple methods are integrated (e.g. DoD, REM, top-of-bank mapping, long-section analysis, and remote vegetation mapping) the resulting geomorphic picture is considerably more robust than any single method could provide. The experience of applying these methods across the Murray River and Mitta Mitta River demonstrates both their practical value and their limitations, and provides a foundation for the continued development of desktop-led geomorphic assessment as a core tool for MDB river management. However, desktop analysis methods have limitations that must be understood to appropriately interpret and apply the analysis.

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