



Murray-Darling Basin Authority
Constraints Management Strategy Costing Project
Easement Costing Methodology

05 December 2014

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1. Introduction

1.1 Background

The CMS is a 10-year phased process to investigate options to modify constraints, to assess the impacts of these changes, to identify and cost the options to avoid or mitigate impacts and to implement solutions. The CMS will be implemented in three phases:

- Phase 1 (pre-feasibility, to the end of 2014);
- Phase 2 (feasibility, to June 2016); and
- Phase 3 (implementation, until 2024).

The strategy has identified seven key areas where the relaxation of constraints needs detailed consideration for pre-feasibility assessments during 2014.

The Murray-Darling Basin Authority (MDBA or the Authority) commissioned GHD to provide expertise and resources, on an ad-hoc basis, to contribute to the Authority's development of the Constraints Management Strategy (CMS).

Specifically, GHD was engaged to develop and document a method for estimating the costs of acquiring easements that may be required to secure the ongoing right to make overbank releases that will cause third party impacts in the reaches relevant to the CMS. Application of this methodology is informing Phase 1 (pre-feasibility) of the CMS.

1.2 Purpose of this report

This report details GHD's proposed methodology for estimating the costs of acquiring easements that might be required to reflect an ongoing right to release overbank flows to meet CMS objectives. In particular, this report relates to the following Terms of Reference:

1. Develop and document a method for estimating the costs of acquiring easements that may be required for increased environmental flows in reaches relevant to the Constraints Management Strategy. This method should:
 - a. reflect and build on previous relevant work undertaken by GHD (eg to estimate the costs of easements in the Hume-Yarrawonga reach, associated with environmental flows of up to 40,000 ML/day), but with appropriate modifications to reflect the different objectives of the CMS Costing Project;
 - b. be built on sound and well-documented assumptions; and
 - c. be able to be applied in any of the CMS reaches (ie Hume-Yarrawonga, Yarrawonga-Wakool, Goulburn, SA Murray, Gwydir, Murrumbidgee, Lower Darling) if required.
2. Prepare draft and final summary reports on the costing method. These reports will include:
 - a. a technical description (for MDBA internal use) of the method which outlines:
 - (i) how it works, including the underlying assumptions;
 - (ii) a summary of the information inputs required to implement the method (eg what flow and hydrological information would be required; area of land inundated, land values, etc);
 - (iii) advice on which of the above information inputs would need to be provided by the MDBA;

- (iv) a summary of information outputs that will be produced by the method; and
 - (v) any caveats that may need to be taken into account when interpreting outputs; and
- b. “Plain English” documentation describing the method, which captures key technical aspects while also being easy to understand and a suitable tool for consultation with stakeholders.

1.3 Scope and limitations

This report has been prepared by GHD for Murray-Darling Basin Authority and may only be used and relied on by Murray-Darling Basin Authority for the purpose agreed between GHD and the Murray-Darling Basin Authority as set out in Section 1.2 of this report.

GHD otherwise disclaims responsibility to any person other than Murray-Darling Basin Authority arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report (refer to Sections 1.5 and 4 of this report). GHD disclaims liability arising from any of the assumptions being incorrect.

1.4 The issue

In each reach, floodplain land use has evolved based on landholder experiences with in-stream and overbank flow regimes. The type and siting of infrastructure located on the floodplain reflect the tolerable limit of damages caused by flood flows experienced over time.

Mitigation measures have been put in place where possible, effective and economically acceptable. By way of example, haysheds are generally located on raised land with reasonable access if on the floodplain; fence construction is robust and minimalistic to avoid the build up of debris causing extensive damages and annual winter cropping and highly improved pastures are uncommon on the lower benches of the floodplains. In some areas, levees have been constructed to reduce the extent of flooding and to protect valuable assets such as buildings.

Implementation of CMS could change frequency, duration, seasonality and extent of overbank flows. A range of flow levels is currently being explored to inform the discussion on CMS implementation.

1.5 Assumptions

The experiences over the past 20 years gained by GHD personnel in quantifying damages caused by flooding (Mirrool Creek 1993); disaggregating damages between a natural event and a special release that extended inundation duration (Murray River 1996/97); quantifying changed flow regime impacts (Mitta Mitta River 1999/2000); investigate the impact of bank full flows in the Tumut River and establish the relationship between pre and post Blowering Dam bank loss and water table movements to assess landholder claims for damages (2001/2003); establishing easements to flood, (Mitta Mitta floodplain 2001/03) and Murray River floodplain between Hume Dam and Lake Mulwala (2004/06); estimating the cost of acquiring easements

for flows 40,000 ML/day (Hume Dam to Lake Mulwala 2011); and survey of perceived impacts from managed releases to 40,000 ML/day (Hume Dam to Lake Mulwala 2011) are valuable in contributing to the Costing Project.

This report is based on the following assumptions:

- the effects due to the proposed change in flow management will impact on agricultural land use arising from changed inundation, high water tables, interrupted access and erosion;
- the overbank flow characteristics that will impact on agricultural land use are timing (season), volumes (ML/day), duration (days overbank) and frequency (events per year);
- the methodologies developed to secure easements in the past are relevant to the acquisition of easements in the future. This assumption is relevant in that the easements obtained in the past were negotiated within the guidelines adopted by NSW and Victorian land titling systems each of which has a long history of these arrangements. However, processes to meet the Commonwealth Government requirements for non-compulsory easement acquisition are yet to be settled as to acceptable practices;
- the definition and recording of affected areas, historically satisfied by 'meets and bounds' survey for easement measurement and documentation, can be satisfied by GPS measurements as the footprint boundaries from water incursion are highly irregular and vary over time. In addition, the boundaries are influenced by small and changing impediments to flow behaviour or are impeded by structures such as levees;
- standard unit rates can be developed from past experience and applied to modelled inundation footprints to contribute to higher level estimates to guide the CMS Costing Project;
- the impacts arising from inundation, interrupted access and erosion are quantifiable with qualified confidence notwithstanding the imprecisely defined proposed environmental flow regimes and the absence of experience over the past 30 or more years in the patterns likely to exist in the future;
- in the absence of experience with managed flow regimes delivering environmental water, modelled flow behaviour is the most appropriate means to provide inundation footprints from which the cost to acquire the lasting right to cause third party impacts can be measured;
- data from state-based agencies, such as NSW Department of Primary Industries and Victorian Department of Environment and Primary Industries, can provide base level inputs to the calculation of costs;
- present land use on the floodplain reflects the tolerable limit of damages caused by overbank flows;
- participation in the easement process would be on a voluntary basis;
- crown land would not be included in the easement process on the basis that it is not traded in the market place;
- where crown land is leased for commercial use with a documented lease arrangement that includes a lease payment and an unexpired term, it may be necessary to pay compensation at a rate reflecting the impact on the residual value of the lease; and
- impacts to land uses other than agriculture (eg tourism, extractive industries) will be considered via a separate process to be determined by MDBA.

1.6 Structure of this report

The key lessons and assessment principles arising from previous relevant work undertaken by GHD are summarised in Section 2. GHD's proposed methodology for estimating the costs of acquiring easements is presented in Section 3. Section 4 discusses the key parameters.

2. Experience with easement cost

Easements have been used in the Murray-Darling Basin to secure additional rights from landholders to flood land, including impeding access to private land and other impacts, as a result of changed flooding regimes that can increase the duration and frequency of inundation. Some examples of previous easements include:

- Murray River between Hume Dam and Lake Mulwala
- Mitta Mitta ex-gratia relief project
- Mulwala surcharge easements
- Other easements created by state agencies.

