The Department of Water Land and Biodiversity Conservation

Assessment of Soil Cracking & River Bank Slumping in the Lower Murray

Part 1 Report

REV C

ARUP

The Department of Water Land and Biodiversity Conservation

Assessment of Soil Cracking & River Bank Slumping in the Lower Murray

Part 1 Report

November 2008

Arup
Arup Pty Ltd ABN 18 000 966 165

Arup
Level 2 431-439 King William Street, Adelaide SA 5000
Tel +61 8 8413 6500 Fax +61 8 8212 5590
www.arup.com

Job number   205527

Job title	Assessment of Soil Cracking & River Bank Slumping in the Lower Murray	Job number 205527
Document title	Part 1 Report	File reference
Document ref		

Revision	Date	Filename	20080811sps Compiled Report_v1.doc		
Draft 1	11/08/08	Description	First draft		
			Prepared by	Checked by	Approved by
		Name	SPS, RCM, WHMM, LS	Authors plus EJS	EJS
		Signature			
Issue	13/08/08	Filename	20080813sps Soil Cracking_Part 1 Report.doc		
		Description	Issued to DWLBC 13 August 2008		
			Prepared by	Checked by	Approved by
		Name	SPS, RCM, WHMM, LS		
		Signature			
Rev A	23/09/08	Filename	20080923sps Soil Cracking_Part 1_Rev A_Issued.doc		
		Description	Incorporated feedback from DWLBC		
			Prepared by	Checked by	Approved by
		Name	SPS, RCM, WHMM, LS		
		Signature			
Rev B	12/11/08	Filename	20081112sps Soil Cracking_Part 1_Rev B_Issue.doc		
		Description	Incorporating comments compiled by DWLBC from EPA, DTEI, MDBC and DWLBC		
			Prepared by	Checked by	Approved by
		Name	SPS, RCM, WHMM, LS	EJS	EJS
		Signature			

Issue Document Verification with Document ✓

Job title	Assessment of Soil Cracking & River Bank Slumping in the Lower Murray	Job number 205527
Document title	Part 1 Report	File reference
Document ref		

Revision	Date	Filename	20081120sps Soil Cracking_Part 1_Rev C_Issue.doc		
Rev C	20/11/08	Description	Included requests from Outstanding Issues Working Group		
			Prepared by	Checked by	Approved by
		Name	SPS	EJS	EJS
		Signature			
		Filename			
		Description			
			Prepared by	Checked by	Approved by
		Name			
		Signature			
		Filename			
		Description			
			Prepared by	Checked by	Approved by
		Name			
		Signature			
		Filename			
		Description			
			Prepared by	Checked by	Approved by
		Name			
		Signature			

Issue Document Verification with Document ✓

Contents

Appendices

Executive Summary

The Department of Water, Land and Biodiversity Conservation (DWLBC) has engaged Arup to identify and visually assess the river banks, levees and control structures; that is the infrastructure necessary to secure water within the river system, between Pomanda Island and Lock 1 on the River Murray.

Our observations suggest that the condition of the river banks is generally satisfactory. If the water level were to drop further they will suffer some erosion and slumping, but this will be little more than usual. If the water level were to rise, they will probably undergo a temporarily higher erosion/slumping rate and then return to normal.

The levees are in varying condition - some satisfactory, others heavily cracked. However, at this stage there is no instability in the levees. If the water level lowers this is likely to lead to more cracking, but extremely unlikely to cause breaching of the levees. If the water level slowly rises to normal pool level, a small proportion of the outer bank will slump. This is very unlikely to lead to a breach, and the distress can be maintained easily once it occurs.

If there is a high flow event, the levees are at risk. It is probable that the ground they are built on has settled and therefore likely that the crest is lower than expected, with the concomitant increase in flood risk. If overtopping occurs we expect breaching of a few levees (in our judgement Monteith, River Glen and Toora are at greatest risk of this) and cause heavy damage to others. We recommend survey of the levees to measure the crest level and an audit of the flood protection they afford. This is most urgent at Monteith, River Glen, Jervois and Toora based on the observed distress to the levees but priorities should also consider the levee crest height relative to the predicted flood levels.

We question the value of attempting to repair cracking in the levees until measures to restore pool level and regulated conditions are implemented. We note that irrigator representatives who attended the public meetings expressed a similar view. While the water level remains low we expect that there will be ongoing development of cracking which could not practically be prevented by maintenance. We understand that DWLBC have undertaken crack repair. We can make no judgement about the efficacy of this work since our assignment involved a once-only assessment. Slumping could be repaired by normal means once it has occurred.

Observations from a selection of reclaimed irrigation areas suggest that these are heavily cracked and out of level, generally. Lowering water levels will increase this and possibly trigger acid sulphate conditions, as appears to be the case at Toora. Raising the water has the potential to increase differential movements and little potential to decrease them. We expect that returning the irrigation areas to a condition allowing farming by present practices will be difficult, time consuming and expensive.

Our observations of the various flow control structures suggest that the backfill behind the wingwalls and around pipes has a moderate probability of being scoured when water levels rise. This will bypass and possibly undermine or topple the structure. One structure appeared to have limited usefulness as a regulating device for water flow.

We recommend auditing of the construction of the various irrigation structures that penetrate the levees (syphons and sluices etc) and those locations where previous structures (typically sluices) have been removed to confirm that the risk of inflows through the levees there is similar to that through the intact levees.

We acknowledge that vermin control is undertaken on the public levees and some private levees. We recommend that measures to manage vermin continue or be implemented where it is not currently practised, and in particular to reduce the extent to which they are able to burrow into the levees.

1 Introduction

Low flow within the River Murray has seen the water level downstream of Lock and Weir 1 decrease to -0.5mAHD and -0.38m local gauge height at the Goolwa Barrages at the end of July 2008. Reports from the area and isolated investigations to date have suggested that due to drying of the soil some structures adjacent the river are cracking, slumping or suffering other related damage. There is the potential that this may affect the security of the water within the river and also affect major and/or important infrastructure and livelihoods.

The Department of Water, Land and Biodiversity Conservation (DWLBC) engaged Arup to undertake a two part first-pass assessment of the project area between Pomanda Point in Lake Alexandrina and Lock 1 near Blanchetown (refer Figure 1):

- Part 1 is to identify and visually assess the river banks, levees and control structures; that is the infrastructure necessary to secure water within the river system
- Part 2 is to identify and visually assess other infrastructure within the wider river valley

Part 1 was undertaken preferentially to allow any water security issues to be addressed as a priority. This document reports the findings of Part 1. The scope of works that was agreed between DWLBC and Arup is reproduced in Appendix A.

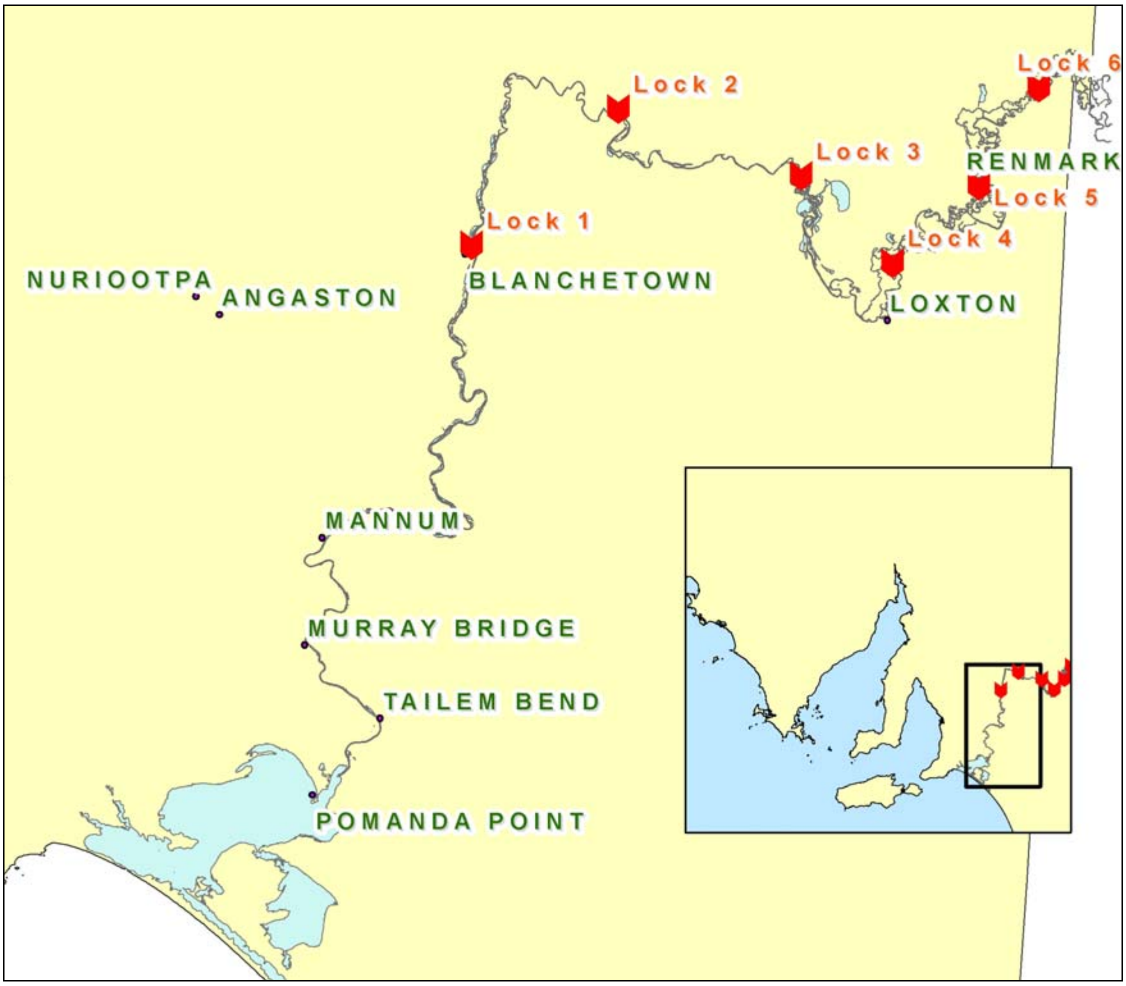


Figure 1 Project Area

2 Scope

Stakeholder consultation:

- engaged with those affected by soil drying within the project area (irrigators, Councils, water boards, the general public etc), allowing them to voice their concerns, and
- identified sites of damage to infrastructure and pasture with a view to streamlining field investigations,

through targeted letters, targeted and public meetings, and direct contact with key people.

The field investigation was undertaken along the River Murray between Pomanda Point in Lake Alexandrina and Lock 1 near Blanchetown.

The scope of the field investigation included observations of

- the River banks
- the wetlands
- the agricultural areas beside the River channel, and
- various structures along the River channel

It also included an assessment of

- the effects of lowering of the River water level on these, and
- the risk to them associated with any future raising of the water level to the previous pool level or beyond.

The scope excluded consideration of the effects of water level movements on built up areas, sections of cliffs or on River infrastructure such as bridges, ferries, boat landings and wharves.

3 Methods

3.1 Consultation

On 14 July 2008, a stakeholder consultation meeting relating to Part 1 was facilitated at Dundee's Hotel at Murray Bridge following a targeted mail out. Presiding officers of the irrigation districts between Mannum and Wellington, and relevant Councils and water boards were invited to attend. The meeting focused on damage at sites directly adjacent the river.

On 4 August 2008, 2 public meetings were held at Murray Bridge and Mannum that focused on damage at sites within the wider river valley for Part 2 of the project.

The information collected at the meetings allowed for targeted site investigation and provided valuable information that reinforced the field investigations.

3.2 Field Investigations

Observations of the River banks and other visible areas from Pomanda Point to around 8 km south of Blanchetown (the River is impassable due to low water levels beyond there) were made from boats on the River. Between Wellington and Swan Reach, use of a houseboat allowed the notes of our observations to be directly correlated with GPS waypoints via a laptop computer. The use of a small boat on the other parts of the River (because the houseboat was not suitable there) meant that the GPS coordinates and observation notes were compiled later. The riverbanks between 8km south of Blanchetown and Blanchetown were not assessed due to the access restrictions mentioned above. Most of the left bank over this length is cliff.

Subsequently, we accessed and viewed the levees of the irrigation areas between just south of Wellington and Mannum from the land. Generally we drove along the crest of the levees, stopping periodically to make observations including GPS coordinates. Some levees were not trafficable by vehicle and these we walked along. Isolated sections of Woods Point, Kilsby, Pompoota and Baseby levees were not viewed due to access constraints.

We met various landholders during our trips and discussed their experiences and observations.

4 Regional Context of the Project Area

4.1 Water Level

The water level at the downstream end of this section of the River is controlled by the Goolwa Barrages. A level at the Barrages of +0.75 m AHD is the nominal pool level for the River between Goolwa and the next upstream control structure at Lock 1 near Blanchetown. The River level has been controlled to this nominal level since construction of the Barrages was completed in 1940.

It is not accurate to assume that pool level is constant along the entire length of this section of the River (around 250 km). The level of water at any point in the River will be affected by, amongst other things, the gradient of the water surface necessary for water to flow, the various inflows at Lock 1 and elsewhere along the River from the local creeks and wetlands, the outflows along the River associated with extraction for agricultural and domestic purposes, evaporation from the river surface and wind effects which push the water level up in the direction the wind blows. Anecdotal information suggests that these effects cause daily fluctuations around ±0.2 m and the variation at particular times may be larger.

