Conceptual arrangements and costings of hypothetical irrigation developments in the Victoria and Southern Gulf catchments

A technical report from the CSIRO Victoria and Southern Gulf Water Resource Assessments for the National Water Grid

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Aspects of the Assessments have been undertaken in conjunction with the Northern Territory and Queensland governments.

The Assessments were guided by three committees:

i. The Governance Committee: CRC for Northern Australia/James Cook University; CSIRO; National Water Grid (Department of Climate Change, Energy, the Environment and Water); Northern Land Council; NT Department of Environment, Parks and Water Security; NT Department of Industry, Tourism and Trade; Office of Northern Australia; Queensland Department of Agriculture and Fisheries; Queensland Department of Regional Development, Manufacturing and Water

ii. The joint Roper and Victoria River catchments Steering Committee: Amateur Fishermen’s Association of the NT; Austrade; Centrefarm; CSIRO; National Water Grid (Department of Climate Change, Energy, the Environment and Water); Northern Land Council; NT Cattlemen’s Association; NT Department of Environment, Parks and Water Security; NT Department of Industry, Tourism and Trade; NT Farmers; NT Seafood Council; Office of Northern Australia; Parks Australia; Regional Development Australia; Roper Gulf Regional Council Shire; Watertrust

iii. The Southern Gulf catchments Steering Committee: Amateur Fishermen’s Association of the NT; Austral Fisheries; Burketown Shire; Carpentaria Land Council Aboriginal Corporation; Health and Wellbeing Queensland; National Water Grid (Department of Climate Change, Energy, the Environment and Water); Northern Prawn Fisheries; Queensland Department of Agriculture and Fisheries; NT Department of Environment, Parks and Water Security; NT Department of Industry, Tourism and Trade; Office of Northern Australia; Queensland Department of Regional Development, Manufacturing and Water; Southern Gulf NRM

Responsibility for the Assessment’s content lies with CSIRO. The Assessment’s committees did not have an opportunity to review the Assessment results or outputs prior to its release.

This report was reviewed by Dr Cuan Petheram (CSIRO).

Acknowledgement of Country

CSIRO acknowledges the Traditional Owners of the lands, seas and waters of the area that we live and work on across Australia. We acknowledge their continuing connection to their culture and pay our respects to their elders past and present.

Photo

Ord Irrigation Area. Source: CSIRO – Nathan Dyer

Director's foreword

Sustainable development and regional economic prosperity are priorities for the Australian, Queensland and Northern Territory (NT) governments. However, more comprehensive information on land and water resources across northern Australia is required to complement local information held by Indigenous Peoples and other landholders.

Knowledge of the scale, nature, location and distribution of likely environmental, social, cultural and economic opportunities and the risks of any proposed developments is critical to sustainable development. Especially where resource use is contested, this knowledge informs the consultation and planning that underpin the resource security required to unlock investment, while at the same time protecting the environment and cultural values.

In 2021, the Australian Government commissioned CSIRO to complete the Victoria River Water Resource Assessment and the Southern Gulf Water Resource Assessment. In response, CSIRO accessed expertise and collaborations from across Australia to generate data and provide insight to support consideration of the use of land and water resources in the Victoria and Southern Gulf catchments. The Assessments focus mainly on the potential for agricultural development, and the opportunities and constraints that development could experience. They also consider climate change impacts and a range of future development pathways without being prescriptive of what they might be. The detailed information provided on land and water resources, their potential uses and the consequences of those uses are carefully designed to be relevant to a wide range of regional-scale planning considerations by Indigenous Peoples, landholders, citizens, investors, local government, and the Australian, Queensland and NT governments. By fostering shared understanding of the opportunities and the risks among this wide array of stakeholders and decision makers, better informed conversations about future options will be possible.

Importantly, the Assessments do not recommend one development over another, nor assume any particular development pathway, nor even assume that water resource development will occur. They provide a range of possibilities and the information required to interpret them (including risks that may attend any opportunities), consistent with regional values and aspirations.

All data and reports produced by the Assessments will be publicly available.

C. Chilcott

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Project Director

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Shortened forms

SHORT FORM	FULL FORM
GRP	glass-reinforced plastic
HDPE	high-density polyethylene
HGL	hydraulic gradeline
P_{99}	99th percentile
SDR	standard dimension ratio
SGG	soil generic group
SILO	Scientific Information for Land Owners

Units

UNIT	DESCRIPTION
GL	gigalitre
ha	hectare
kW	kilowatt
L	litre
m	metre
ML	megalitre
mm	millimetre
MW	megawatt
s	second

Preface

Sustainable development and regional economic prosperity are priorities for the Australian, NT and Queensland governments. In the Queensland Water Strategy, for example, the Queensland Government (2023) looks to enable regional economic prosperity through a vision which states 'Sustainable and secure water resources are central to Queensland's economic transformation and the legacy we pass on to future generations.' Acknowledging the need for continued research, the NT Government (2023) announced a Territory Water Plan priority action to accelerate the existing water science program 'to support best practice water resource management and sustainable development.'

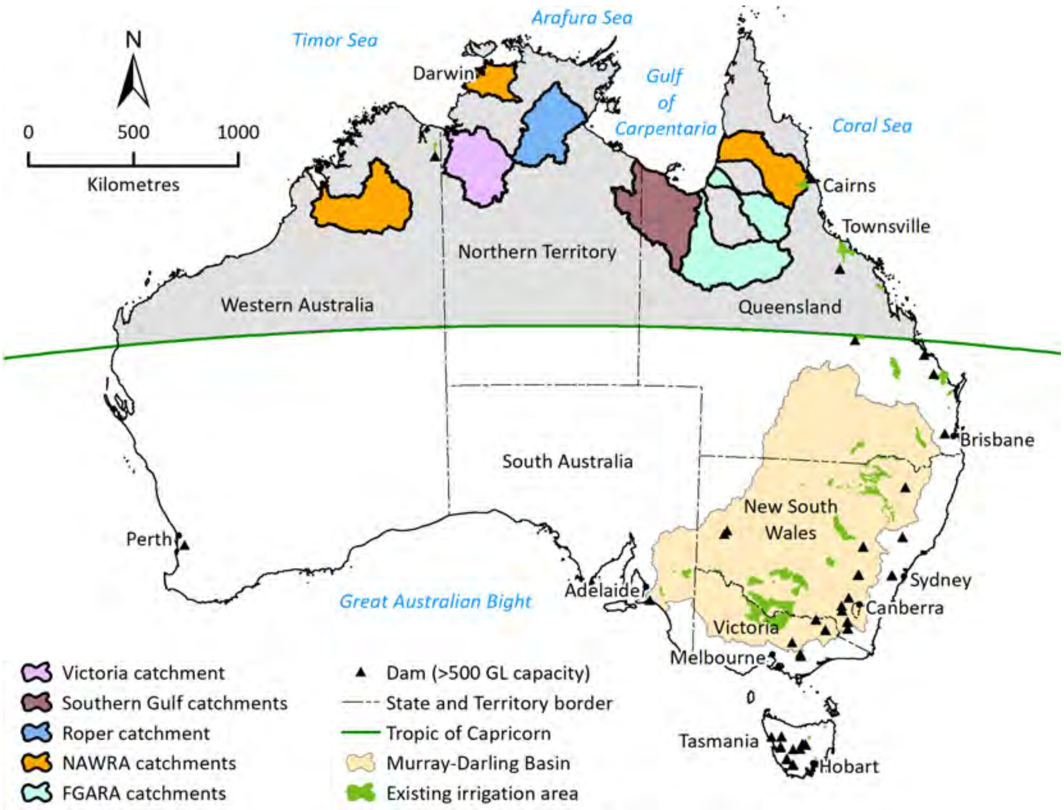
Governments are actively seeking to diversify regional economies, considering a range of factors, including Australia's energy transformation. The Queensland Government's economic diversification strategy for north west Queensland (Department of State Development, Manufacturing, Infrastructure and Planning, 2019) includes mining and mineral processing; beef cattle production, cropping and commercial fishing; tourism with an outback focus; and small business, supply chains and emerging industry sectors. In its 2024–25 Budget, the Australian Government announced large investment in renewable hydrogen, low-carbon liquid fuels, critical minerals processing and clean energy processing (Budget Strategy and Outlook, 2024). This includes investing in regions that have 'traditionally powered Australia' – as the North West Minerals Province, situated mostly within the Southern Gulf catchments, has done.

For very remote areas like the Victoria and Southern Gulf catchments, the land (Preface Figure 1-1), water and other environmental resources or assets will be key in determining how sustainable regional development might occur. Primary questions in any consideration of sustainable regional development relate to the nature and the scale of opportunities, and their risks.

How people perceive those risks is critical, especially in the context of areas such as the Victoria and Southern Gulf catchments, where approximately 75% and 27% of the population (respectively) is Indigenous (compared to 3.2% for Australia as a whole) and where many Indigenous Peoples still live on the same lands they have inhabited for tens of thousands of years. About 31% of the Victoria catchment and 12% of the Southern Gulf catchments are owned by Indigenous Peoples as inalienable freehold.

Access to reliable information about resources enables informed discussion and good decision making. Such information includes the amount and type of a resource or asset, where it is found (including in relation to complementary resources), what commercial uses it might have, how the resource changes within a year and across years, the underlying socio-economic context and the possible impacts of development.

Most of northern Australia's land and water resources have not been mapped in sufficient detail to provide the level of information required for reliable resource allocation, to mitigate investment or environmental risks, or to build policy settings that can support good judgments. The Victoria and Southern Gulf Water Resource Assessments aim to partly address this gap by providing data to better inform decisions on private investment and government expenditure, to account for intersections between existing and potential resource users, and to ensure that net development benefits are maximised.



Preface Figure 1-1 Map of Australia showing Assessment areas (Victoria and Southern Gulf catchments) and other recent CSIRO Assessments

FGARA = Flinders and Gilbert Agricultural Resource Assessment; NAWRA = Northern Australia Water Resource Assessment.

The Assessments differ somewhat from many resource assessments in that they consider a wide range of resources or assets, rather than being single mapping exercises of, say, soils. They provide a lot of contextual information about the socio-economic profile of the catchments, and the economic possibilities and environmental impacts of development. Further, they consider many of the different resource and asset types in an integrated way, rather than separately.

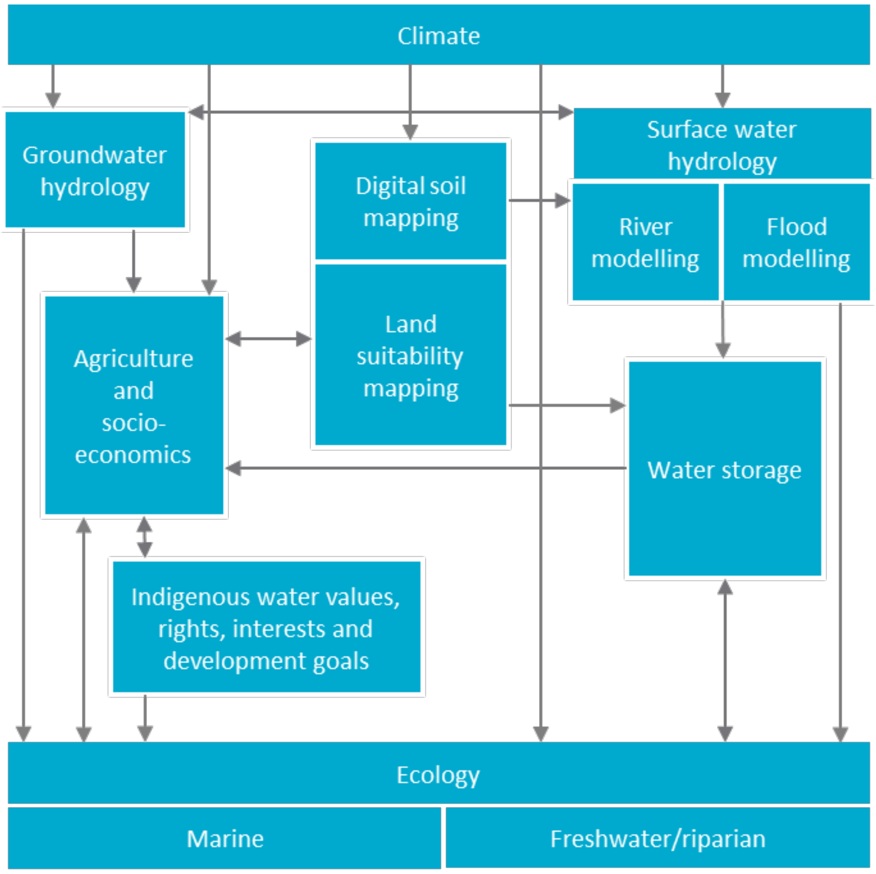
The Assessments have agricultural developments as their primary focus, but they also consider opportunities for and intersections between other types of water-dependent development. For example, the Assessments explore the nature, scale, location and impacts of developments relating to industrial, urban and aquaculture development, in relevant locations. The outcome of no change in land use or water resource development is also valid.

The Assessments were designed to inform consideration of development, not to enable any particular development to occur. As such, the Assessments inform – but do not seek to replace – existing planning, regulatory or approval processes. Importantly, the Assessments do not assume a given policy or regulatory environment. Policy and regulations can change, so this flexibility enables the results to be applied to the widest range of uses for the longest possible time frame.

It was not the intention of – and nor was it possible for – the Assessments to generate new information on all topics related to water and irrigation development in northern Australia. Topics not directly examined in the Assessments are discussed with reference to and in the context of the existing literature.

CSIRO has strong organisational commitments to Indigenous reconciliation and to conducting ethical research with the free, prior and informed consent of human participants. The Assessments allocated significant time to consulting with Indigenous representative organisations and Traditional Owner groups from the catchments to aid their understanding and potential engagement with their requirements. The Assessments did not conduct significant fieldwork without the consent of Traditional Owners.

Functionally, the Assessments adopted an activities-based approach (reflected in the content and structure of the outputs and products), comprising activity groups, each contributing its part to create a cohesive picture of regional development opportunities, costs and benefits, but also risks. Preface Figure 1-2 illustrates the high-level links between the activities and the general flow of information in the Assessments.



Preface Figure 1-2 Schematic of the high-level linkages between the eight activity groups and the general flow of information in the Assessments

Assessment reporting structure

Development opportunities and their impacts are frequently highly interdependent and, consequently, so is the research undertaken through these Assessments. While each report may be read as a stand-alone document, the suite of reports for each Assessment most reliably informs discussion and decisions concerning regional development when read as a whole.

The Assessments have produced a series of cascading reports and information products:

- Technical reports present scientific work with sufficient detail for technical and scientific experts to reproduce the work. Each of the activities (Preface Figure 1-2) has one or more corresponding technical reports.
- Catchment reports, one for each of the Victoria and Southern Gulf catchments, synthesise key material from the technical reports, providing well-informed (but not necessarily scientifically trained) users with the information required to inform decisions about the opportunities, costs and benefits associated with irrigated agriculture and other development options.
- Summary reports, one for each of the Victoria and Southern Gulf catchments, provide a shorter summary and narrative for a general public audience in plain English.
- Summary fact sheets, one for each of the Victoria and Southern Gulf catchments, provide key findings for a general public audience in the shortest possible format.

The Assessments have also developed online information products to enable users to better access information that is not readily available in print format. All of these reports, information tools and data products are available online at https://www.csiro.au/victoriariver and https://www.csiro.au/southerngulf. The webpages give users access to a communications suite including fact sheets, multimedia content, FAQs, reports and links to related sites, particularly about other research in northern Australia.

Executive summary

This report seeks to highlight the types of considerations necessary in designing potential irrigation schemes in northern Australia by developing four conceptual arrangements of hypothetical irrigation schemes in the Victoria and Southern Gulf catchments and developing estimates of their cost. For comparison, conceptual arrangements and costings for two water harvesting schemes were also developed. Importantly, the intention is to define what a possible development might look like and cost based on the information available rather than to define the optimum development for each area. A summary of the hypothetical irrigation schemes, two water-harvesting schemes and two hypothetical irrigation schemes assessed as part of the Victoria, Roper and Southern Gulf Water Resource Assessments are summarised in Table 1-1.

Table 1-1 Summary of hypothetical irrigation schemes in the Victoria, Roper and Southern Gulf catchments

CATCHMENT	POTENTIAL DAM SITE.	SCHEME CHARACTERISTICS	SERVICED AREA (HA)	LOCAL DEVELOPMENT UNIT COST ($/HA)	TOTAL SCHEME DEVELOPMENT UNIT COST ($/HA)
Victoria	Wickham River	Pipeline-based system, involving pumping to high-level balancing storages Two re-regulation weirs in Wickham River Two pump stations serving three discrete areas	17,953	16,200	104,931
	Leichhardt Creek	Channel-based system, involving supply from an offstream storage One re-regulation weir on West Baines River Low-lift pump station supplying the offstream storage	3,780	3,351	104,761
	Flood harvesting along West Baines River	Channel-based system with water-harvesting supply Low-level weir on Wickham River Pump station and inlet channel leading to storage cells Four large storage cells with centrally located pump transfer box Small main channel system	2,000	18,300	18,300
Southern Gulf	Gunpowder Creek	Pipeline-based system, with low boost pumping at offtake Re-regulation weir on Gunpowder Creek Low-lift (8 m) pump station supplying pipeline distribution system	11,734	27,200	93,077

CATCHMENT	POTENTIAL DAM SITE.	SCHEME CHARACTERISTICS	SERVICED AREA (HA)	LOCAL DEVELOPMENT UNIT COST ($/HA)	TOTAL SCHEME DEVELOPMENT UNIT COST ($/HA)
	Gregory River FSL 145 mEMG96	Channel-based system, to maximum serviced area Re-regulation weir on Gregory River Pump station serving start of channel system	19,710	3,180	Not calculated
	Gregory River FSL 138 mEMG96	Channel-based system, to lower level of development based on dam not encroaching on national park Re-regulation weir on Gregory River Pump station serving start of channel system	11,398	3,336	62,259
	Flood harvesting along the Gregory River	Channel-based system, with water-harvesting supply Pump station supplying directly to storage cells by five rising mains Four large storage cells, with transfer box pumps separating the northern three cells Dual channel system, located on the high ground to the south and west of the serviced area	2,000	15,913	15,913
Roper	Waterhouse River	Fully piped system directly from the dam site to areas riparian to Waterhouse River Pump station providing 10 m boost at dam site 48.5 km pipeline system to areas on both sides of the river	9,560	41,680	Not calculated
	Flying Fox Creek	Channel-based system, supplied from a re-regulation weir at AMTD 36 km on Flying Fox Creek, some 53 km below the dam site (not included in costs) Pump station and 2.6 km rising main to head of channel system 21 km channel system featuring three siphons	5,200	10,046	Not calculated

Scheme costs on a per hectare basis varied from $3180/ha to $41,580/ha. It was found that channel-based schemes were significantly less costly to develop than piped schemes in the same catchment, based on locally derived costs, though scheme-scale costs were small relative to the cost of the potential dams servicing the hypothetical irrigation areas. Once potential water storage (i.e. instream dam or earth embankment ringtank) costs were included in the calculation, water-harvesting schemes were found to have significantly lower development costs per hectare.

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Part I Introduction and overview

1 Potential irrigation development in the Victoria and Southern Gulf catchments

1.1 Scope of report

Potential water storage sites for irrigation development have been identified in both the catchment of the Victoria River and the catchments of the Southern Gulf rivers, that is Settlement Creek, Gregory–Nicholson River and Leichhardt River, the Morning Inlet catchments and the Wellesley island groups (see companion technical report on surface water storage, Yang et al., 2024). For this report and highlighting the types of considerations necessary in designing potential irrigation schemes in northern Australia, two potential dam sites in each study area were select upon which to develop conceptual arrangements of hypothetical irrigation schemes and estimate their cost.

In the Victoria catchment, these sites are on Leichhardt Creek adopted middle thread distance (AMTD) 26 km, a tributary of the West Baines River and the Wickham River AMTD 63 km upstream of the Victoria River junction (Figure 1-1). In the Southern Gulf catchments these sites are on the Gregory River AMTD 174 km and Gunpowder Creek AMTD 66 km (Figure 1-2). This report examines the scope for broad-scale irrigation development serviced by each of those storages. The intention is to define what a possible development might look like from the information available rather than to define the optimum development for the areas. Indicative costings are presented for each of the hypothetical developments.

For the site on the Wickham River in the Victoria catchment and the site on the Gregory River in the Southern Gulf catchments, the costs of potential flood harvesting developments are provided for comparative purposes. This information is presented by way of comparison with dam-based options only, and it does not represent the extent of water-harvesting possibilities in the two study areas.

It should be noted that development decisions will be influenced by laws, policies and regulations about land tenure, land ownership, land use, water management and environmental protection, as well as by production costs and market demands. In reality, the nature and scale of potential future development will depend heavily upon community and government values about desirable forms of development and the balance of potential benefits and impacts, including impacts to communities and water-dependent ecosystems.

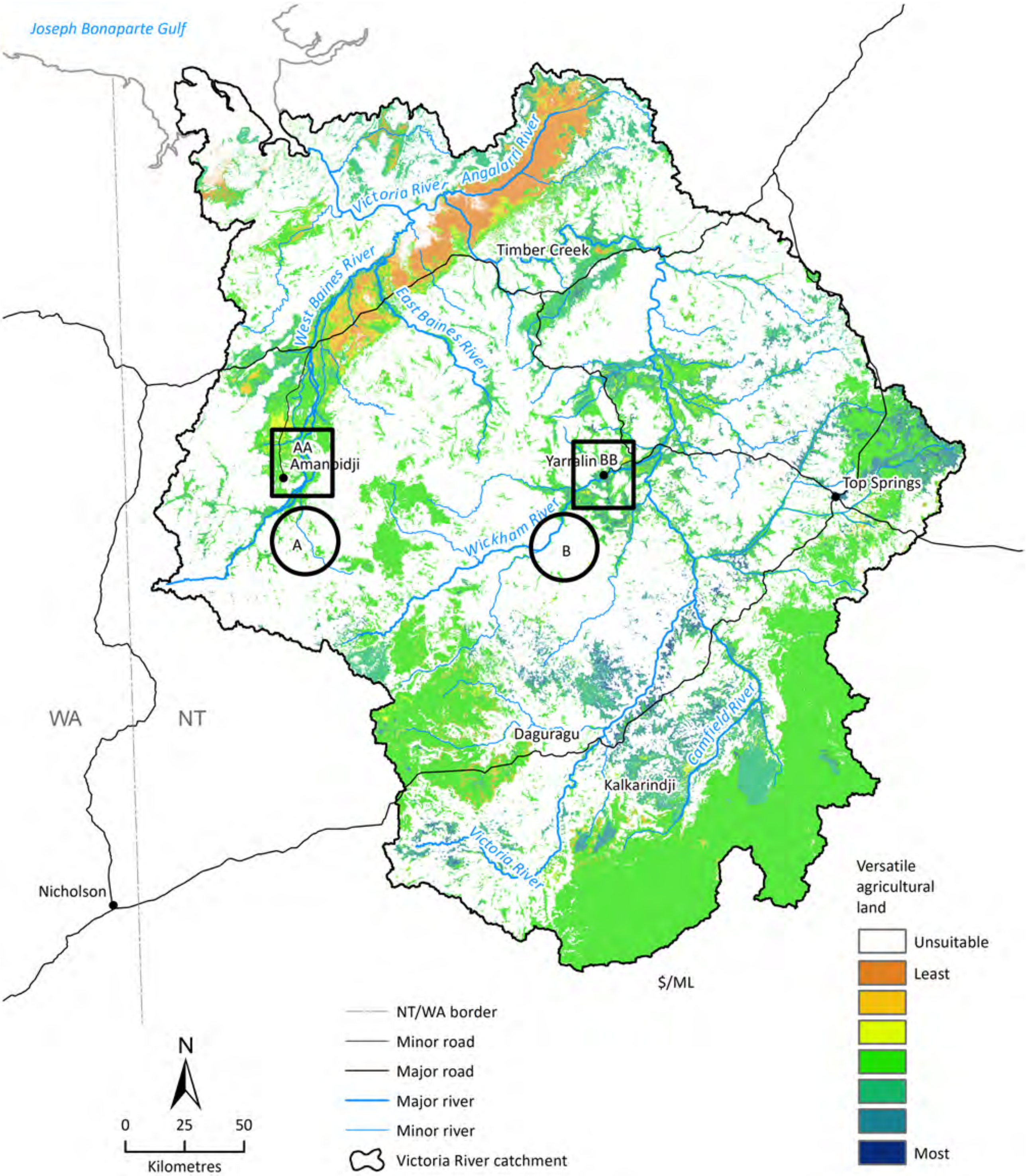

Figure 1-1 Selected potential dam sites and hypothetical irrigation areas in the Victoria catchment

The black circles and squares indicates the general location of the two potential dam sites (A and B) and the general location of their associated hypothetical irrigation areas (AA and BB) overlaid on versatile agricultural land (see companion technical report on digital soil mapping and land suitability, Thomas et al., 2024a). A is Leichhardt Creek AMTD 26 km; B is Wickham River AMTD 63km.