The methodology developed to acquire easements to flood for the Murray River reach between Hume Dam and Lake Mulwala is explained in the *Report for Full Regulated Flow Easement – Hume Dam to Lake Mulwala End of Assignment Report* dated 15 July 2013 prepared for MDBA by GHD. This easement acquisition was not compulsory and followed extensive consultation with stakeholders during the development of the process to provide compensation for the easement under the label of "by agreement". The adopted process reflected an agreement between the affected landholders and the Murray Darling Basin Commission on quantification of the impacts.

On the Mitta Mitta, establishing easements to flood followed the more traditional process of negotiations between two registered land valuers, one representing each party. It was based largely on detailed analyses of recent comparable land sales. Experience elsewhere particularly with highway upgrades and power lines passing through agricultural land has followed this procedure when dealing with land or easement acquisition.

In all cases, the process involved recognition that the altered circumstances led to a changed value of the residual land asset due to reduced income earning potential and/or to increased costs that are reflected in the productive component of the asset and subsequently its market worth.

For the Hume Dam to Lake Mulwala bank full flow easements, the level of compensation for the easements was reached by application of a set of principles that were developed from the following information:

- footprint for instream flows at 25,000 ML/day measured at Doctors Point;
- land use by property (ha) – livestock dominated the land use;
- stocking rate by affected property (dse/ha) – data from 1994, 1995, 1996 and 2004 field surveys;
- agricultural land worth by livestock unit (\$/ha) – derived by sales analyses identifying the worth of pastured, watered and fenced land principally used for grazing and affected by the flows to 25,000 ML/day;
- areas (ha) affected by inundation, high water table, seepage, interrupted access and erosion from anabranch development identified from field inspection and use of high quality orthorectified aerial photography overlaid with the relevant cadastre;
- affected areas (ha) separated into freehold and Crown Land title¹ (ha); and
- infrastructure impacts based on field survey data.

¹ *The decision was taken that only freehold land would be considered for easements on the basis that crown land is not traded in the market place and hence does not experience diminution in value for which compensation should be considered.*

For the Hume Dam to Lake Mulwala cost estimate relating to the impacts from managed releases for environmental flows up to 40,000 ML/day, the following information was assembled:

- footprint for flows at 40,000 ML/day measured at Doctors Point generated from Lidar data;
- incremental areas for the major impacts;
- an estimate of the change in agricultural land worth derived from data supplied by NSW Land & Property Information published data and applied to the 2004 agricultural land worth;
- data from a survey of floodplain stakeholders on the anticipated impacts from the increased limit of managed releases to meet environmental purposes – the surveyed stakeholders were provided with individual property aerial photographs overlaid with the footprint boundaries for 25 and 40,000 ML/day flows; and
- degree of affectation for each major impact based on the 2004 easement process – the adopted affectation was 100% for anabranch erosion, 49% for inundation, high water table and seepage and 5% for interrupted access. These multipliers represent the average of all observations derived from detailed paddock by paddock inspections made in the company of the landholder. The scoring principles that guided field determination of the degree of affectation reflecting the diminution in productivity were as follows:
 - inundation and seepage based on floodplain level and the condition of the land ranging from 20% (small) to 100% (large);
 - interrupted access based on duration of the interruption ranging from 50% to 100% of the measured land worth after recognising the level of interruption prior to managed flows;
 - water table impacts based on tree density ranging from 50% to 100% and pasture composition ranging from 40% to 80%;
 - bank erosion associated with existing anabranches at 100%; and
 - future bank erosion based on an allowance for actively eroding sections.

Main stem erosion was ignored on the basis that this occurred in the past and that experience suggested that erosion of consequence was occurring in the anabranches and not the main stem.

For the overbank flow cost estimate referred to above, it should be noted that:

- no cost was included for the on-costs associated with field work, administration, professional fees (legal, survey) or other costs to implement;
- no cost was recognised for the possible interventions that might reduce impacts;
- the 2004 process was not compulsory; and
- no account was taken of the changed frequency of over bank flows or of the duration of these flows both of which are key determinants of the degree of affectation. This aspect is likely to affect interrupted access initially and it will only be with experience that mitigation management measures to reduce the impacts can be developed.

In summary, the approach involved the following steps each of which is detailed in the following section:

- identifying the marginal impacts from altered flow behaviour (season, duration, volume and erosion) on productivity;
- multiplying areas inundated and experiencing interrupted access by a factor reflecting the degree to which the productive land worth is affected by altered flows (degree of affectation);

- disaggregating the sales evidence into the components giving value namely agricultural production worth, infrastructure worth and amenity worth; and
- including additional costs associated with anabranch erosion and mitigation.

2.1 Marginal impacts from increased flows

Marginal impacts are expected outcomes from changes to flow regimes. The impacts include:

- inundation due to ponding and seepage;
- interrupted access to land areas that are not flooded;
- water table changes that promote timber regrowth (suckers) and reduce pasture health; and
- erosion and silt deposition along anabranches (but not the main stem of the river).

The above impacts affect agricultural productivity and profitability, for example:

- inundation and water table changes can reduce crop and pasture growth, promote weed incursion and potentially damage or kill pastures necessitating expenditure on re-establishment; and
- interrupted access leads to lost grazing opportunities and/or interruptions to crop and livestock husbandry that could reduce production.

Production impacts will change depending on the type of land use (eg grazing versus cropping) and also from property to property eg depending on the type of enterprise and the proportion of the total property affected.

In some circumstances, changes to an existing flooding regime may result in increases in crop and pasture production. This will depend on antecedent conditions including prior rainfall, soil type, pasture response to inundation and land use.

One risk that was encountered during assessment of the impacts from the extended duration flows following the special release from Hume Dam in 1996 was levee failure due to lengthened challenge (extended duration) and/or poor maintenance. Failure tended to penalise those landholders downstream from the break as the intruding water was unable to escape back into the waterway and subsequently did considerable damage to crops and pastures.

2.2 Assessment of agricultural land worth

A property's market value, based on sales evidence, can be divided into three components:

- agricultural worth;
- infrastructure (buildings, livestock handling facilities, water supply, internal access roads etc); and
- lifestyle or amenity worth.

For the purposes of the methodology described in this report, increased flows are assumed to impact on the agricultural worth of the land and potentially infrastructure, but not the lifestyle value. The agricultural worth is the base market value for cleared, fenced, watered and pastured land (known as "ex buildings") sourced from recent disaggregated property sales.

Key assumptions

- Agricultural land worth reflects the net present value of future income derived from agriculture.
- Implementation of CMS will alter the productive capacity and consequently the agricultural land worth.

- Increased damage to infrastructure causing increased cost of production will reflect on agricultural land worth.
- Land supporting mature and immature timber is valued separately to cleared land based on productivity.

2.3 Degree of affectation

Assumptions are made as to the extent of production impacts from the CMS regime compared to the behaviour of flows that have given rise to the current production systems. For grazing enterprises, this impact will be reflected in a reduced carrying capacity of the land which can be expressed as a foregone income or as additional cost. The percentage difference is referred to as the “degree of affectation” and is a permanent reduction in the productive capacity of the agricultural land.