The River level has also been affected periodically by flooding. After the Barrages construction in 1940 major flooding occurred in 1956, 1974 and 1992, but the flood of 1917 was also referenced in our discussions with various landholders. Observations of the River level recorded in 1956 at various locations between Pomanda Island and Blanchetown suggest that the level may have been more than 2 m above nominal pool level during that flood.

4.2 Landforms in the River Valley

The alignment of the Murray River valley reflects structural lineaments in the underlying bedrock[1]. The River valley is bounded by cliffs with the River channel meandering in the valley between these.

The River channel between Wellington Lodge on the shore of Lake Alexandrina and Blanchetown is generally nearly flat-bottomed, typically 8 m to 15 m deep with relatively steep sides underwater. The boundaries of the channel may be formed by cliffs, river banks or wetlands.

The wetlands are bordered on their River side by levees and typically on the other side by cliffs or hill slopes. The water levels and flows within the wetlands are artificially controlled where the former wetlands are used for agriculture and in some cases are artificially controlled where the wetland is not so used. Elsewhere the levels and flows are not controlled except by the level of water in the River channel.

The levees may be natural or artificially constructed, or natural levees enhanced by construction.

4.3 Soils in the River Valley

Published references indicate that the soils in the River valley comprise alluvium of the River Murray (the Coonambidgal Formation; generally fine-grained sand and sandy clay)[2]. They also indicate that the depth of alluvial soils may be up to 20 m below present River level - that is 10m to 15 m below the present bed level. Previous experience in the study area indicates the presence of zones of highly organic soils including peat within the alluvial deposits.

[1] Firman JB Structural Lineaments in the Murray Basin of South Australia, Quarterly Geological Notes Number 35, SA Department of Mines, July 1970

[2] Drexel JF & Preiss WV The Geology of South Australia Volume 2 The Phanerozoic. Bulletin 54 Geological Survey of South Australia (1995)

By its nature, alluvial deposition leads to varying soils being present along the River channel and banks. Typically the characteristic dimension of the variation is a few tens of metres.

4.4 Levee Formation and Construction

Levees form naturally along the course of flooding rivers. When waters spill over the banks in a high flow event, suspended sediment is preferentially deposited in the slower-moving waters outside of the main river channel. Once the high flow event subsides the levees form an effective barrier to lateral flow away from the river, protecting the near-channel lands against flooding (unless of course the river flow is sufficient to overtop the levee). Because they are raised above the level of the nearby land, levees allow the river level to be above the adjoining land. The construction of the Goolwa Barrages allowed long-term raising of the water level which could be exploited for irrigation.

The manner in which levees are deposited at the crest of the river bank gives them a characteristic form, steeper on the river side than the land side. This means that the faces of the levees are more stable on the landward side than on the river side. Generally the river or - as referred to in the present report - outside face of the levees will be close to the steepest possible long-term stable angle; it is the nature of the geological processes to produce only just enough stability.

Along some stretches of this section of the Murray the natural levees have been raised and augmented to facilitate management of water flows onto agricultural land. The augmentation has used both materials from nearby borrow pits (ie the alluvial materials of the River valley) and imported materials from further upslope. Both materials are generally clays or sandy clays but are quite distinct; the alluvial materials are generally black and the imported materials red or red-brown.

The construction process is most likely to proceed from and along existing levees. There would have been relatively little opportunity to work from the River bank side depending on the level of River water and the stability of the River banks which – as noted above – are generally no more stable than they have to be under natural forces.

We assume that on the River side of the levee, material would have been pushed over the crest and allowed to find its own landform with little effective compaction being possible. On the land side and along the levee, compaction could and probably would have been applied, even if this only comprised driving beasts over the soil or rolling with the wheels or tracks of the earthmoving machinery. The process would have maintained or exaggerated the disparity in stability between the land and River faces of the levees.

We understand that the water retention of the constructed levees was satisfactory.

We also understand that planting of willows was undertaken on the river banks adjacent to the constructed levees as an erosion protection measure. This is observable in the reach of the river below Mannum. We further understand that there is ongoing debate about the outcomes from this practice which include colonisation and hence narrowing of the river stream, the effect of shade on habitat, and leaf drop. We observed that, for the most part, the river banks where willows are present appear to be stable at the current water level.

4.5 Operation of the Reclaimed Irrigation Areas

The ground level of paddocks reclaimed from the river valley by levees is below regulated river level to allow diversion for irrigation by gravity.

A group of paddocks is commanded by a sluice or syphon which fills a supply channel (sometimes known locally as the “river” channel). From the supply channel, control structures allow water onto a paddock and water is turned off when the advancing irrigation front is well into the second half of the length of a paddock. Excess irrigation application, if any, and drainage from the sub-soils is collected in paddock side drains and the main or salt drain at the end of paddocks and disposed of to the river or used on adjacent highlands by pumping. Some irrigation areas have a “back” supply channel, also filled from the river by gravity, and a centre drain.

Efficient irrigation relies on evenly graded paddocks free of undulations and excessive cracking. Metered diversions are now contributing to efficiency improvements together with rehabilitation of supply infrastructure.

5 Community Consultation

As part of the soil cracking and river bank slumping project three community meetings have been held in the Lower Murray. These meetings were held with the following aims:

- To inform the community about the project aims and methodology
- To collect information from the community about specific soil cracking issues and identify areas of concern for inclusion in field surveys
- To provide the irrigation community with an opportunity to voice specific concerns about the issue of soil cracking on their property and along the river banks and levees
- To provide the broader community with opportunities to give the project team general and specific information about soil cracking issues on private and public property within the wider Murray valley.

The meeting attendances were varied but each meeting provided the project team with valuable information for use in the field investigations, plus concepts and concerns for consideration for the future management of the soil cracking issues.

5.1 Consultation Process

The community consultation process was conducted in line with the project brief in two main stages:

- Part 1: Stakeholder meeting with irrigation trust presiding officers and other key representatives (by invitation) held on Monday 14 July 2008 in Murray Bridge.
- Part 2: Two open community meetings held on Monday 4 August 2008 in Murray Bridge and Mannum. Information collected at the meeting did not impact on the Part 1 assessment and is not included in this report.

The stakeholder meeting was organised as follows:

1. Key stakeholders, including irrigation trust presiding officers, government and non-government agencies, were identified by DWLBC.
2. Each identified stakeholder was telephoned to introduce the project and invited to attend the project meeting. Where individuals had not been spoken directly to after two telephone call attempts, a second message was left on answering machines introducing the project, providing contact details and leaving information about the meeting. Where email addresses were available information was also sent electronically. A database of the stakeholder names, contact details and method of communication was developed.
3. A letter officially introducing the project and including an invitation to the project meeting was posted to all stakeholders. Enclosed with the letter was a map of the relevant irrigation area and an information collection pro forma which irrigators were asked to makes notes on and bring to the meeting. An example of the letter sent is included in Appendix B.
4. The meeting was held at Dundee's Hotel on Monday 14 July 2008 at 10:30am. The meeting was held in an open discussion format with everyone invited to discuss general and site specific issues. Prior to and after the main group discussion, individual discussions were held to collect site specific information and to identify areas of interest for the field survey. Maps detailing the length of river involved in the project were displayed at the meeting such that attendees could mark information on relevant maps.

5.2 Consultation Outcomes

The stakeholder meeting was well attended by the Irrigation Trust Presiding Officers (see Appendix B for the attendance list).

As with any stakeholder consultation, Arup may not necessarily agree with the opinions and comments arising from the meeting. This section is intended to be a record of the discussions and issues raised by the stakeholders, not an assessment of them by Arup.

The discussion was informal and did not follow a continuous thread or idea. We have taken the key points from these discussions and tried to group related information under appropriate headings.

Ownership Boundaries and Liability for Private Irrigation Areas

Private irrigators raised concerns of:

- Potential legal liability - private irrigators own the land right to the river bank and concern was noted that they may be liable if infrastructure, livestock, vegetation (red gums and willows) or humans (specifically houseboat and jet ski users) are impacted due to collapsing river banks or other associated processes.
- Lack of procedure within and between state and local government departments to organise assistance with removing trees and livestock
- Cost associated with removing fallen trees and livestock

Other River Users

Irrigators raised the issue of potential increased damage by other river users such as:

- Increased erosion and destabilisation of the river banks due to larger boats now used for wake-boarding. These boats cause larger waves and more of the river bank is now exposed increasing erosion issues.
- Houseboat users causing further damage to unstable vegetation (red gums and willows). Irrigators noted that some houseboat users pull down river bank vegetation, presumably for use in fires, and also moor the houseboats to trees which causes further destabilisation.
- Jet skis are able to access routes that are unsuitable (backwaters). This may cause further damage to the river banks but is also a liability risk as the users may not be aware of the instability issues.

Engineering Investigations

Irrigators were made aware that as part of the project a civil and a geotechnical engineer would be undertaking field investigations of affected areas. Irrigators raised the following concerns about these investigations:

- Concern that assessment from river would not provide as much information as access to banks is often limited by willows etc. General opinion that on-ground assessment more suitable.
- Assessment of levee banks will need to be on foot for some areas as there is no vehicle access. Point was raised that it would provide a better assessment if all levees were walked along.
- Will the assessment outcomes be consistent with irrigator views? Irrigators that raised this concern indicated that they were willing to walk along their length of levee/riverside with engineers to discuss the assessment.
- Note that irrigators would like as much warning as possible prior to notification of dates/times that engineers will be present.

Examples and Issues of Soil Cracking and Slumping

A lengthy discussion was held regarding examples of soil cracking and it was agreed that the issue was varied and widespread

The following points about soil cracking and bank slumping were raised:

1. Examples of soil cracking and slumping:
    - Riverbanks have slumped into river significantly in some locations, example of a 2 meter slump along approximately 30m of water frontage.
    - Cracks greater than 2 meters deep and 10's of centremeters wide in the irrigated paddocks.
    - Levee bank cracking varied throughout districts
2. Causes of cracking
    - Differences in cracking possibly attributable to:
        - Length of time since last watering. The longer the period since last watering, the worse the cracking. Noted that areas that have not been irrigated since restructuring are impacting neighbouring pastures as well. Point raised that had the Environmental Land Management Allocation (ELMA) water at least been applied then it is possible that cracking would not be so bad.
        - Different soils. Cracking is possibly worse where black swamp soils are present. Noted that Martin Philcox has lots of local knowledge about this. Note that DWLBC has the soil information for all the irrigation areas in GIS.
        - Differing views on impact of laser levelling. Some indicated that cracking was worse in these pastures.
3. Issues pertaining to soil cracking
    - Cracks present danger to livestock
    - Soil cracking varied between irrigation areas and different pastures
    - Levee bank cracking on the surface is not necessarily indicative of extent of issue, more likely to be structurally undermined from beneath or within.
    - Some disagreement with levee bank works proposed by SA Water (e.g. filling cracks with bentonite)
    - Water table has dropped
    - When water is available it is very possible that it may flow under the levees and pastures as the water table returns to higher level.
4. Future management of the issue
    - Uncertainty of what might happen in the future, reporting needs to be clear that the assessment is for this specific time.
    - Little point in undertaking remedial action until there has been some watering and the soils on both side of levee have had a chance to return to 'normal' state otherwise once water does come remedial works may be undermined also.
    - Getting some water is a key factor to practically understanding extent of the problem.
    - Important to note areas where impacts are not as bad – should try to find causes and potentially pass information on.

Other Information

Several people present indicated that they had additional information that they had been collecting about the soil cracking issue. It was organised to share this information.

5.3 Summary of Consultation

The issue of soil cracking is wide spread and is an additional concern to irrigators during a time of existing high stress. Irrigators are amenable to the soil cracking investigation but the following concerns were raised at more than one meeting:

1. The destabilisation of river banks causes concern about liability should an accident occur or infrastructure fall into the river.
2. The information collected during this project must be considered a snap shot of the issue as a future lack of water will have further impacts.
3. The whole of the levee bank including foundations must be considered for remediation works – a “patch-up” job on the top will not suffice.
4. Water is needed back in the system to understand the full extent of the issue.
5. The differing length of time since last irrigated has an impact on the extent of the cracking.
6. Management options for remediation of damage should only be considered once water levels have returned to “normal” in the river otherwise they are likely to be pointless. It was noted the “normal” water levels may be lower than previously.
7. People are concerned about the potential cost of remediation and funding will be vital.
8. Current on-farm management needs to be considered when allocating future funding.

6 Assessment of River Banks

For the most part, the river banks are inaccessible by existing vehicle or foot tracks. Observations of the river banks between Pomanda Point and 8km south of Blanchetown were made from a boat. The river is impassable above this point, and localised observations were only possible where existing access tracks allowed.

Further, from the river side the extensive stands of willows often prevent direct observation. From the levee bank side, the river bank is often 10s of meters distant and concealed by the willows.

However, where the banks were observable, we assessed them to have remained stable, possibly as a result of the reinforcing effect of the willow roots.

There are instances where there are no willows and bank damage has occurred as described in the following sections. Appendix C contains a set of drawings showing the location of sites of interest to this project, including the following river bank slumps.

6.1 Jaensch Property

Description

This property is at the north end of Toora Irrigation Area. Approximately 50m of bank has slumped by about 1m and has stayed largely intact. The section is about 4m wide at the widest point. A short section of willows remain within the slumped part.

The adjacent river is reported by the landowner to have very steep banks below water and the water is approximately 20m deep within 5m of the slumped section.