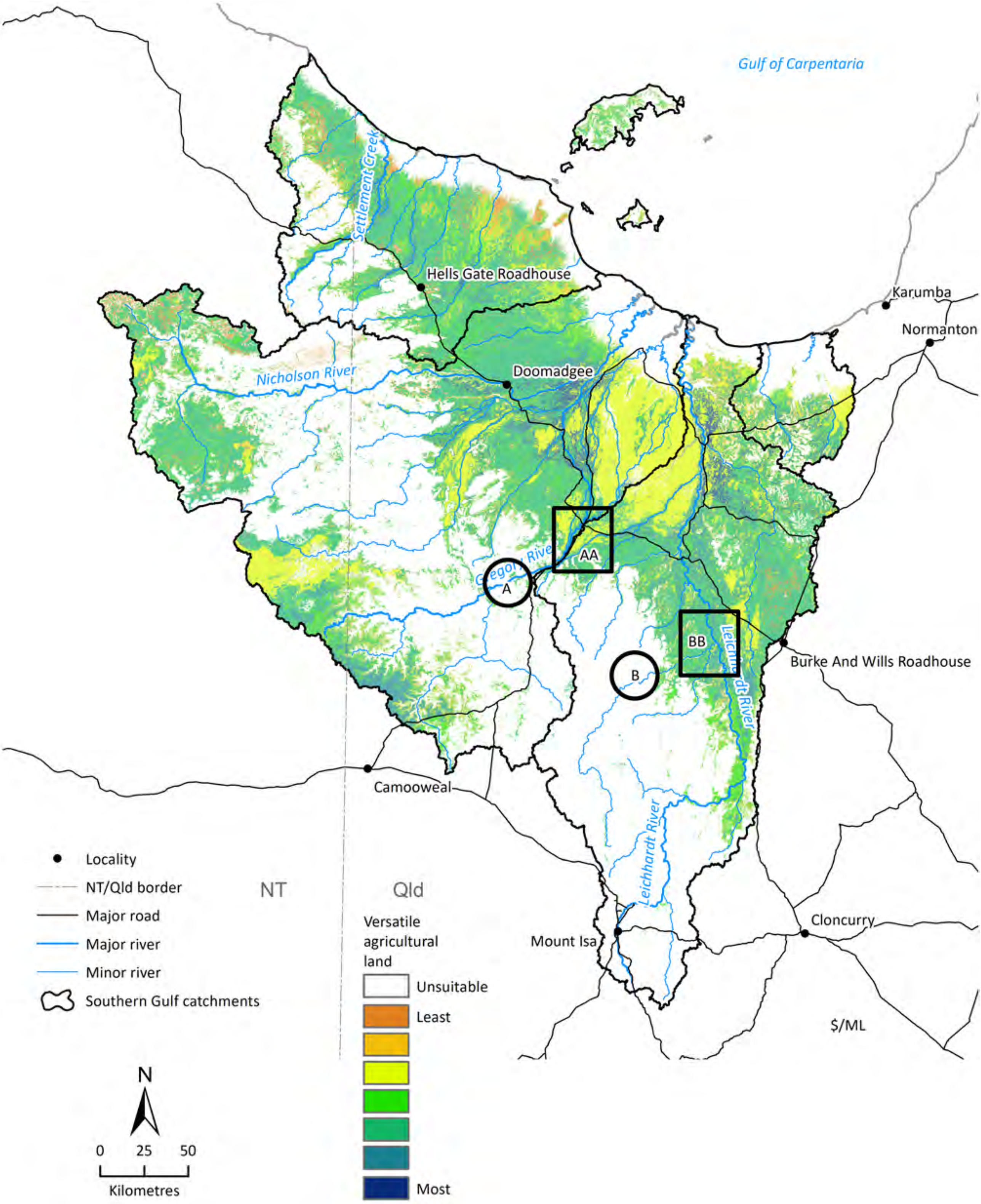

Figure 1-2 Selected potential dam sites and hypothetical irrigation areas in the Southern Gulf catchment

The black circles and squares indicates the general location of the two potential dam sites (A and B) and the general location of their associated hypothetical irrigation areas (AA and BB) overlaid on versatile agricultural land (see companion technical report on digital soil mapping and land suitability, Thomas et al., 2024b). A is Gregory River AMTD 174 km; B is Gunpowder Creek AMTD 66km.

1.2 Selection of development area

An investigation into the suitability of the soils of the Victoria catchment and Southern Gulf catchments (see companion technical reports on land suitability in the Victoria and Southern Gulf catchments, Thomas et al., 2024a,b) indicated that there were relatively small areas of suitable soils in the immediate vicinity of potential storage sites. Hence, the areas to be serviced by potential dams were selected using the following criteria:

- Suitable soils are present in aggregations rather than isolated patches. Thus, the main targets of potential development will be the alluvial soils downstream of the storage site on the banks of the streams being impounded and adjacent areas of suitable soils within practical reach of the river channel.
- The development area is close to the storage site. The storages identified are relatively modest in size, the Leichhardt Creek and Gunpowder C potential sites being particularly so. Proximity of soils suitable for irrigated agriculture is important for two main reasons. It limits the capital cost of transfer infrastructure to transfer the water from the source impoundment, whether that be by connector pipeline or channel or by downstream regulating structure and re-lift. Also, it limits losses in transferring the water from source to point of use in all cases other than the fully piped option. These losses arise mainly from accessions to the riverbed and operational losses, such as that resulting from rain rejection (i.e. when irrigation demand reduces following rainfall, after water has been released from the storage in anticipation of demand).
- Planned development is compatible with topography, not requiring extreme land levelling or expensive reticulation to adjacent subcatchments. In both cases, the hypothetical storages are located in sections of the river where the stream is relatively incised, and distribution by releases to the downstream stream, or by channel conveyance, will only potentially serve areas down the catchment. Distribution by pipeline has the potential to reach downstream adjacent subcatchments but at the expense of additional re-lift pumping. In all the hypothetical developments, the targeted area is downstream of the dam site, and adjacent to the stream.
- Soils in the development area are compatible with a range of crop types rather than a limited suite of crops.

The inescapable conclusion for the potential dam sites is that the potential for irrigation development in the immediate proximity to the dam sites is minimal. Hence, the most crucial consideration will be how the water is conveyed from the storage to the development area.

1.2.1 Soil generic groups

The soils of the Victoria and Southern Gulf catchments are presented in a soil generic group (SGG) classification (Table 1-1). These are described in detail in the companion technical reports on land suitability in the Victoria and Southern Gulf catchments (Thomas et al., 2024a,b). These groupings provided the Assessment with a means of aggregating soils with broadly similar properties and management considerations. The distinctive groupings have different potential for agriculture, some with almost no potential, such as the shallow and/or rocky soils (SGG 7), and some with moderate to high potential (e.g. SGG 9) assuming other factors such as flooding and the amount of salt in the profile are not limiting. Selected SGGs discussed in this report are listed in Table 1-1.

Table 1-1 Selected soil generic groups (SGGs) descriptions

Partially reproduced from Thomas et al. (2024a,b).

SGG	SGG OVERVIEW	GENERAL DESCRIPTION
1.1	Sand or loam over relatively friable red clay subsoils	Strong texture contrast between the A and B horizons: A horizons generally not bleached; B horizon not sodic and may be acid or alkaline. Moderately deep to deep well-drained red soils
2	Friable non-cracking clay or clay loam soils	Moderate to strongly structured, neutral to strongly acid soils with little or only gradual increase in clay content with depth. Grey to red, moderately deep to very deep soils
4.1	Red loamy soils	Well-drained, neutral to acid red soils with little or only gradual increase in clay content at depth. Moderately deep to very deep red soils
9	Cracking clay soils	Clay soils with shrink–swell properties that cause cracking when dry. Usually alkaline and moderately deep to very deep

1.3 Learnings from other northern Australian irrigation developments

A number of schemes have seen larger scale irrigation developments in the northern part of Australia in recent decades, and these hold potential lessons for any potential irrigation development in the Victoria and Southern Gulf catchments. This analysis draws on such lessons from:

- the Emerald Irrigation Scheme in Central Queensland, which involves both in-situ derived basaltic soils and associated alluvial deposits along the Negoa River
- the Burdekin Irrigation Scheme in north Queensland, which involves a range of soil types on the Burdekin and Haughton River floodplain, and associated upslope areas
- the Ord River Irrigation Scheme – Stage 2 in the Kimberley region of WA, which involves mostly clay alluvium deposits on the Weaber Plain
- cane supplementation schemes, in particular by the Pioneer Valley Water Board and the Proserpine Water Board, which involve pumping from rivers and piped reticulation.

Pumping pools are important for any river re-lift pumps to ensure adequate submergence and avoid complications from flood siltation. The total river flow for a good proportion of the year will only comprise the irrigation releases, and at least for the smaller Leichhardt and Gunpowder creeks storages is likely to only average around 200 or 900 ML/day, respectively, at the dam, and be decreasing downstream. Therefore providing adequate submergence will normally mean either a flow constriction or a constructed re-regulating weir. For all potential dam sites, the solutions examined in detail involve one or two discrete re-lift points rather than the alternative of multiple pump installations along the river course. The reasons are slightly different for each catchment but can be summarised as follows:

- The Leichhardt Creek downstream area is very small, and the key to achieving acceptable transmission efficiencies will be a steady release pattern and pumping at one site.
- For the Wickham River site, the targeted areas are in three separate areas spread out over 45 km of the river. Cost effectiveness and efficiencies of operation will dictate the minimum

number of re-regulation weirs and pump sites. Accordingly, the nominal conceptual arrangement involves two potential weirs for this site.

- The Gunpowder Creek sections offer limited sites for effective re-lift pools.
- The Gregory River site has a likely serviced area generally falling away from the river re-lift point.

It is important to align infrastructure to cater for flood flows in internal and adjacent catchments. This is more of an issue for schemes involving open-channel reticulation than those involving piped and pumped schemes, but it will apply to some degree for all schemes, such as those where the primary soils to be developed are riparian alluvia. It is particularly important in this instance for the Gregory River and Leichhardt Creek developments where the areas targeted are floodplain soils, but it will also apply to the Wickham River development if water-harvesting storages are constructed. It is less critical, but still important for both the Gunpowder Creek and Wickham River developments.

Irrigation design is best shaped by existing topography and soils distribution, not the other way around, where excessive land levelling and manipulation of soil profiles is used to give a particular irrigation layout. This is especially the case for spray irrigation systems, where spray system design can cater for reasonably irregular layouts.

Hydrogeology is critical to long-term sustainability, and any irrigation system must contain a mechanism to cater for the increased accessions to groundwater that are an unavoidable part of irrigation. This is mainly because accessions from rainfall are greater in irrigated areas than in dryland, due to the higher mean antecedent moisture profile in the soil. In this situation, riparian lands, above but adjacent to a river system, are normally better situated to avoid long-term salinisation than isolated lands without drainage incisions. Natural landscape slope also plays a part in this requirement.

Water use efficiency needs to be designed in at the start, for example, by incorporating high-quality flow measurement, and supervisory control of channel or pipeline structures, such as Total Channel Control (a proprietary open water control system from Rubicon Water). This particularly applies to the downriver releases but is also important for open-channel distribution systems. Long systems involving substantial travel time can be inefficient and waste valuable water in operational overflows if the above components are not included.

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Part II Victoria catchment

2 Potential dam site on Wickham River AMTD 63 km

2.1 Options evaluated

The Wickham River potential dam site has an annual water yield of some 196 GL at 85% annual reliability. If water from the storage is distributed downstream by river releases to a re-regulation point, this water could irrigate up to 20,000 ha, assuming piped reticulation from the river re-regulation point to the field. More than that amount of land seems to be available, but it is in a number of discrete parcels (Figure 2-1).

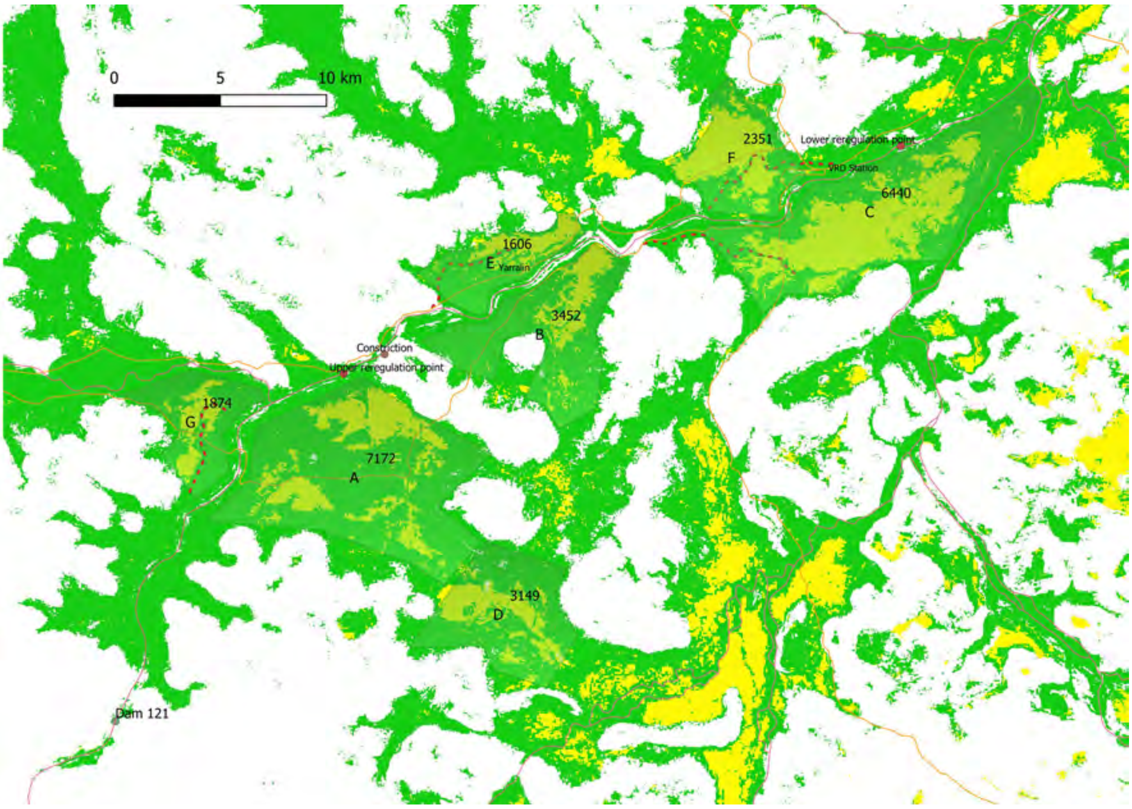

Figure 2-1 Potential development areas for the Wickham River potential dam site

Development areas are overlaid on levels of suitability for dry-season spray-irrigated cotton or grains, green Class 2, yellow Class 3. Numbers are the gross area of soils (ha) suitable for dry-season spray-irrigated cotton in the particular potential development area (A to G). Red dotted lines are prior stream remnants that will complicate irrigation development.

If distribution occurred via a channel network, the lower efficiency of that distribution may mean that slightly less than 20,000 ha could be irrigated. However, the major difference between the piped reticulation and channel network options is that it is probably not practical to have a channel system on both sides of the river, which would limit development to the southern side of the river. Nevertheless, the gross suitable area on the southern side would still fully utilise the above yield. Development on the southern side would also avoid conflict with the Yarralin town and surrounds and the infrastructure around the Victoria River Downs homestead.

A third option is that the development may involve flood harvesting to offstream storages. This option would not involve a major storage at the Wickham River potential dam site but would have a small storage in the river to provide a suitable pumping pool and individual offstream storage systems serviced by pump stations on the river bank. A water-harvesting option based on Area C is discussed further in Section 4.

Details of the two reticulation options for the Wickham River potential dam site, and their advantages and disadvantages, are presented in Table 2-1.

Table 2-1 Evaluation of development options

DEVELOPMENT OPTION	MAJOR ELEMENTS	ADVANTAGES	DISADVANTAGES
River release and re-regulating storage to piped network	• Wickham River potential dam site • Re-regulating weir on Wickham River near lower end of Area A (Figure 2-1) • Pipe network downstream on south bank serving the three areas on the river (A, B and C) and potentially the smaller area away from the river (D) • Separate pipe network for areas on the north side (G, E and F) • There is the potential for a second pump station on the existing pool opposite Victoria River Downs homestead to service Area C. This is similar to the site discussed in Section 4.2 for the water-harvesting options	• Potentially allows for serviced areas on both sides of the river, albeit at high expense on the northern bank • Major dam can provide high-reliability water supply	• Pipe network will be long, and have relatively flat grades (about 1:1500), which implies it will be expensive • Very difficult alignment past the hilly area shown as ‘Constriction’ in Figure 2-1 • Viability of north-side system will be very questionable due to the long runs at limited grade between areas G, E and F
Channel network to south bank areas	• Wickham River potential dam site • Channel system directly from the dam outlet to the serviced areas on the south bank • Separate pipe networks to supply each irrigated area	• Approximately 60 km of open channel will provide the connection between the south bank areas, with piped networks to the individual serviced areas • Major dam can provide high-reliability water supply	• Areas north of the river are unlikely to be practical to service • An almost impossible alignment required at the point labelled ‘Constriction’ • Large sections of any channel alignment will require either earth lining with imported material or membrane lining

Given the above, the following conclusions can be drawn:

- The option offering the most potential is a piped reticulation system to the south of the river only based on a re-regulation weir at the upper site. An interconnecting pipeline will be evaluated against a second re-lift point to service Area C.
- The piped reticulation option is likely to result in better use of the available resource, both in terms of the amount of land serviced and the reliability of the resulting irrigation operation.

The piped reticulation option from a potential dam at the Wickham River potential dam site is examined below.

2.2 Layout for re-regulation with piped distribution

As summarised above, a piped distribution system from a re-regulation point (or points) would allow utilisation of the full yield of the potential storage, less distribution losses to the re-regulation point(s). Also, it avoids the difficulty of the major soil types encountered on any likely alignment being unsuitable for earth channel construction without lining, either by over-excavation and backfill or membrane lining.

The major elements of the piped reticulation option, and the reasons for those choices, are as follows:

- The scheme will only target suitable lands on the southern side of the river. Areas to the north are more fragmented and have greater complications from prior streams and existing infrastructure. The total area of suitable soils on the southern side is sufficient to fully utilise the available yield from the Wickham River potential dam site.
- Two pumping sites could be constructed: one near the downstream end of Area A and the other towards the upper end of Area C (across the river from the Victoria River Downs homestead). This will require two re-regulating weirs, but both are on existing rock features in the riverbed, meaning lower constructed height, and less expensive bed protection. The locations are shown in Figure 2-2. Both weirs will only be of nominal height, sufficient only to provide pump submergence, and both are located on significant existing waterholes.
- The operational strategy used for both pump stations and the associated reticulation networks is to pump to an elevated balance tank, and then supply the serviced area by flow from the balance tank, and to pump from the river as required. The main reason for this arrangement is to create an open system to limit transient pressure surges that would otherwise dominate the design of these systems. This is because being spray irrigated implies re-pumping at the offtake to a particular paddock, and these offtakes will be subject to power failure if they are electrically driven. In a long, closed system, this would create a major pressure transient in the pipeline network. Even if the individual offtakes were diesel powered, starting and stopping the river pumps could also induce major pressure transients if the system was fully closed.

The adopted layout is shown in Figure 2-2.

This site has the potential to serve up to 17,350 ha, assuming:

- Dam yield at 85% annual reliability is 196 GL/year.
- Crop demand assuming dry-season field crops or perennial trees under spray is 8 ML/ha.
- Irrigation efficiency for spray application is 85%.
- Irrigation efficiency for trickle application is 90%.
- Distribution efficiency for piped reticulation is 98%.
- River reticulation efficiency is 85%.
- Net area irrigated is 95% of gross area.

The total area identified in Figure 2-2 is 17,953 ha. Note that part of Area D has been removed compared to Figure 2-1 to give the reduced area. While this is slightly larger than the figure of 17,350 ha derived above, it is appropriate since some of the irrigation may be by trickle.

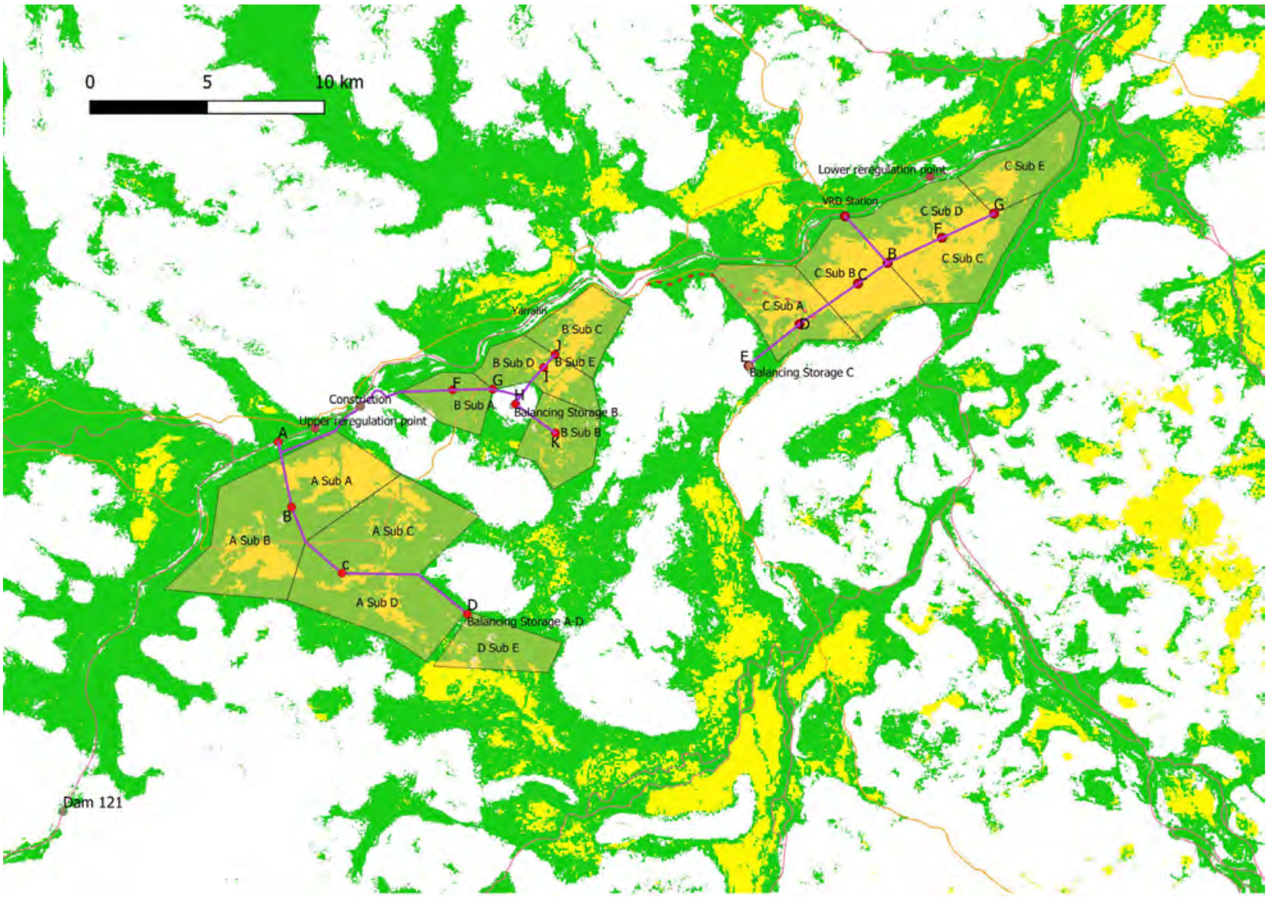

Figure 2-2 Piped reticulation layout for Wickham River potential dam site

Main pipelines, pump stations and balancing storage sites are overlaid on levels of suitability for dry-season spray-irrigated cotton or grains. Nomenclature for serviced areas is A Sub B, where A refers to the gross areas from Figure 2-1 and the Sub B is the section used for flow calculations. Red dot locations are used in the flow calculations below.

2.3 Piped reticulation design capacities

Flow-rates for the reticulation pipelines were based on the following calculation.