The use of gross margins impacts from events that cause losses (or gains) incorporated into a frequency sequence allows calculation of the degree of affectation when compared to unaffected gross margins.

Key assumptions

- Existing overbank flows cause impacts to agricultural production.
- These impacts are understood by affected landholders.
- The current land use reflects an acceptance of the risks from current pre-CMS flow regime.
- The degree of affectation is the marginal impact resulting from CMS implementation.
- The lifestyle component of the land value is assumed to be unaffected by changes to managed flows.

2.4 Additional impacts

Additional impacts include marginal changes to the following:

- erosion and/or silt deposition along anabranches (note that main stem erosion is excluded on the basis that this occurs during the normal course of events) resulting in the permanent loss of land area available for agricultural production;
- damage to infrastructure (fences, water points, irrigation infrastructure, internal roads etc);
- cost of mitigation measures; and
- management interruption caused by a flooding event that requires the land manager to incur additional costs (eg fuel, communications, repairs and reinstatement) to ensure the efficient operation of agricultural land. In addition, diversion of land manager time to flood management could reduce oversight of agricultural enterprises which in turn could cause production losses.

The combination of all of the above impacts will lead to a permanent reduction in agricultural production on the affected land and consequently the agricultural worth of the land.

3. Methodology to cost easements

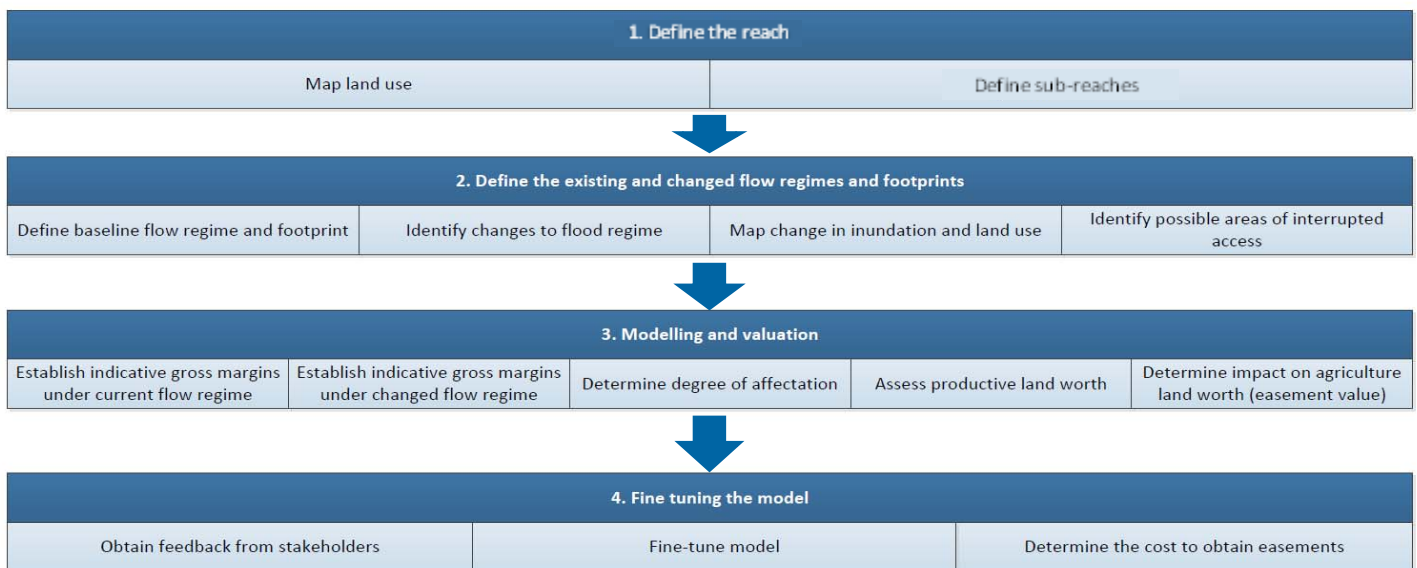
GHD proposes a methodology for establishing the costs of easements in each reach based on the following four steps:

1. Defining the reach;
2. Defining the existing and changed flow regimes and footprints;
3. Modelling and valuation of impacts; and
4. Fine tuning the model.

Modelling will be based on the development of a generic Excel model with key variables that calculate the cost of easements. The model will enable changes in key variables to be adopted for each of the reaches and flows under consideration. The values adopted in the model will be based on the best available information. A range will be provided where robust information is not readily available.

The methodology applies to estimating costs at a regional level. It will be structured to provide cost estimates for a range of overbank flows. Figure 1 shows a summary of the methodology.

Figure 1 Summary of methodology



3.1 Describe the reach

This step involves developing an understanding of the extent of a reach, its land uses, agricultural enterprises and natural characteristics. Within each reach, areas of like land use and topography may be divided into sub-reaches to improve the accuracy of the model.

Each reach will be broadly defined based on available data (MDBA, Australian Bureau of Statistics, Bureau of Meteorology, and other) in following terms:

- Hydrology
- Topography
- Agricultural enterprises
- Agricultural land use by area (ha)
- Rainfall or access to irrigation
- Agricultural capacity (stocking rates, crop yields).

3.1.1 Map land use

Land use will be mapped in each reach using the catchment-scale land use data available through the Australian Department of Agriculture's Australian Collaborative Land Use and Management Program (ACLUMP) or other more current available land use data sources. ACLUMP uses the Australian Land Use and Management (ALUM) classification system that provides a nationally consistent method to present land use information across Australia. This mapping will identify the broad classifications of agricultural land use which have been aggregated into the following categories²:

- Grazing Tolerant Pasture
- Grazing Vulnerable Pasture
- Cropping
- Horticulture

Where appropriate similar land use types will be aggregated based on comparable profitability and/or response to overbank flow challenges.

In each reach, areas will also be separated into privately leased and public lands, including national and state forests.

3.1.2 Define reaches

The reach may be divided into sub-reaches to add precision to the estimated cost to acquire easements. To achieve benefits from the subdivision, it is desirable to disaggregate on the bases of like land use and land use combinations.

The profile of land use will form the basis for measuring impacts. This information will be amended and added to over the course of the project, as more information becomes available.

² Note the land use categories for the Goulburn reach have been defined by previous work from Water Technology Pty Ltd (2014).

3.2 Define the flow regime and footprint

3.2.1 Define the baseline flow regime and footprint

The baseline flow regime in the CMS reach will be described using flow characteristics (volume, frequency, duration and seasonality). It is assumed that current land use, agricultural management and provision of infrastructure has now stabilised in response to the current flow regime and this establishes a baseline from which proposed changes in flow can be measured and impacts identified. The prime measurements are areas inundated (ha), duration (hydrograph showing days at given flows), season and frequency.

3.2.2 Identify changes to overbank flow regime

In each CMS reach, a range of different flow regimes will be explored. These flow regimes will be defined based on expected flow characteristics (volume, frequency, duration and seasonality) for each reach and sub-reach. This information will be obtained from MDBA modelling.

The underlying assumption regarding the baseline flow regime is that the existing land use reflects the tolerable economic limit from impacts from overbank flows experienced since flow management became possible. The major factors influencing the decisions on land use have been the volume, frequency, duration and seasonality of overbank flows combined with bank full flows servicing consumptive demands.

The flow regimes being explored in the CMS would change the volume, frequency, duration, seasonality and inundation footprints. To estimate the cost of securing easements that would be required to secure an ongoing right to deliver these flows, there is a need to identify the increment for each characteristic and their combined impacts on the profitability of the land use with the proposed CMS flow regime characteristics (see hypothetical example in Table 1).