Assessment

The slumped section does not appear to pose any threat to the remaining adjacent bank not to any built infrastructure in the vicinity.

It is unlikely that the slumped section could be reclaimed. It most likely would break up and slump further into the adjacent deep water. Having been weakened, it is also unlikely that the slumped section would support fill if an attempt was made to rebuild that section of bank.

Without detailed survey, it is not possible to accurately assess the extent to which the slumped section might be inundated and lost due to more slumping when the river level returns to fluctuating around pool level. Some additional erosion can be expected when wave action occurs at the normal operating level. Remediation of the “new” bank alignment by piling might be possible subject to further assessment.

6.2 Avoca Dell

Description

This site is practically opposite the Jaensch property and is at the base of low cliffs at the northern end of Avoca Dell reserve. Similar to the Jaensch site, about 30m of bank has slumped, remained intact and continues to support willows. The slumped section has moved away from the adjacent cliff forming an “island” and it is apparent that vessels have attempted to enter the newly created channel

Assessment

We consider that there is no practical way to remediate this slump. It is highly likely that the island will break up over time, particularly as river level returns to more usual operating levels. Apart from releasing some willows into the river stream, no adverse outcome is expected.

6.3 Long Island Marina

Description

About 30m of bank has slumped penetrating up to 5m into the pre-existing alignment and the slump mass has largely disappeared. The adjacent banks and the eroded face we judge to have been filled ground. We understand that observations at the time of the movement were that tree stumps and other logs floated away with the slump mass. We understand that there is a sewerage pressure pipeline near the edge of the recently formed bank.

Assessment

Tenure and future use of the allotment adjacent to this site was not researched by us. Much of the allotment has been filled to an unknown extent.

Upstream from the site there is a section of flat beach which may be artificial. This may mean that the slumped site could be filled and made stable perhaps at a lower level.

As above, there is presumed to be an easement for the pipeline. It is known that SA Water is making periodic observations and may to choose to take remedial action.

6.4 Walker Flat

Description

Adjacent to and downstream from the Walker Flat ferry crossing on the right bank is a reserve with amenity grassed area and small boat mooring. There is a houseboat mooring downstream from the small boat mooring.

The small boat mooring area has been treated with gabions in the erosion zone now exposed by the lower river level. These gabions are not recent and may have been used to manage wave action from the ferry and other vessels. A small number of the gabions have slumped. It is impossible to confirm that this is a direct result of lowering of the water level although the possibility cannot be ruled out. We judge it more likely that the recent lowering of water level has revealed the extent of slumping previously concealed by the water.

Assessment

Remediation is judged to be unnecessary other than for appearance sake. The stability of the bank area is not likely to be affected by further fall or later rise in river level. Public safety might require some warning or bunting to be placed to prevent walking close to the edge.

6.5 Houseboat Concepts Slipway

Description

The houseboat construction site is adjacent to Kia Marina at Younghusband.

There are signs of instability in the bank particularly at the downstream face of the slipway entry channel (refer photo below). The management representative advised that this was recent erosion and occurred at the time of the extension of their slipway rails. This required the slipway entry channel to be coffer dammed and removal of the coffer resulted in disturbance of the adjacent bank.

Assessment

Houseboat Concepts has remedial action planned.

6.6 Effect of Water Level Change Observations and Inferences

The effect of the water level lowering has been to lower the level of the normal River bank erosion. The lowered water level has exposed sections of bank that were previously subject to normal level fluctuation and wave effects with the River at pool level. Not all sections of bank have been exposed because there are extensive stands of willows along the River banks and the weeping limbs have generally moved down with the falling water providing some protection against erosive forces and preventing the banks being viewed.

Where willows are absent, in the more clayey sections of bank the exposed bank generally exhibits a near-vertical face up to about 1 m high at close to the nominal pool level. The limited observations possible at present suggest that a similar bank form is developing at the new lowered level. Similarly where willows are absent in sandy stretches of bank, the falling water has generally exposed a flatter beach and we presume that this beach continues below the present water level.

In a very few locations there has been slumping of the banks. We observed three locations where this had occurred at relatively large scale – immediately north of Long Island Marina, at the Jaensch property just north of Toora irrigation area, and nearly opposite there across the River at the base of the cliffs at the northern end of Avoca Dell – although in all cases the length is very minor when compared with the length of riverbank assessed. The length of the bank involved was between about 30m and 50m in each case.

The lack of detailed investigations in the immediate aftermath of the ground movement affects the reliability of any assessment of mechanisms, but the precedent lowering of the River level might suggest that 'rapid drawdown', during which the water pressures within the soil cannot dissipate as fast as the water level lowers, has contributed to the slumping. This is considered to be unlikely, as the records of River level measurements that we have been able to access are not consistent with what usually constitutes rapid drawdown. However, the possibility cannot be ruled out on the basis of our present knowledge.

At a number of other locations we observed what may have been slumping of the banks, typically over lengths less than 10 metres and involving up to about 10 cubic metres (say 20 tonnes) of soil. We cannot confirm the timing of these events, which may precede any lowering of the water level. We would expect periodic small scale slumping to be a normal and ongoing process within the River banks and on the steeper slopes present on the outside (river side) of the levees as a result of the usual erosion forces.

The observed bank slumping totals around 100 m length and around 10 m width over a total river frontage (excluding cliffs) of around 300 km. Assuming that slumping continues annually at this rate (which we judge to be a very conservative assumption) this is equivalent to an average recession rate of around 3 mm per year over the whole of the river bank length.

Although outside our scope, informal observations of the rate of landsliding (i.e. the equivalent behaviour) in the roughly 100 km of cliff along the stretch of river that we passed through suggests that at least 1% of the total length recedes by about 1 m per 10 years. That is an average recession rate of around 10 mm per year over the total cliff length.

The latter appears to be of little concern, even though there is development relatively close to the top of the cliffs at many locations. Note that if the cliffs are around 10 times as high as the river banks the relative rate of mass lost (as opposed to crest recession) is correspondingly around 10 times as high.

Our observations suggest that the condition of the river banks is generally satisfactory. The effect of water level lowering has been - in those sections of bank not protected by willows - to produce a similar landform at lower level to the landforms occurring previously at pool level. If the water level were to drop further we expect these sections of banks to move towards similar landforms at a level matching the river. This would involve a temporary increase in erosion, but this will be little more than usual and the effect would stabilise over time. If the water level were to rise, there would be similar effects at a higher level.

There has been slumping of some isolated sections of river bank. We observed three instances totalling around 100 m length in the approximately 300 km of river bank we studied. The reported timing of the slumping suggests that this may be associated with the changes in river level, although there is no wholly satisfactory technical explanation of the cause. We cannot rule out the possibility of future water level movements (up or down) triggering similar behaviour. We know of no practical method of predicting the location or extent of that. In view of the very limited extent of the slumping that has occurred to date we suggest that the risk of future slumping would be acceptable. If it occurs, repair (if it is deemed to be required and in many cases it may not) could be effected by normal means.

7 Assessment of Levees

Table 1 summarises the ownership details of the 21 levees inspected. A summary of the history, physical form, construction material and overall assessment of the levees at each of the irrigation areas is contained in Appendix D.

Table 1 Levee Ownership Details

Irrigation District	Ownership
Baseby	Private
Burdett	Government
Cowirra North	Government
Cowirra South	Government
Glen Lossie	Private
Jervois	Government
Long Flat	Government
Long Island	Private
McFarlanes	Private
Mobilong	Government
Monteith	Government
Mypolonga	Government
Mypolonga North	Government
Neeta	Government
Neeta North	Private
Pompoota	Government
River Glen	Private
Toora	Private
Wall Flat	Government
Woods Point	Private
Yiddinga	Private

Irrigation areas where the levees appear to be in good condition include those that have had rework in the 6 weeks prior to our visit. We cannot assess whether the work done will be of lasting benefit. It might have been preferable to have waited until after return of pool level and irrigation and then observed what, if any, changes took place. We judge that those levee crests that have been crowned to assist with drainage of stormwater are more likely to sustain a benefit from the recent work.

The following describes the levees at the irrigation areas where we assessed the condition to be poor.

7.1 Mobilong

This irrigation area has been retired although water remains in the drains, possibly from seepage from the Preamimma Creek diversion works at the rear of the reclaimed area, from adjacent (un-irrigated) highland or from stormwater.

The levees have longitudinal cracking extending over at least 50% of their length. There is limited cracking of the inside face. Despite the cracking, vehicle access remains possible although the levee is narrow at the south end.

Despite their condition, the levees appear to be sound enough to isolate the reclaimed area in a regime of pool level fluctuating around pool level during regulated flows. If a high river event occurs overtopping the levee, we consider it likely they would fail over long lengths. Any maintenance of these levees would depend on policy in relation to retired irrigation areas.

7.2 River Glen

The levees at River Glen are a mixture of red clay construction at the north end and black clay at the south end and are in poor condition with extensive longitudinal and inside face cracking. The bank faces are generally 1 horizontal to 1 vertical which is far steeper than would be considered good practice for permanent water retaining structures. Vehicle access is not possible.

These levees will require close observation when the river levels return to levels that will allow irrigation to recommence. It cannot be accurately predicted how raising of the water table within the levees will affect stability. If a high river flow were to occur such that the banks were overtopped causing water to wet the outside face of the levees, their integrity might be threatened. Any overtopping of the levees themselves is likely to cause breaching in many places.

Reshaping and topping these levees would be very expensive. We have done limited research but understand that rebuilding levees could cost at least $1 million per kilometre.

7.3 Jervois

While it appears that the levees at Jervois have been maintained over time, their extent and localised cracking poses a threat to the whole area. A breach or series of breaches would result in temporary loss of the area at least to one side of the causeway to the ferry. Breaching is only likely if a high river event occurs resulting in overtopping of the levees.

Limited reshaping and topping of these levees could be considered. Even restricted repairs would be expensive but might be judged worthwhile given the extent of the area and the existence of other dairy-related infrastructure investment.

7.4 Glen Lossie

This irrigation area can be characterized by the history of ownership. There are 3 current owners. The north end is in generally good condition with levees constructed from black clay and reasonably well formed.

The centre portion has not been watered for several years and has the appearance of being neglected. Its singularly good feature is the condition of the levee. It is a remnant from the early period of construction when local black clay was used and placement and compaction was provided by animals and form was decided by following the shape of natural levees. It is deficient to the extent that it would not withstand overtopping. The raising that has taken place is very poor being only 0.5m wide and poorly levelled.

The southern end seems to have been constructed from local black clay and has been topped with red clay. Vermin holes show the core material overlaid by the later topping. These vermin holes may prove to be a localised weakening of the levee but some limited reconstruction could ensure integrity for the whole area.

7.5 Monteith

There is extensive cracking and very poor formation of the levees at Monteith. We understand that this irrigation area is notable for a history of bank cracking. Maintenance over time has resulted in graded windrows spilling from the crest forming steep inside and outside bank slopes. Vehicle access remains possible.

We judge that the banks would continue to be functional with a river level returned to pool and fluctuating with regulated flows. A high river event that resulted in the levees overtopping would most likely result in major breaches and temporary loss of the area.

We judge that remedial work for this irrigation area would be very expensive. Reshaping and topping of the banks would need to be considered at a cost approaching $1 million per kilometre of levee.

7.6 Westbrook

Westbrook is a small irrigation area between Murray Bridge and Tailem Bend. The banks are generally well formed although the side slopes are steep. There is no extensive cracking of the levee but the causeway at the south end is cracked and in poor condition. There is wetland to one side and reclaimed swamp to the other, the formation has a narrow crest and vehicle access is poor in wet conditions.

The integrity of the river levee and the causeway does not appear to be threatened by a return to pool level and fluctuation due to regulated flows. A high river event that overtopped the causeway could result in breaching and temporary loss of the area.

7.7 Miscellaneous Observations

A number of things became apparent during the fieldwork that are not strictly relevant to the scope of our services. However, they may be useful in future operations and maintenance of the levees and reclaimed irrigation areas and are presented here for that reason.

Vermin Holes

We observed a number of vermin holes in the levees and on several occasions saw foxes and rabbits on the reclaimed irrigation areas. The most spectacular vermin holes were near the southern end of Glen Lossie and appeared to be a warren of fox holes. These had penetrated deep enough for spoil from the original black clay core to be exposed on the newer red clay surface. We also observed ant action on the levee banks at various locations.

DWLBC have advised that regular fox baiting and rabbit control programmes, amongst other pest management practises, has been undertaken on the public levees for the past 4 years. The extent to which this has extended to the private levees is unknown however DWLBC suspect it is limited.

We cannot guess the extent of the vermin holes or ant nests, nor the effect that they might have on the integrity and stability of the levee banks. Suffice to say that they will not improve either integrity or stability.

Black Clay

Our observations also suggest that the older, black clay levees are less cracked and less distressed than the later red clay additions or constructions. This may be partly associated with the form of the black clay levees, which generally use flatter slopes on the inside, but our judgement is that the black materials are less movement-sensitive.

We presume that the constructors of the black clay levees were attempting to match, or at least conform with, the shape of the natural levees. This appears to be a sensible approach, as the form of the natural levees has been shaped by the river forces to be stable under most circumstances.

We saw no evidence to suggest that the black clays are dispersive, while there were abundant signs that the red clay from the slope above the River would disperse. This may also have affected the relative performance of the levees.