Daily crop demand was based on

$$E_t = p \times f_1 \times 0.8 \times E_0 \qquad (1)$$

where:

- p is climate factor, assumed as 0.7
- f_1 is crop factor, assumed as 1.0
- E_0 is assumed at 11.475 mm/day, based on values from the Scientific Information for Land Owners (SILO) database for Victoria River Downs (99th percentile (P_{99}) of 4-day mean E_0). Victoria River Downs Station is virtually in the middle of the serviced area, and while only having 53 years of evaporation data, is the closest site with relevant climate data. The other station in the vicinity (Kidman Springs) gave similar results.

E_t is therefore 6.43 mm/day.

Irrigation demand is 7.56 mm per day per hectare, assuming spray irrigation.

No diversity factor was applied, as the total area is small and soil types are reasonably uniform.

The adopted flow-rates are as shown in Table 2-2.

Table 2-2 Adopted flow-rates for the piped reticulation

Nomenclature follows Figure 2-2.

SECTION	REACH	LENGTH (M)	CUMULATIVE CHAINAGE (M)	INCREMENTAL AREA SERVICED (HA)	CUMULATIVE GROSS AREA SERVICED (HA)	NET CUMULATIVE AREA SERVICED (HA)	DESIGN FLOW-RATE (M^3/S)
Areas A and D	A–B	2943	2,943	3459	8064	7661	6.7
	B–C	3719	6,662	3707	4605	4375	3.8
	• C–D	5903	12,565	898	898	853	0.7
Area B	• A–F	9048	9,048	672	3456	3283	2.9
	• F–G	1710	10,759	498	2784	2645	2.3
	• G–H	1449	12,207	0	2286	2172	1.9
	• H–I	1881	14,088	399	1328	1262	1.1
	• I–J	741	14,829	929	929	883	0.8
	• H–K	1982	1982	958	958	910	0.8
Area C	• A–B	2747	2747	0	6460	6137	5.4
	• B–C	1560	4,307	0	6460	6137	5.4
	• C–D	3071	7,378	1436	2810	2670	2.3
	• D–E	2688	10,066	1374	1374	1305	1.1
	• B–F	2573	2,573	2548	3650	3468	3.0
	• F–G	2469	5,042	1102	1102	1047	0.9

Some assumptions made in deriving the capacities in Table 2-2 are as follows:

- In general, capacities are calculated assuming the flow is coming from the pump stations, not the balancing storage. In practical terms this is reasonable, since this will be the case at full flow. The main roles of the balancing storage are to have a stable method of controlling the pump flow and to reduce the potential for destructive pressure surges due to rapid flow changes.
- Flow changes are generally at the centroid of the serviced areas. This is an approximation, and in any final design, the capacities would be more closely tied to the actual locations of individual offtakes from the mainline. It is, however, an acceptable approximation of the actual requirements.
- The flow capacity of the final link to the balancing storage will limit the rate of filling of the balancing storage. However, if the storage is being filled without major demand to the rest of the serviced area, there will be significant additional head to be dissipated across this last leg, so the flow able to be delivered will be significantly higher than the nominal capacity noted above. When storage fill corresponds to a period of heavy demand on the system, the storage will fill slowly. However, this will not be an operational limitation as the primary purpose will be flow-rate setting in response to level change in the storage.

2.4 System pipe sizing

Pipelines were designed for the above network to meet a number of criteria, including the following:

- Two different approaches were used for sizing the pipelines. In general, pipelines supplied directly from the balancing storages (such as Area B and legs H–K and H–I–J) were designed as simple gravity lines from the lower operational level of the storage. The remaining lines were designed as pump rising mains, for which the combined variable capital cost of the pipeline and pump installation were combined with the capitalised cost of annual energy for the pump station to give the best economic option, subject to the other limitations noted below.
- Preference was given to lower pumping heads if the life cycle costs outlined above are similar, since this avoids high pipeline pressures and consequent transient pressure issues on power failure.
- Likewise, pipeline velocity at full flow was limited to below 2 m/second to also help moderate transient pressures on pump power failure or abrupt changes of demand. An exception was short lateral channels, where slightly higher velocities (up to 2.2 m/second) were allowed.
- Pipelines were designed to produce a minimum of 2 m residual head at the take-off point. This is conservative, as there will be some re-pumping at this point for travelling irrigators or filtering for trickle, but it ensured that there was some flexibility in the location of the re-pumping.
- In general, glass-reinforced plastic (GRP) pipelines were considered for this project as they represent the minimum cost solution for the pressures and flow-rates involved. In some cases of relatively smaller flow-rates, it was possible that high-density polyethylene (HDPE) lines could be used but installed costs were similar. The use of GRP pipe throughout was selected, mainly driven by the large diameters required. An effective roughness of k = 0.06 mm was assumed; this represents an achievable long-term value. Head loss was calculated using the Colebrook–White equation.

The results of this analysis are shown in Table 2-3.

Table 2-3 Adopted pipe requirements

Area and reach refer to the points defined in Figure 2-2.

AREA	REACH	LENGTH (M)	FLOW (L/S)	PIPE REQUIREMENTS
Area A and D	A–B	2943	6700	DN2000 PN10 GRP
	B–C	3719	4800	DN1800 PN10 GRP
	C–D	• 5903	1700	DN1000 PN10 GRP
Area B	A–F	• 9048	2900	DN1400 PN10 GRP
	F–G	• 1710	2300	DN1400 PN10 GRP
	G–H	• 1449	1900	DN1200 PN10 GRP
	H–I	• 1881	1100	DN750 PN10 GRP
	I–J	• 741	800	DN675 PN10 GRP
	H–K	• 1982	800	DN675 PN10 GRP

AREA	REACH	LENGTH (M)	FLOW (L/S)	PIPE REQUIREMENTS
Area A and D	A–B	2943	6700	DN2000 PN10 GRP
Area C	A–B	• 2747	5400	DN2000 PN10 GRP
	B–C	• 1560	5400	DN2000 PN10 GRP
	C–D	• 3071	2300	DN1200 PN10 GRP
	D–E	• 2688	1100	DN900 PN10 GRP
	B–F	• 2573	3000	DN1400 PN10 GRP
	F–G	• 2469	900	DN675 PN10 GRP

2.5 The Wickham River potential dam site pumping requirements

Details of the two pump stations required for the layout shown in Figure 2-2 are given in Table 2-4.

Table 2-4 Pump station details for the Wickham River potential dam site

PUMP STATION LOCATION	CAPACITY (M^3/S)	HEAD AT MAX FLO (M)	INSTALLED POWER (KW)
Pump for areas A and D	6.7	42	3400
Pump for Area B	2.9	45	1600
Pump for Area C	5.4	26	1750

Of particular note in Table 2-4 are the installed power figures. These effectively mean that this type of installation will only be practical with access to a mains electricity supply.

As outlined above, both sites will require augmentation of the existing waterholes to provide adequate submergence for what are very significant pump stations. Estimates for the cost of these structures are only approximate, but have been based on the following assumptions:

- Upper pump site
  - The assumed submergence required is 2 m.
  - The existing pool provides at least 0.5 m of reliable water depth.
  - The re-regulating weir provides an additional 1.5 m of water depth.
- Lower pump site
  - The assumed submergence required is 1.75 m.
  - The existing pool is very substantial and is likely to provide at least 1.0 m of reliable water depth.
  - The re-regulation weir provides an additional 0.75 m of water depth.

2.6 The Wickham River potential dam site reticulation costing

The above works were costed (Table 2-5) based on a number of assumptions, including:

- Pipelines were costed at unit rates derived by Rider Levett Bucknall (RLB) (2024) and adjusted where necessary for actual sizes and pressure classes. A percentage allowance was made for normal pipeline appurtenances, such as air valves, scours, swabbing facilities, thrust blocks, specials and valving.

- The three balancing storages are only of nominal size and were costed as membrane-lined panel tanks. This is the likely solution for tanks B and C, since the soils at those locations are likely to be minimal and permeable, but Tank A is located in suitable soils and could potentially be a small earth tank. In any event, the impact on scheme pricing is small.
- The pump stations are substantial structures. Each requires multiple pump units in a range of sizes, both to meet the total capacity requirement and to allow the necessary downturn to meet low-demand periods. To date, little is known about the actual site, so it was not feasible to make any sort of preliminary design. Therefore, some costing curves derived from investigating SunWater pump stations of a range of sizes in north Queensland were used to estimate likely cost ranges.
- Costs for both re-regulating weirs were based on using a low-level reinforced concrete slab with upstands.

The total capital cost of the Wickham River potential dam site reticulation infrastructure (Table 2-5) represents a development cost of some $16,200 per spray-irrigated hectare for the backbone infrastructure only. The total cost to move the water to the paddock will also include distribution from the main reticulation network to the individual irrigators required for the irrigated area.

Table 2-5 Cost summary for the Wickham River potential dam site reticulation infrastructure

COST CATEGORY	ITEM	CAPITAL COST ($)
Capital costs – direct	Pump station (areas A, B and D)	26,500,000
	Pump station (Area C)	9,330,000
	Re-regulating upper weir	4,685,500
	Re-regulating lower weir	5,610,500
	Area A mainline	53,268,000
	Area B mainline	43,960,000
	Area B lateral H–K	2,412,000
	Area B lateral H–I–J	902,000
	Area C mainline	42,532,000
	Area C lateral B–F–G	12,530,000
	Pipeline appurtenances	7,780,000
	Storage tanks	250,000
	Total direct cost	290,778,000
Indirect costs	Design and documentation	4,196,000
	Site supervision	10,490,000
	Insurance	5,245,000
	Environmental approvals	12,588,000
	Total project costs	242,315,000
Risk adjustment	20% of total project costs	48,463,000
Total capital cost		290,778,000

3 Potential dam site on Leichhardt Creek AMTD 26 km

Leichhardt Creek potential dam site is a very small site of only some 60 GL annual water yield, and it is located a significant distance upstream of any significant areas of soil suitable for irrigated development.

Nevertheless, the site was examined in a similar method to that used for the Wickham River potential dam site to ascertain what development, if any, would be feasibly fed from that site.

Given the small yield, and the distance to potential serviced lands, a targeted development of less than 4000 ha will be likely.

3.1 Identification of potential lands for development

Lands potentially suited for development serviced from the Leichhardt Creek potential dam site were selected on the following bases:

- The area is relatively close to the river course below the dam. A feature of the river network below the dam site is a multi-branched channel with multiple flood runners. The areas between the major channels were avoided as being too flood prone.
- The soils involved are uniform in their soil generic group (SGG) classification (see Thomas et al., 2024). In some cases, the complexity meant that two SGG classifications were involved, and areas of highly complex distributions were excluded. Preference was given in the evaluation to the more uniform soil types within a particular area to aid irrigation management.
- Soils are suitable for a range of crop options. The most likely appear to be either cucurbits under dry-season trickle irrigation, or cotton or grains under dry-season spray irrigation.
- Topography is not complicated; for example, it lacks features such as prior streams or overbank flow paths.

The four areas identified for further study are shown in Figure 3-1. Details of the selected areas, and their advantages and disadvantages, are presented in Table 3-1.

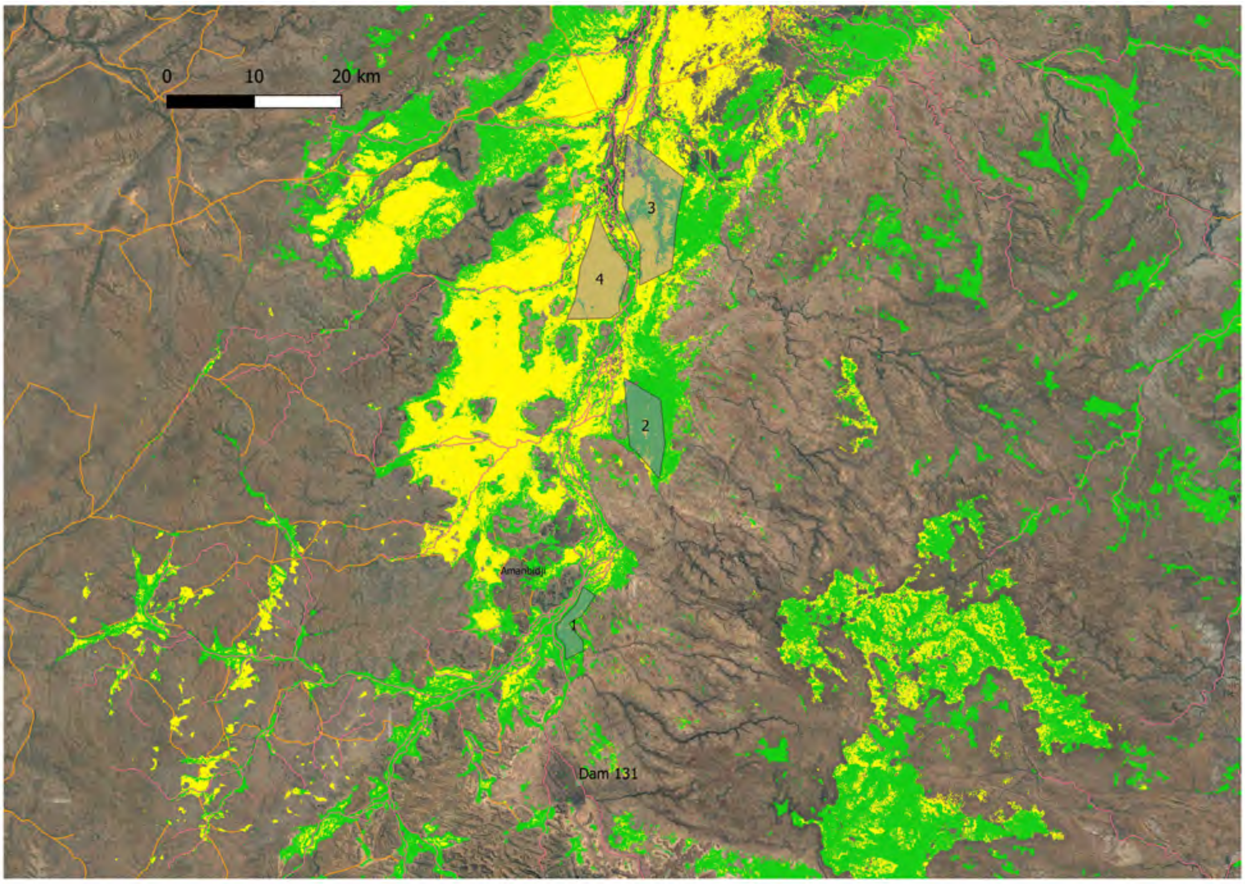

Figure 3-1 Potential development areas for the Leichhardt Creek potential dam site

Development areas are overlaid on levels of suitability for dry-season spray-irrigated cotton or grains and Google imagery.

Table 3-1 Details and comparison of potential development areas below the Leichhardt Creek potential dam site

AREA NO.	AREA (HA)	DOMINANT SGG† CATEGORIES	ADVANTAGES	DISADVANTAGES
1	1460	41 (56%) and 2 (44%)	• Closest to Leichhardt Creek potential dam site (top of Area 1 is 18 km downstream) • Good suitability for cotton or grains under dry-season spray irrigation (94% is Class 2 soils) • Similar suitability for cucurbits under dry-season trickle irrigation (94% Class 2)	• Extremely complicated topography with a number of prior streams and over-break channels, indicating high susceptibility to flooding • No obvious opportunity for a re-regulating weir at the top of the area • The two major SGGs will require quite different irrigation management
2	• 350 1	62 (72%), 41 (20%) and 2 (8%)	• Most soils have high suitability for cotton or grains under dry-season spray irrigation (91% Class 2) and slightly less suitability for cucurbits under dry-season trickle irrigation (52% Class 2) • Should be relatively flood free from main West Baines channel • Potential re-regulation point opposite the top of Area 2, one of the rare locations where the West Baines complex is confined to one channel	• The potential re-regulation point is some 50.5 km downstream from the Leichhardt Creek potential dam site • A comparatively long distance from potential re-regulation point to top of Area 2 (10 km) • Topography indicates regular inundation, from the local stream to the east of the area, and subsequent erosion

†SGG = soil generic group.

AREA NO.	AREA (HA)	DOMINANT SGG† CATEGORIES	ADVANTAGES	DISADVANTAGES
3	• 8035	2 (59%), 9 (39%) and 41 (2%)	• Most soils have good suitability to cotton or grains under dry-season spray or trickle (28% Class 2 and 70% Class 3) • Has a reasonably confined section of the river to have a re-lift, albeit with no obvious location for a weir structure	• Some major flood runners originating further upstream run longitudinally down the area. This will be a major limitation on cultivation and irrigation • Area 3 is some 71 km downstream of the Leichhardt Creek potential dam site. Distribution losses for small releases over this distance will be very large
4	• 4926	9 (89%) and 2 (11%)	• Best uniformity of soil types of the four areas • Fairly uniformly sloped to the north, at about 0.08%, with only minor drainage channel evident to the northern end • Good flexibility for crop type, with Class 3 suitability for either dry-season cotton or grains under spray or furrow irrigation, and dry-season cucurbits under trickle irrigation	• The most likely re-regulation point for this area is some 66 km downstream of the Leichhardt Creek potential dam site, so it is subject to large distribution losses • While some constriction is evident between local hills at the re-regulation point at the southern end of Area 4, there is no evidence of any bed outcrop, and the river bank looks particularly friable at this point

3.2 Selection of area for development

Table 3-1 shows that each identified area has significant limitations. However, since there are no alternative areas closer to the dam site, and since other more uniform areas will be even further downstream from the dam, an assessment was required to compare the limitations of the four areas.

The following comments, while subjective, can be made:

- Area 1 has limitations that probably rule it out from contention. It is too small to fully utilise the potential yield, has diverse soil types, and has prior streams that make it too flood prone for development.
- Area 3 is too far from the dam site and has flood runners that will be difficult to divert around in any large-scale irrigation development. It is also probably ruled out for those reasons.
- Area 4, despite being the most uniform area, also suffers from being a long way downstream. It has the best crop flexibility of the four areas. One advantage it has over the other areas is that the soils are all suitable for ringtank construction. A mechanism whereby releases are passed down the river in substantial slug flows and picked up and stored on-site in an offstream storage for gradual release to irrigation demand is possible. This would reduce the challenges posed by the distance from the Leichhardt Creek potential dam site. The practicality of this option is discussed below.
- Area 2 seems the most attractive at first: it is almost large enough and has the best suitability (most Class 2 soils) of the four areas. However, the need for a 10 km rising main will be a serious limitation to the development of this area. At 50.5 km downstream, it has only a very marginal advantage over Area 4 at 66 km. Furthermore, it has no area suitable for ringtank construction to mitigate that distribution distance.

Considering all the above points, Area 4 was the one targeted for derivation of a development option.

3.3 Operation of potential scheme

Area 4 is far from ideal for development because of the long distance from the potential storage at the Leichhardt Creek potential dam site to the likely re-regulation point and re-lift from the river. Additionally, the upper 40 km of that river channel was predicted to be SGG 4.1 (the red loamy soils), which would result in significant accessions from the bed to underlying strata.

Three different approaches could address these issues:

- Release down the river to a re-regulation point that will be of sufficient capacity to handle any 'rain rejection' inflows. This refers to potential losses that can occur if significant rain falls in the irrigated area when an irrigation release is underway, cancelling the need for irrigation that cycle. If the water on its way down the river is not stored somewhere then it is lost downriver, adding to system losses. A normal allowance would be to make the river storage equal to at least twice the design release rate by the likely transit time. In this case, where the transit time is likely to be of the order of 2 days, the operating volume required will be some 1200 ML. With a bed slope of about 0.045%, this will be very difficult to achieve, given the friable banks noted above and the consequent need to limit afflux for any instream structure. Instream storages above about 400 ML will be difficult and expensive.
- Release down the river to a smaller re-regulation storage but with the ability to re-pump to an offstream storage that would form a buffer between the releases from the dam and the actual irrigation demand. This can easily and cost effectively be a much larger storage than would be possible in the river. Indeed, the area immediately next to the river lends itself to a storage of some 5000 ML. In this option, the river pumps have only to be sized to the maximum irrigation demand, and the re-regulation weir can be sized only to provide the required pump submergence.
- The final variation is to have the release in higher slugs, rather to the maximum irrigation demand, in the hope that this will reduce the transmission losses from the dam to the re-regulation re-pumping. However, a couple of factors make this approach difficult. First, the river channel capacity is very limited before it braids significantly, limiting the amount of any slug flow. Second, there is no real evidence that higher slugs will significantly reduce transmission losses. In fact, some factors, such as the need for wetting flows, and the likely higher losses at higher stages indicate that this may be counterproductive. Finally, as noted in the first option above, there will be real limits to the height of any practical re-regulation weir, so achieving pump submergence will be more difficult for the larger extraction flows necessary for this option.

Considering the above, the second approach was chosen for further development: release down the river to a smaller re-regulation storage but with the ability to re-pump to an offstream storage.

3.4 Elements of potential scheme

General details of the major elements of the scheme and further details of the sizing of some of those elements are provided below:

- Re-regulation weir. This is at a point where the banks are high from some remnant hills on the northern side and a localised high point on the southern side. The practical limit of any storage will be limited by the friable nature of the banks, however, and it is assumed that any attempt to construct a weir greater than 1 m operating height will be problematic due to the amount of protection required downstream. A sheet piling structure or a low concrete slab structure, with significant rock mattress protection to the abutments and downstream, will be required. No specific allowance will be made for releases due to the small nature of the storage. An effective height of only 0.75 m is assumed.

- Pump site. This is chosen as an apparently stable section of river bank close to both the re-regulation point and the offstream storage. The pump station would feature bank-mounted axial-flow pump units at 30 degrees with control equipment located on an elevated platform out of flood reach on the upper river bank.
- Offstream storage. This is sized at 4000 ML, which provides a working range of at least one irrigation watering for the potential irrigation area, and sited immediately adjacent to the river to minimise works from the river to the storage. The storage will be constructed from banks formed from material won from within the storage area, taken from strata that do not affect the low permeability of these cracking clay soils. The banks will require water and compaction during construction, not just cross dozing as commonly used for smaller storages. The inner batters will need to be flat enough to handle the relatively rapid filling and emptying of the storage. Ratios of 1 vertical: 3 horizontal internal and 1:2 external will be used for the preliminary costing.
- Final targeted area. The area immediately downslope of the above offstream storage is targeted for development, but with a few modifications to the gross area identified in Figure 3-1. The area is reduced to be parallel sided in the north–south direction to facilitate a furrow-irrigated layout. The total targeted area is reduced to about 3900 ha to allow for the likely limit of serviced area taking into account the available water, net of transmission, distribution and irrigation losses.
- Main distribution channel. The mechanism for delivery of irrigation water from the offstream storage to the individual paddocks is a main distribution open channel down the middle of the serviced area. Regardless of whether the irrigation is by furrow or spray, this is a sensible method of distribution as the grade downslope is 0.08%, making distribution by pipeline uneconomic. This, of course, could be changed by re-pumping at the storage, but that solution is unlikely to be adopted early in the development. Main channel distribution by open channel, and then lateral distribution by either open channels cross slope or pipelines, depending on the final method of irrigation, will be the mechanism detailed below.

In summary, the scheme described below features releases downriver to a pump station near the top of the area that is fed by a small re-regulation structure in the river. The pumps deliver water to a balancing storage on the left bank of the river with releases to a main channel down the middle of the area. Distribution from the main channel will depend on the crop type and irrigation method chosen and will not be detailed for this analysis. Details of those costs will be included with the land development component.

3.5 Area irrigated

This site is of modest size and suffers from the long downriver release path, which leads to high losses. Using similar criteria to those developed for the Leichhardt Creek potential dam site, it has the potential to serve up to 4000 ha, depending on the distribution and irrigation method chosen, assuming:

- Dam yield at 85% annual reliability is 60 GL/year.
- Crop demand assuming dry-season field crops is 8 ML/ha.
- Irrigation efficiency for spray application is 85%.
- Irrigation efficiency for trickle application is 90%.
- Irrigation efficiency for furrow irrigation is 80%.
- Distribution efficiency for open-channel distribution is 90%.
- Distribution efficiency for piped reticulation is 98%.
- River reticulation efficiency is 70%.
- Net area irrigated is 95% of gross area.

Targeted gross areas are therefore between 3780 ha (open channel and furrow) and 4252 ha (piped and spray).

The layout of the above infrastructure, plus the land parcels assumed for the flow calculations are shown in Figure 3-2.