Table 1 Flow regime parameter definition

Parameter	Definition	Value ranges
Volume	Expressed in ML/day by range eg 10,000 to 12,000 ML/day.	Range identified at a number of recording points along the river from the storage to the confluence with the Murray River
Frequency	Expressed as number of events per year	Determined by MDBA modelling over past 114 years
Duration	Expressed in days by the volume being examined	≤7 days and >7 days
Seasonality	Captures the different stages of the growing season when overbank flows occur	Slow (Jul-Aug) Active (Sept-Oct) Mature (Nov-Dec)
Inundation footprint	Expressed in hectares	Differentiate inside and outside levees
Interrupted access	Expressed in hectares	If measurable, in hectares, if not measurable, link to area inundated
Land use	Expressed by enterprise by hectares	Determined by reference to ACLUMP

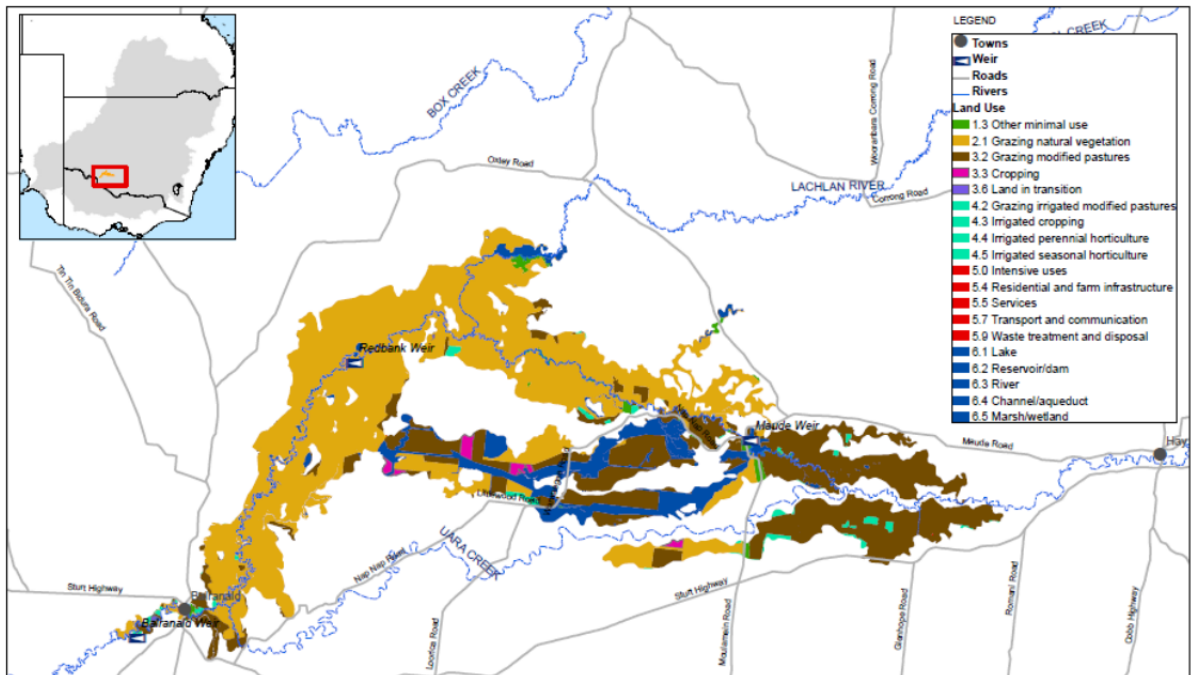
3.2.3 Mapping change in inundation and land use

MDBA will provide data for each reach (including sub-reach) showing the expected inundation footprint and these will be overlaid with land use data to determine area of land potentially impacted by land use type. Figure 2 provides an example of an inundation footprint by land use map for the Lower Murrumbidgee. Ideally, based on hydrology modelling, the maps could show duration and season of

flooding for each land use type. Alternatively, MDBA will provide tables that show changes in duration and season of flooding for the different land use types.

MDBA will also provide details on privately leased and public lands, including national and state forests.

Figure 2 Example of inundation and land use mapping (Lower Murrumbidgee)³



3.2.4 Identifying potential areas of interrupted access

MDBA's inundation extents will be used to estimate areas of potentially interrupted access for each of the flow regimes. These will initially be identified through islands of dry land within the inundation extent and review of access roads to these areas. At this level of investigation, it will be difficult to identify areas of interrupted access where individual landholders have parcels closed off by neighbouring landholdings.

Consideration will be given to the delay in gaining access post recession and to the need to repair access tracks within properties.

3.3 Modelling and valuation

The purpose of this step is to develop and apply a model to determine the change in agricultural land worth as a result of changes to flow regime. Broadly this step involves assessing the current productive land worth, and the degree to which this will be affected by changes in flows.

An Excel-based model will be developed to bring together the elements of the cost to acquire the easements the components of which will include the following:

- profile of land use by reach (and sub-reach);
- changes in flow regime;
- agricultural land worth;
- production impacts; and

³ MDBA 2012. *Assessment of Benefits of the Basin Plan for Primary Producers on Floodplains in the Murray-Darling Basin*. Note this map depicts the total inundated area, rather than the marginal inundated areas.

- degree of affectation.

The model will provide an indicative easement cost for each reach and sub-reach.

3.3.1 Establishing indicative gross margins under current flow regime

Indicative annual gross margins (\$/Ha) will be established for each type of land use within the inundation area. Indicative gross margins will be linked to rainfall and indicative productivity (DSE/Ha) given the existing flow regime. As a result gross margins will vary for different land uses and within different reaches.

It is assumed that the majority of affected land is grazing land with combinations of natural and improved (annual and perennial) pastures. Where land use is dominated by dryland grazing on the floodplain, stocking rates are generally linked to rainfall.

3.3.2 Establish indicative gross margins under changed flow regime

Indicative gross margins under the changed flow regime will be established by subtracting indicative costs and production impacts associated with each additional flow or change in flow characteristics. The costs and production impacts arising from the changed flow regime will be identified and estimated based on the framework provided in section 4.

There are circumstances where the change in inundation will deliver benefits. For these circumstances the following factors will be considered:

- pasture types that have tolerance to inundation;
- pre flood event stocking rate;
- duration of exclusion from grazing the area inundated;
- benefit from increased stocking rate by duration when access becomes available; and
- weed control where applicable.

The plan is to treat factors that give rise to costs as positive in the sense that we are identifying the cost to acquire easements and benefits as negative as they should reduce the cost.

3.3.3 Determine degree of affectation

The degree of affectation represents the degree to which the impacts identified above will affect the productivity and profitability of the land.

For each land use, the degree of affectation will be determined by comparing the indicative gross margins under the current flow regime with those of the changed flow regime.

The degree to which the gross margin is affected by the changed flow regime, will be considered the degree of affectation for that particular land use.

3.3.4 Assess productive land worth

For this project, agricultural land worth (\$/hectare) for different types of land uses in different reaches will be obtained from public sources. In NSW, values are available from the Land and Property Information (LPI) division of the NSW Department of Finance and Services. LPI disaggregates sales evidence to record the land value only. Land improvements such as clearing, filling and draining are included in the assessed agricultural land worth.