Dispersion / Crab Holes

Dispersion is triggered by accumulation of fresh water in the soil. That accumulation can be periodic. We noticed a trend of crab holes (the product of dispersion) occurring in the wheel tracks along the levee crests. We presume that even slight rutting is allowing water to pond at times and facilitating dispersion. The effect was noticeably less marked where the levees had a crowned crest, or as at Wall Flat a constructed road pavement at the crest. It may be sensible to adopt suitable crest treatments during future maintenance works, subject to appropriate Health and Safety protocols.

7.8 Effect of Water Level Change Observations and Inferences

The levees appear to have settled much more evenly than the reclaimed irrigation areas and we judge that they have settled far less than the reclaimed irrigation areas in absolute terms. We observed practically no lateral (ie across the crest) cracking of the levees which would indicate differential settlement along the levee's length.

The relative lack of settlement may be because the soil water conditions are more consistent under the levee. The effects of evaporation would be much reduced by the extra metres of low permeability soil above the groundwater and the change in groundwater level being less here than in the reclaimed irrigation areas because the only effect operating is the River level lowering, not irrigation stopping.

The reduced settlement is also likely to result from improvement of the natural ground during the construction of the levees - the ground must have been densified and stiffened to place the soils over the natural levee and denser, stiffer ground settles less. It is also likely that there has been additional improvement in strength and stiffness over time (some of the levees are over 90 years old and none apparently less than 30) as a result of consolidation of the ground by the weight of the levee banks.

Most, but by no means all, of the levees show some settlement-related distress. Typically this comprises longitudinal cracking of the crest, often with parallel cracking of the inside (land side) face of the levee (refer Figure 2). We infer that the settlement of the nearby reclaimed irrigation areas has extended to the toe or possibly inside of the levee bank. We also infer that the ground under the levees has been more stable than that further away.

This will lead to an overall tilt of the ground – including the levee shoulders - and cracking in the upper surface of levees and shoulders.

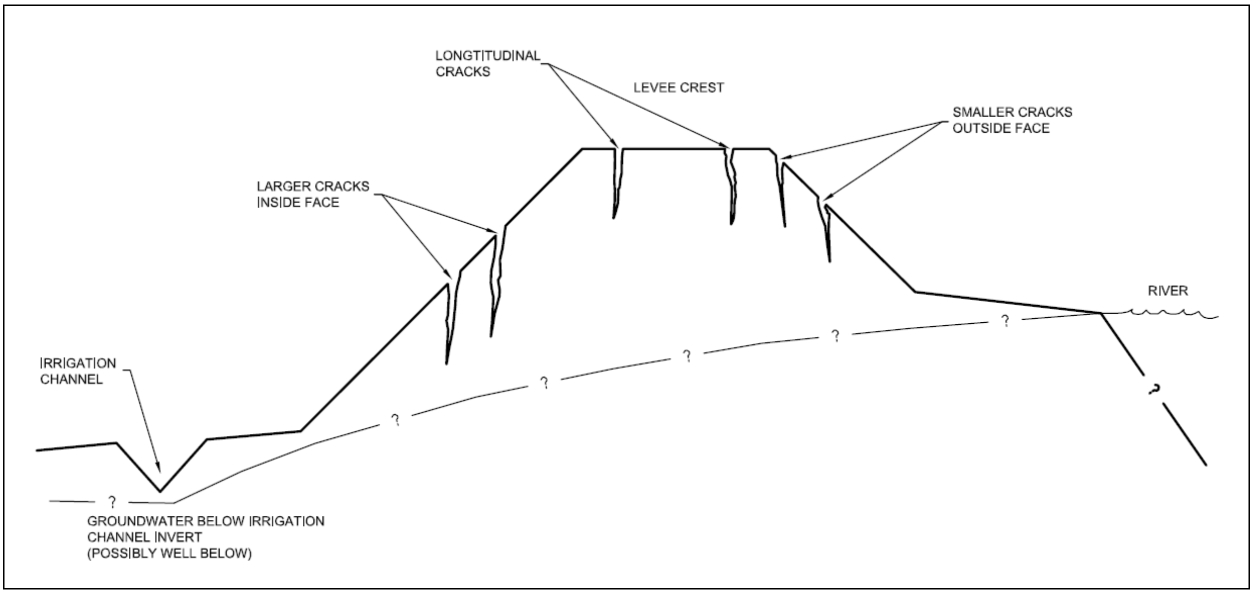


Figure 2 Levee At Present (typical)

In a few places we observed apparent slumping of the inside face, where we infer that the cracking has extended close to the toe of the bank, allowing a section of the soil to fall (refer Figure 3). However, this is relatively rare and we could not be sure that this had happened as a consequence of the reclaimed irrigation area's settlement.

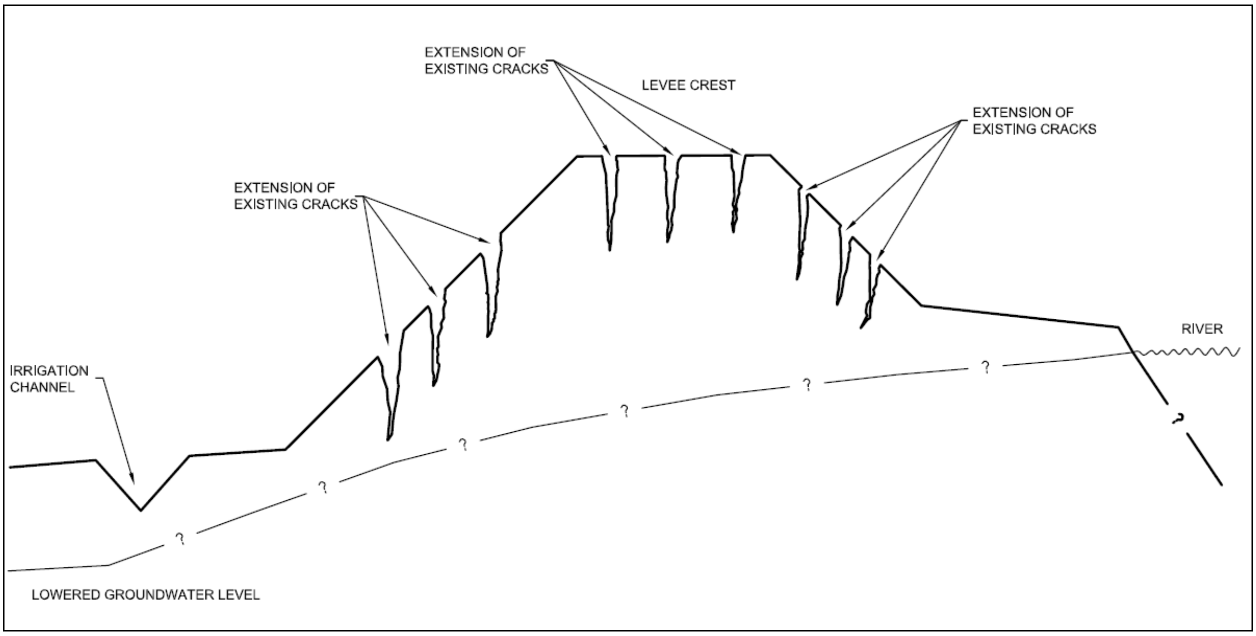


Figure 3 Lowered Water Level

Most of the levee faces are steeper (in some places far steeper) than we would consider good practice in construction of permanent water retaining structures. Typically [3,4,5] it is

[3] US Department of the Interior Bureau of Reclamation 'Design of Small Dams' (1987)
[5] US Department of the Interior Bureau of Reclamation 'Design of Small Dams' (1987)
[4] Lewis B, 'Farm Dams Planning Construction and Maintenance' Landlinks Press (2002)

recommended that these have face slopes no steeper than 2.5H:1V or 3H:1V. We observed slopes as steep as 1H:1V in many locations along the levees. These steep slopes may have led to slumping of the faces before there were changes in the water level and would have increased the risk of slumping during or following such changes.

We observed some longitudinal cracking of the outside crest together with face cracking (and occasionally some slumping) of the outside face of the levee. This was less common than for the inside faces, which is probably because the River banks have settled less than the reclaimed irrigation areas.

The materials used may also have contributed to the development of longitudinal cracking. We saw 'crab holes' in the crest of the levees where red clay was present and similar holes in the quarry near Kilsby irrigation area, which we infer to be the source of construction materials for that levee. These are indications that the red clay materials are slightly dispersive – they erode in fresh water. The longitudinal cracks are often along the wheel tracks on the levee crest. Ruts may act to concentrate stormwater and therefore trigger the dispersive erosion that leads to crab holes.

In some cases the crab holes were large enough potentially to have undermined a tyre. Although we did not actually experience this during fieldwork, we were told that it had occurred to a person laying out fox baits.

Anecdotal evidence suggests that cracking may always have been present along the levees. That would be unsurprising, these are made of clayey soils and are far enough above the permanent water level to be subject to periodic wetting and drying cycles. We consider it impractical to estimate how much of the existing cracking or distress to the levees is a direct result of water level changes.

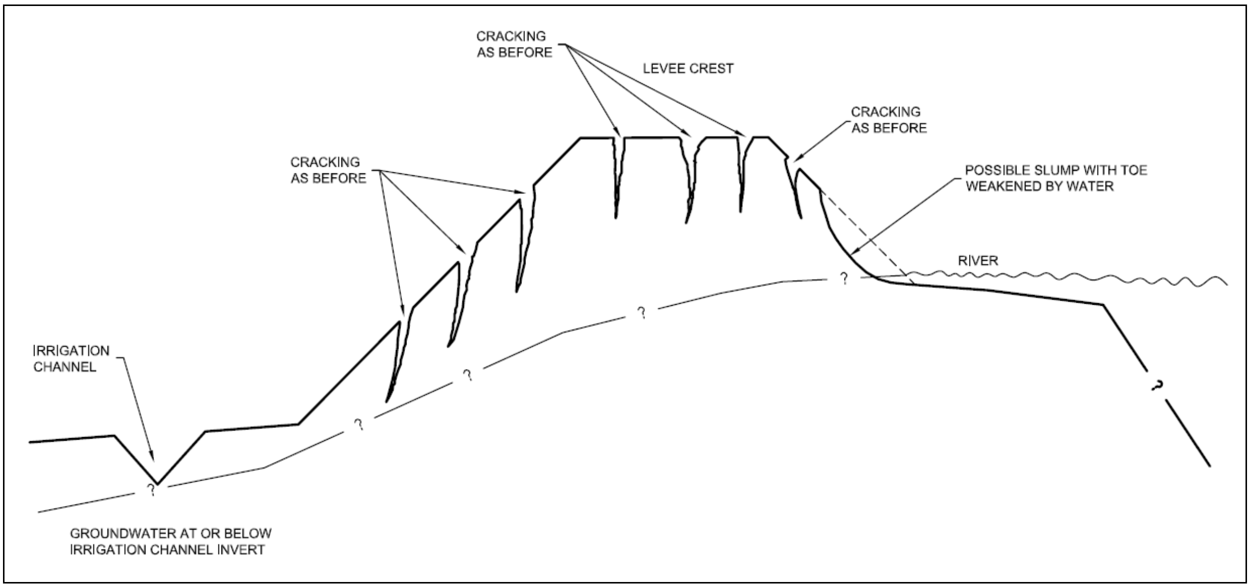


Figure 4 Restoration of Pool Level

We conclude that there is little reason to expect breach of the levees if pool level and regulated conditions are restored (refer Figure 4). We recommend that contingency planning be put in place to detect and repair the slumping of the outside bank that we expect to accompany such restoration.

[5] Fell R, MacGregor P and Stapledon D 'Geotechnical Engineering of Embankment Dams' Balkema, Rotterdam (1192) Section 13.7

We question the value of attempting to repair cracking in the levees until measures to restore pool level and regulated conditions are implemented, noting that irrigator representatives had the same opinion. The cracks do not presently pose an unacceptable risk of breach. While the water level remains low we expect that there will be ongoing development of cracking which could not practically be prevented by maintenance. Slumping could be repaired by normal means once it has occurred.

8 Assessment of Floodplains / Irrigation Areas

An assessment of the floodplains and irrigation areas, whilst not strictly required for Part 1, is included below to allow a holistic understanding of the current situation.

8.1 Effect of Water Level Change Observations and Inferences

Our remarks are generally confined to the reclaimed irrigation areas as we had limited opportunity to observe the effect of water lowering on the existing unreclaimed wetlands. Trivially, the soils in those must have dried to an extent depending on their 'normal' (ie Barrages-maintained) water level. Where we have visited unreclaimed wetlands (as part of our observations of the control structures that have been placed near these) our observations suggest dry soils at surface level and some cracking of the ground surface. We cannot comment on the state of the surface when the River is at 'normal' level as we have not observed this.

The effect of the water level lowering on the reclaimed irrigation areas appears to have been greater than in the unreclaimed areas, presumably in part because for the last 70 years at least these areas have been irrigated and farmed. The irrigation must have – was designed to – raise the moisture content of the ground. It must also have raised the level of the ground water surface.

From what we could see, and what we were told by various farmers, the reclaimed irrigation areas have settled since the water level has lowered. That is consistent with expectations of alluvial deposits. The mechanism is likely to be a combination of shrinkage of clayey and organic soils because the soils are drier and consolidation of all the alluvial soils because the proportion of the weight of overlying soil carried by groundwater pressure is transferred to the soil skeleton. It is impossible to assign the relative effects of these mechanisms on the basis of the present studies.