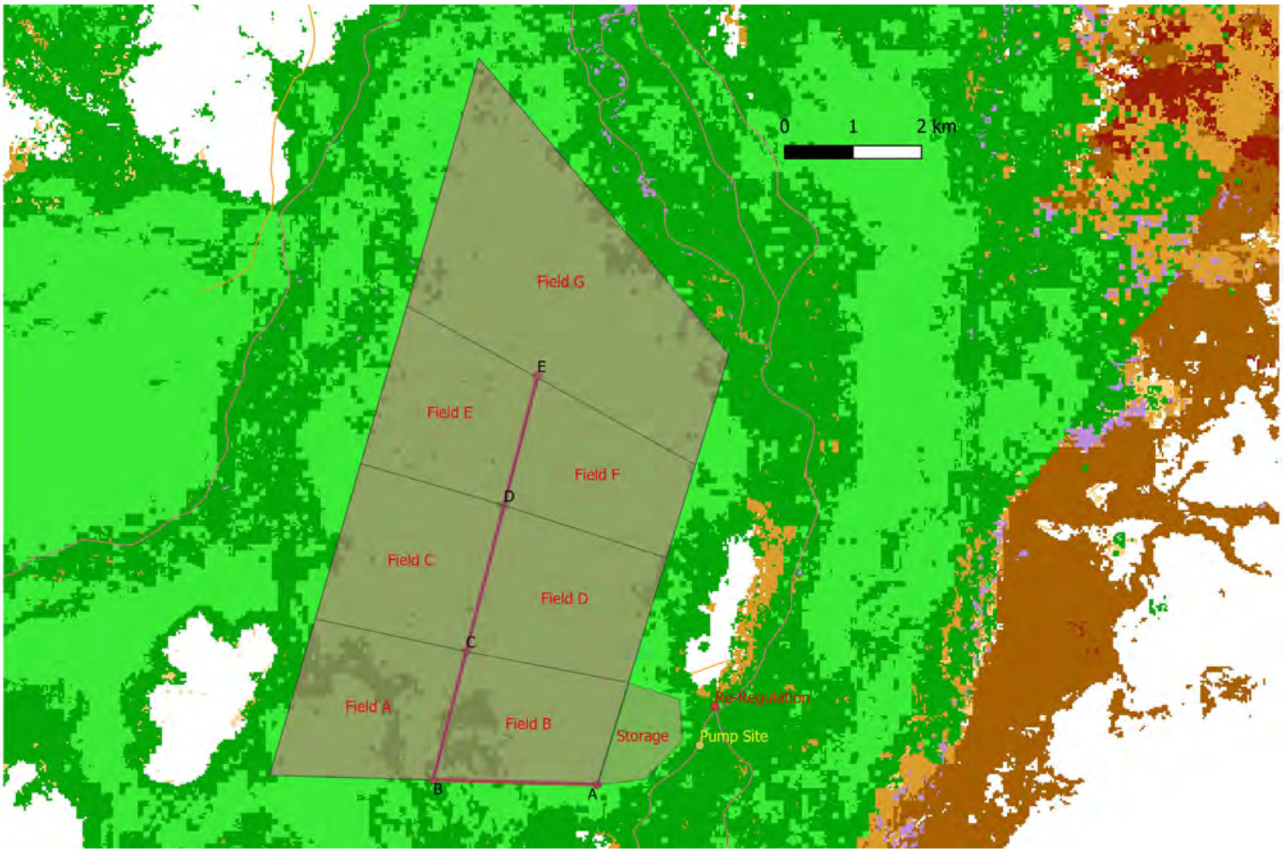

Figure 3-2 Adopted layout for furrow irrigation to Area 4 for the Leichhardt Creek potential dam site

Layout is overlaid on SGG predictions. Individual fields and reach points on the reticulation are labelled for flow calculation purposes. Re-regulation, pump site and offstream storage sites shown.

3.6 Design capacities

Flow-rates for the reticulation pipelines were based on the following calculation.

Daily crop demand was based on

$$E_t = p \times f_1 \times 0.8 \times E_0 \qquad (2)$$

where:

- p is climate factor, assumed as 0.7
- f_1 is crop factor, assumed as 1.0
- E_0 is assumed at 11.825 mm/day, based on SILO values for Rosewood Station (P_{99} of 4-day mean E_0). Rosewood Station is some 85 km west-southwest of the serviced area and gave slightly higher values than those used in Section 2.3 for Victoria River Downs.

E_t is therefore 6.62 mm/day.

Irrigation demand is 8.28 mm per day per hectare, assuming furrow irrigation.

No diversity factor was applied, as the total area is small and soil types are reasonably uniform.

The adopted flow-rates are as shown in Table 3-2.

Table 3-2 Channel flow-rate determination

CHANNEL	REACH	LENGTH (M)	CUMULATIVE CHAINAGE (M)	INCREMENTAL AREA SERVICED (HA)	CUMULATIVE GROSS AREA SERVICED (HA)	NET CUMULATIVE AREA SERVICED (HA)	DESIGN FLOW-RATE (M^3/S)
Mainline	A–B	2395	2395	0	4230	4019	3.9
	B–C	2003	4398	937	3293	3128	3.0
	C–D	2270	6668	1043	2250	2138	2.0
	D–E	2016	8684	920	1330	1264	1.2

The adopted gradeline from the earthwork runs for the main channel is shown in Figure 3-3.

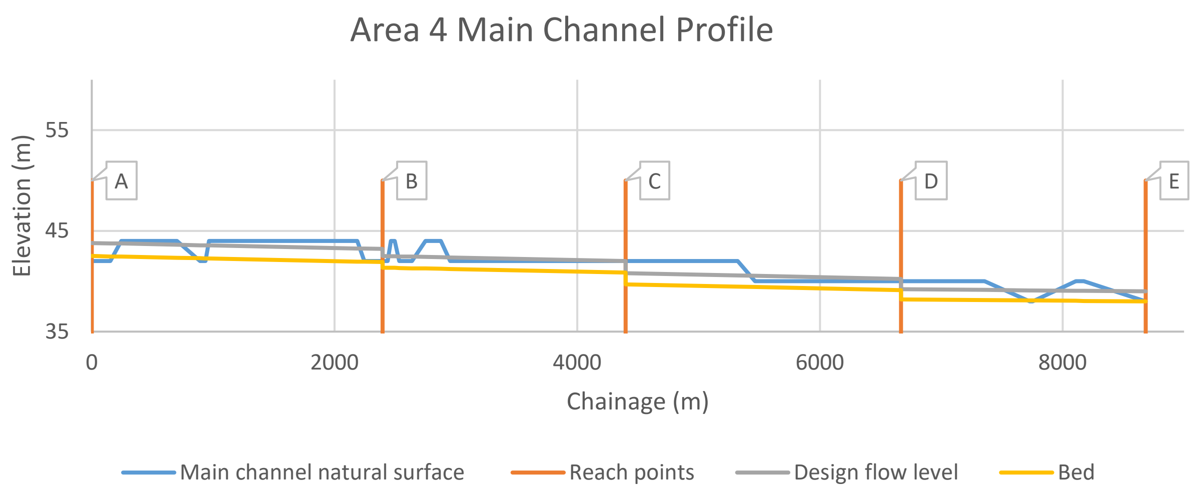

Figure 3-3 Adopted gradeline for the Leichhardt Creek potential dam site Area 4 main channel

Reach points refer to the locations shown in Figure 3-2.

In the derivation of the earthworks required for the above channel profiles:

- The profile, consisting of deep cracking clay soils, is assumed to be suitable for bank construction without modification or lining of the cut profile following over-excavation.
- Minimums have been assumed for water depth (for reasons of weed control) and bed width (to allow practical construction by scraper). In some cases, the actual capacity is above the nominated capacity due to the above minimums.
- Design flow levels are adjusted so there is no net borrow requirement within each of the above reaches. Some minor additional excavation will be necessary to ensure longitudinal drainage on the high side of the channel (particularly in reach A–B), but this will be costed separately to the main channel profile.

Adopted parameters are shown in Table 3-3.

Table 3-3 Adopted main channel parameters

REACH	DESIGN FLOW-RATE (M^3/S)	BED WIDTH (M)	WATER DEPTH (M)	FREEBOARD (M)	SLOPE (M/KM)	VELOCITY (M/S)
A–B	3.9	5	1.3	0.3	0.25	0.43
B–C	• 3.0	5	1.15	0.3	0.25	0.40
C–D	• 2.0	3	1.10	0.3	0.25	0.36
D–E	• 1.2	4	1.0	0.3	0.1	0.23

3.7 The Leichhardt Creek potential dam site channel reticulation costing

A number of assumptions and choices were made for the costings detailed in Table 3-4, of which the more important are:

- At each drop in design flow level noted above (Figure 3-3), a control structure is located on the upstream side of an access crossing. A conventional outlet structure is used on the outlet side. This arrangement achieves both flow control and cross-channel access at the same location. Rubicon FlumeGates will be assumed to be the flow control device.
- The storage is designed as a single water body. This is probably realistic, but a more cautious design would include a wave break barrier in the middle to limit wind-induced wave fetch.
- No specific allowance is made for borrow, which reflects the basis of selection of design flow levels noted above.
- A separate allowance will be made for any necessary longitudinal catch drainage excavation and banks, particularly for Reach A–B.

Note that the costs used for this estimate were those appropriate for a corporate-scale irrigation project. This total development, at approximately 4000 ha, is not beyond the scope of a single farming entity. In that case, the design reliability of the supply and the standard of the works might both be less than presented here. This represents an internalising of risk not possible or practical for a larger scale corporate development. In a single enterprise case, it is expected that these costs may overestimate the expenditure required.

The total capital cost represents a development cost of some $3350 per irrigated hectare for furrow irrigation for the backbone infrastructure only. As outlined above, the total cost to move the water to the paddock will also include distribution from the main channel to the paddock, depending on the type of irrigation adopted.

Table 3-4 Leichhardt Creek potential dam site reticulation costing

COST CATEGORY	ITEM	CAPITAL COST ($)
Capital costs – direct	Re-regulating weir	1,897,900
	Pump station	592,000
	Rising main	717,000
	Storage	3,411,719
	Channel A–B	800,844
	Channel B–C	575,397
	Channel C–D	527,716
	Channel D–E	487,085
	Freight and SCADA†	130,250
	Total direct cost	9,139,911
Indirect costs	Design and documentation	182,798
	Site supervision	456,996
	Insurance	228,498
	Environmental approvals	548,395
	Total project costs	10,556,597
Risk adjustment	20% of total project costs	2,111,319
Total capital cost		12,667,916

†Refers to the channel control system – supervisory control and data acquisition.

4 Water-harvesting options along West Baines River

This section examines the potential for flood harvesting, but only in the areas examined above for service from the two dam sites being investigated in the catchment of the Victoria River. Leichhardt Creek potential dam site can effectively be discounted, as the area serviceable from the dam is small and that able to be serviced from a water-harvesting operation would be even smaller. This leaves the areas targeted downstream from the Wickham River potential dam site.

4.1 Evaluation of water-harvesting options

Examining the potential to service the areas identified in Figure 2-1 gave the two water-harvesting options outlined in Table 4-1.

Table 4-1 Evaluation of water-harvesting options

DEVELOPMENT OPTION	MAJOR ELEMENTS	ADVANTAGES	DISADVANTAGES
Smaller scale flood harvesting (Scale 1)	• No major dam • Minor instream storage at point labelled 'Lower re-regulation point' in Figure 2-1 • Pump stations to service areas C and F • Major offstream storage complexes on both sides of the river, located on the cracking clay soils • Piped distribution networks from the offstream storages	• Targets the most attractive and uniform area (Area C) • Has cracking soils potentially suited to offstream storage construction near the river for both areas • The 'Lower re-regulation' point is at the lower end of an existing very substantial pool, providing good flexibility for pump station locations	• Likely to be limited to 7500 ha of suitable land once allowance for storage construction allowed • Areas C and F both contain some prior stream sections (shown as red dotted lines on Figure 2-1), which may further limit suitability. However, the prior stream sections cover relatively small areas • Depending on pumping capacity and storage capacity, this option is likely to be less reliable than the dam-based options

DEVELOPMENT OPTION	MAJOR ELEMENTS	ADVANTAGES	DISADVANTAGES
Larger scale flood harvesting (Scale 2)	• As above for Scale 1, plus the following: • Minor re-regulating weir at the site marked 'Upper re-regulation point' in Figure 2-1. Note this weir will effectively have no operating range due to the presence of the downstream storage, so will be very low • Pump stations to service both areas A and G • Offstream storage complexes for both sides of the river, although the requirements for Area G are likely to be only one storage cell • Piped networks to supply areas A and G	• Has potential to irrigate more than the likely yield from an offstream water-harvesting operation in this area	• Areas A and G are far less uniform than the downstream areas • Siting storages will be difficult, especially for Area G • Areas A, B and G have very limited areas of soil suitable for storage construction without membrane lining. In areas A and B, these limited areas of suitable soils are at the downstream end of the areas, necessitating re-lifting internally • Area G also features a notable prior stream feature, potential further limiting suitability • Reliability as for Scale 1 option

The following conclusions can be drawn:

- A water-harvesting operation, based on a minor instream storage to provide a suitable pumping pool, at the lower alternative site, with major offstream storage complexes on both sides of the river is the more practical option. Based on rough rules of thumb, full development of these areas is likely to involve about 3 km^2 of storage cells on the north bank and 9 km^2 on the southern side.
- Scale 2 is discounted due to the lack of sites for storage construction.
- Water-harvesting options are likely to cost less than the dam and reticulation options canvassed above and may be more likely to achieve regulatory approval, given the lower impact on the river environment.

As a result, Scale 1 water harvesting was examined further below.

4.2 Details of water-harvesting operation

While the nominated water-harvesting (Scale 1) scheme is described in Table 4-1, this discussion of major elements is based on the following assumptions:

- Development of the full Scale 1 area will be problematic due to the conflict with infrastructure around Victoria River Downs, so this discussion refers to the development of the area to the south of the river only. This is essentially Area C in Figure 2-1.
- The pumping pool will be formed by a low weir constructed at the natural rocky constriction some 4 km below the Victoria River Downs homestead. Weir height is based on the required pump submergence discussed below.
- The pump submergence required will assume bank-mounted inclined 24-inch flood lifters, arranged as a bank of pumps on the southern bank. Pumps will be uncontrolled, and flow will be determined by the number of pumps started. While larger diameter flood-lifter pumps are available, they would require greater submergence, which would be difficult in this river. Twenty-four-inch pumps are commonly used for larger water-harvesting operations. Assuming a

30-degree installation, minimum submergence requirements will be around 1.5 m, with a further 0.3 m below the pumps. This gives 1.8 m total. Other types of pumps such as submersible mixed-flow volute types would be theoretically possible but are not favoured as they would require even greater submergence. Based on an assumed existing waterhole depth at this site of 1 m, a small weir will likely be required at this site, depending on the likely starting flow requirements for water-harvesting diversions. To keep cost estimates conservative, the same weir costs as developed for the dam-based developments at this site will be assumed (Table 2-5).

- Pumps sites:
  - must be on the existing Victoria River Downs lagoon (to minimise the height of weir)
  - must be in a relatively stable section of bank
  - must be in proximity to an area of cracking clay soils for storage construction
  - if possible, must be in proximity to an area of clay soils for construction of a lead-in channel to the storages. Note this is a second order requirement, as clay material could be imported for this purpose.
- Storages are based on:
  - an effective water depth of up to 7 m with a further 1 m of freeboard. This avoids the mandatory failure impact assessment and referable dam processes. It is also the common limit for storages constructed without fully engineered embankments. Material for the banks will be sourced from borrow areas within the storage area and so become part of the stored volume. Note that this represents the upper limit of storage depth, as cell cost increases rapidly with overall depth, and smaller developments will favour lower height cells
  - a maximum fetch of 1.5 km, to limit wave-induced erosion damage. This will also tie in with the aim of producing a matrix of storages to minimise evaporative losses by pumping to a smaller number of storages as available supply decreases. For these reasons, the storages will be assumed to be cells of up to 1.2 by 1.2 km and 7 m effective storage. The capacity of each storage cell will be up to about 9900 ML.
- The amount of storage necessary to fully develop Area C will depend heavily on a range of factors such as the area lost to storage cells, the timing and duration of flood flows, and the crop timing, which will determine evaporative losses. As an initial indicative estimate, up to 60,000 ML of gross storage would appear to be the upper limit of viable storage at this site. This implies at least six cells of storage, which will be confirmed by streamflow analysis once the major elements are sited. However, the full area will include substantial areas that can only be effectively irrigated by spray techniques. An initial development would undoubtedly focus on the cracking clay areas able to be flood irrigated, to limit total expenditure. This will be a substantially smaller enterprise.
- Storages will be sited entirely within the cracking clay SGG 9 unit, limiting the potential sites. A notional area of 2.5 by 3.7 km will be required for the full development.
- Given the need to limit the length of the inlet channel and keep the storages near the pump site, the site chosen for investigation is the one shown in Figure 4-1.

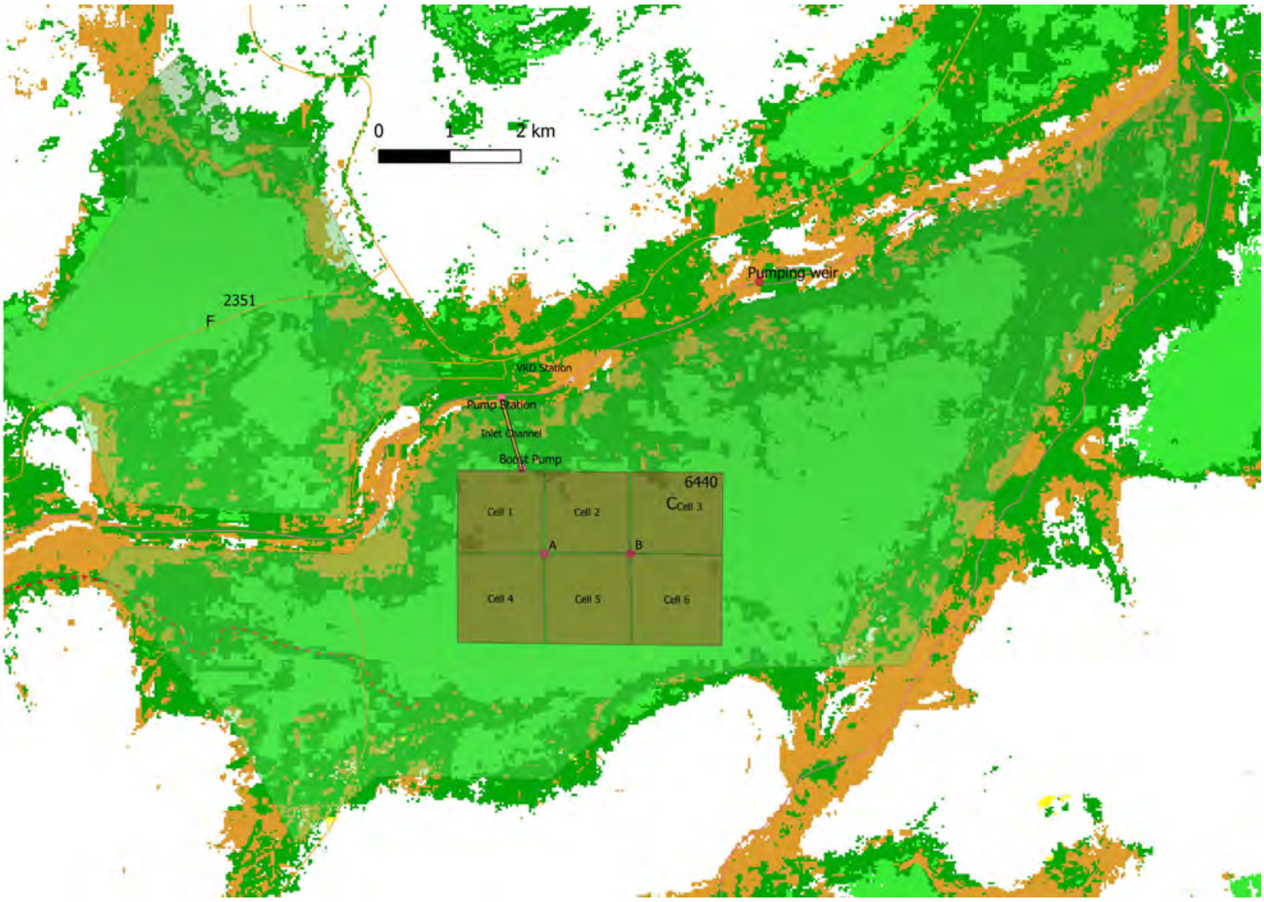

Figure 4-1 Notional water-harvesting layout for full development of Area C

Development area is overlaid on SGG predictions and Google imagery. The boundaries of areas C and F as per Figure 2-1 are also shown.

4.3 Major elements of the notional water-harvesting scheme

While it is noted that full development of Area C under a water-harvesting scheme is unlikely due to the total cost, the major elements of such a scheme are briefly described to highlight the salient differences to a more likely scheme that focuses on the cracking clay areas. Major elements of the total development scheme for Area C are:

- a pump pool weir on the Wickham River, noted as 'Pumping weir' on Figure 4-1
- a pump station complex of axial-flow flood-lifter-type pumps located on the river bank at the location, noted as 'Pump station' on Figure 4-1
- an inlet channel some 1.1 km in length that leads to storage cell 1. The channel is assumed to be an earth channel formed from local borrow. It will have a design flow level at the storage of EL 92 m (elevation), equivalent to 1.0 to 3 m above natural surface
- a low-head pump station at the end of the inlet channel to lift the water to the storage at higher elevations
- a system of up to six storage cells, arranged as shown in Figure 4-1. The full supply levels of the cells will decrease west to east for the six-cell case

- a system of axial-flow box-mounted pumps to allow both interconnection of the cells and transfer from any one cell to an adjacent cell. These are located at the points labelled A and B on Figure 4-1
- a system of channels or pipelines to convey the stored water to individual irrigation paddocks. This will depend on the crop and irrigation technique chosen, but general comments can be made on this aspect. The majority of the suitable area is cracking clay soils (classified SGG 9, see Thomas et al., 2024a), which are potentially suited to furrow irrigation depending on the crop. However, not all areas of SGG 9 to the east of the potential storage cells are rated suitable for furrow irrigation, due to slope. This could be remedied by extensive land levelling. A likely arrangement is that the areas of SGG 9 to the west of the storage cells would be designed for furrow irrigation, as would one block to the east of the storage cells. The balance of the serviced area, consisting of red loamy soils, grading to friable non-cracking clays, or clay loams, grading to cracking clays, will be best irrigated by spray and would be served by a pipeline system
- the existing drainage feature to the south of the area. This will be utilised as the drainage mechanism for the total area. It lends itself to a tailwater return system discharging back to the storages.

A total gross area of some 4460 ha was identified in the layout in Figure 4-2, being about 40% furrow and 60% spray. Some area was lost due to irregular shapes, so an effective gross area of 4200 ha was assumed. For the purposes of this feasibility design, this was divided into 1700 ha furrow and 2500 ha spray.

The supply system to move irrigation water from the storages to the field is only detailed as far as the main infrastructure, as for the Wickham River potential dam site and the Leichhardt Creek potential dam site developments outlined in sections 2 and 3, respectively. Channel and pipeline alignments are shown in Figure 4-2.