The Victorian Valuer General can also provide land value data (collected for rating purposes) aggregated by municipality and land use. These data can be presented in terms of unimproved, productive value, equivalent to the data provided in NSW.

For those areas not covered satisfactorily by the two departments, it will be advantageous to consult a local experienced land valuer to assist establish a base or land worth for the main land uses.

It should be noted that grazing land worth is often expressed in terms of \$'s per dry sheep equivalent (dse) and when combined with livestock carrying capacity (ie dse/ha) this enables a mechanism of checking agricultural land worth.

The costing project will require agricultural land worth for each sub-reach where the sub-reach reflect different land use characteristics and or have different levels of productivity.

3.3.5 Determine impact on agricultural land worth (easement cost)

Multiplying the degree of affectation by the productive land worth will determine the indicative impact, or easement cost for each type of land use in each reach. Aggregating the impacts for all land uses across all sub-reaches will provide the total estimate of easement costs. The final estimate will consider the costs of mitigation and miscellaneous impacts.

3.4 Fine-tuning the model

This step will involve testing and amending the assumptions in the model and developing the final estimated easement cost.

3.4.1 Advice from stakeholders

The assumptions that underpin the estimation of the cost to acquire easements would benefit from advice from stakeholders that could inform improvements to the assumptions that underpin the calculations.

3.4.2 Determining the estimated cost of easements

MDBA will be provided with a brief report outlining the estimated cost of easements for each CMS reach. The cost of easements will be expressed as a range recognising that values adopted in the model are first best estimates. The range will highlight the key drivers of cost and the sensitivity to the assumptions.

3.4.3 Administrative costs of establishing easements

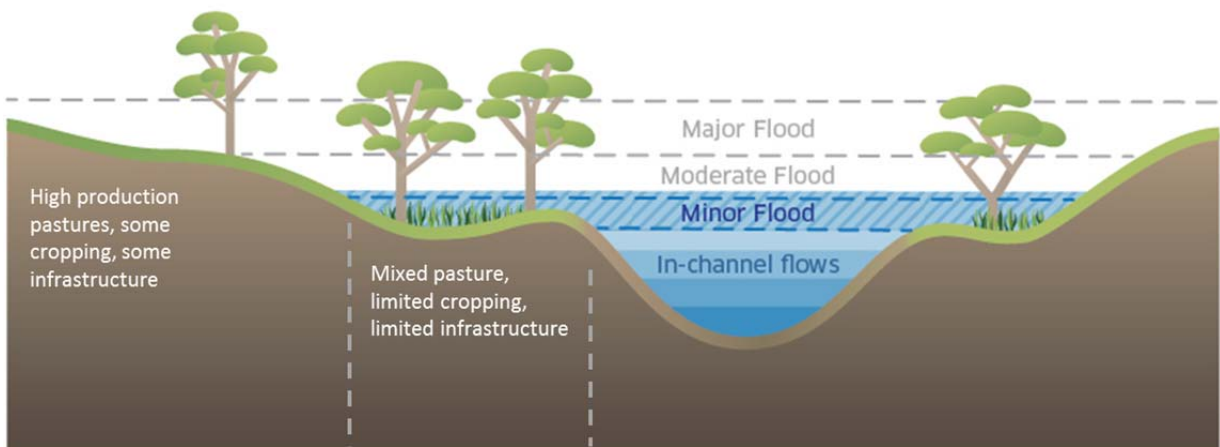
If it is decided during CMS implementation that easements should be acquired in a reach, there will be administrative costs required to negotiate and establish easements with individual land owners. These costs include establishing the criteria for calculation of the level of compensation, site inspections and negotiations with land owners and legal costs to include easements on land titles. For the purposes of developing pre-feasibility cost estimates, GHD will adopt a multiplier based on previous experience with easement projects.

4. Model parameters

Following are the various parameters for assessing flow impacts and the approach for including each within a model to calculate the cost of acquiring easements. The impacts of flow regime change are a function of biophysical interactions within the soil-plant-livestock-climate complex. This complexity means it is difficult to be precise about the impacts. Scientific literature and past experience are combined to provide a range of likely values for incorporation in the model, but the values include simplifying assumptions necessitated by the unavailability of firsthand experience with the proposed managed flows to meet desirable environmental outcomes.

The model parameters will be developed on the assumption that the flow regimes being explored through the CMS would (if implemented) be managed events, with the aim of getting water to low-lying floodplain forests and wetlands that are already flood-prone. Our experience is that flooding associated with such events is on lower benches which are characterised by mixed pasture, limited cropping and limited infrastructure. A schematic outlining these characteristics is outlined below in Figure 3.

Figure 3 Schematic cross section of a river showing flood levels and the range of flows being explored through the Strategy



Source: Adapted from MDBA (2013) Constraints Management Strategy 2013 to 2024

4.1 Inundation impacts on crops and pastures

The major thrust of research work examining the relationship between inundation and plant responses has been driven by:

- an interest in the physiological responses and the causes of plant reaction to inundation that have explained what happens during and following inundation. A paper titled “Response and adaptation by plants to flooding stress” by Jackson and Colmer, June 2005 draws attention to the molecular, biochemical and development processes that impact on flooding tolerance by plants.
- an interest by irrigated agriculture in minimising water application and optimising plant responses with reference to pastures and crops. Application of flood irrigation practices involves saturating soils as occurs with flooding and causes disturbance to plant growth for all the reasons explained by Jackson et al.

The State Departments of Agriculture publications draw attention to the characteristics of inundation that give rise to adverse impacts namely duration, the pasture species/crop type, the amount of

residual silt and debris and the season or growth phase of the plants. The valuable guidelines emerging from these papers include:

- short term duration (less than 7 days) can (a) damage sensitive species and (b) can deliver subsequent benefits by wetting the soil profile to depth that enables active growth after recession;
- medium term duration (from 7 days to 14 days) can severely affect sensitive species more particularly during active growth and leave tolerant species to dominate pasture swards; and
- extended duration (more than 14 days) will kill introduced productive pasture species and will set back moderately tolerant species.

Inundation impact will be a function of crop or pasture types and volume, duration, seasonality and frequency of flows. Crop and pasture response will vary accordingly and GHD will construct a model that recognises the interactions and calculates responses. Damage to pasture and crop yields are modest at low flows duration and then increase before reaching a threshold level that causes pasture and crop death. For some soil types, the residual moisture following an overbank flow provides the opportunity to obtain substantial crop benefits subsequently. Damaged pastures that require renovating that will incur direct costs for seed, fertiliser etc while killed pastures must be re-established. An additional cost arises from foregone grazing for the period while the establishing pasture reaches maturity. A convenient measure of this cost is the cost of agistment for the period during which grazing is not possible.

4.1.1 Flood duration

Overbank flow impact studies by GHD, undertaken prior to assessing flood damages in 1997 on the Murray River floodplain below Hume Dam, indicate yield declines up to 26% for improved pastures (Table 2) depending on duration of flooding. For the CMS costing project, GHD will develop a series of response curves (or tables) similar to the conceptual diagram shown in Figure 4 to model yield decline for crops and pastures within the reaches. Examination of published papers indicated the paucity of relevant research on the impacts of interest. Since then, published work has largely confirmed the earlier work and discussions with experience observers gives credibility to the duration/season interactions.