As far as we are aware there are no reliable measurements of absolute settlement, but comparison between more stable areas (those where tree plantings have previously lowered the moisture level in the soil, for example) and the presumably less stable irrigated areas suggests that at least 0.3 m settlement has occurred in many areas, and there is a reasonable likelihood that settlements could have exceeded this in some. An overall settlement of 0.3 m or more is consistent with the unevenness – the relative settlement from point to point - of the reclaimed irrigation areas that typically appears to be between about 0.15 m and 0.2 m. It is also consistent with the approximately 0.3 m settlements that were reported in the reclaimed irrigation area near the Swanport Bridge (now called Long Island) during dewatering of the ground for the bridge construction in 1975 and 1976.

There are significant differences in the apparent settlement behaviour of the various reclaimed irrigation areas. The present limited scope of investigations has not allowed us to correlate the various factors that might have contributed to this and we doubt that any reliable correlation can be devised given the absence of reliable information regarding the water content and level of the reclaimed irrigation areas before the water level began to lower.

As well as uneven settlement within the individual paddocks, deep and sometimes wide (to 200mm) cracks have appeared. These also occur in the inverts of the river channel and side drains (refer following picture). The centres of paddocks would have dried and settled first. The side drains would have remained wetter for longer and settled later. This would result in tilt within the paddock resulting in the invert cracks seen.

Any attempt to obtain correlation would have to include assessment and understanding of the shape, size and boundary conditions of the reclaimed irrigation area, the composition, depth and lateral variation of the soils, the distribution of groundwater, the timing and amount of irrigation, the rainfall and evaporation and the water demands of the various crops or other purposes to which the irrigation has been directed. We suspect that this will be impractical.

Lowering of water level within soils containing organics – as the soils of the reclaimed irrigation areas do – carries the risk of activating acid sulphate soil conditions. We have been informed by Tim Seeliger at Toora irrigation district that this has occurred already on his property; a verbal water quality result taken from a crack in a Toora paddock reportedly has pH 4.5. We have not been advised of, nor did we observe, any other cases. Notwithstanding it is therefore possible that acid sulphate conditions have already or will develop in some other reclaimed irrigation areas.

8.2 Syphons

As part of the general rehabilitation process for the reclaimed irrigation areas, it was a requirement that irrigation flows be metered. The choice was offered to install syphons or to line sluices with pipes which in both cases allowed fitting of metering devices. The number of diversion points was also reduced, so some former sluices and syphons were removed.

The new syphons consist of a 600mm pipe fabricated using polyethylene pipe and installed into a trench with variable amounts of cover over the pipe barrel. In every case, the pipe invert is above pool level. The syphons were installed adjacent to sluices and the sluices were then removed and the levee reinstated.

There appears to be 2 short comings with the outcome.

- The backfill material used around the syphons in most cases appears to be granular. While this is sound practice for pipes buried in most instances, it may prove to be a point of weakness in a water retaining structure such as a levee in a situation of high flow. If water were to make its way through the granular material it may cause a breach of a levee to occur. This phenomenon is known as “piping failure” but may not be associated with a pipe in a trench. Water under pressure finding its way through granular material in an embankment may lead to the same type of failure. It would be preferable to encase the syphons in clay-rich material or bentonite and for the whole backfill to be water tight. The problem will not manifest until a high flow event reaches the invert of the syphon.

- Some of the bank reinstatement following sluice removal is very steep. It is apparent that the well-intentioned effort to provide some riprap protection using small stone has failed and might continue to fail at current and future higher river levels. Some slumping has already occurred. Flatter embankments would have been closer to accepted practice. It is accepted that some difficulties may have occurred due to the confines of the inlet channel and having to avoid the new syphon.

Auditing of the construction of the various irrigation structures that penetrate the levees (syphons and sluices etc) and those locations where previous structures (typically sluices) have been removed may confirm, or prove otherwise, the risk of inflows through the levees. It would be desirable if inflow through the levee at these locations is similar to that through the intact levees.

9 Assessment of Wetland Control Structures

The following structures assist in containing water within the main river stem and were assessed in this light. DWLBC note that ownership details of the following structures is unclear and resolution would aid in the future management of the structures.

9.1 Morgan's Lagoon

Description

The structure comprises 6 bays of culverts set into a concrete base slab, topped with a concrete slab and has wing walls both sides projecting at approximately 45^{o} with a concrete slab continuous with slab over the culverts. There are trash racks to the river side and stop log grooves on the wetland side.

Functionality

The stop logs are not functional. Several attempts appear to have been made to make the structure retain water in the wetland including use of silicon, a render, and plastic sheeting backfilled with uncompacted rubble. A supplementary embankment had been placed on the wetland side of the structure and this is poorly compacted.

It is not clear how the trash racks would be cleared.

Construction

The wing wall space has been backfilled with unselected, uncompacted material containing rock to 200mm. There are evident cavities in the backfill and it is apparent that some of the fines have been washed from the backfill.

The concrete work is of a poor standard, with the topping slab not levelled. This does not impair the functionality.

Assessment

A modest level of differential pressure from water retained in the wetland or a river level held back by blocked trashracks will result in the backfill being scoured from around the structure and bypass occurring. Overtopping by a high flow event would hasten this process. The end result may be undermining and toppling of the structure. At the very least its functionality will be nonexistent due to bypassing.

Remediation

The following works ensure the stability of the structure and do not address inherent functional deficiencies.

Excavate the existing backfill behind the wingwalls and replace it with well compacted appropriate material e.g. cement-stabilised sand (CLSM). Possibly extend this in trenches laterally away from the structure to increase the seepage path length.

Undertaking remediation works prior to a return to 'normal' water level could avoid the need for a small coffer dam and dewatering.

A budget estimate of $20,000 for the above works is thought reasonable.

9.2 Avoca Inlet

Description

The structure comprises 4 bays of culverts presumed to be set into a base slab and capped with a concrete slab. The abutments comprise a facing slab and short wing walls either side. There are trashracks on the river side with a manual rotation system consisting of 2 baffles for each culvert bay.

Functionality

There are no stoplogs or other water retaining mechanism. An attempt appears to have been made to retain water in the wetland using plywood and plastic sheeting backfilled with rubble. The base slab is concealed with silt and other debris to the extent that the trash baffles could not be rotated. If they were to be turned, the trash would enter the wetland defeating their ostensible purpose. We are unsure how cleaning of the trash rack is intended to be carried out.

Construction

Backfill appears to comprise granular material and gabions have been placed adjacent to the outer edges of the abutment.

The concrete work is poorly levelled, and the concrete approach path has settled to the point of presenting a trip hazard. The soffit of the structure was cast-in-place. The aggregate and fines in the face are exposed – there is little or no cement paste apparent in the soffit face.

There are multiple 50mm nominal diameter polyethylene pipes passing through the downstream abutment.

Assessment

The lack of a ready mechanism for retaining water in the wetland limits the functionality of the structure. The trashracks would be difficult to operate and self-defeating.

We consider it highly unlikely that the backfilling around the polyethylene pipes is of low permeability and extremely unlikely that it could have been packed around the pipes to form an effective barrier to flow. There is a moderate probability that the backfill material around the pipes and behind the wingwalls would erode allowing the structure to be bypassed and possibly undermined and toppled. A high flow event would bypass the structure through the adjacent Avoca Landing area.

Remediation

The following works ensure the stability of the structure and do not address inherent functional deficiencies.

Excavate the existing backfill behind the wingwalls and replace it with well compacted appropriate material e.g. cement-stabilised sand (CLSM). Possibly extend this in trenches laterally away from the structure to increase the seepage path length.

Undertaking remediation works prior to a return to ‘normal’ water level could avoid the need for a small coffer dam and dewatering.

A budget estimate of $20,000 for the above works is thought reasonable.

9.3 Paiwalla Wetland

Description

The Paiwalla Wetland control structure comprises a submerged pipe through the embankment with an upturned bellmouth in the wetland and a handwheel operated sluice valve at the river side. The sluice valve operating mechanism which incorporates a linear position indicator, is accessed by a walkway bridge extending from the levee, braced by cables attached to piles. There is a floating boom across the inlet channel to protect against floating debris and to discourage mooring in the channel.

Functionality

The design appears to have been well considered. There is nothing to suggest that the structure would not perform as required although anecdotal reports are that it is not fail-safe. If debris enters the valve mechanism, water will be lost from the wetland until an alternative is put in place on the form of a temporary plate over the bellmouth. This would be a hazardous operation.

Construction

The pipe was trenched into the embankment and an anecdotal report is that the pipe trench was backfilled using a clay surround to the pipe including bentonite. The visible parts of the backfill show clay material and the levee has been topped using clay-rich rubble. The walkway is constructed of non-corrosive material and the valve guides appear to be aluminium.

Assessment

As above, the design appears to have been well-considered. The construction appears sound and the structure appears to be adequate for the purpose and robust enough to withstand high flow events. A large floating object would only threaten the structure in an extreme high flow event exceeding 3-4m above pool level.

9.4 Kroehns Landing

Description

This structure comprises 2 concrete culvert bays forming a bridge for a minor track extending from the rear of the shacks. The track is over the inlet to the wetland and provides access to farmland between the river and the wetland currently sown to what appears to be a cereal crop.

There are no flow control or trash arresting mechanisms.

Functionality

Without flow control, the structure would be unable to retain water in the wetland other than by use of temporary baffles or backfilling.

Construction

The structure appears sound as a bridge and the earthen abutments support vehicles. There are no rails or crash barriers.

Assessment

The structure appears to have limited usefulness as a regulating device for water flow into the wetland.

9.5 Reedy Creek

Description

The Reedy Creek Regulator consists of a series of connected bays with a mix of half height trash racks above stoplogs and full height stoplog bays. The structure is approximately 900mm high and is constructed from piles supporting the bays and their stoplog channels. The stoplogs are held captive by caps between the piles and screwed down using coach bolts. There is no skirt on either side of the structure.

Functionality

It appears that the structure would allow river water to enter and be retained or to hold back Reedy Creek flow to create a shallow wetland. It would appear that the structure could not be easily activated to regulate and retain Reedy Creek flows. The capture mechanism for the stoplogs could only be activated manually and by standing in water. It is doubted if the process could be done in a timely manner for an ephemeral stream and would be hazardous. The trashracks could only be cleaned by tipping the trash where it was not intended.

Construction

The piles, stoplogs and capping are a plastic material and the trashracks appear to be aluminium. The piles are not all vertical, with increasing out-of-vertical from south to north across the structure. This has meant that the trashracks have had to be altered to fit between the piles and into the tapering bays.

Assessment

The structure is built into clay material which is expected to have acceptable properties for water retaining structures. It could be expected that high flow from Reedy Creek ("flash flooding") could cause some wash and erosion initially but that water entering from the river would be at low velocity. Because of the low height of the structure, it will overtop and bypass spill will occur due to the flatness of the surround terrain.

9.6 Sugar Shack

Description

The structure comprises 3 bays of culverts placed over a concrete floor slab and topped with a concrete slab. There are wing walls on all sides projecting at approximately 45º. The spaces behind the wing walls have been backfilled with what appears to be granular material including paddock rocks – these do not appear to have been crushed – up to small boulder size (around 200 mm nominal dimension). There is no evidence that this backfilling has been compacted.

There are trash racks or fish screens on the wetland side and stoplog grooves with stop logs on the anabranch side. There was no water in the wetland or anabranch on 19/8/08.

Functionality

The stop logs have no longitudinal seals between them and the seals in the stoplog grooves are on the inside, so that they would function to prevent water from entering the wetland but not to retain water above anabranch level. The fish screens/trash racks could only be cleaned by rotating them, with the risk of allowing trash to move to where it was not preferred.

As the fish screens/trash racks are not easily removable it would appear to be necessary to enter the water to clean these depending on the flow conditions at the time. This may pose a risk to workers.

Construction

The concrete work is of a poor standard with evident honeycombing, cracking and signs of irregular formwork.

The backfill is unselected, uncompacted material containing rock to 200mm. The backfill material has also been placed against the outer faces of the wingwalls and is likewise uncompacted. We expect that the backfilling will provide little effective water retention in either direction.

The locking mechanism for the fishscreens/trash racks relies on 2 pop rivets which could be easily sheared. It is likely that these rivets will be subject to galvanic corrosion, which will increase the risk of failure over time.

We have reservations that the stoplogs may be neither strong nor rigid enough to withstand differential pressure if the water level is unequal on either side of the structure.

Assessment

We consider it virtually certain that the stoplogs will leak between each other. In the situation when the water level is higher in the wetland, the seals at the ends of the stoplogs will be ineffective. Even if a differential head can be maintained by the stoplogs, leakage will occur past the structure through the backfill and will only be moderately delayed by the "extra" backfill placed outside the wing walls. Overtopping by a high flow event would hasten the process and may lead to the structure being undermined.

There appears to be remnants of a pipe culvert around the downstream abutment that may allow the structure to be bypassed through this abutment.

Remediation

At the very least remedial works must include replacing the backfill material with clay-rich material, properly compacted. It would be prudent to confirm that the piped culvert in the downstream abutment is effectively blocked and that the backfilling around this prevents water flows. It would also be prudent to improve the sealing between stoplogs and to install full seals in the stoplog grooves on the culverts. We estimate the cost of remedial works to be up to about $20,000, if this can be done in dry conditions and potentially substantially more if it were necessary to manage water around the site.

9.7 Moorundie Wetland

The Moorundie Wetland is on the right bank of the wider river valley and stretches for several kilometres south from Blanchetown.