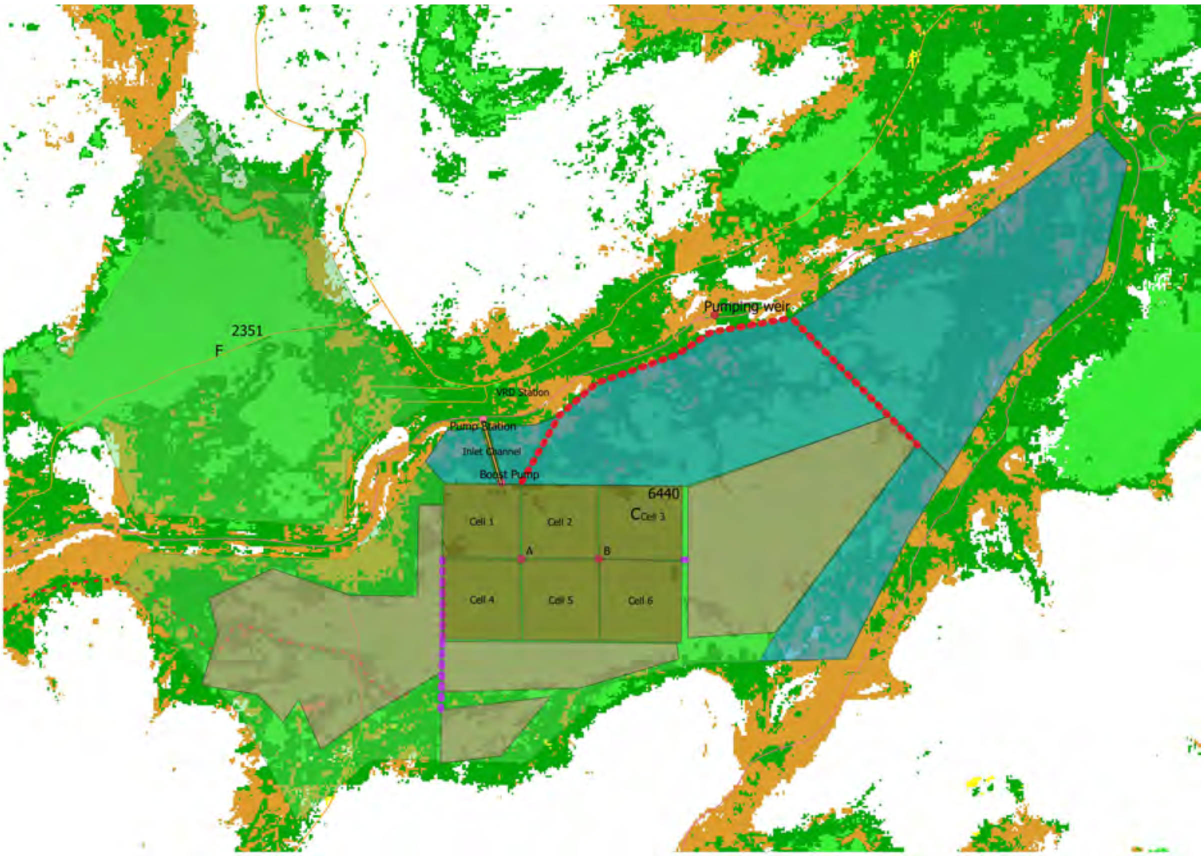

Figure 4-2 Flood-harvesting channel and pipeline layout

Furrow area shown in light green shading, spray area in light blue shading. Channel alignments shown in purple, and pipelines in red.

4.4 Likely scope of development – furrow-irrigated water-harvesting-based scheme

As outlined above, a development focusing on furrow irrigation of lands in reasonable proximity to the storage cells is more likely to be economically attractive than one focusing on developing all of Area C. Assumed details of a furrow-irrigated water-harvesting-based scheme are as follows:

- Total gross area serviced as shown in Figure 4-3 is 2181 ha, but this is assumed to be 2000 ha for the purposes of determining channel capacities due to irregular shapes.
- Gross water demand allowing for storage purposes to irrigate this serviced area can be assumed to be 21,000 ML out of the storages, based on:
  – crop demand of 8 ML/ha
  – furrow irrigation efficiencies of 80%
  – channel efficiencies of 95%.
- Four storage cells will have a notional capacity of 27,400 ML at 5 m depth to allow for evaporation and seepage. Note that this is a notional allowance, as the relative timing of the pumping window, and subsequent irrigation demand, along with soil and climate data will require a full hydrological simulation in later stages of design.

- Pump capacity at the river will be based on full demand over 50 days, which gives 6.5 m^3/second against an assumed static lift of 9 m during flow conditions. Pumps will be assumed to be axial-flow flood lifters, installed on the river bank.
- The intake channel will be at the same level and freeboard as the west end storage cells. This is possible in this instance as the cells are lower than that assumed for the full development case. A control structure at the downstream end will allow distribution to, and isolation from, the storages cells.
- The capacities of the channels, calculated using the method outlined in Section 2.3, are as follows:
  – channel B–C is 0.9 m^3/second
  – channel C–D is 0.1 m^3/second
  – channel E–F is 0.9 m^3/second.

The assumed layout for the furrow-irrigated development as described is given in Figure 4-3.

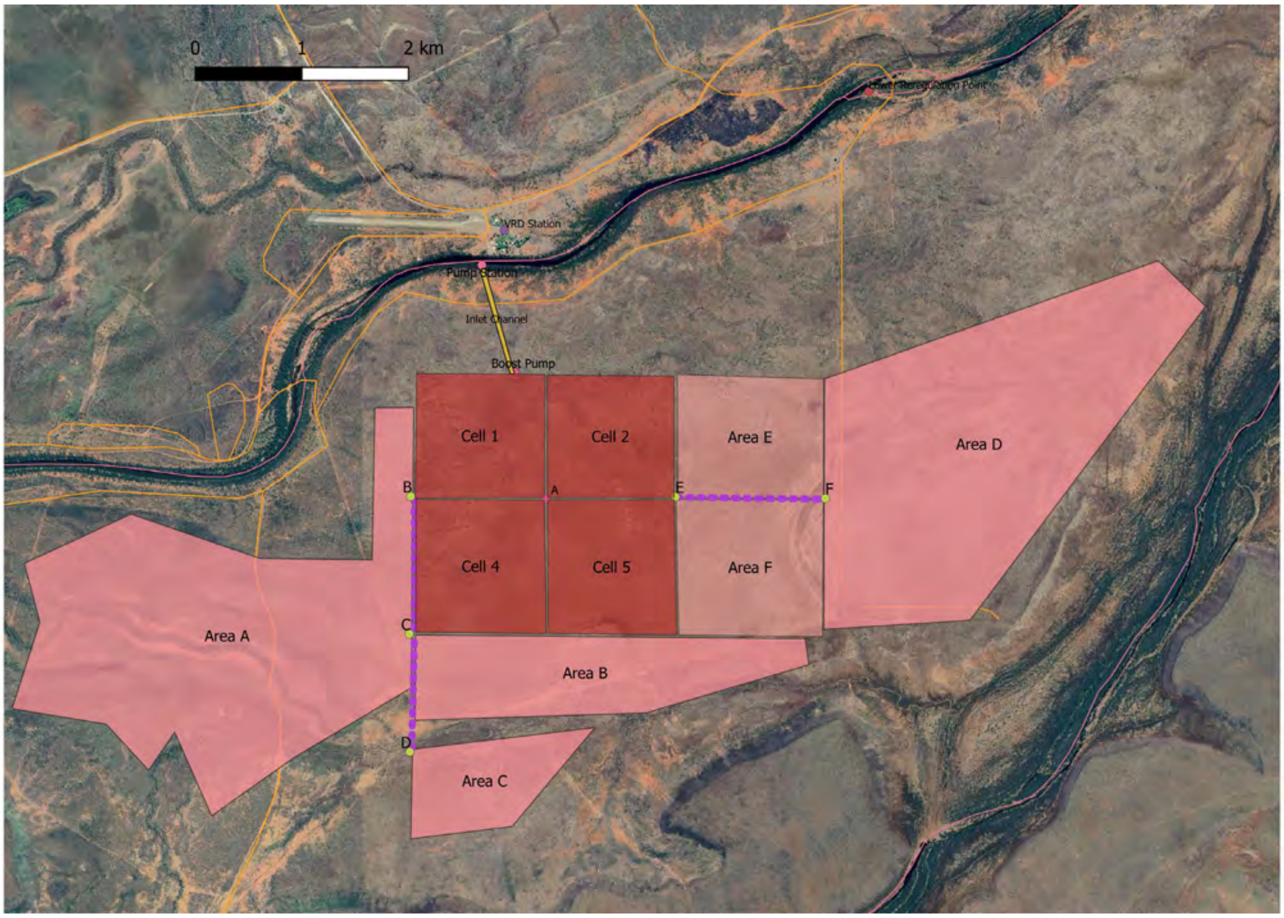

Figure 4-3 Layout for furrow irrigation development

Serviced area shown in light pink. Main channels shown as purple dashed lines.

4.5 Water-harvesting cost estimation

Final details of any design will be heavily dependent on the crop type and irrigation method. However, to allow some meaningful comparison with the dam-fed irrigation layouts derived for this area in Section 2, cost estimates (Table 4-2) were prepared on the basis of the following assumptions:

- The area of soils targeted for development is the SGG 9 unit, and channels were only defined for costing to the extent of primary infrastructure as defined in Section 4.4. This is to keep assumptions in line with those used in sections 2 and 3. Other distribution to individual fields will be required, but these will be assessed under the 'farm development cost' category.
- Water-harvesting developments by their nature are more likely to be sole-enterprise developments, which can tolerate a lower standard of design than is possible in larger dam-based irrigation developments. This has a consequence for the method of construction of the major storage cells, which are mostly constructed by cross dozing from borrow from within the ponded area near the alignment. For lower storage levels, this is invariably associated with dozer-only compaction. For the levels assumed in this case, side dozing and compaction by vibratory compactor will be assumed. This is still a much cheaper method of construction than that of conventional channels, which entail excavation and hauling with pushed scrapers, and moisture conditioning, compacting and trimming with water trucks, compactors and graders. The cheaper construction results in a greater potential failure rate for the storages, but the higher maintenance is accepted as a necessary trade-off for the lower capital cost.
- The arrangement shown in Figure 4-3 will feature a second pump at location A. This will be a box-mounted column-less axial-flow diaphragm pump that will allow gravity diversion between all cells and pumped diversions from either eastern cell back to either western cell. It will also allow pumping between the two western cells. In this way, water held at the end of the growing period can be moved progressively to a smaller number of cells to limit evaporative losses.
- All pumping will be diesel powered.

The below cost estimate equates to $18,300 per irrigated hectare. It is not valid to compare this directly with the equivalent costs derived in sections 2 and 3 since there is no dam involved in this development, only the weir to raise pump section levels. It is also not valid to directly compare the costs per ML of water utilised in the dam and water-harvesting cases, as factors such as differing reliability of supply and differing efficiencies of transfer of water from a dam to the serviced area complicate the issue. The above estimate shows that by far the majority of the costs are associated with the water capture and conservation elements rather than the irrigation reticulation components. Assuming the 21,000 ML effective yield of the system, the cost per ML of annual yield is $1740.

Table 4-2 Furrow-irrigation water-harvesting cost estimate

COST CATEGORY	ITEM	CAPITAL COST ($)
Capital costs – direct	River weir	5,610,500
	River pump station	2,406,150
	Intake channel	3,618,622
	Storage cell 1	4,153,564
	Storage cell 2	3,205,275
	Storage cell 4	2,141,484
	Pump between cells	1,270,000
	Channel B–C	274,507
	Channel C–D	182,496
	Channel E–F	519,992
	Total direct cost	26,395,826
Indirect costs	Design and documentation	527,917
	Site supervision	1,319,791
	Insurance	659,896
	Environmental approvals	1,583,750
	Total project costs	30,487,179
Risk adjustment	20% of total project costs	6,097,436
Total capital cost		36,584,615

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Part III Southern Gulf catchments

5 Potential dam site on Gunpowder Creek AMTD 66 km

The Gunpowder Creek potential dam site has an annual water yield of approximately 129 GL at 85% annual reliability.

On this basis, and taking into account transmission losses and other factors, the serviced area will be around 10,000 ha (depending on crop type and method of distribution).

The site is further limited by the fact that the first 15 km downstream of the dam is much incised, with typical side gradients above likely flood levels of above 1 in 3. This effectively rules out distribution by open-channel or flume systems, and pipelines would be very expensive in that terrain. Tunnelling would be possible but at even greater expense. The inescapable conclusion is that distribution via river releases to a downstream re-regulation and pumping point is the only practical alternative. Both sites identified in Figure 5-1 are on the downstream end of significant existing waterholes where pump submergence could be achieved with a very modest weir height at the natural restriction. Alternative 2 has the additional advantage that there is only one active watercourse at this point, while Alternative 1 has a high-level flood runner to the immediate south. It is notable that Alternative 2 is presently used for a station track crossing.

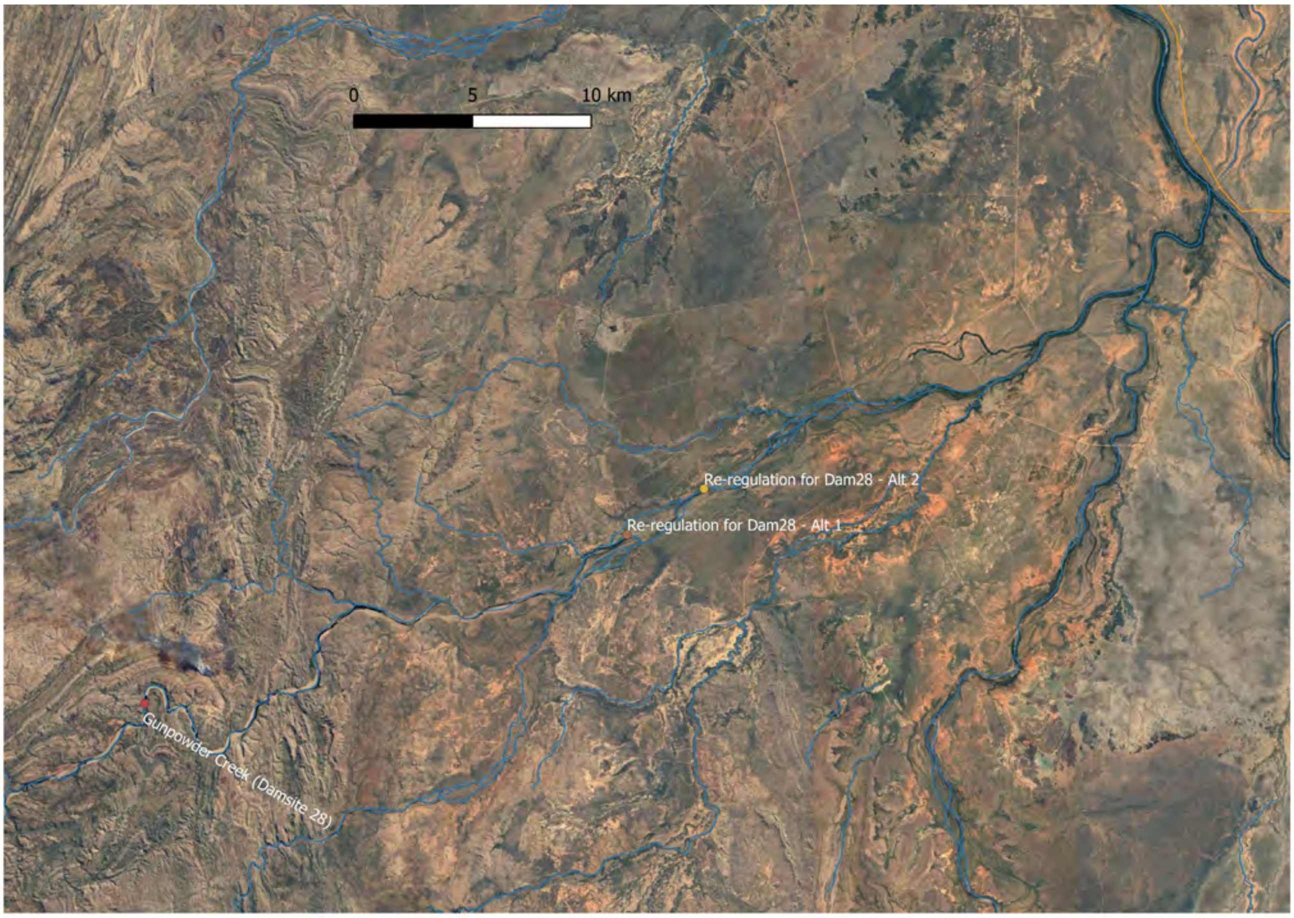

Figure 5-1 The Gunpowder Creek potential dam site and potential diversion locations

Taking into account the likely location of a downstream re-regulation and pumping point, the area examined below was limited to that potentially serviced by releases to Gunpowder Creek down to the junction with the Leichhardt River.

Three major areas of potentially suitable soils, identified as A, B and C in Figure 5-2 and the discussion below, met the criterion outlined above. The three potential serviced areas are compared in Table 5-1.

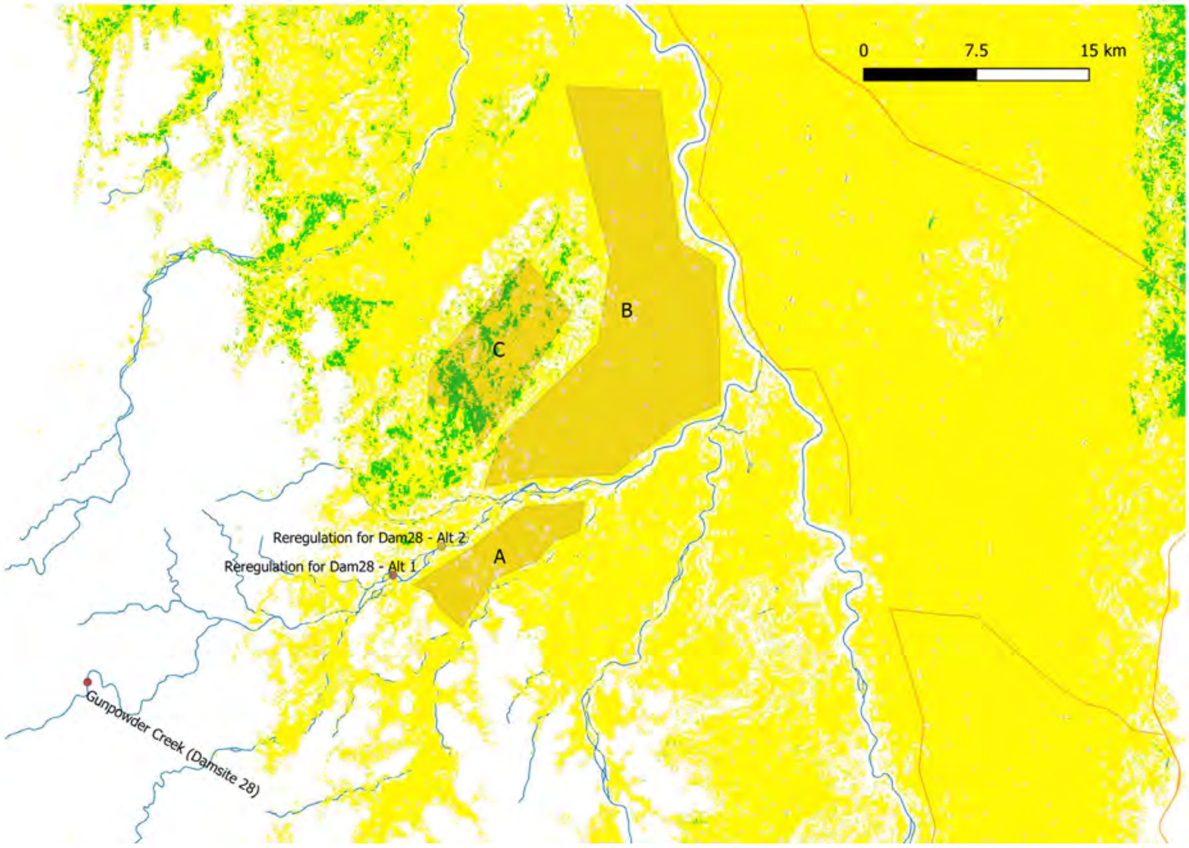

Figure 5-2 Potential development areas for Dam site 28

Development areas are overlaid on levels of suitability for dry-season spray-irrigated cotton or grains.

Table 5-1 Evaluation of alternative development areas for potential Dam site 28

AREA NO.	GROSS AREA (HA)	ADVANTAGES	DISADVANTAGES
A	3,602	• Most upstream area • Generally suited to dry-season spray-irrigated cotton and trickle-irrigated cucurbits • Overall slope is around 1:800 with some noticeable micro relief	• Contains significant unsuitable areas • At only 3602 ha gross, will require a second area to maximise use of water available. This will require a second pump and distribution set-up • Some evidence of significant distributary flood overflow on the mid north-western boundary will require special treatment by levees or dedicated flood channels • A complex mixture of soil types. Major units are SGG 1.1, SGG 4.1, SGG 9 and SGG 2. These will require differing management strategies

AREA NO.	GROSS AREA (HA)	ADVANTAGES	DISADVANTAGES
B	20,870	• Large contiguous area • Overall slope is around 1:1000 with less micro relief than Area A • Predominant soil unit is SGG 9, with significant areas of SGG 1.1 and lesser areas of SGG 2. The larger units will aid cropping flexibility without unduly increasing complexity of management • Good suitability for dry-season cucurbits under trickle irrigation and cotton under spray irrigation • The overall layout will favour a downslope backbone channel towards the left side of the development, with distributary laterals and associated drainage facilities to the right-hand side. Drainage not directed for re-use would be directed to the Gunpowder Creek and Leichhardt River courses • The layout would favour an in-line storage towards the bottom of the serviced area to counter distribution losses and to allow efficient capture of tailwater returns	• An area along the southern edge shows a deep gully in the imagery that does not show in the available Digital Terrain Model. This may limit potential development in this area only • At full development, the area is over 30 km long, making transit time for supply an issue
C	• 5,800	• Topographically more complex than the other two areas, but overall slope similar at about 1:800 • Good suitability for dry-season cucurbits under trickle irrigation and cotton under spray irrigation • Potentially fewer issues with flooding and wet-season workability than the other areas	• More remote from the main Gunpowder Creek alignment and would require a dedicated lateral channel to this area. The lateral channel would have to cross some significant local drainage • Both topographical complexity and soil type distribution would make farm layouts complex in this area

Note that other areas of large aggregations of cracking clay were present both immediately upstream of the Gunpowder Creek – Leichhardt River junction and on the east side of the Leichhardt River alignment. These were not pursued for a number of reasons. The former would require very significant pumping from the river up to the suitable lands. The latter would involve a much more expensive re-regulating structure since it would be in the main Leichhardt River channel. It would also be subject to more losses, being much further downstream. Note, however, that there may be more available yield in this location due to the dam yield being used in conjunction with the natural flow in the Leichhardt River. Given the aim of the study, the upstream areas were favoured.

Area B was chosen for further investigation because of the advantages outlined above. It is more than capable of meeting the scope of development supported by the potential dam.

5.1 Re-regulation weir for Gunpowder Creek potential dam site

With Area B as the target development area, Alternative 2 in Figure 5-1 was the chosen diversion point. This is still approximately 5 km upstream of the start of the serviced area, but no more favourable sites exist downstream of this diversion point.

An indication of the type of structure required is outlined below:

- Due to the site being only 35 km below the dam, and the creek section being relatively steep at 1:1000, the operational range of the re-regulation storage can be assumed to be modest (0.3 m).
- The imagery indicates that existing water depth is at least 1 m with the north abutment about 1.5 m high and the south side only 1 m high. If these depths can be assumed as indicative, and assuming that the pumping is only very low head and likely to involve axial-flow pumps, the submergence requirements will be modest, and a total water depth of 1.5 m will be adequate. This assumes either angled bank-mounted axial-flow pump units incorporating screening, or vertically mounted axial-flow pumps in a chamber in the bank, with screening on the inlet. This implies a total weir height of about 0.8 m, which should be achievable within the assumed section with acceptable afflux during flood flow conditions.

5.2 Irrigation layout

A number of assumptions and choices were made for the purposes of this study.

Piped reticulation from the re-regulation weir pump station was assumed for the following reasons:

- The country slope of 1:1000 and steeper will make piped reticulation possible.
- The potential for outflows from the main creek line during flood events will require substantial cross-drainage capacity for a channel network. This significant cost involving cross drains or inverted siphons will be avoided for below-ground pipelines.
- The likely application methods of spray or trickle will be more amenable to pipe networks than a channel network. This will alleviate the need for tailwater return systems and buffer storages to cater for rain rejection events, which would be a necessary feature of open-channel systems.

This site has the potential to serve up to 11,200 ha, assuming:

- Dam yield at 85% annual reliability is 119 GL/year.
- Crop demand assuming dry-season field crops or perennial trees under spray is 8 ML/ha.
- Irrigation efficiency for spray application is 85%.
- Irrigation efficiency for trickle application is 90%.
- Distribution efficiency for piped reticulation is 98%.
- River reticulation efficiency is 85%.
- Net area irrigated is 95% of gross area.

Targeted gross areas are therefore between 10,500 ha and 11,200 ha, depending on crop type, irrigation method and reticulation arrangement.

The total area of Area B is many times the targeted area outlined above. The area selected for notional design was arrived at by:

- removing the area of the gully system referred to in Table 4-1
- including enough area to exceed the upper limit of 11,200.

The reduced Area B, as shown in Figure 5-3, has a gross area of some 11,700 ha.