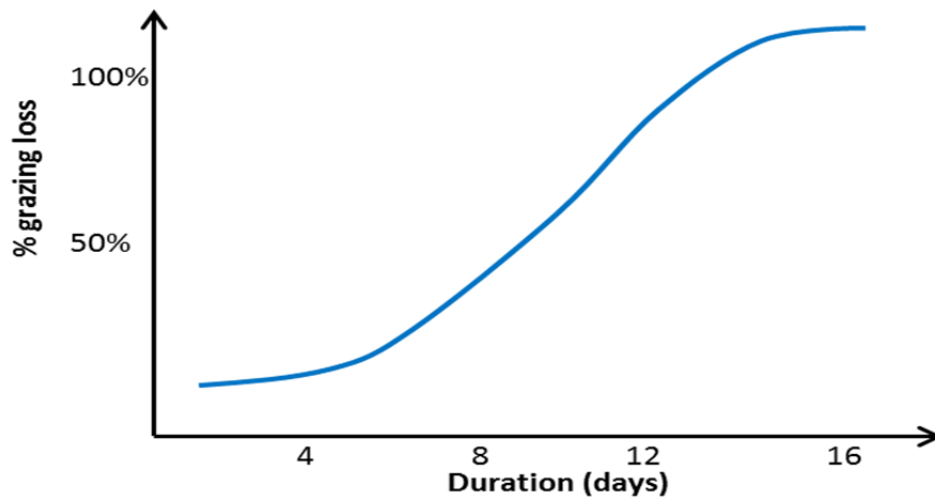
The survival of inundation tolerant species is common on the lower benches of upstream floodplains that experience regular inundation. These areas tend to be productive sometime after an event and can be very valuable where native legumes are a feature of post inundation growth. However, the major surviving species are relatively low producing and weed invasion is a serious challenge.

Table 2 Yield depression for improved pastures

Crop	Reference	Location	Length of waterlogging (days)	Yield decline (%)
Perennial Pasture - white clover, ryegrass, paspalum	Blaikie and Martin (1987)	Kyabram, Victoria	1	25% in white clover and 0% in paspalum
Perennial Pasture - ryegrass	Rogers and Davies (1973)	Tatura, Victoria	112	25%
Perennial Pasture - ryegrass	Donohue et al (1985)	Griffith, NSW	8	25%
Annual Pasture - subterranean clover	Francis and Devitt (1969)	Western Australia	21	26%

Downstream in the drier areas, inundation experienced in the cooler months produces enhanced pasture production that delivers economic benefits.

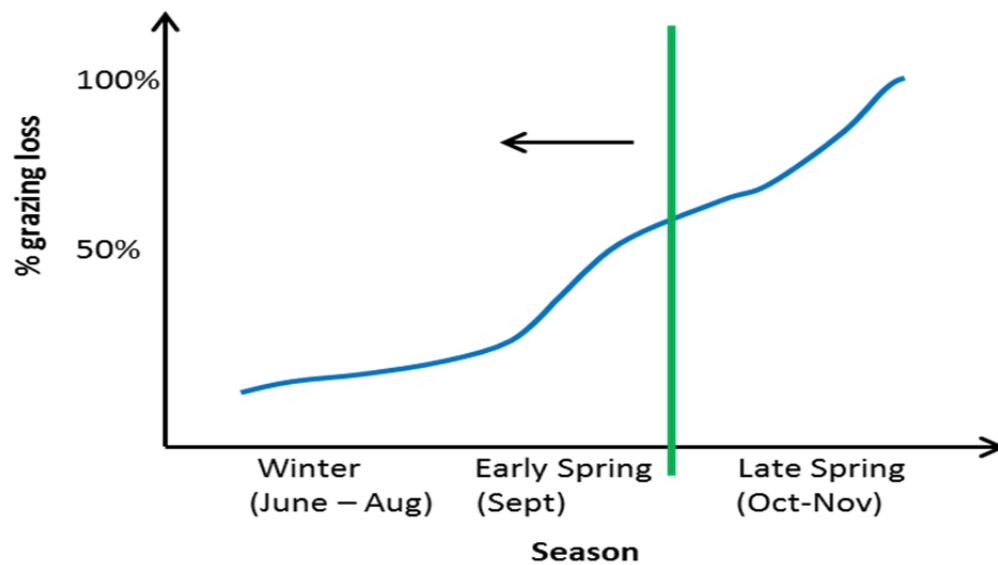
Figure 4 Yield depression by duration of flooding on pastures (not to scale)



4.1.2 Seasonality

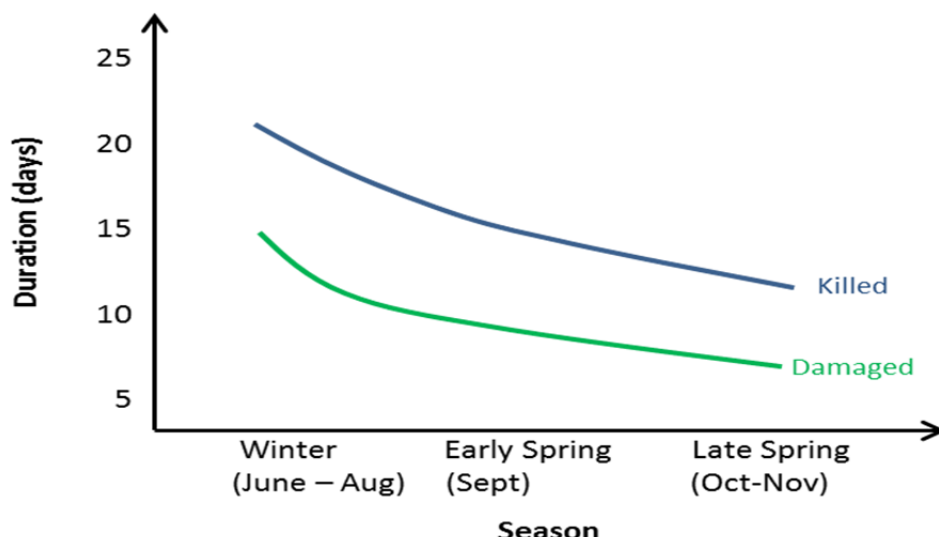
Similar to 4.1.1, response curves (or tables) will be generated for yield depression as a function of season of inundation noting that yield depression increases as the season of flooding progresses from winter to late spring. It is assumed that there will be no managed releases in summer. A conceptual response curve is shown in Figure 5.

Figure 5 Yield depression by season of flooding (not to scale)



An alternate way of presenting the interaction is shown below.

Figure 6 Duration season interaction on crops and pastures



4.1.3 Frequency

Increasing frequency of flood events has a clear impact on productivity, and will be factored into the model. However, importantly, the model will account for the fact that two or three flood events occurring within a short period of time, will not result in twice or three times the impact of a single flood event. This is because the damaged pasture and infrastructure will not have recovered or been replaced from the first flood.

To account for this feature, the model will apply a series of multipliers to discount the damage associated with floods which follow prior flood events. Table 2 provides an indicative set of multipliers which were applied to the Murray River segment of the Murray and Mitta Mitta flood damages study (MDBA 1997). These multipliers may be adjusted for different reaches or rivers. The estimates were generated from extensive workshop sessions with affected floodplain landholders.

Table 2 Proportion of previous damage which second flood causes

Time since last flood	Murray River
<30 days	30%
<90 days	70%
90 days – 1 year	81%
> 1 year	91%
>2 years	97%
>3 years	100%

For each land use, a matrix of yield depression will be constructed based on duration, seasonality and frequency and the combined result of crop and pasture depression will be used as the degree of affectation for calculating the cost of easements.