There are inlets to the wetland through the shack areas at Blanchetown, Portee Creek and Morgans Lagoon and there are connecting works at Sweeney Lagoon, Morgans Lagoon and South Causeway.

The scope of services did not include reporting on the connecting works at Morgans Lagoon and South Causeway.

9.8 Blanchetown Inlets 1, 2 and 3

Description

These consist of culverts under the road that provides access to the shack sites east and south from the golf course and caravan park. Only 2 culverts were found. It may be that the remaining inlet has been dammed by earthworks for the road construction

Functionality

There are no controls on these inlets. They could only provide regulation by virtue of their elevation above river level. Since the road way is effectively top of levee bank in the vicinity, the culverts would only discharge into the wetland at a relatively high river event, which we judge by eye would probably be close to the 1974 high river level.

Construction

The culverts are concrete pipes and have various amounts of cover under the road. They appear to have been in place for several years.

Assessment

These culverts have been included in this report for completeness. They appear sound and would be able to provide inflow to the wetland although they are potentially subject to blockage by trash or deliberately.

9.9 Blanchetown Inlet No. 4

Description

The structure is part of a crossing of an inlet creek to the wetland which is a narrow causeway with Armco railings.

The structure comprises 2 culverts placed over a concrete base slab and topped with a concrete slab. There are headwalls above the culverts at each end approximately 0.5m high and 4m long. These retain the filling below the road and the road pavements . The fill and pavement structure are approximately 1.5m thick above the culvert capping slab. The filling above these retaining slabs has a face angle of around 40°. The slabs are supported at their ends by fabricated steel frames taking the loads into the culverts. The frame on the north east corner is missing and may not have been installed

There are wingwalls on both sides at both ends of the culverts extending at approximately 45° from the culvert face.

There are fish screens/trash racks on the river side of the structure and stoplog grooves on the wetland side.

Functionality

Without stoplogs, the structure cannot prevent entry to or retain water in the wetland. The seals in the stoplog grooves have perished.

The fish screens/trash racks are significantly lighter and less robust than those at Sugar Shack, Avoca Dell, and Morgans Creek. There is a much higher risk of floating matter damaging these fish screens/trash racks and we judge that their resistance to willful damage (this area is open to the public) would be slight.

The retaining stops for the fish screens have already been bent (we do not know whether this is accidental or willful damage, but it gives an indication of the strength of the structure).

The screens cannot close because stone pitching above the wingwalls has collapsed onto the apron and into the culverts.

The fish screens/trash racks could only be cleaned by rotating them, with the risk of allowing trash to move to where it was not preferred.

As the fish screens/trash racks are not easily removable it would appear to be necessary to enter the water to clean these depending on the flow conditions at the time. This may pose a risk to workers.

The supports for the headwalls are much lighter than we would expect based on our experience. The headwall on the wetland side has cracked in a pattern suggesting that its strength and serviceability may not match the normal requirements for retaining structures. We judge it likely that the slab on the other side has not cracked because there is no horizontal support at one end, allowing the head wall to be pushed out by the 'retained' soil and decreasing the applied load. That lack of support may also be associated with the erosion of material from that part of the embankment which has collapsed onto the apron and into the culverts.

The material above the retaining wall is close to its angle of repose and we judge that the risk of slope failure far higher than is usually acceptable in trafficked areas, and particularly in a road embankment of such a height. We also judge from the face angle that there has been little effective compaction of the material close to the slope face.

The backfilling around the structure includes paddock rocks – these do not appear to have been crushed – up to small boulder size (around 200 mm nominal dimension).

Armco railing is usually installed so that the overlaps face away from the direction of traffic flow to decrease the risk if a collision occurs. On the river side, one of the overlaps has been installed with the overlap facing the other way.

Construction

The concrete work is generally of poor standard. The headwalls appear to have been cast off site on ground rather than formwork. There is some honeycombing in the wingwalls.

The backfill over and around the structure that forms the base for the road is coarse and the stone pitching has slumped.

The screen rotation mechanism is lightly welded to the screen frame.

Assessment

This structure forms the single route for north-south traffic in the area, which must logically include laden trucks carrying construction materials.

We have no details of the design and construction of the structure and our comments are therefore based only on what we were able to observe during a site visit.

On that basis, we have grave concerns about this structure. We doubt that the design and construction of the retaining walls that support the road match the applicable standards. The cracking in the concrete slabs and the flimsiness of the support structures suggest that the walls/supports may have already been stressed beyond their capacity.

The backfilling behind and above the retaining walls appears not to have been compacted effectively near the slope face, which suggests that the risk of slope failure in the backfilling is higher than is generally acceptable. Given the narrowness of the causeway and the relative width of the road, a slope failure - should it occur - is likely to affect the integrity and stability of the roadway.

If this part of the backfilling is – as we suspect - relatively lightly compacted, the structural soundness and serviceability of the Armco railing and its supports is likely to be affected.

We cannot confirm the structural capacity of the culverts to carry the loads applied by the overlying fill and traffic passing over.

The intended function of this structure as a control for water flows between river and wetlands could be impaired by other aspects of its construction including the lack of stoplogs and the lack of effective seals in the stoplog grooves. We are unable to know the extent or quality of the backfilling in the abutments to the structure. The presence of generally granular filling on the surface suggests that the backfill may be more permeable than the banks of the inlet itself. If so, there is a risk of the control structure being short-circuited around its abutments and a smaller risk that erosion could affect the integrity of the structure itself.

Because the risk of slope instability and retaining wall failure is increased when water is present and because of the risk of erosion of the backfilling we judge that a high river event could result in significant damage to the causeway. This could lead to opportunities for wetland management being lost.

We strongly recommend that the capacity of the structure to support a public roadway should be assessed by the relevant authority (which we assume would be the Mid Murray Council). That assessment should include detailed review of the design documents and construction records to confirm that these meet appropriate standards.

Remediation

We cannot guess the scope of rectification works, which could potentially involve complete reconstruction of the structure if the culverts themselves have inadequate structural capacity. The cost of the works will be affected by this being the only present north-south route through the area, which would presumably mean that an alternative temporary route would be required, or that the works would have to be completed piecemeal. The cost will also be affected by whether the works are carried out in the wet or in the dry.

We could not rule out rectification costs involving six figures.

9.10 Portee Creek Inlet

Description

The structure comprises 2 bays of culverts set into a concrete base and capped by a concrete slab. There are wing walls both sides projecting at approximately 60º to the axis of the culverts. There are headwalls above the extremities of the culverts and these are approximately 0.5m high and 4m long retaining around 0.3 m depth of unsealed pavement.

Backfilling around the culverts and wingwalls comprises what appears to be granular material including paddock rocks – these do not appear to have been crushed – up to small boulder size (around 200 mm nominal dimension). There is no evidence that this backfilling has been compacted.

There are fish screens/trash racks on the river side and stoplog grooves on the wetland side of the structure.

Functionality

There are no stoplogs and the seals in the stoplog guides have perished.

The fish screens/trash racks are similar to those at Blanchetown Inlet No 4 – relatively light and flimsy. There is a significant risk of floating matter damaging these fish screens/trash racks and we judge that their resistance to willful damage (this area is closed to the public but the inlet is close to a public area and the gates and fences do not provide effective barriers to foot traffic) would be slight.

The fish screens/trash racks could only be cleaned by rotating them, with the risk of allowing trash to move to where it was not preferred.

As the fish screens/trash racks are not easily removable it would appear to be necessary to enter the water to clean these depending on the flow conditions at the time. This may pose a risk to workers.

Construction

The structure is poorly built. In particular it is not clear how the headwalls are attached to the slab or culverts although the lack of buttresses suggests that the headwalls cantilever from slab or culvert to act as a retaining wall. The grout has spalled from the line of contact between slab and headwalls. There are cracks in the wing walls.

The backfill material is granular and uncompacted and stone pitching has collapsed.

Assessment

There are signs that the roadway over this structure is regularly trafficked - many people have access as evidenced by the number of locks in the gate at the end of the sealed road. This traffic must apply loads to the headwalls and how these loads are resisted is unclear.

The structure’s capacity for water flow control is likely to be compromised by seepage through the backfill even if stoplogs were present. The perished seals for the stoplogs would compromise their effectiveness. A high flow event may have the capacity to affect the stability of the backfilling and the headwalls.

We cannot confirm the structural capacity of the culverts to carry the loads applied by the overlying fill and traffic passing over.

We recommend that the capacity of the structure to support a semi-private roadway should be assessed by the relevant authority. That assessment should include detailed review of the design documents and construction records to confirm that these meet appropriate standards.

Remediation

We cannot guess the scope of rectification works, which could potentially involve complete reconstruction of the structure if the culverts themselves have inadequate structural capacity. The cost of the works will be affected by any requirement to maintain a north-south route across Portee Creek for the duration of the works, and whether the works are conducted in the wet or in the dry

We could not rule out rectification costs involving several tens of thousands of dollars.

9.11 Sweeney Lagoon Inlet

Description

This structure comprises one culvert placed on a concrete floor slab with wingwalls both sides.

There are no controls or screening mechanism.

Functionality

This structure appears to function solely to carry traffic over a connector between two parts of the wetland. The track can only be accessed through a locked gate at the end of the sealed road into the shack area. We are unsure of the security of the access in the other direction, which we did not attempt.

Construction

The concrete work is not of a high standard.

There is coarse granular backfill around the structure and very coarse base material for the track that crosses. The backfill has been poorly placed.

Assessment

There is potential for water to seep around the structure. This might have implications for the track although we doubt that there will be high flow velocity in a relatively small internal flow path within the wetland, unless trash blocks the culvert.

Remediation could follow after an erosion event if it occurs.

10 Miscellaneous Field Observations

East Wellington Recreational Lake

We are advised by DTEI that East Wellington Recreational Lake was substantially a lake before development – excavation to create the residential fingers and an even depth for navigation – took place. Arup estimate that less than one-third of the marina is in use and while an excavated site, it may be that water depth is insufficient for passage by houseboats. Several are moored in the river adjacent to the site. Nevertheless, the whole inundated site approaches 40 hectares in area and requires continual top up from the river to make up for evaporation.

Tailem Bend Developments

On the east bank upstream from and adjacent to Tailem Bend are several excavated channels. These sites were not inspected from land and their intended function is not apparent. It may include mooring sites or pumping station intakes. There is no reclaimed irrigation land in the vicinity. All represent loss from the river due to evaporation and seepage.

11 Risks from Future Water Level Changes

Future water level changes will have different effects and pose different risks to the River banks, reclaimed irrigation areas and levees. Accordingly these are dealt with separately below. The risks are also different depending on the extent of the water level change and we have separated these also.

When we refer to restoration of pool level, this should be understood to imply both restoration of the River level and a regulated flow regime to maintain that level.

11.1 Further lowering of the water level

River banks

Any lowering of the water level in the River is likely to trigger similar behaviour to that observed as a result of the existing water level lowering. That is, there will be erosion developed at a lower level on the banks and there is the potential for some slumping of the banks due to rapid drawdown.

There are good reasons to think that the consequences are likely to be similar to those already experienced – a slight increase in erosion and slumping of some tens of metres of River bank. We do not consider this to be significant risk in the context of maybe 300 km of river bank (not cliffs) in the 250 km of river involved, and having regard to the ongoing erosion that is a natural process in river banks

Reclaimed Irrigation Areas

Again, lowering of the water level is likely to trigger more of the ground behaviour that has already been experienced. The reclaimed irrigation areas will settle, the surface will become more uneven and there will be a higher risk of acid sulphate conditions developing.

Levees

We expect that the levees will be affected by lower water levels much as has been documented above. Cracking of the levees is likely to increase, although the extent of this is impractical to predict given that we cannot confidently attribute what portion of the existing cracking is a consequence of the currently lowered water levels and what is inherent in the levee construction and maintenance regime.

11.2 Restoration of pool level

River banks

Restoration of pool level in the River is likely to return erosion to the areas previously eroded. Where these are cracked, and if the water level rise is quick enough there will be some temporary increase in erosion. However, if the water level rise is slow enough for the soils to wet up naturally, we expect little effect on bank erosion.

Even if the soil cracking closes due to slow water level rise, we expect that there may be some slumping of the banks as the raised water levels enter the cracked areas and destabilise these. However, we judge it unlikely that the extent of slumping will be much different from what has accompanied the lowering of the water level – a few tens of metres in several hundred kilometres.

Reclaimed Irrigation Areas

Restoration of pool level in the River can be expected to cause swelling of some of the soils in the reclaimed irrigation areas and therefore to raise the overall ground level. It will not restore the ground to its original level – some of the changes in the soils are irreversible. All this is likely to make the surface more uneven than it is now. If the restoration of pool level is accompanied by irrigation being restored, whether partially or fully, these effects will be exacerbated.

Restoration of pool level implies restoration of irrigation flows. The ground of the reclaimed irrigation areas is presently cracked. Restoring pool level will not fully close all the cracks and where the cracks appear to have closed the ground will not have healed. We expect that there will be grave difficulty in maintaining flow in the existing irrigation infrastructure (the various channel and sluices) without losing significant amounts of water into the ground.

It may be practically impossible to restore the channels to their previous water-holding capacity. We observed cracks in the reclaimed irrigation areas extending at least 1.5 m below surface. Unless the ground was disturbed and remoulded to that depth (or beyond, depending what the maximum depth of cracking actually is, as opposed to the depth we saw) it is impossible to rule out irrigation waters seeping away through the base of the channels.