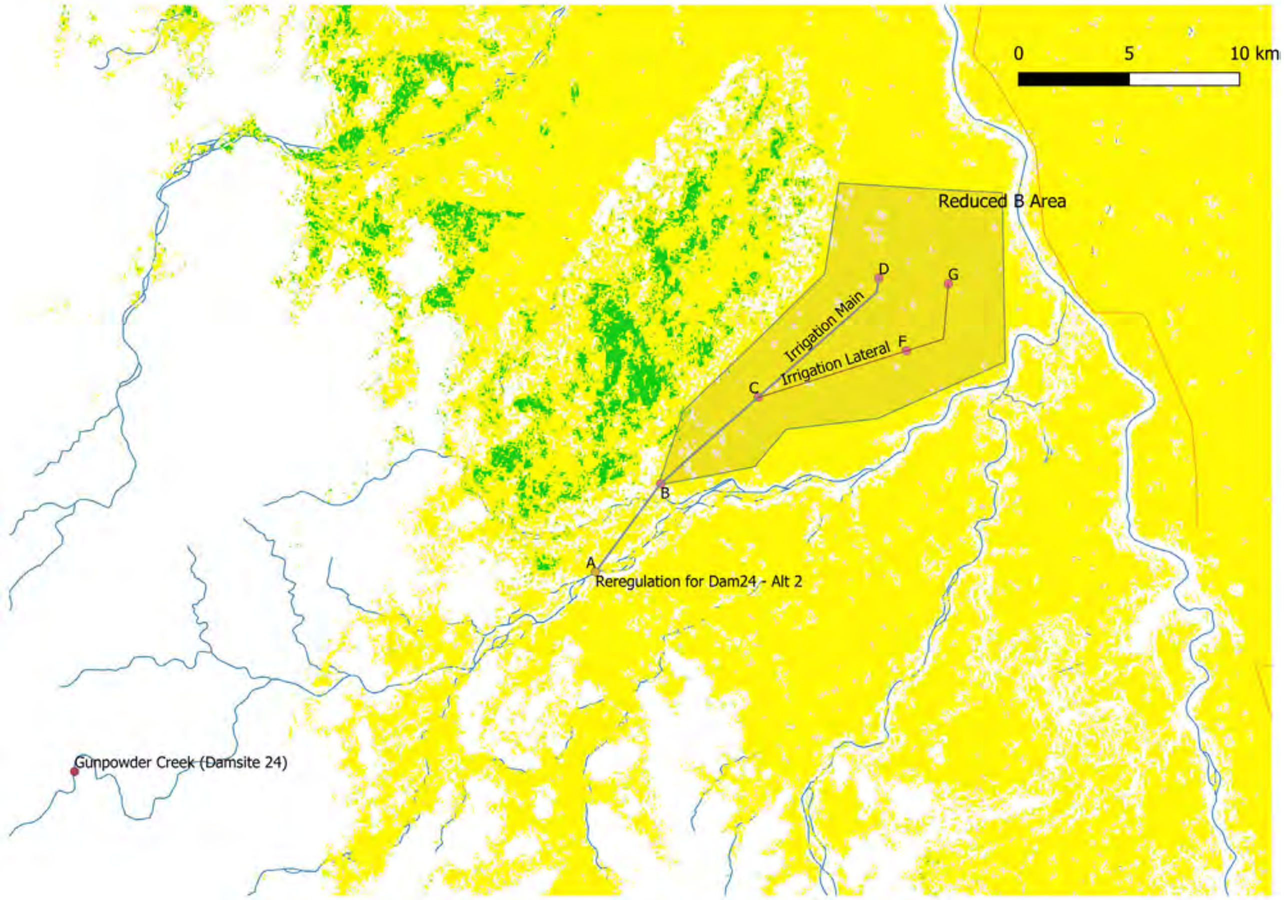

Figure 5-3 Targeted development area (reduced Area B) and pipeline infrastructure for potential Dam site 28

Development area is overlaid on levels of suitability for dry-season spray-irrigated cotton or grains.

The notional layout of the pipeline infrastructure (Figure 5-3) was derived on the following basis:

- The mainline is positioned so that supply to travelling irrigators or centre pivots will be possible to both sides of the alignment, with a maximum diameter of the irrigation span of approximately 2.5 km.
- A lateral is positioned to the east of the above mainline to meet the 2.5 km maximum diameter of the irrigation span criterion.
- Both the mainline and lateral channels are orientated primarily downslope to minimise pipe diameter.

5.3 Piped reticulation design

Flow-rates for the reticulation pipelines were based on the following calculation.

Daily crop demand was based on

$$E_t = p \times f_1 \times 0.8 \times E_0 \tag{3}$$

where:

- p is climate factor, assumed as 0.7
- f_1 is crop factor, assumed as 1.0

- E_0 is assumed at 12.3 mm/day, based on SILO values for Kamilaroi (P_{99} of 4-day mean E_0). Kamilaroi Station, some 20 km south-east of the serviced area, is the closest site with climate data. Other more distant meteorological stations in the vicinity gave similar results.

E_t is therefore 6.89 mm/day.

Irrigation demand is 8.1 mm per day per hectare, assuming spray irrigation.

No diversity factor was applied, as the total area is small and soil types reasonably uniform.

Flow-rate at the head of the system is therefore 10.5 m^3/second, with flow decreasing progressively downstream as areas are serviced (Table 5-2).

The areas serviced above, assuming 95% utilisation of the gross area, are described in Table 5-2 using the nomenclature of the points in Figure 5-3. For the purposes of this feasibility design, the flow-rate changes were assumed to occur at the mid-point of the area serviced. It can be assumed that any final design will have a more graduated change of flow-rate, but the overall impact will be small.

Table 5-2 Adopted flow-rates for piped reticulation

CHANNEL	LEG	LENGTH (M)	CUMU-LATIVE CHAINAGE (M)	INCREMENTAL AREA SERVICED (HA)	CUMU-LATIVE GROSS AREA SERVICED (HA)	CUMU-LATIVE NET AREA SERVICED (HA)	DESIGN FLOW-RATE (M^3/S)	CHAINAGE OF FLOW-RATE CHANGE (M)
Mainline	A–B	5140	5,140	1785	11,734	11,147	10.5	8,160
	B–C	6040	11,180	2962	9,949	9,452	8.9	15,200
	C–D	8040	19,220	1774	1,774	1,685	1.6	19,220
Lateral	C		0	1554	5,213	4,952	4.6	3,538
	C–F	7075	7,075	1972	3,661	3,478	3.3	9,294
	F–G	4438	11,513	1689	1,689	1,605	1.5	11,513

A couple of other assumptions were made prior to the pipeline selection for this area, including:

- In this instance, a full gravity pipeline is not possible, and some re-lift must be provided at the point of re-regulation. While the re-lift level is optimised to minimise life cycle cost, the minimum re-lift head options are favoured to avoid high pipeline pressures and consequent transient pressure issues on power failure.
- For this exercise, only single re-lift solutions are examined. This is a relatively simple layout, and multiple re-lift pumps are unlikely to be cost effective. However, the fact that re-pumping for filtering and/or re-pressurisation for travelling irrigators may be required means that this conclusion will need to be re-examined in the later stages of the design.

5.4 Pipe system type

Two main types of pipeline were considered for this project: high-density polyethylene (HDPE) and glass-reinforced plastic (GRP). While both are considered flexible pipelines for installation purposes under the relevant Australian Standard (AS/NZS 2566), they are quite different in characteristics, as described below. Hence, for some applications one will be more suited than the other.

HDPE pipe

- HDPE pipe is extruded as a solid wall product from a feedstock normally consisting of pellets or reconstituted polyethylene. All pipe made in Australia currently is formed from PE100 material. This rating relates to the material strength of the pipe and is reflected in the design SDR (standard dimension ratio). A low-pressure pipe such as PN4 (40 m working pressure approximately) is SDR41, meaning the pipe diameter is 41 times the wall thickness.
- Pressure ratings up to PN10 are available for HDPE pipe in the larger diameters required for irrigation projects. However, this pipe (SDR17) is very expensive due to its heavy wall thickness. Supply price for HDPE is closely correlated with the amount of material in the pipe.
- Diameters up to DN900 readily available.
- Installation to the standard required by AS/NZS 2566 is important for any flexible pipeline, but HDPE is more forgiving than the equivalent GRP product. In higher SDR ratings, it is an extremely flexible product, so correct backfill of bedding and haunch material is crucial to ensuring the required limits to deflected shape are achieved to avoid buckling under load.
- The product is delivered in individual lengths (12 to 20 m) for larger diameters (smaller diameters typically come rolled) and is jointed by a hot-fusion welding process either prior to installation in the trench or after installation by ‘belling’ the excavation at the joint. Larger diameter, higher pressure lines are typically installed by ‘belling’, as the pipe flexibility becomes the limiting factor.

GRP pipe

- GRP pipe is manufactured by winding glass filaments, resin and sand filler on a spinning mandrel.
- Has greater diameters and pressure capability than HDPE. Theoretically available up to DN4000 and PN16. Diameters up to DN1700 are available up to PN32.
- The product is normally supplied in 12 m nominal lengths.
- They are rubber ring jointed in a GRP coupling that is pre-installed on one end of the pipe.
- Routinely supplied as two stiffness ratings: SN5,000 and SN10,000. Both ratings are stiffer than the equivalent-pressure HDPE pipe, but they are still classified as flexible pipe and installed to AS/NZS 2566.
- Equivalent pressure ratings are thinner and lighter than the HDPE pipe.
- Bedding is critical to avoid leakage at joint collars, and particular care is required to bed and haunch.

The comparison indicates that GRP will have significant advantages over HDPE for larger flows to be carried by pipelines. The changeover point at which the installation ease of HDPE overcomes the size range and cost competitiveness of GRP will depend on specific site circumstances, but for the purposes of a preliminary design, it will be safe to assume that for sizes above 675 mm diameter, GRP will be cost effective.

5.5 System pipe sizing

Pipelines were designed and pipe sizes selected for the network to meet a number of criteria:

- The gradeline was selected to produce a hydraulic gradeline (HGL) with sufficient positive head to help avoid negative pressure surges during abrupt flow changes. In effect, the velocity limitation noted below dominated in most cases, and the HGL selected was the maximum possible without affecting maximum velocity.
- Low-lift pumps were favoured to suit axial-flow pumps whose power demand is practical for diesel power. Higher lift pumps were able to reduce the life cycle cost of the installation, but they involve a power demand likely to be beyond the practical limits of readily available diesel power packs. Low-lift pumps are also more practical in this instance due to the limited submergence available in the pumping pool.
- Pipeline velocity at full flow is limited to below 3 m/second to help moderate transient pressures on pump power failure or abrupt changes of demand.
- Pipelines are designed to produce a minimum of 2 m residual head at the take-off point. This is conservative, as there will be some re-pumping at this point for travelling irrigators or filtering for trickle irrigation, but it ensures that there is some flexibility in the location of the re-pumping.
- In general, GRP pipelines are favoured for this project because they represent the minimum cost solution for the pressures and flow-rates involved. It is possible that HDPE lines could be used in some cases of relatively smaller flow-rates, but installed costs are estimated to be higher for all these cases. Thus, GRP pipes are selected for use throughout the project, mainly driven by the large diameters required. An effective roughness of k = 0.06 mm is assumed, representing an achievable long-term value. Head loss is calculated using the Colebrook–White equation.

The results of this pipe size analysis are shown in Table 5-3.

Table 5-3 Adopted pipe requirements

Line nomenclature follows Figure 5-3.

PIPELINE	REACH	LENGTH (M)	FLOW (M^3/S)	PIPE REQUIREMENTS
Mainline	A to mid B–C	8160	10.5	DN3000 PN10 GRP
	Mid B–C to C	3020	8.9	DN2000 PN10 GRP
	C to mid C–D	4020	4.3	DN1800 PN10 GRP
	Mid C–D to D	4020	1.6	DN1100 PN10 GRP
Lateral C–H	C to mid C–F	3538	4.6	DN1800 PN10 GRP
	Mid C–F to mid F–G	5756	3.3	DN1800 PN10 GRP
	Mid F–G to G	2219	1.5	DN1200 PN10 GRP

5.6 The Gunpowder Creek potential dam site reticulation costing

Costing for the above works necessitated a number of assumptions and choices, of which the more important were:

- Pipelines were costed at unit rates derived by Rider Levett Bucknall (2024), adjusted where necessary for actual sizes and pressure classes. A percentage allowance was made for normal pipeline appurtenances, such as air valves, scours, swabbing facilities, thrust blocks, specials and valving.
- The pump stations, as detailed above, are low-head structures, suited to axial-flow pumps mounted on the batter of the river bank. For this exercise, Batescrew axial-flow pump models 24/30 (or similar) were assumed. These pumps are mostly used for installations for flood harvesting, but are also quite suitable for this application. Six units were required for this installation, and they are assumed to be diesel powered.

Table 5-4 Cost summary for the Gunpowder Creek potential dam site reticulation

COST CATEGORY	ITEM	CAPITAL COST ($)
Capital costs – direct	Re-regulation weir	4,565,600
	Pump station	1,564,000
	Mainline	154,466,000
	Lateral C–H	58,689,000
	Pipeline appurtenances	10,658,000
	Total direct cost	229,942,000
Indirect costs	Design and documentation	4,599,000
	Site supervision	11,497,000
	Insurance	5,749,000
	Environmental approvals	13,797,000
	Total project costs	265,583,000
Risk adjustment	20% of total project costs	53,117,000
Total capital cost		318,700,000

The cost calculated in Table 5-4 represents a development cost of some $27,200 per irrigated hectare of spray or trickle irrigation for the backbone infrastructure only. The total cost to move the water to the paddock will also include distribution from the main reticulation network to the individual irrigators required for the irrigated area.

This estimated cost is expected to be greater than that feasible for a remote agricultural investment. The main driver for the high cost is the very high cost of large-diameter pipe, such as that detailed for use in this instance. Smaller diameter pipelines would normally be possible but are not used in this instance due to the velocity limits imposed on the design and the fact that high-lift pumps would require more submergence than is achievable in the small stream. The total cost raises the question as to whether an open-channel solution, even though extremely difficult, would be more cost effective in this instance. It is worthwhile revisiting the reasons and assumptions that led to the open-channel solution being discarded to gauge the difficulty in implementing that solution. These factors are discussed in Table 5-5, in which it is assumed that the same alignments would be used.

Table 5-5 Factors against open-channel reticulation and potential strategies to negate

FACTORS AGAINST OPEN CHANNEL	IMPACT	STRATEGIES TO NEGATE	NOTES
Highly complex soil distribution	• Soils for the mainline and lateral channels are mostly SGG 9, but there are very significant areas of SGG 1.1 and SGG 4.1 • Neither of the latter is likely to be suitable for channel construction without unacceptable losses	• Borrow for over-excavation and earth lining • Membrane line the channel	Given the complexity of the soils distribution, it is likely that suitable borrow could be found nearby, making earth lining the likely best option
Flood prone	• Channels must be built higher than flood level to avoid catastrophic damage from flood events • Potential of open-channel network to affect the patterns of overland flow	• One side of the channel could conceivably be constructed as a levee to stop flood ingress	Not possible to estimate the extent of levees required at this time without flood modelling, but the general direction of flood flows indicates that this approach should work
Creek crossing	• Large openings in any channel are necessary to pass flood flows	• Siphons will be one way to dissipate some head in the system. If high velocities are utilised, this will dissipate significant head, albeit at the expense of a dissipater outlet	This point mainly applies to the creek crossing at about 4.2 km on the mainline
Distribution efficiency	• Without any terminal storage, the network will be at risk of losses in the system from rain rejection	• The bottom bay in both the mainline and the lateral channels could be significantly widened to function as an in-line storage, limiting losses from rain rejection and operational overflows	Distribution efficiency will still be less than for a piped system, but with the in-line storages, and with Total Channel Control on all regulation points, it should be acceptable
Country slope	• Any channel system will feature multiple bays and associated drop structures to dissipate head	• Earth-lined channels could conceivably be constructed at slopes as steep as 1 in 1500. This implies approximately 16 m lost in channel slope and 6 m lost in drops for the mainline. The lateral channel is less steep	Very steep channels will require particular management, as minimum water depths to control weed flow may not be possible. This also introduces energy dissipation issues on flow start-up

The conclusion from the above points is that an open-channel solution should be possible, and it may be possible at significantly less cost than the piped option detailed above. It will service a smaller area due to the reduced transmission efficiency, but at least it may be economically possible, which the piped design is probably not.

6 Potential dam site on Gregory River AMTD 174 km

The Gregory River potential dam site was assessed at two full supply levels (FSL), 138 mEMG96 and 145 mEMG96. At a FSL 145 mEMG96, the reservoir would extend into the Boodjamulla National Park and would have an annual water yield of approximately 232 GL at 85% annual reliability. At a FSL of 138 mEMG96 the reservoir does not extend into the national park and the yield is 133 GL at 85% annual time reliability. Both yields take into consideration existing entitlement holders. See companion technical report on river model simulation in the Southern Gulf catchments (Gibbs et al., 2024).

Two irrigation scheme conceptual arrangements and costings were prepared: the first, assuming the larger 232 GL yield, was fully examined and preliminary costings were prepared. The second, of 133 GL, was examined on the basis of the changes induced by the lower figure of water availability. The purpose of evaluating irrigation schemes at two different FSL was to understand how the cost of the scheme scales.

With the 232 GL yield and taking into account transmission and other losses, the serviced area will be approximately 20,000 ha (depending on crop type and method of distribution).

While there is negligible land suited to irrigated agriculture in the immediate vicinity of the dam, the situation changes dramatically some 26 km below the dam, where extensive areas of soils suitable for broad acre irrigation spread out from the river course, especially on the eastern bank.

6.1 Conceptual irrigation scheme arrangement for Gregory River potential dam with FSL 145 mEMG96

6.1.1 Selection of area for development

The main factors influencing the selection of the preferred development area were as follows:

- The east bank of the river offers more potential than the west side, so attention is focused on this area.
- It will be important not to interfere with the flooding pattern across this land, the defining feature of which is a slope away from the river, and discrete major outflow points. Two important outflow points in this area are Cartridge Creek to the south and Millar Creek to the north. The aim of the potential layout is to leave these waterways unaffected by the development.
- The major roads, the Gregory Downs – Camooweal Road to the west and the Wills Development Road through the middle of the serviced area, will be left intact on their current alignments.

- While the lands are potentially suited to both furrow and spray irrigation, the notional areas will be selected on the basis of furrow irrigation. This method is the more restrictive in terms of suitability, and selecting it will preserve flexibility in development options.

The extent of the area for development was derived assuming:

- Dam yield at 85% annual reliability is 232 GL/year.
- Crop demand assuming dry-season field crops is 8 ML/ha.
- Irrigation efficiency for spray application is 85%.
- Irrigation efficiency for furrow irrigation is 80%.
- Distribution efficiency for open-channel distribution is 90%.
- Distribution efficiency for piped reticulation is 98%.
- River reticulation efficiency is 85%.
- Net area irrigated is 95% of gross area.

Targeted gross areas are therefore between 17,750 ha (open channel and furrow irrigation) and 20,500 ha (piped and spray irrigation).

The area chosen for further investigation is shown in Figure 6-1.

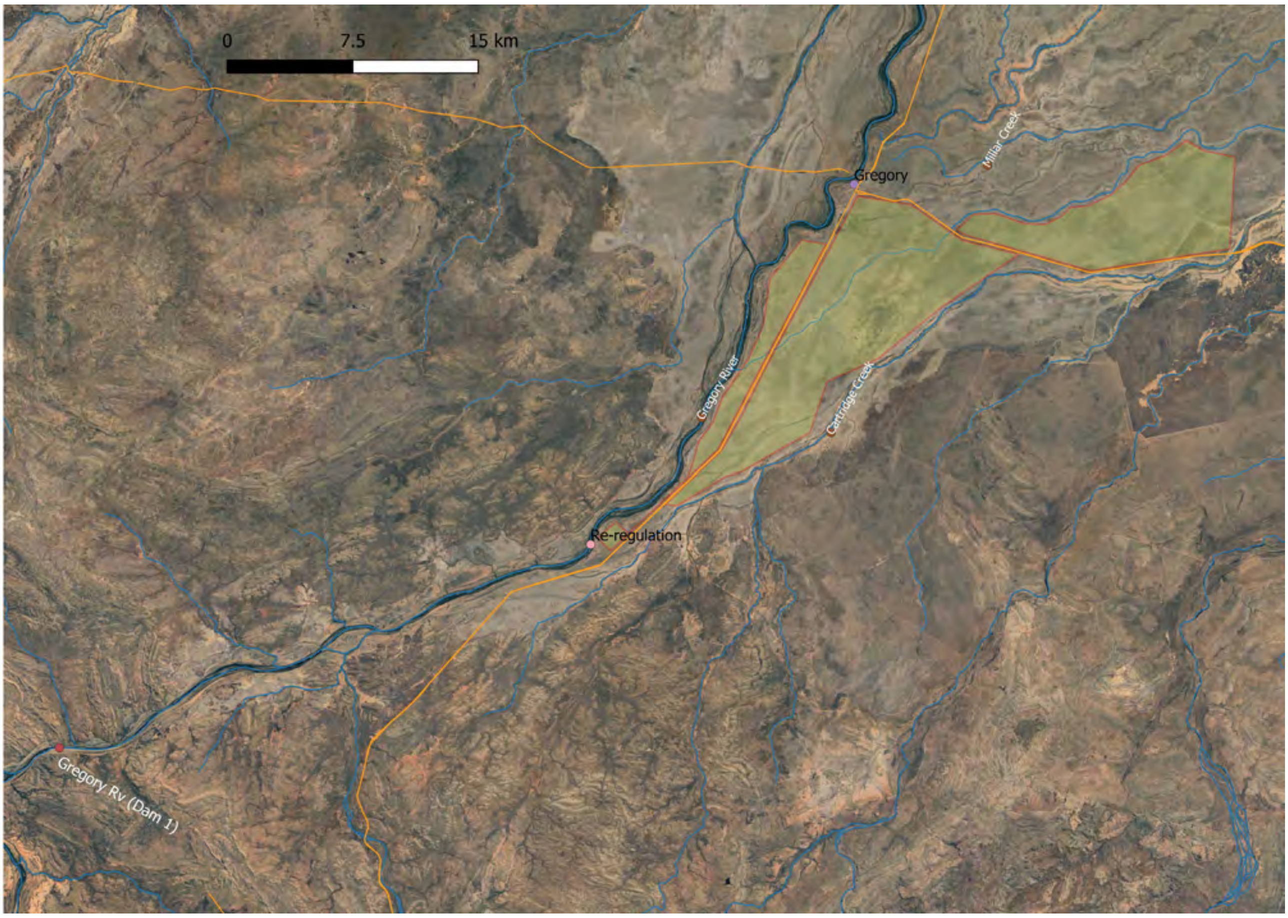

Figure 6-1 The Gregory River potential dam site and potential diversion and development areas
Shaded area denotes areas targeted for development, serviced from the re-regulation point.

The gross total size of the above areas is around the upper limit of the potential development at some 20,236 ha. Allowing for infrastructure losses, this should still yield some 19,200 ha potentially suited for development.

6.1.2 Method of supply

The suitable areas for development commence some 35 km downstream of the dam site. This stretch of river is well confined, and the land immediately adjacent to the river becomes increasingly steep nearer to the dam site. Accordingly, it will prove uneconomic to convey water from the dam site to the suitable areas by open channel or bench flume. Rather, a solution involving releases to the river, with re-regulation at the point identified in Figure 6-1, above will be more viable.

The re-regulation point is a natural bar in the river with a substantial 2.5 km long pool upstream. The depth of the pool suggests that a very modest piling weir, less than 2 m high, should provide an adequate pumping pool at this point.

Reticulation from the re-lift pump point to the area serviced is by open channels constructed from the in-situ cracking clay soils. Two main alignments will be used. The first will follow the north bank of Cartridge Creek, essentially to the eastern extent of the serviced area. The second alignment will follow the Gregory Downs – Camooweal Road for about 20 km to a location south of Gregory Township, where it will cross the road and service the lands to the east.

Notional alignments for the above channels are shown in Figure 6-2. Also shown are the parcel boundaries for the calculation of required flow-rates.