4.1.4 Pasture restoration and weed control

Under certain flooding conditions (ie above threshold levels as a result of the interaction of duration, seasonality and frequency) pastures may be severely damaged or killed and thus require resowing/renovating to restore their productive capacity to pre-flooding levels. This will require direct costs of pasture re-establishment (seed, fertiliser, herbicides, machinery, labour etc) and also the cost

of providing feed for livestock (eg agistment) for a period (the de-stocking period) while the newly sown pasture becomes established.

Weed control

Floods can promote weed invasions on crop and pasture land. Flood affected pastures are less vigorous and therefore less able to out-compete weeds (including suckers of timber species). In addition, the flood event provides an opportunity to carry novel weed seeds onto the floodplain and creating a need for costly control.

The cost of weed control will be included in the cost to floodplain landholders.

4.2 Interrupted access

Interrupted access occurs on land that is not directly flooded but which cannot be accessed by property managers during a flood event. Interrupted access is a function of the topography of the land and internal road network (including crossings such as bridges and culverts). Impacts can be many and varied. Comments from surveys undertaken in 2011 raised the following points:

- crops and pastures (including for hay), harvest delay results in loss of production and/or quality, delay in applying herbicides or insecticides can reduce yield; and.
- livestock – mustering delays reduces marketing opportunities potentially impacting on price received; inability to provide timely animal health treatments (drench, vaccines) reduces production (eg growth rates) or increases mortality; inability to provide supervision at critical times (eg calving, lambing) causes reproductive losses; confinement causes overgrazing of pastures impacting on both livestock production and pasture survival.

In each case, extending the warning period will increase the opportunity to mitigate impacts.

The model will adopt a value for the extent of interrupted access and adopt an average gross margin reduction for calculating the easement cost. In the absence of mapping from which areas can be measured, the proposal is to link interrupted access to area inundated.

4.3 Inundation impacts on infrastructure

The flow regimes being considered through the CMS would (if implemented) be managed events. Generally, the farm infrastructure reflects location and standard of knowledge of floodplain flow behaviour of the current natural and managed flow regime. Landholders have a maintenance and replacement schedule for infrastructure that reflects the impacts of periodic flooding. However, incremental flows under consideration may result in increased maintenance costs and an accelerated replacement schedule. The model will recognise this and will reflect the changes using an appropriate multiplier.

The multiplier will include recognition of damages to fences, internal roads and bridges, dams and water supply (pumps, pipes).

Infrastructure is generally more intensive for smaller farm sizes and the multiplier will include an adjustment to reflect this.

4.4 Stream bank erosion

There is potential that the flow regimes under consideration will result in flows along existing or developing anabranches that will cause stream bank soil erosion. This land will no longer support agricultural production. An estimate of the extent of land lost to erosion, valued at its agricultural worth, will be included within the easement costing model.

4.5 Interruption to management

Landholders are required to divert time and energy away from normal property management when confronted with flooding. Also, they incur additional costs on management activities including fuel for crop and livestock inspections and communication costs such as phone calls.

The model will incorporate a provision to reflect interruption to management.

GHD's proposed assessment framework is summarised in Table 3 below.

4.6 Summary of actions

Figures 7 and 8 present a diagrammatic representation of the processes involved in estimating the cost of obtaining easements.