The foregoing suggests that significant rework of the reclaimed irrigation areas is likely to be required to restore them to their previous utility. Because the swelling of the ground will not be instantaneous following recovery of water levels in the River and because we cannot reliably predict the extent or magnitude of ground movements, the rework is likely to have to be undertaken over a number of episodes. Depending on the present viability of the various reclaimed irrigation districts, that may have limited economic rationale.

If acid sulphate conditions have developed, restoring the ground water level within the reclaimed irrigation areas has the potential to generate subsurface flows which move the acid groundwater to locations beyond its pre-existing footprint.

Levees

If the water level in the River is restored to pool level, we expect that the toe of the outside banks of the levees will be generally at or below water level. Where cracking of the outside face has extended to this level, the risk of slumping of that face of the levee will be higher. It is practically impossible to quantify this – the difficulties of even seeing most of the outside bank toes due to existing vegetation preclude any reasonable estimate of the extent to which cracking is present there.

However, that may not be critical because in our opinion the risk of this leading to rupture of the levee is extremely low. It is possible that existing slumped areas may be re-activated and new slumps may develop. The geometry of the slumps that we observed in the levees suggests that these will not extend beyond the outer wheel path or equivalent position on the levee crest. That would allow a strategy of waiting for the slumps to develop, then repairing them using conventional earthmoving methods – dig out, prepare the surface for filling and refill. Placing of filling may be expected to strengthen the natural subgrade over time – as has happened over the existing footprints of the levees.

Because the toe of the inside face of the bank will not be inundated at pool level, the risk of triggering slumping in the inside faces by water entering the cracks is expected to be extremely low.

It is reasonable to expect that some of the cracking in the levee banks will close if the River water level is restored to the pool level. However, the cracks will not heal.

11.3 High flow event

River banks

A high flow event carries risk for the River banks. We expect that there would be increased erosion of the banks and the potential for slumping of the banks. The extent of these would depend on the magnitude of the event. We presume that sufficient records exist of previous high flow events to allow estimation of the risks to a much greater reliability than could be achieved in the present study.

Reclaimed Irrigation Areas

A sufficiently large high flow event will lead to inundation of the reclaimed irrigation areas. That would lead to loss of shape of the ground that would require reworking if the present agricultural practices are to be maintained.

It also has the potential to trap water (many of the reclaimed irrigation areas are too flat and level to allow practical pumping of flood water off the land) in a way that would allow anaerobic conditions to develop. The 1992 experience on Mobilong irrigation district may serve as an example.

Levees

It should be noted that the ongoing settlement of the ground (and not all of this is related to the recent lowering of water levels, we expect that there has been and would continue to be settlement of the ground in the reclaimed irrigation areas even if the River water level were held absolutely constant) has very probably led to the crest level of the levees being lower than their level at the time of construction or subsequent overtopping. That may have implications for the protection level provided by the levees against high flow events.

Whilst DWLBC hold survey information on Government levees from 2005, we expect settlement to have continued since then and hence the information may not be valid. We recommend that the crest of both Government and private levees should be (re)surveyed to confirm what high flow event protection is currently available.

If a high flow event overtops the levees there is the potential for significant damage to these. The overtopping water would enter the cracks in the crest and could destabilise both faces of the levees (refer Figure 5). We cannot rule out breaching of the levees if this were to occur. The proportion of levees affected would vary from irrigation area to irrigation area according to the extent of cracking present, but could not be ruled out even where there is no apparent cracking because generally the face slopes on the levees are steeper than documented good practice suggests.

Incidentally any breaching or overtopping of the levees, whether this occurred before or after the current conditions, would result in potentially significant quantities of water gravitating to the irrigation bays or retired land, depending on its location.

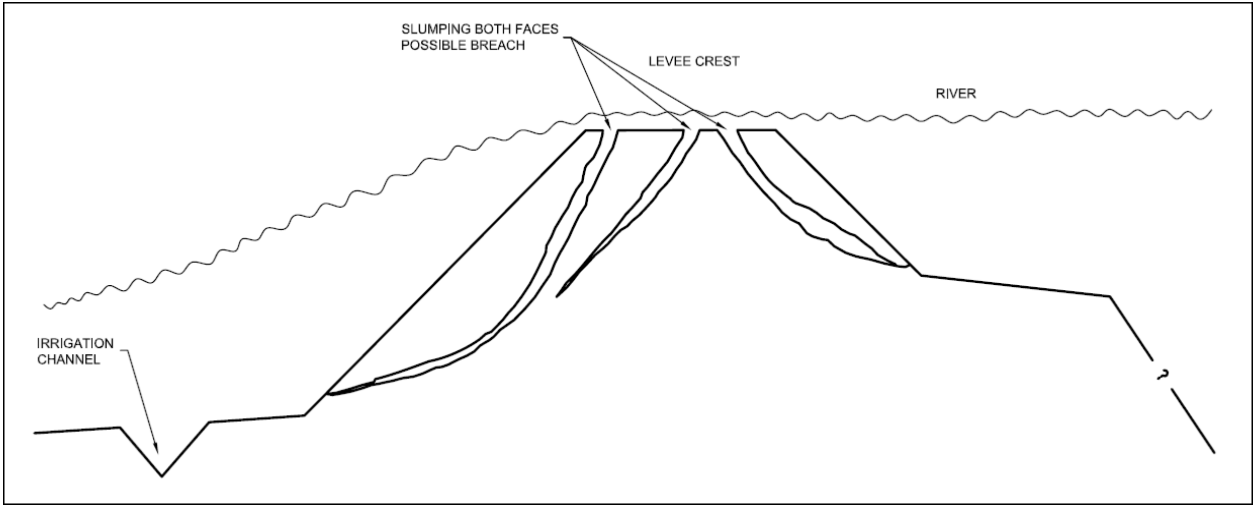


Figure 5 High Flow Event

We expect that the levees around some reclaimed irrigation areas – Mobilong, Monteith, River Glen and Toora are examples – would be heavily damaged by any overtopping event. It may be prudent to assess the economics of providing protection to these reclaimed irrigation areas.

Even if overtopping does not occur, there is risk to the levees associated with the various penetrations - sluice gates and syphons – providing irrigation water to the reclaimed irrigation areas. We have not examined these in detail in the present studies. However, as described previously there are reasons to suggest that some of these may not be as water-tight as the actual levee banks. If this is true and water passes through these areas, there will be a risk of damage to inside and outside banks and a risk of rupture of the levee.

Similar risks apply to the presence of vermin burrows in the levees. These are not, according to our observations, as prevalent as the irrigation infrastructure. However, they must produce uncontrolled voids within the levees which may carry a higher risk per unit occurrence of triggering breaches in a high flow event.

12 Summary and Recommendations

Our observations suggest that the condition of the river banks is generally satisfactory. There has been slumping of some isolated sections of river bank. We observed three instances totalling around 100 m length in the approximately 300 km of river bank we studied. We cannot rule out the possibility of future water level movements (up or down) triggering similar behaviour. We know of no practical method of predicting the location or extent of that. In view of the very limited extent of the slumping that has occurred to date we suggest that the risk of future slumping would be acceptable. If it occurs, repair (if it is deemed to be required and in many cases it may not) could be effected by normal means.

We conclude that there is little reason to expect breach of the levees if pool level and regulated conditions are restored. We question the value of attempting to repair cracking in the levees until measures to restore pool level and regulated conditions are implemented. The cracks do not presently pose an unacceptable risk of breach. While the water level remains low we expect that there will be ongoing development of cracking which could not practically be prevented by maintenance. Slumping could be repaired by normal means once it has occurred.

Many of the wetland control structures require potentially significant remediation works, predominately to the backfill. In two cases complete reconstruction may be warranted.

We recommend:

1. A level survey of the Government and private levee crests to confirm the level of protection afforded by the levees at their present height. That survey may indicate that additional construction would be warranted.
2. That consideration is given to upgrading the levees to match present documented good practice in water-retaining structure. That should include assessment of the risk of breach due to overtopping in the present form, which was beyond the scope of the present studies. That might involve consideration of the economics of providing appropriate protection to several of the reclaimed irrigation areas via levees. A consequence of flattening the inside faces of the levees will be a requirement to reconstruct river/supply channels on many irrigation areas adding further to cost.
3. Auditing of the construction of the various irrigation structures that penetrate the levees (syphons and sluices etc) and those locations where previous structures (typically sluices) have been removed to confirm that the risk of inflows through the levees there is similar to that through the intact levees.
4. That contingency planning be put in place to detect and repair the slumping of the outside bank that we expect to accompany such restoration.
5. Measures to manage vermin, and in particular to reduce the extent to which they are able to burrow into the levees.
6. The relationship between soils, time since last watering and the extent of soil cracking in pastures may be worth investigating to assist with future management of drought issues.

Appendix A

Agreed Scope of Works

4 Scope Definition

4.1 Physical Limits

The physical limits of this project will be:

- At the upstream end, those structures downstream of (and excluding) Lock 1 on the River Murray
- At the downstream end, Pomanda Island
- On either side of the River Murray between the upstream and downstream limits, the extent of the 1956 flood

4.2 Scope of Services

This proposal is based on Arup providing the following scope of services.

Part 1: Main River Stem Assessment

Arup will:

- Identify soils within the project area via existing soil maps provided by DWLBC to allow soils to be correctly named during field assessment
- Contact approximately 15 key stakeholders identified by DWLBC and hold a stakeholder meeting at Murray Bridge with a view to obtaining information relating to damage adjacent to the river channel attributable to the drought.
- Go to reasonable lengths to obtain permission to access levees on private property. We will rely on DWLBC providing contact details (preferably telephone numbers, but also postal addresses).
- Identify and assess damage to riverbanks, wetlands and water control structures between Lock 1 and Pomanda Island via houseboat and dinghy. We have allowed two continuous working weeks for this component of work.
- Assess damage to public and private levees between Lock 1 and Pomanda Point via vehicle or foot. We have allowed one continuous working week for this component of work.
- Prepare a Part 1 assessment report

Part 2: River Valley Assessment

Arup will:

- Organise and facilitate two community consultation events on the same day at separate locations within the study region with a view to obtaining information relating to damage within the study area attributable to the drought.
- Attempt to make contact with up to 15 additional key stakeholders who may be able to provide information relating to damage within the study area attributable to the drought. Arup will rely on DWLBC providing appropriate contact details for these stakeholders.
- Identify known infrastructure with the potential to be affected by drying of the soils and that if damaged would have a meaningful impact on the security of water within the river, the environment or the community.

- Categorise the sites identified during community consultation, stakeholder discussions and know infrastructure for prioritisation and approval by DWLBC.
- Assess damage to as many of the prioritised sites as possible. We have allowed for one continuous working week in the field. Additional sites identified along the way will also be assessed as time permits.
- Prepare a Part 2 assessment report

Presentation to Steering Committee and Water Security Task Force

Arup will

- Prepare one PowerPoint presentation following completion of Parts 1 and 2
- Present once to the Steering Committee and Water Security Task Force (WSTF) in Adelaide. We have nominally allowed for a 1 hour presentation over a 3 hour period.

4.3 Assumptions

The following assumptions have been made whilst preparing this proposal:

- DWLBC will provide the information requested in this proposal at the time of award
- Data provided to Arup is current and valid
- Access to private property (where required) is obtainable within a time period commensurate with the programme and as described in the methodology
- Information obtained through community consultation and stakeholder engagement will be useful to this project

4.4 Exclusions

The following are excluded from this proposal:

- Non-visual assessments
- Assessment of underground infrastructure
- Assessment of cliffs
- Itemised costing of remedial works
- Detailed assessment of soil maps, targeted assessment based on soil conditions, and extrapolation to areas outside those areas assessed for damage due to a particular soil type

Appendix B

Consultation

1. Example letter to key stakeholders
2. Follow up letter to key stakeholders
3. Advertisement in Murray Valley Standard
4. Meeting attendance list

Our ref 205527/whmm
Date 4 July 2008

Level 2 431-439 King William Street
Adelaide SA 5000
Tel +61 8 8413 6500
Fax +61 8 8212 5590
whendee.moore@arup.com.au

www.arup.com

Richard Reedy
PO Box 1379
MURRAY BRIDGE SA 5253

ARUP

Dear Richard,

Introduction to Assessment of Soil Cracking Damage and River Bank Slumping in the Lower Murray

The Department of Water, Land and Biodiversity Conservation (DWLBC) has initiated an assessment of the extent of damage to infrastructure along the Lower Murray due to soil cracking and river bank slumping associated with prolonged low water levels in the River Murray.

Reports from the Lower Murray and investigations to date have indicated that due to the drying of the soil some structures adjacent the river are cracking, slumping or suffering other related damage. There is the potential that this damage may affect the security of the water within the river and also cause damage to major and/or important infrastructure.

We are inviting concerned stakeholders to participate in the project by assisting us identify affected infrastructure and areas within your jurisdiction (e.g. irrigation trust area, LAP, Council etc) and along the river in general. The types of infrastructure that we expect to be identified include:

- River banks
- Levee banks
- Water control structures e.g. inlets, sluices etc
- Roads
- Aboveground utilities
- Flood plain pasture (mainly looking for cracks 7cm wide and greater)
- Other built structures e.g. pump stations

This project will be undertaken in two stages:

Stage 1: Damage on and adjacent to river bank and levees

Step 1: Identifying affected infrastructure, mainly through consultation with stakeholders such as you. Information relating to areas adjacent the river banks and levees will be used in Step 2 of Stage 1, while information within the river valley will be used in Stage 2.