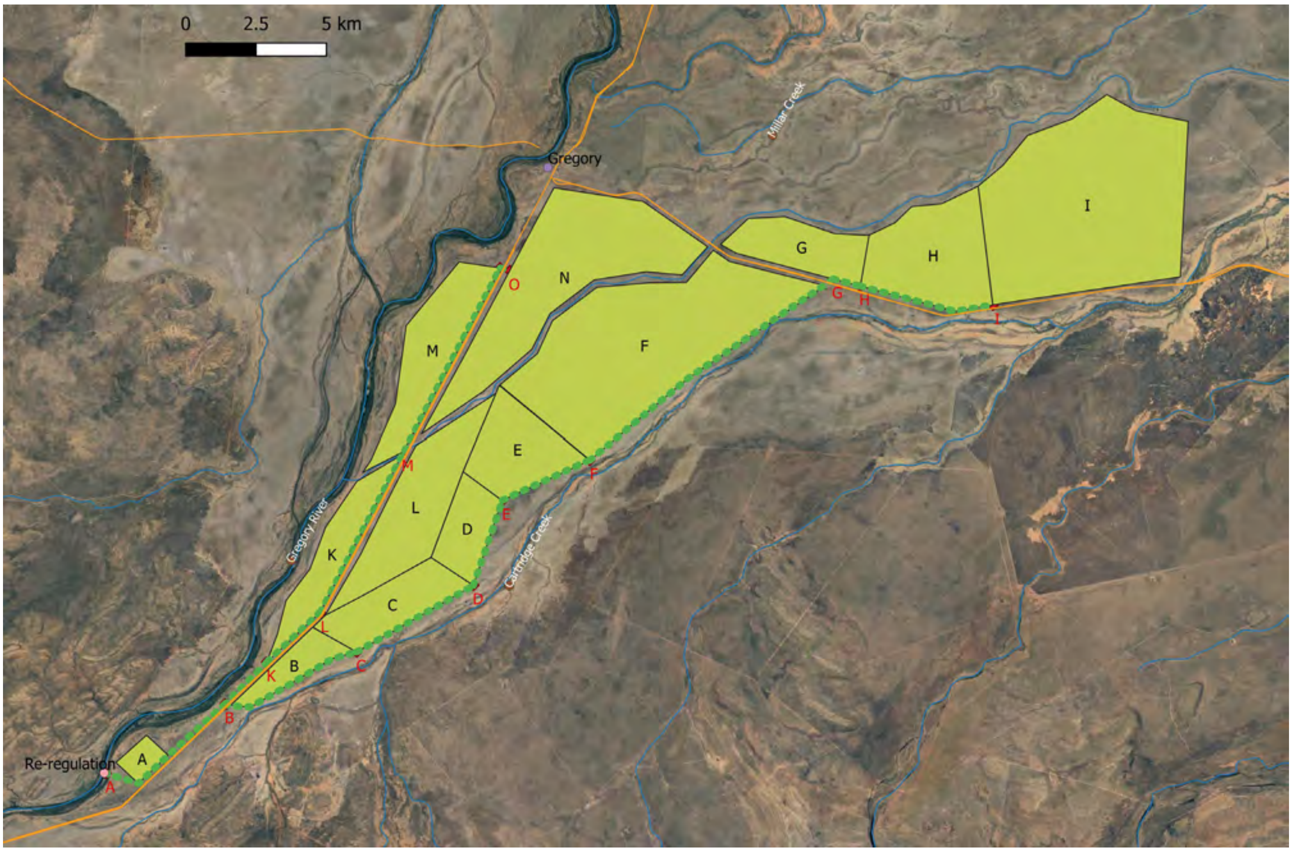

Figure 6-2 Channel layout and serviced areas

Channel layout shown as dotted green lines, with the individual areas and points used in the flow calculation.

6.1.3 Channel reticulation design

Flow-rates for the main channels were based on the following calculation.

Daily crop demand was based on

$$E_t = p \times f_1 \times 0.8 \times E_0 \qquad (4)$$

where:

- p is climate factor, assumed as 0.7
- f_1 is crop factor, assumed as 1.0
- E_0 is assumed at 11.6 mm/day, based on SILO values for Augustus Downs (P_{99} of 4-day mean E_0). Augustus Downs Station is the closest site with climate data, at some 66 km east of Gregory. Other more distant meteorological stations in the vicinity gave similar results.

E_t is therefore 6.5 mm/day.

Irrigation demand is 8.7 mm per day per hectare, assuming furrow irrigation.

No diversity factor was applied, as the total area is small and soil types are reasonably uniform.

Flow-rate at the head of the system is therefore 18.9 m^3/second, and flow decreases progressively downstream as areas are serviced (Table 6-1).

The areas serviced above, assuming 95% utilisation of the gross area are described in Table 6-1 following the nomenclature of Figure 6-2. For the purposes of this feasibility design, the flow-rate change was assumed to occur at the mid-point of the area serviced. It can be assumed that any final design will have a more graduated change of flow-rate, but the overall impact will be small. However, significant drops in design flow level can be expected to correspond to the existing leg boundaries, as some of these correspond to road crossings and other features. So, as a compromise for this preliminary design, the drops were assumed to occur at the existing leg boundaries, but the capacities of the channels designed were weighted to cater for the more likely centre of demand described in Table 6-1. The adopted longitudinal profiles are shown for the main channel in Figure 6-3 and for the lateral channel in Figure 6-4.

Table 6-1 Channel flow-rate determination

CHANNEL	REACH	LENGTH (M)	CUMULATIVE CHAINAGE (M)	INCREMENTAL AREA SERVICED (HA)	CUMULATIVE GROSS AREA SERVICED (HA)	DESIGN FLOW-RATE (M^3/S)	CHAINAGE OF FLOW-RATE CHANGE (M)
Mainline	A	0	0	164	19,710	18.9	2,772.5
	A–B	5,545	5,545	407	19,546	18.7	8,165.5
	B–C	5,241	10,786	833	12,994	12.4	13,205
	C–D	4,838	15,624	575	12,161	11.6	17,295.5
	D–E	3,343	18,967	966	11,586	11.1	20,691
	E–F	3,448	22,415	3904	10,620	10.3	27,908.5
	F–G	10,987	33,402	794	6,716	6.4	33,895.5
	G–H	987	34,389	1500	5,922	5.7	36,820
	H–I	4,862	39,251	4422	4,422	4.2	39,251

CHANNEL	REACH	LENGTH (M)	CUMULATIVE CHAINAGE (M)	INCREMENTAL AREA SERVICED (HA)	CUMULATIVE GROSS AREA SERVICED (HA)	DESIGN FLOW-RATE (M^3/S)	CHAINAGE OF FLOW-RATE CHANGE (M)
Lateral	B	0	0	0	6,145	5.9	1,086
	B–K	2,172	2,172	797	6,145	5.9	3,495
	K–L	2,645	4,817	1446	5,348	5.1	8,173
	L–M	6,712	11,529	1192	3,902	3.7	15,293
	M-N	7,679	19,208	0	2,710	2.6	19,208
	N–O	350	19,558	2710	2,710	2.6	19,558

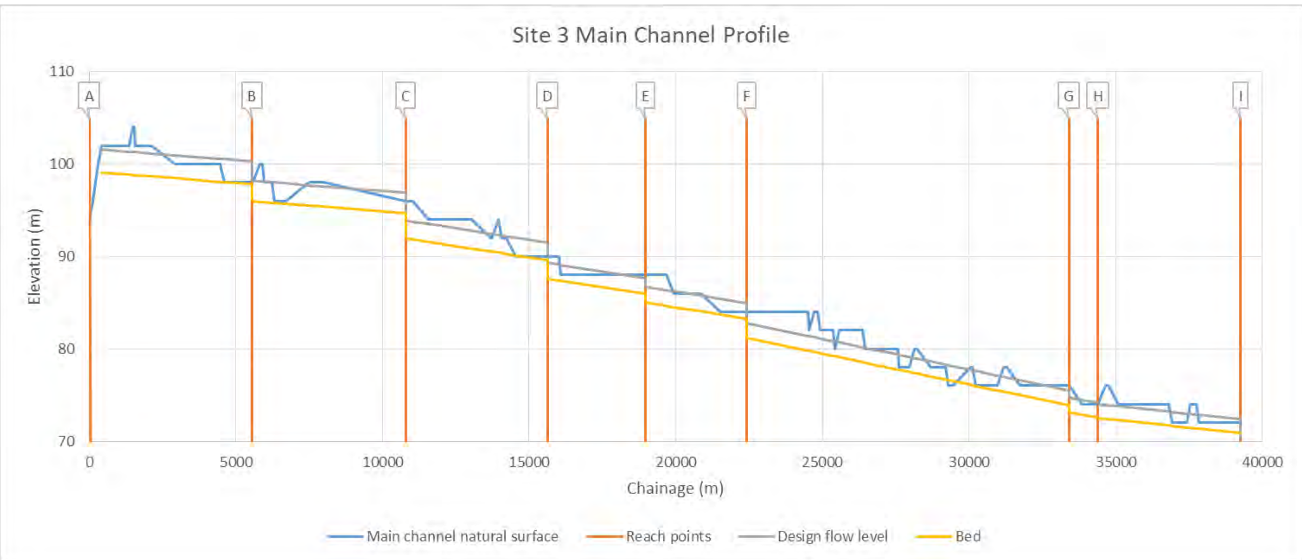

Figure 6-3 Adopted gradeline for Gregory River potential dam site main channel

Reach points refer to the locations shown in Figure 6-2.

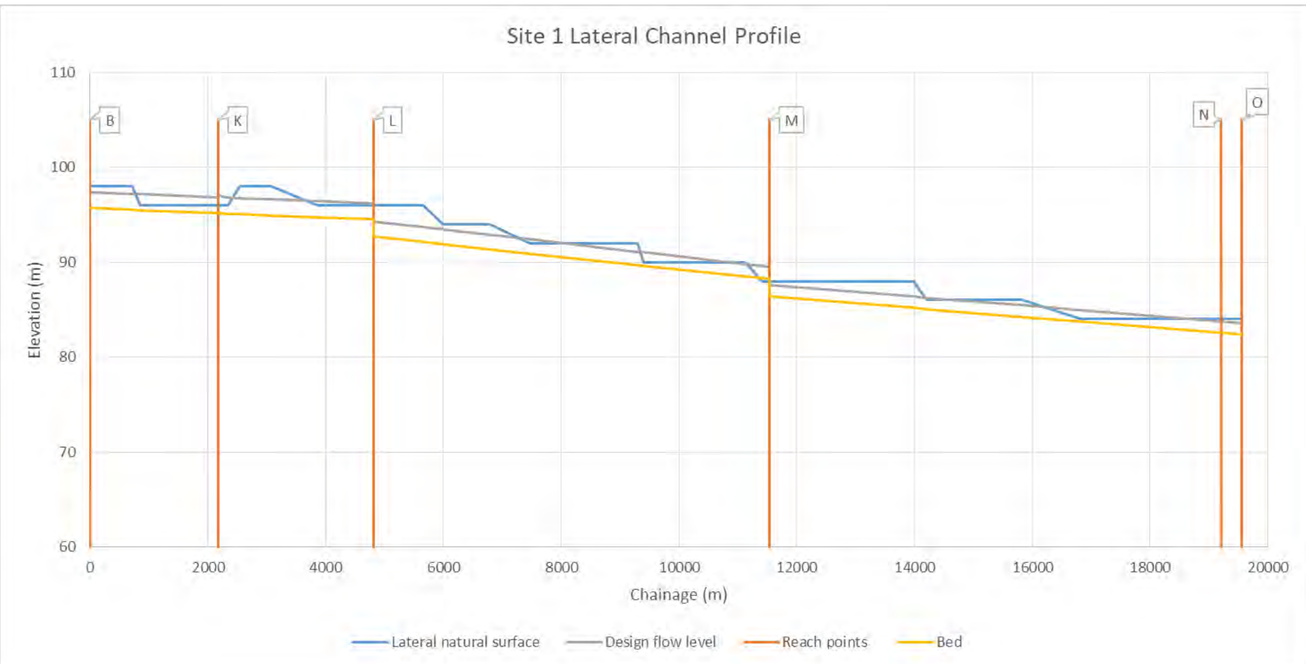

Figure 6-4 Adopted gradeline for Gregory River potential dam site lateral channel

Reach points refer to the locations shown in Figure 6-2.

In the derivation of the earthworks required for the above channel profiles:

- The profile, consisting of deep cracking clay soils, was assumed to be suitable for bank construction without modification or lining of the cut profile following over-excavation.
- Freeboards were varied based on the depth of flow.
- Design flow levels were adjusted so there was no or negligible borrow requirement within each reach.
- Any borrow required was assumed to be available within close reach of the channel alignment. This reflects the point that some limited longitudinal drainage will be required on the upslope side of the channel.

Adopted parameters are shown in Table 6-2 and Table 6-3.

Table 6-2 Adopted main channel parameters

REACH	DESIGN FLOW-RATE (M^3/S)	BED WIDTH (M)	WATER DEPTH (M)	FREEBOARD (M)	SLOPE (M/KM)	VELOCITY (M/S)
A–B	18.9	8	2.5	0.4	0.25	0.64
B–C	• 12.4	6	2.2	0.4 t	0.25	0.58
C–D	• 11.6	5	1.9	0.4	0.5	0.74
D–E	• 11.1	6	1.7	0.3	0.5	0.71
E–F	• 10.2	6	1.7	0.3	0.5	0.71
F–G	• 6.4	3	1.6	0.3	0.67	0.73
G–H	• 5.7	3	1.6	0.3	0.5	0.63
H–I	• 4.2	3	1.5	0.3	0.33	0.50

Table 6-3 Adopted lateral channel parameters

REACH	DESIGN FLOW-RATE (M^3/S)	BED WIDTH (M)	WATER DEPTH (M)	FREEBOARD (M)	SLOPE (M/KM)	VELOCITY (M/S)
B–L	5.9	4	1.7	0.4	0.25	0.48
L–M	• 3.7	3	1.3	0.3	0.71	0.67
M–O	• 2.6	3	1.2	0.3	0.5	0.54

Note that sections of both the main channel and the lateral channel feature some very steep sections in which the zero-flow situation will involve dry sections of channel. This creates two issues: it can allow drying of the channel profile, and it may lead to bed erosion on flow start-up. While the extent to which this is a problem is a function of the characteristics of the soil used, it will be prudent to assume a mechanism is used to counter this issue. The normal method of dealing with this problem is to use fixed long-crest weir overflows, so that a series of pools is created in the zero-flow case, and there is minimal head loss in the full flow situation. This solution will be used here.

6.1.4 Channel reticulation costing

A number of assumptions were made for the costings detailed in Table 6-4, of which the more important are:

- At each drop in design flow level noted above, a control structure is located on the upstream side of an access crossing. A conventional outlet structure is used on the outlet side. This arrangement achieves both flow control and cross-channel access at the same location. Rubicon FlumeGates were assumed to be the flow control device. For larger structures, pre-cast concrete deck units would be used to form the access crossing.
- The long-crest weirs detailed above would be used to hold pool level in the long steep reaches.
- Road crossings were assumed to be at regulator structures, but incorporated a wider road crossing downstream of the control structure regulators.
- Regulator gates required (using Rubicon nomenclature) were as follows:
  – Site B road crossing – three of model FGB-1790-2186
  – Site C – two of model FGB-1675-2186
  – Site D – two of model FGB-1675-2186
  – Site E – three of model FGB-1675-1804
  – Site F – two of model FGB-1675-1804
  – Site G road crossing – two of model FGB-1675-1587
  – Site H – two of model FGB-1675-1587
  – Site B lateral – two of model FGB-1675-2186
  – Site L – one of model FGB 1675-1804
  – Site M – one of model FGB-1485-1437.
- The pump station at the river to service this area would be a major structure with installed capacity of approximately 20 m^3/second (without redundancy) and installed motor power of at least 2.9 MW. This assumed mains supply, and given the paucity of site information, was costed on the basis of the cost curves developed by SunWater for north Queensland river pump stations.
- The re-regulation weir was based on an assumed crest height above existing bed level on a rocky outcrop of 1.5 m. The estimate included a basic fish ladder.

Table 6-4 The Gregory River potential dam site channel reticulation costing

COST CATEGORY	ITEM	CAPITAL COST ($)
Capital costs – direct	Re-regulating weir	2,609,300
	Pump station	18,100,000
	Channel A–B	4,513,560
	Channel B–C	2,945,598
	Channel C–D	2,554,649
	Channel D–E	1,552,918
	Channel E–F	1,613,013
	Channel F–G	3,784,212
	Channel G–H	441,690
	Channel H–I	1,323,830
	Lateral channel B–L	1,794,730
	Lateral channel L–M	1,835,964
	Lateral channel M–O	1,807,580
	Freight and SCADA†	321,000
	Total direct cost	**45,207,045**
Indirect costs	Design and documentation	904,141
	Site supervision	2,260,352
	Insurance	1,130,176
	Environmental approvals	2,712,423
	Total project costs	52,214,137
Risk adjustment	20% of total project costs	10,442,827
Total capital cost		62,656,964

†Refers to the channel control system – supervisory control and data acquisition.

This represents a development cost for the backbone reticulation only of some $3180 per irrigated hectare. To this must be added the cost of the re-regulating weir and any distribution and land development costs downstream of the backbone infrastructure.

6.2 Conceptual irrigation scheme arrangement for Gregory River potential dam with FSL 138 mEMG96

This analysis utilised the same method as used in Section 6.1 for the larger yield dam site. While the criteria used for selection of the targeted area were the same as outlined in Section 6.1.1, priority was given to a compact development where supply costs could be minimised.

6.2.1 Selection of area for development

Using the criteria outlined in Section 6.1.1, the area for development ranges from 10,175 ha (open channel and furrow irrigation) to 11,770 ha (piped reticulation and spray irrigation).

The area shown in Figure 6-5 totals 11,398 ha, and this was used as the gross area to recalculate the design flows for the channel network.

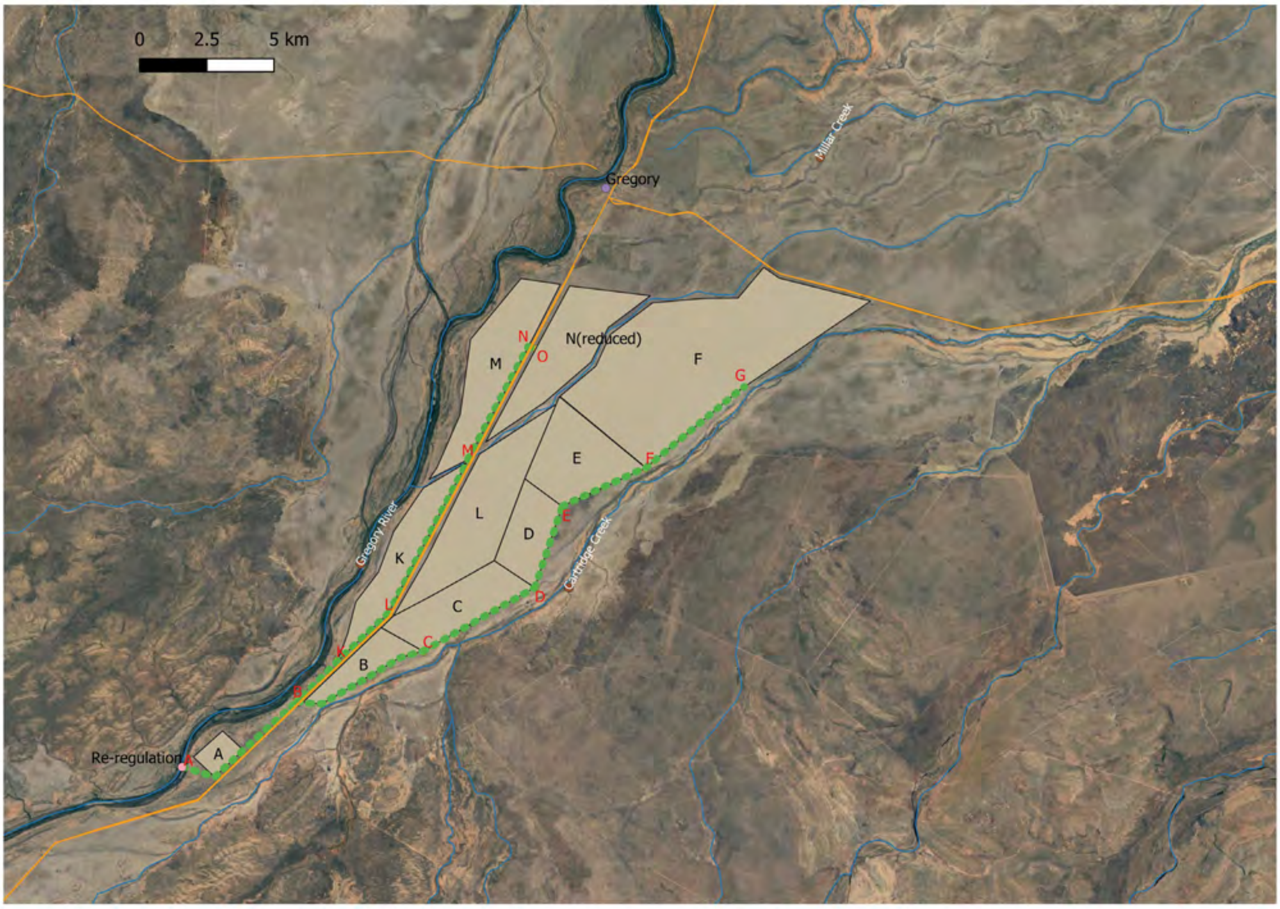

Figure 6-5 Area for reduced development

Showing sub-area labels, location labels and channel alignments overlaid on Google imagery.

6.2.2 Channel design

The applicable channel parameters, using the method outlined in Section 6.1.3, are given in Table 6-5 and Table 6-6.

Table 6-5 Adopted main channel parameters

REACH	DESIGN FLOW-RATE (M^3/S)	BED WIDTH (M)	WATER DEPTH (M)	FREEBOARD (M)	SLOPE (M/KM)	VELOCITY (M/S)
A–B	10.9	6	2.0	0.4	0.25	0.55
B–C	• 6.0	5	1.7	0.4	0.25	0.49
C–D	• 5.2	4	1.4	0.3	0.5	0.61
D–E	• 4.7	4	1.3	0.3	0.5	0.58
E–F	• 3.7	4	1.2	0.3	0.5	0.56
F–G	• 1.9	3	1.0	0.3	0.4	0.44

Table 6-6 Adopted lateral channel parameters

REACH	DESIGN FLOW-RATE (M³/S)	BED WIDTH (M)	WATER DEPTH (M)	FREEBOARD (M)	SLOPE (M/KM)	VELOCITY (M/S)
B–L	4.4	4	1.5	0.4	0.25	0.45
L–M	• 2.2	3	1.0	0.3	0.71	0.58
M–N	• 1.6	3	1.0	0.3	0.5	0.49
N–O	• 1.1	3	1.0	0.3	0.2	0.31

Adopted longitudinal profiles are shown for the main channel in Figure 6-6 and for the lateral channel in Figure 6-7.

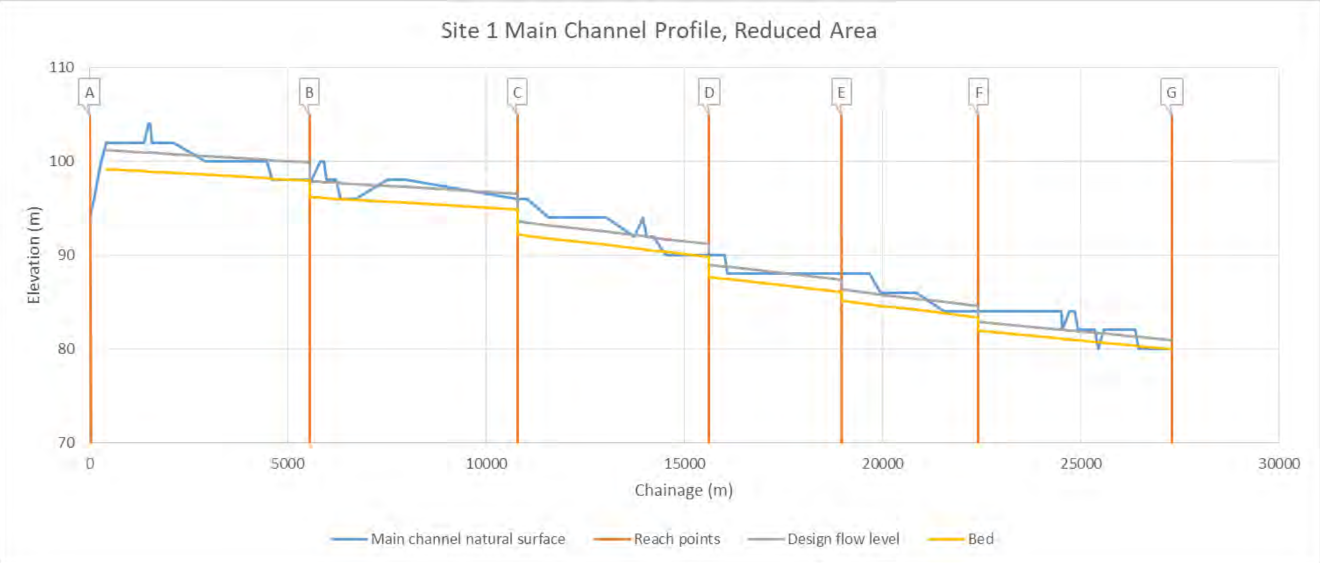

Figure 6-6 Main channel profile for the 131 GL development

Reach points refer to the locations shown in Figure 6-5.