Figure 7 Process for establishing base line flow and landuse

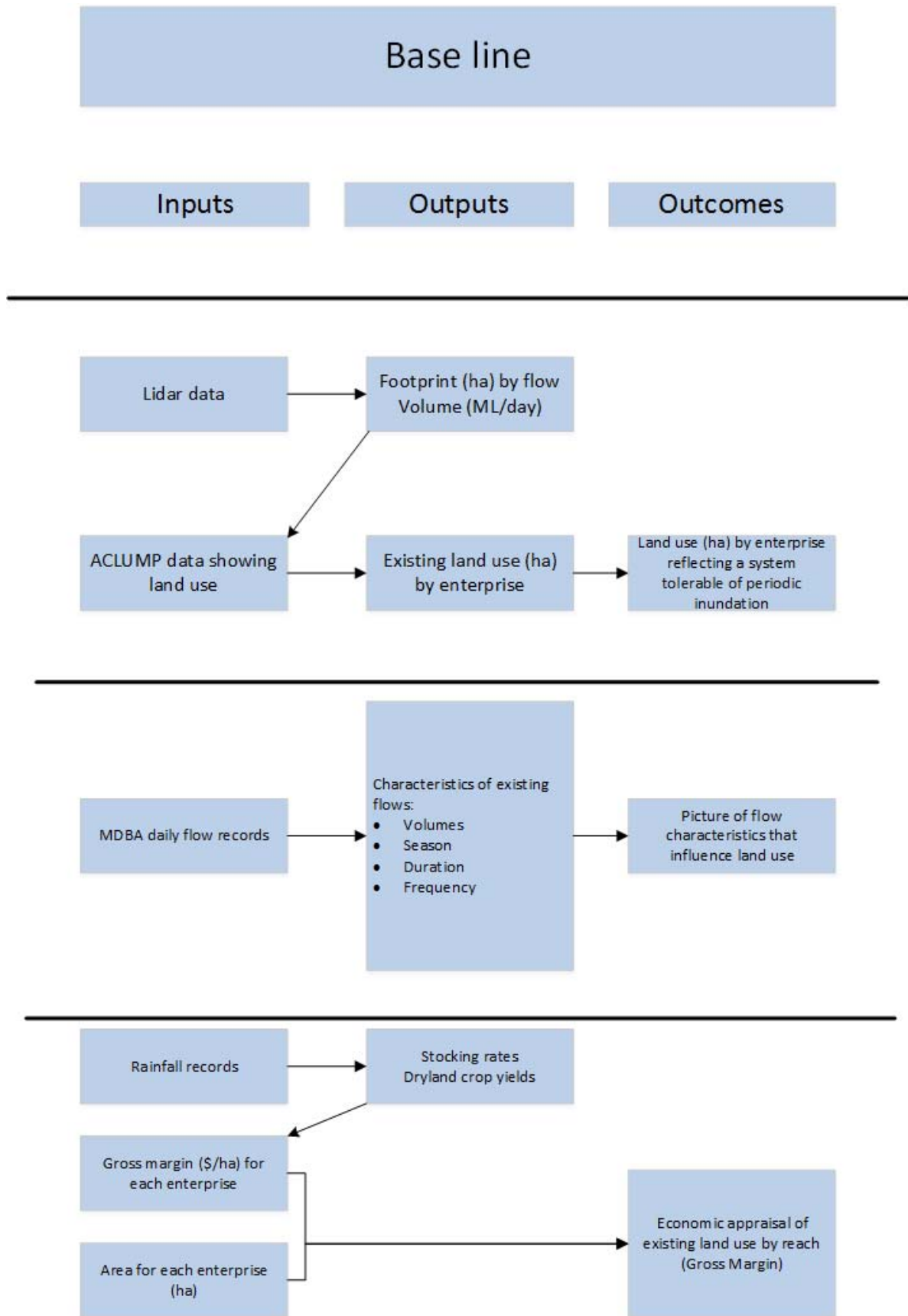


Figure 8 Process for establishing changed flow regime and easement value

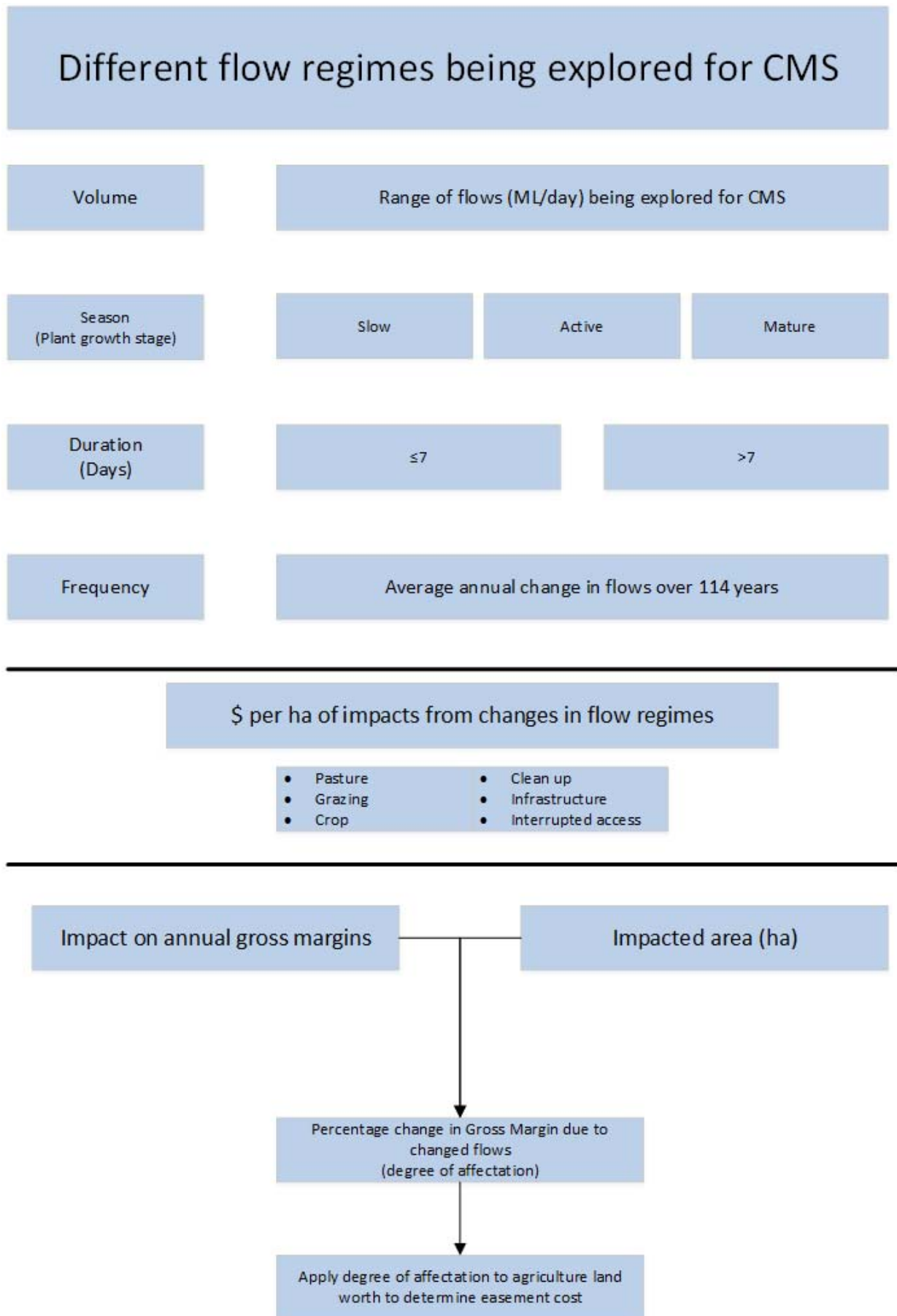


Table 3 Assessment framework

Impact	Land use (ACLUMP)	Output	Input (marginal impacts)	Data required and potential sources of information	
Inundation (also factoring in change in frequency, duration and seasonality)	Crops and pastures	Area inundated (ha), degree of affectation (% reduced production)	Seasonal influence, weed control, pasture restoration, foregone grazing, duration, frequency, agricultural land worth	Stocking rate (dse/ha) and average yields (t/ha)	NSW Department of Primary Industries: http://www.dpi.nsw.gov.au/agriculture/farm-business/budgets/livestock/sheep/background/dse Ground-truthing with expert panel
				Land worth (\$/ha)	Land valuation reports from Land and Property Information (LPI) division of NSW Department of Finance and Services: http://www.valuergeneral.nsw.gov.au/your_land_value/historical_land_values If not available, MDBA to engage land valuers
				Footprint mapping (marginal change including any planned mitigation works)	MDBA, including overlay of ACLUMP to determine areas of different land uses impacted.
				Hydrology modelling (volume, duration, frequency, seasonality)	MDBA, including overlay of ACLUMP to determine areas of different land uses impacted
				Cost of pasture damage, foregone grazing, crop damage, clean up, fencing and impeded access	Previous GHD / Hassall reports, previous relevant MDBA reports, other relevant research reports available in the public domain. Ground-truthing with expert panel
Interrupted access	Crops and grazing enterprises	Area interrupted (ha), degree of	Seasonal influence, weed control, duration,	Stocking rate (dse/ha) and average yields (t/ha)	NSW Department of Primary Industries: http://www.dpi.nsw.gov.au/agriculture/farm-business/budgets/livestock/sheep/background/dse Ground-truthing with expert panel

Impact	Land use (ACLUMP)	Output	Input (marginal impacts)	Data required and potential sources of information	
		affectation (% reduced production)	frequency, agricultural land worth, degree of affectation	Land worth (\$/dse)	Land valuation reports from Land and Property Information (LPI) division of NSW Department of Finance and Services: http://www.valuergeneral.nsw.gov.au/your_land_value/historical_land_values If not available, MDBA to engage land valuers
				Footprint mapping and identification of 'islands' (marginal change including any planned mitigation works)	MDBA, including overlay of ACLUMP to determine areas of different land uses impacted
				Hydrology modelling (volume, duration, frequency, seasonality)	MDBA, including overlay of ACLUMP to determine areas of different land uses impacted
				Cost of weed control, etc	Previous GHD / Hassall reports, previous relevant MDBA reports, other relevant research reports available in the public domain
Stream bank erosion	All	Value of eroded land	Anabranch length by width of erosion, agricultural land worth	Linear length (km) and width of anabranches	GIS analysis. In the absence of GIS data, adoption of multipliers based on previous GHD reports
				Land worth (\$/ha)	Land valuation reports from Land and Property Information (LPI) division of NSW Department of Finance and Services: http://www.valuergeneral.nsw.gov.au/your_land_value/historical_land_values If not available, MDBA to engage land valuers
Damage to infrastructure	All	\$/ha inundated	Apply multipliers for different land uses.	ACLUMP data to determine land use	Apply estimate based on previous GHD / Hassall reports, previous relevant MDBA reports, other relevant research reports available in the public domain. Estimates will vary by reach (or sub-reach) as intensity of infrastructure will differ. Ground-truth with URS where applicable.
Management interruption	All	\$/ha inundated	Apply multipliers for different land uses.	Landholder time and notice of flood	Apply estimate based on previous GHD / Hassall reports, previous relevant MDBA reports, other relevant research reports available in the public domain.

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