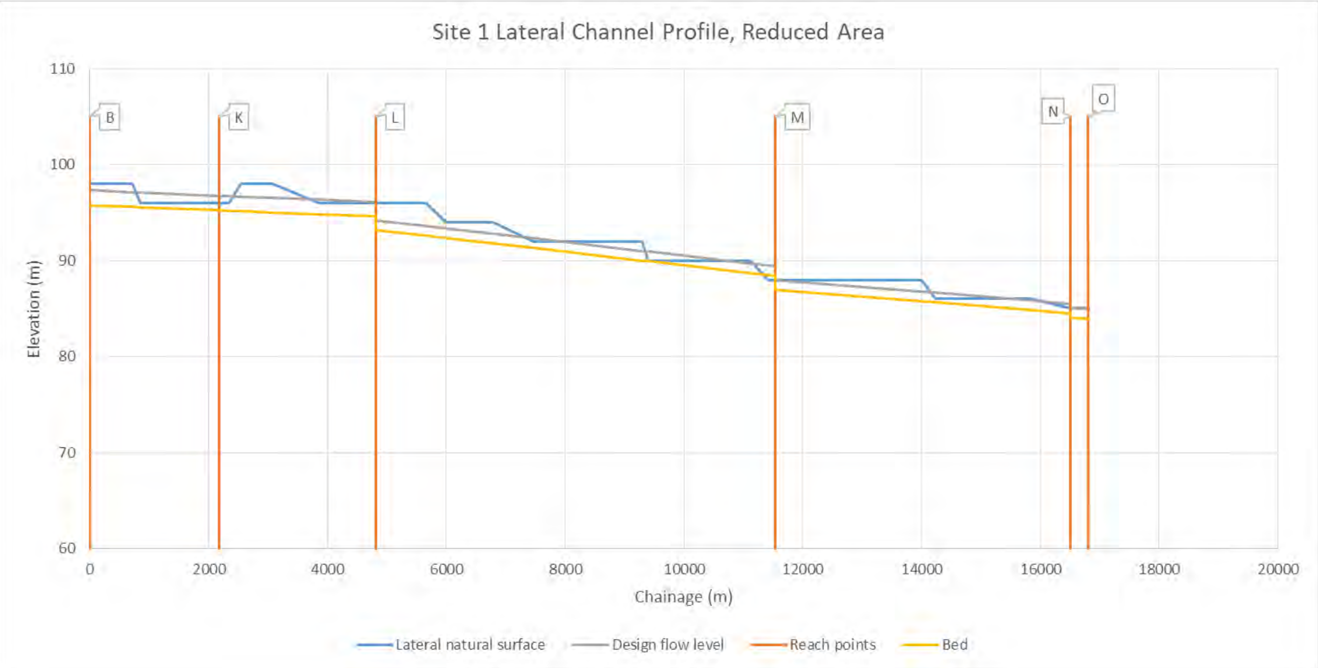

Figure 6-7 Lateral channel profile for the 131 GL development

Reach points refer to the locations shown in Figure 6-5.

6.2.3 Channel reticulation costing – reduced area

The estimated costs for the 131 GL scheme are presented in Table 6-7. They were calculated using the method and assumptions outlined in Section 6.1.4, amending the channel, structure and regulator sizes according to the reduced demand.

Table 6-7 The Gregory River potential dam site channel reticulation costing – reduced area

COST CATEGORY	ITEM	CAPITAL COST ($)
Capital costs – direct	Re-regulation weir	2,609,300
	Pump station	9,910,000
	Channel A–B	3,137,575
	Channel B–C	2,114,298
	Channel C–D	1,756,259
	Channel D–E	994,284
	Channel E–F	1,067,352
	Channel F–G	1,133,145
	Lateral channel B–L	1,619,060
	Lateral channel L–M	1,605,954
	Lateral channel M-–N	1,072,150
	Lateral N–O	91,494
	Freight and SCADA†	321,000
	Total direct cost	27,431,871
Indirect costs	Design and documentation	548,637
	Site supervision	1,371,594
	Insurance	685,797
	Environmental approvals	1,645,912
	Total project costs	31,683,811
Risk adjustment	20% of total project costs	6,336,762
Total capital cost		38,020,573

†Refers to the channel control system – supervisory control and data acquisition.

This represents a development cost for the backbone reticulation only of some $3340 per irrigated hectare. To this must be added the cost of any distribution and land development costs downstream of the backbone infrastructure.

Comparing this to the price derived for the larger 232 GL development outlined in Section 6.1 indicates that there may be little penalty attached to smaller scale developments, at least down to the scale of the 131 GL development.

7 Water-harvesting options along the Gregory River

Of the two sites investigated in sections 5 and 6 above, only the Gregory River potential dam site in Section 6 lends itself to a water-harvesting option. To allow meaningful comparisons with the Wickham River site detailed in Section 4, the same broad scale of development will be detailed, namely:

- storage capacity of about 28,000 ML
- irrigated area of about 2000 ha
- river pump capacity of 6.5 m^3/second.

Channel design capacities are calculated using the method outlined in Section 6.1.3.

7.1 Major elements of the notional water-harvesting scheme

The adopted layout is shown below in Figure 7-1.

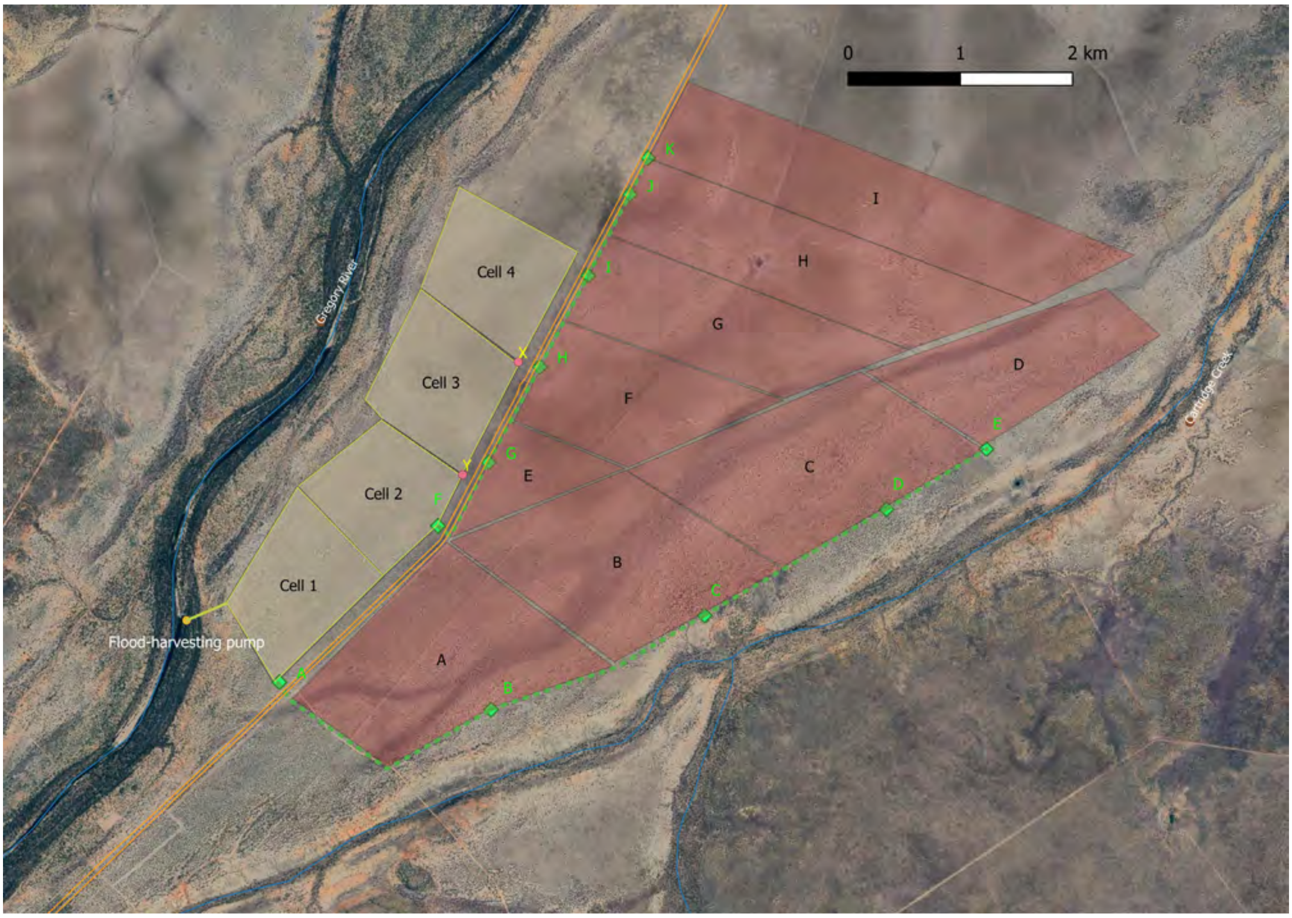

Figure 7-1 Layout of water-harvesting scheme

Irrigated areas shown in red, with channel alignments as green dashed lines and points for flow calculation in green.

Major elements of the layout are:

- A river pump station, consisting of five axial-flow, two-stage flood-lifter pumps located on the river bank, and each discharging to a separate rising main some 380 m long with a downstream flap valve. Pump duty is 1.6 m^3/second at 14 m total head.
- A system of storage cells, with a full supply level decreasing to the north by approximately 1 to 1.2 m between adjacent cells. Water depth at full supply is 5.5 m.
- The arrangement shown in Figure 7-1 will feature two minor pump stations at locations X and Y. These will be a box-mounted column-less axial-flow diaphragm pumps that will allow gravity diversion between adjacent cells and pumped diversions from northern cells back to the adjacent southern cell. In this way, water held at the end of the growing period can be moved progressively to a smaller number of cells to limit evaporative losses.
- Two channel alignments service the supplied area, preserving the natural drainage line between the north and southern sections. As a later addition, a tailwater return system could be relatively easily incorporated into this layout, but is not included in this case.
- The channels feature check and drop structures at the mid-point of each of the blocks labelled in Figure 7-1. An automated Rubicon Flume Gate is allowed for each of those structures.

7.2 Water-harvesting cost estimation

The same assumptions as outlined for the Wickham River water-harvesting option in Section 4.5 are used for this cost estimate (Table 8-1).

Table 7-1 Furrow-irrigation water-harvesting cost estimate

COST CATEGORY	ITEM	CAPITAL COST ($)
Capital costs – direct	River pump station	4,273,,475
	Rising main outlet	40,000
	Storage cell 1	4,947,378
	Storage cell 2	3,096,031
	Storage cell 3	3,766,521
	Storage cell 4	3,451,741
	Pumps between cells	750,000
	Channel A–B	445,369
	Channel B–C	307,482
	Channel C–D	326,574
	Channel D–E	227,823
	Channel F–G	339,186
	Channel G–H	270,530
	Channel H–I	263,195
	Channel I–J	258,556

COST CATEGORY	ITEM	CAPITAL COST ($)
	Channel J–K	198,946
	Total direct cost	22,962,809
Indirect costs	Design and documentation	459,256
	Site supervision	1,148,140
	Insurance	574,070
	Environmental approvals	1,377,769
	Total project costs	26,522,045
Risk adjustment	20% of total project costs	5,304,409
Total capital cost		31,826,454

The above cost estimate equates to $15,913 per irrigated hectare. As for the Wickham River water-harvesting scheme, it is not valid to compare this directly with the equivalent costs derived in sections 2, 3, 5 and 6 since there is no dam involved in this development. It is also not valid to directly compare the costs per ML of water utilised in the dam and water-harvesting cases, as factors such as differing reliability of supply and differing efficiencies of transfer of water from a dam to the serviced area complicate the issue. The above estimate shows that by far the majority of the costs are associated with the water capture and conservation elements rather than the irrigation reticulation components. Assuming the 21,000 ML effective yield of the system, the cost per ML of annual yield is $1515.

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Part IV Discussion

8 Discussion

Comparing the results for the notional schemes outlined in sections 2, 3, 4, 5 and 6 is useful to highlight advantages that some schemes offer over others. Also included in the comparison are the schemes in the catchment of the Roper River detailed in Assessment of surface water storage options and reticulation infrastructure in the Roper catchment (Petheram et al., 2022). In the case of these schemes, cost estimates have been updated using rates derived from the companion technical report on water infrastructure related costs for the Victoria and Southern Gulf catchments (Rider Levett Bucknall, 2024), to allow meaningful comparisons with the schemes in this report. See Appendix A for full details of those revised estimates.

Table 8-1 Key characteristic for reticulation sites examined

CATCHMENT	POTENTIAL DAM SITE.	REFERENCE SECTION	SCHEME CHARACTERISTICS	SERVICED AREA (HA)	LOCAL DEVELOPMENT UNIT COST ($/HA)	TOTAL SCHEME DEVELOPMENT UNIT COST ($/HA)
Victoria	Wickham River	2	Pipeline-based system, involving pumping to high-level balancing storages Two re-regulation weirs in Wickham River Two pump stations serving three discrete areas	17,953	16,200	104,931
	Leichhardt Creek	3	Channel-based system, involving supply from an offstream storage One re-regulation weir on West Baines River Low-lift pump station supplying the offstream storage	3,780	3,351	104,761
	Flood harvesting along West Baines River	4	Channel-based system with water-harvesting supply Low-level weir on Wickham River Pump station and inlet channel leading to storage cells Four large storage cells with centrally located pump transfer box Small main channel system	2,000	18,300	18,300
Southern Gulf	Gunpowder Creek	5	Pipeline-based system, with low boost pumping at offtake Re-regulation weir on Gunpowder Creek Low-lift (8 m) pump station supplying pipeline distribution system	11,734	27,200	93,077

CATCHMENT	POTENTIAL DAM SITE.	REFERENCE SECTION	SCHEME CHARACTERISTICS	SERVICED AREA (HA)	LOCAL DEVELOPMENT UNIT COST ($/HA)	TOTAL SCHEME DEVELOPMENT UNIT COST ($/HA)
	Gregory River FSL 145 mEMG96	6.1	Channel-based system, to maximum serviced area Re-regulation weir on Gregory River Pump station serving start of channel system	19,710	3,180	Not calculated
	Gregory River FSL 138 mEMG96	6.2	Channel-based system, to lower level of development based on dam not encroaching on national park Re-regulation weir on Gregory River Pump station serving start of channel system	11,398	3,336	62,259
	Flood harvesting along the Gregory River	7	Channel-based system, with water-harvesting supply Pump station supplying directly to storage cells by five rising mains Four large storage cells, with transfer box pumps separating the northern three cells Dual channel system, located on the high ground to the south and west of the serviced area	2,000	15,913	15,913
Roper	Waterhouse River		Fully piped system directly from the dam site to areas riparian to Waterhouse River Pump station providing 10 m boost at dam site 48.5 km pipeline system to areas on both sides of the river	9,560	41,680	Not calculated
	Flying Fox Creek		Channel-based system, supplied from a re-regulation weir at AMTD 36 km on Flying Fox Creek, some 53 km below the dam site (not included in costs) Pump station and 2.6 km rising main to head of channel system 21 km channel system featuring three siphons	5,200	10,046	Not calculated

The results above imply a very wide range of development costs, but it is important to keep in mind the relevant differences between schemes so meaningful conclusions can be developed. The following conclusions are indicated:

- The water-harvesting schemes based on the serviced area alongside the Wickham River, and to the east of the Gregory River clearly represent the better value. This can’t be directly compared to the above sites, as the reliability of the water-harvesting operation is likely to be less than the 85% annual reliability quoted for the dam-based developments. However, given vast disparity of costs, and given that the above development costs include both headworks and reticulation works, they are the more cost effective schemes.

- Channel-based schemes are significantly less costly to develop than piped schemes in the same catchment, based on local costs, though scheme scale costs were small relative to the cost of a potential dam.
- Of the channel schemes, the potential lower-level dam on the Gregory River at the Gregory River potential dam site appears to offer the most potential. Local development costs for the potential scheme on Leichhardt Creek in the West Baines system are similar, but this development represents higher risk due to a number of factors, including the large distance between the dam and the development area, the risk of flooding and the extremely friable nature of the river at the development site. It is also a very small development. The other channel system scheme is the potential Flying Fox Creek AMTD 105 km in the Roper catchment. This is an expensive scheme, reflecting the long rising main from the weir to the serviced area, and the drainage provisions necessary for the channel constructed on contour.
- None of the piped schemes appear to be cost effective, and they all compare unfavourably to flood harvesting and to a lesser extent to channel-based schemes. The reasons are slightly different for each scheme but can be summarised as follows. The Wickham River scheme has more favourable local cost, but once the dam costs are included, shows no advantage over other options. The Gunpowder Creek scheme has low available land gradients, and a fair run of infrastructure before land is serviced. The Waterhouse River scheme is very elongated down the river, and serviced land is on both sides of the river.

Another perspective on the above costs is to compare them with irrigation schemes constructed in the last two decades in Tasmania, representing the most intensive irrigation development undertaken in Australia in those decades. However, a number of factors make this comparison less than ideal. Using the example of Midlands Irrigation District, the largest of those schemes, the more important of those factors are:

- The irrigation demands are different in nature, with the Tasmanian schemes being more of a supplementary nature, whereas those required for the hypothetical northern Australian schemes, due to the pronounced nature of the dry season, represent the full crop demand. For example, the Midlands scheme supplies a total of 38.5 GL to a total of 105 landholders on over 250,000 ha of existing holdings. By contrast, the Wickham River potential dam site based on reticulation detailed in Section 2 above has 17,900 ha serviced by some 196 GL/year. Since the Midlands scheme is a piped and river reticulated scheme it will bear the most similarities to the Wickham River site, of the schemes examined in this report.
- The reliability of the water supplied by the schemes is different, with the Midlands being 95% annual reliability, whereas the Wickham River and other schemes examined in this report are based on 85% annual reliability.
- Topography is dramatically different, with Midlands having some excess head from the upper Arthurs Lake hydro-electric storage being dissipated in a mini power station incorporated into the project. By contrast, all the schemes examined in this report are much flatter, with grade induced by pumping.
- Crop selection, crop timings and irrigation method will be markedly different for the two areas. Current production in Midlands includes poppies, cereals, canola, pasture seeds, lucerne,

potatoes, and pasture for livestock finishing. This involves a reasonably constant demand over the full year, with entitlements differentiated between summer and winter demands.

- The geographic environment is quite different between central Tasmania and northern Australia. The former is closely settled, with a fair distribution of services for the existing agriculture and power industries. By contrast, the parts of the catchments of the Victoria River and the catchment of the Southern Gulf rivers (that is Settlement Creek, Gregory–Nicholson River and Leichhardt River, the Morning Inlet catchments and the Wellesley island groups) are extremely remote, and this would be reflected in contract rates for construction.
- The irrigation demand, using the same methodology of Section 6.1.3 is significantly less for the Midlands scheme. An E_0 of 7.15 mm/day, based on SILO values for York Plains, near the centroid of Midlands Irrigation District (P_{99} of 4-day mean E_0) compares to 11.5 mm/day for the Wickham River catchment scheme. While both climate factor and crop factor may vary for specific crops, the crop mix outlined above would indicate that the values used in Section 2.3 would still be applicable for this design. So, the design capacity of the reticulation infrastructure based on the lower value would be proportionally lower.

Given the above factors, it will be of limited value to directly compare the two schemes. Nonetheless, the sensitivity of the Wickham design has been evaluated against the lower evaporative rate to gauge the cost sensitivity to that variable. The comparable numbers to those given in Table 8-1 and in Section 2 are that total capital cost decreases to $211,139,766, or some $11,760 per serviced hectare, compared to $16,200 as per Table 8-1.

References

Budget Strategy and Outlook (2024) Budget 2024-25. A future made in Australia. Viewed 11 September 2024, https://budget.gov.au/content/factsheets/download/factsheet-fmia.pdf.

Department of State Development, Manufacturing, Infrastructure and Planning (2019) North west Queensland economic diversification strategy 2019. Viewed 12 September 2024, https://www.statedevelopment.qld.gov.au/regions/regional-priorities/a-strong-and-prosperous-north-west-queensland/north-west-queensland-economic-diversification-strategy.

Gibbs M, Hughes J, Yang A, Wang B, Marvanek S and Petheram C (2024) River model scenario analysis for the Southern Gulf catchments. A technical report from the CSIRO Southern Gulf Water Resource Assessment for the National Water Grid. CSIRO, Australia.

NT Government (2023) Territory Water Plan. A plan to deliver water security for all Territorians, now and into the future. Viewed 6 September 2024, https://watersecurity.nt.gov.au/__data/assets/pdf_file/0003/1247520/territory-water-plan.pdf.

Petheram C, Yang A, Seo L, Rogers L, Baynes F, Devlin K, Marvanek S, Hughes J, Ponce Reyes R, Wilson P, Stratford D, Philip S (2022) Assessment of surface water storage options and reticulation infrastructure in the Roper catchment. A technical report from the CSIRO Roper River Water Resource Assessment for the National Water Grid. CSIRO, Australia.

Queensland Government (2023) Queensland Water Strategy. Water. Our life resource. Viewed 11 September 2024, https://www.rdmw.qld.gov.au/qld-water-strategy/strategic-direction.

Thomas M, Philip S, Stockmann U, Wilson PR, Searle R, Hill J, Gregory L, Watson I and Wilson PL (2024) Soils and land suitability for the Victoria catchment, Northern Territory. A technical report from the CSIRO Victoria River Water Resource Assessment for the National Water Grid. CSIRO, Australia.

Thomas M, Philip S, Zund P, Stockmann U, Hill J, Gregory L, Watson I and Thomas E (2024) Soils and land suitability for the Southern Gulf catchments. A technical report from the CSIRO Southern Gulf Water Resource Assessment for the National Water Grid. CSIRO, Australia.

Yang A, Petheram C, Marvanek S, Baynes F, Rogers L, Ponce Reyes R, Zund P, Seo L, Hughes J, Gibbs M, Wilson PR, Philip S and Barber M (2024) Assessment of surface water storage options in the Victoria and Southern Gulf catchments. A technical report from the CSIRO Victoria River and Southern Gulf Water Resource Assessments for the National Water Grid. CSIRO Australia

Part IV Appendices

Appendix A Roper catchment dam site developments, updated cost estimates

A.1 Cost estimate basis

These cost estimates take the design outlined in Assessment of surface water storage options and reticulation infrastructure in the Roper catchment (Petheram et al., 2022) and update the costs using rates derived from Water infrastructure related costs for the Victoria and Southern Gulf catchments (Rider Levett Bucknall, 2024).

A.1.1 Dam 55 – 10 m boost reticulation costs

Apx Table A-1 Dam 55 – 10 m boost reticulation costs

COST CATEGORY	ITEM	CAPITAL COST ($)
Capital costs – direct	Pipe supply and install	
	DN2000 PN10 GRP	219,917,360
	DN1500 PN10 GRP	37,025,205
	DN1100 PN10 GRP	14,329,173
	DN375 PN10 GRP	666,400
	Pipe procurement costs	13,596,907
	Pipeline structures	
	Air valves	970,000
	Scours	300,000
	Thrust blocks	364,500
	Flow control valves	210,000
	Isolation valves	315,000
	Pump station at dam	1,910,000
	Earth-lined balance tank	300,000
	Control and monitoring	100,000
	Total direct cost	290,004,545
Indirect costs	Design and documentation	5,800,091
	Site supervision	14,500,227
	Insurance	7,250,114
	Environmental approvals	17,400,273
	Total project costs	334,955,249
Risk adjustment	20% of total project costs	66,991,050
Total capital cost		401,946,299

A.1.2 Dam 79 reticulation costs

Apx Table A-2Table A2 Dam 79 reticulation costs

COST CATEGORY	ITEM	CAPITAL COST ($)
Capital costs – direct	Rising main	
	DN1800 PN10 GRP	15,054,620
	Pipe procurement costs	752,731
	Pipeline structures	
	Air valves	60,000
	Scours	30,000
	Thrust blocks	21,000
	Flow meter and NRV	50,000
	River pump station	3,448,295
	Outlet structure	92,261
	Channel earthworks and structures	
	Channel earthworks A–B	2,279,232
	Channel earthworks B–C	6,888,401
	Channel earthworks C–D	3,372,158
	Channel earthworks D–E	1,110,536
	Cross drainage	571,175
	Siphon A	1,352,984
	Siphon B	2,118,664
	Siphon C	1,599,294
	Minor structures	156,661
	Total direct cost	38,958,012
Indirect costs	Design and documentation	779,160
	Site supervision	1,947,901
	Insurance	973,950
	Environmental approvals	2,337,481
	Total project costs	44,996,503
Risk adjustment	20% of total project costs	8,999,301
Total capital cost		52,242,693

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