Step 2: Assessing affected infrastructure and the associated soils. Engineers will be in the area for approximately 3 weeks undertaking a visual inspection of the identified infrastructure along the river banks and levees.

Stage 2: Damage within the river valley

Step 1: Identifying affected infrastructure within the wider river valley through consultation with the wider community. We anticipate that up to two public meetings will be held in the project area.

../2

Step 2: Assessing affected infrastructure and the associated soils. Engineers will be in the area for approximately 1 week undertaking visual inspections.

Please note that we may not be able to inspect all identified infrastructure. However we will pass all information gathered on to DWLBC.

In order to initiate the project and collection information, we are holding a meeting at

10:30am on Monday 14th July at Dundee's Hotel (3166 Jervois Road, Murray Bridge)

which we hope you, or your representative, will be able to attend.

During the meeting we will:
- Discuss the project
- Discuss the infrastructure affected
- Collect specific information in the form of the maps and forms (where available)
- Provide an opportunity to discuss the potential impact of the damage

Enclosed with this letter is a map covering what we understand to be your jurisdiction. To assist us in maximising the infrastructure we are able to identify, it would be most appreciated if you could:
- Indicate on the map areas and infrastructure with known damage that could be attributed to soil drying. We have included numbered stickers that can be stuck on the maps at the site identified sites, while the numbers can be cross-referenced on the form (see next dot point).
- On the forms, cross-reference the sticker number and provide a description of the infrastructure/area (e.g. levee bank, concrete channel inlet etc), the damage it has sustained (e.g. crack approx 15cm wide and 10m long, falling into river etc), and any other information that you think may assist us.

If you run out of stickers please mark the drawing clearly with a permanent marker. We will collect this information at the meeting.

If you or a representative is unable to attend the meeting, then please contact me to discuss an alternative method of collecting any information you can provide to us. It is important that we include your information so that DWLBC understands the full extent of the damage.

Hopefully I will already have spoken to you by the time you receive this letter, however, if not or you wish to discuss the project further, then please feel free to call me on 0411 069 038. Alternatively, my colleague Simon Schutz can be contacted during business hours on (08) 8413 6500.

I look forward to meeting you on Monday 14th July.

Yours sincerely

(for)

Whendee Moore
Environmental Engineer

Our ref 205527/whmm

Date 22 July 2008

Level 2 431-439 King William Street
Adelaide SA 5000
Tel +61 8 8413 6500
Fax +61 8 8212 5590
Direct Tel +61 8 8413 6500

www.arup.com

Richard Reedy
PO Box 1379
MURRAY BRIDGE SA 5253

ARUP

Dear Richard

Soil Cracking Project Information for Burdett Presiding Officer

We'd like to thank everyone who has assisted us so far with the Soil Cracking Assessment project by providing us with information about their irrigation trust area and particularly to those who attended the meeting on the 14th of July. The meeting was very informative and enclosed is brief summary of the main points that were raised in addition to the individual irrigation area information.

Further to the initial data collection and meeting we'd like to let you know, in your role as Presiding Officer, of two important upcoming components of the project:

1: Community Meetings
We will be holding two community meetings on Monday the 4th of August at:

1. Murray Bridge Community Centre at 10:30am
2. Mannum Community Centre at 2:00pm

This will be an opportunity for all land owners and interested community members to provide site specific information about the soil cracking issues so that Department of Water, Land and Biodiversity Conservation has the most complete set of data possible.

We would appreciate it if you could let other land owners in your district know about these meetings. The meeting will also be advertised in the local newspaper, but we have enclosed a few leaflets that you might be able to pass on. The more information we can collect, the better the Department is aware of the extent of the issues.

Please note that these community meetings will be covering the same issues as we did at the meeting held on July 14th, so if you attended it is not necessary to attend one of the community meetings (but feel free to if you wish).

2. Field Inspections
The field assessments are now underway with a majority of the riverbanks already examined from the river. In the week starting Monday 28th July, two field engineers, Campbell McKnight and Lyn Sanders will be conducting assessments of the levee banks and some pastures and on-farm infrastructure.

Some people have expressed an interest in being present during the assessments to highlight areas of concern. This is another opportunity to ensure that as much information as possible is presented to the Department and

../2

Arup
Arup Pty Ltd ABN 18 000 966 165

we are happy to meet with you while we are in your area. We will endeavour to accommodate individual requests; however we can not guarantee that this will be possible in all instances as we have considerable ground to cover.

At this stage we plan to be in Burdett on Tuesday the 29th of July. Campbell or Lyn will give you a call the day/evening before to let you what time during the day they are likely to be in your area to:

- organise a meeting place;
- organise access where required; and/or
- provide you with an opportunity to let them now about specific locations of interest in the case that you will not be with them the next day.

Thank you again for all the assistance and information we have received to date, we look forward to meeting you (again) and seeing many of you and your neighbouring land owners on August the 4th.

If you have any queries please don't hesitate to contact Whendee Moore or Hilary Pocock on (08) 8413 6500.

Yours sincerely

(for)
Whendee Moore
Environmental Engineer

Brief Summary of Main Points Raised at the July 14 Meeting

Please note that this is intended as a short summary of a lengthy meeting for your information only

Riverbank slumping, pasture cracking and levee cracking

- Riverbank slumping is very varied but in some areas it has occurred significantly. An example included a 6 foot slump along approximately 30m of water frontage.
- Soil cracking varies between irrigation areas and different pastures but cracks greater than 6 feet deep and several inches wide were reported
- Cracks present danger to livestock
- Differences in cracking possibly attributable to:
    - Length of time since last watering.
    - Different soils, cracking possibly worse where black swamp soil present
    - Areas that have or have not been laser levelled.
- Levee bank cracking varied throughout districts
- Levee bank cracking on the surface is not necessarily indicative of extent of issue, more likely to be structurally undermined from beneath or within

General views and issues

- Views expressed that there is little point in undertaking remedial action until there has been some watering and the soils on both sides of levee have had a chance to return to 'normal' state
- Views expressed that getting some water is a key factor to practically understanding the extent of the problem and working towards a solution
- Water table has dropped and when water is available it is very possible that it may flow under the levees and pastures as the water table returns to higher level
- Uncertainty of what might happen in the future, reporting needs to be clear that the assessment is for the specific time
- Important to note areas where impacts are not as bad – should try to find causes and potentially pass information on

Government of South Australia

Department of Water, Land and Biodiversity Conservation

Issue of Soil Cracking and Related Damage on the Lower Murray Floodplain (Lock 1 to Wellington)
Notice of Community Meeting

The Department of Water, Land and Biodiversity Conservation (DWLBC) is seeking information from the community to assess the extent of damage to public and private River or water infrastructure due to soil cracking. This information will form the basis of a more extensive field assessment. Two community meetings will be held at the following locations.

Murray Bridge Community Club
Monday 4th August at 10:30am

AND

Mannum Community Club
Monday 4th August at 2:00pm

To register your attendance, or for further information please contact Hilary Pocock of Arup Water on (08) 8413 6534

To	Part 1 Report	Reference number	
cc		File reference	
From	Simon Schutz	Date	12 August 2008
Subject	Soil Cracking in Lower Murray - Meeting Attendees		

Stakeholder Meeting, Dundee's Hotel, 10.30am 14 July 2008

Attendees	**From**
Terry Franklin	DWLBC Murray Bridge
Richard Reedy	Chairman LMI
David Allen	Rural City of Murray Bridge
Darren Attrill	Yiddinga (Montieth)
Timothy Seeliger	Toora - Murray Bridge
Warren Doecke	Yiddinga
Glen Dorsey	Jervois Trust
Ian Mueller	River Glen
Don Llewellyn	Montieth
Owen Rothe	Long Island
Kathryn Rothe	Long Island
Graham Smart	Mypolonga North
Les Martin	Wall Flat
Kristy Kowald	Toora
Matt Jaensch	Toora
Sharyn Linder	Pompoota
Vanda Hayward	Pompoota
Andrew Copus	DWLBC
Richard Brown	DWLBC
Katie Hollingsworth	MDBC
Rajiv Mouveri	DWLBC
Whendee Moore	Arup
Simon Schutz	Arup

Community Meeting, Murray Bridge, 10.30am 4th August 2008

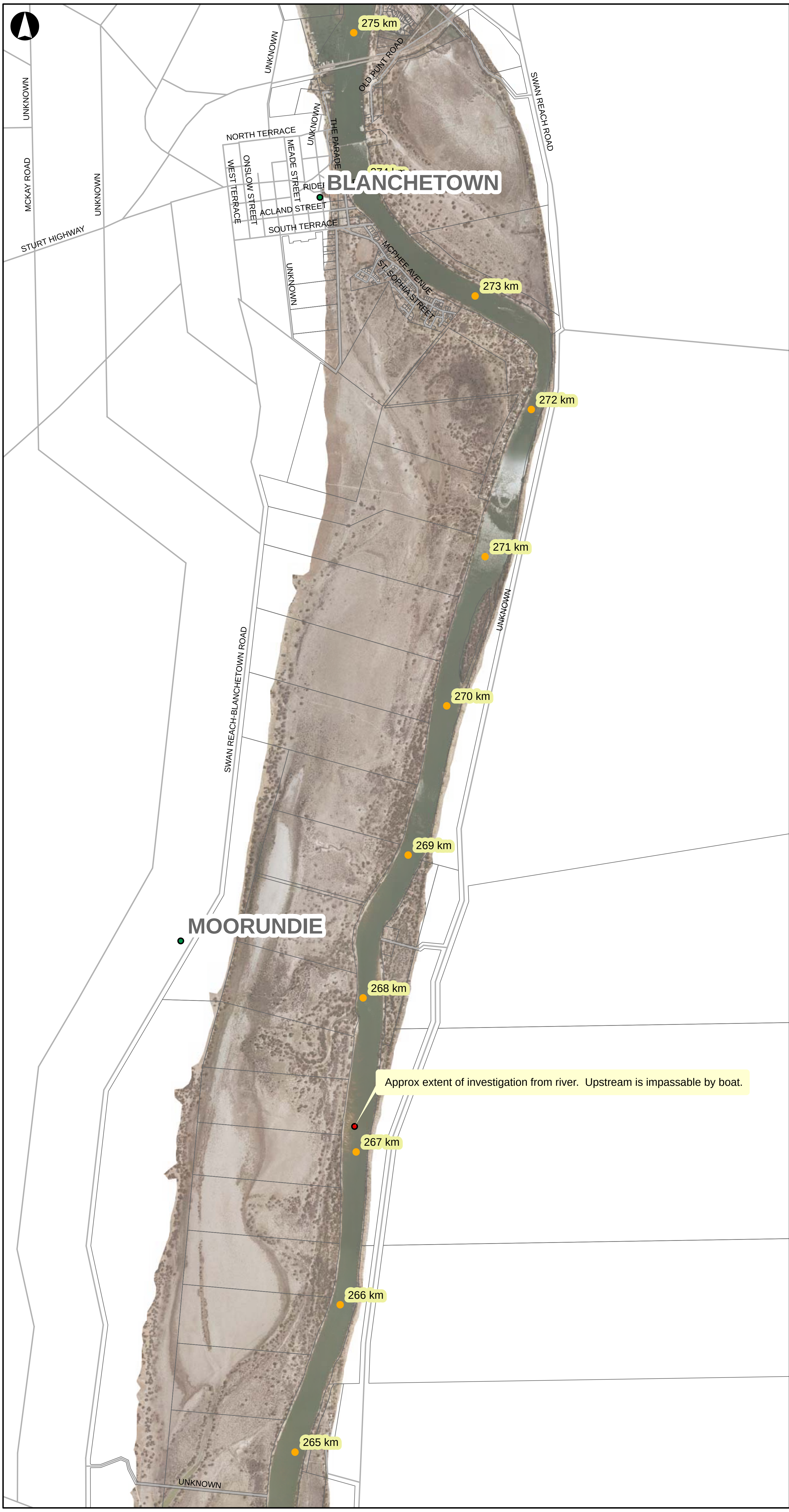
Attendees	**From**
Richard Reedy	Chairman LMI
Carmel Critchley	Wall Flat
Andy Frith	
Stephen Packer	EPA
Steve	Mypo Traders
Trevor	Adrian Pederick MP Office
Prue	MV Standard
Ian Mueller	River Glen
Andrew Copus	DWLBC
Richard Brown	DWLBC
Whendee Moore	Arup
Simon Schutz	Arup

Community Meeting, Mannum, 2.00pm 4th August 2008

Attendees	**From**
Kelvin Gladstone	Mid Murray Council
Dave	Councillors
Phil	Councillors
Raelene Cook	Home Owner, Mannum
Tony Cook	Home Owner, Mannum
Tim Seeliger	Toora
Andrew Copus	DWLBC
Richard Brown	DWLBC
Rajiv Mouveri (part of)	DWLBC
Whendee Moore	Arup
Simon Schutz	Arup

Appendix C

Sites of Interest Drawings



Legend

- Sites of Interest
- River Chainage, km
- Towns
- Cadastre

Issue	Date	By	Chkd	Appd
F1	2008-11-05	SS	SS	EJS

Metres
0 250 500 1,000

ARUP

Level 2 Optus Centre
431- 439 King William St, Adelaide 5000
Tel +61 8 8413 6500 Fax +61 8 8212 5590
www.arup.com

Client
Department of Water, Land and Biodiversity Conservation

Job Title
Soil Cracking Damage in Lower Murray

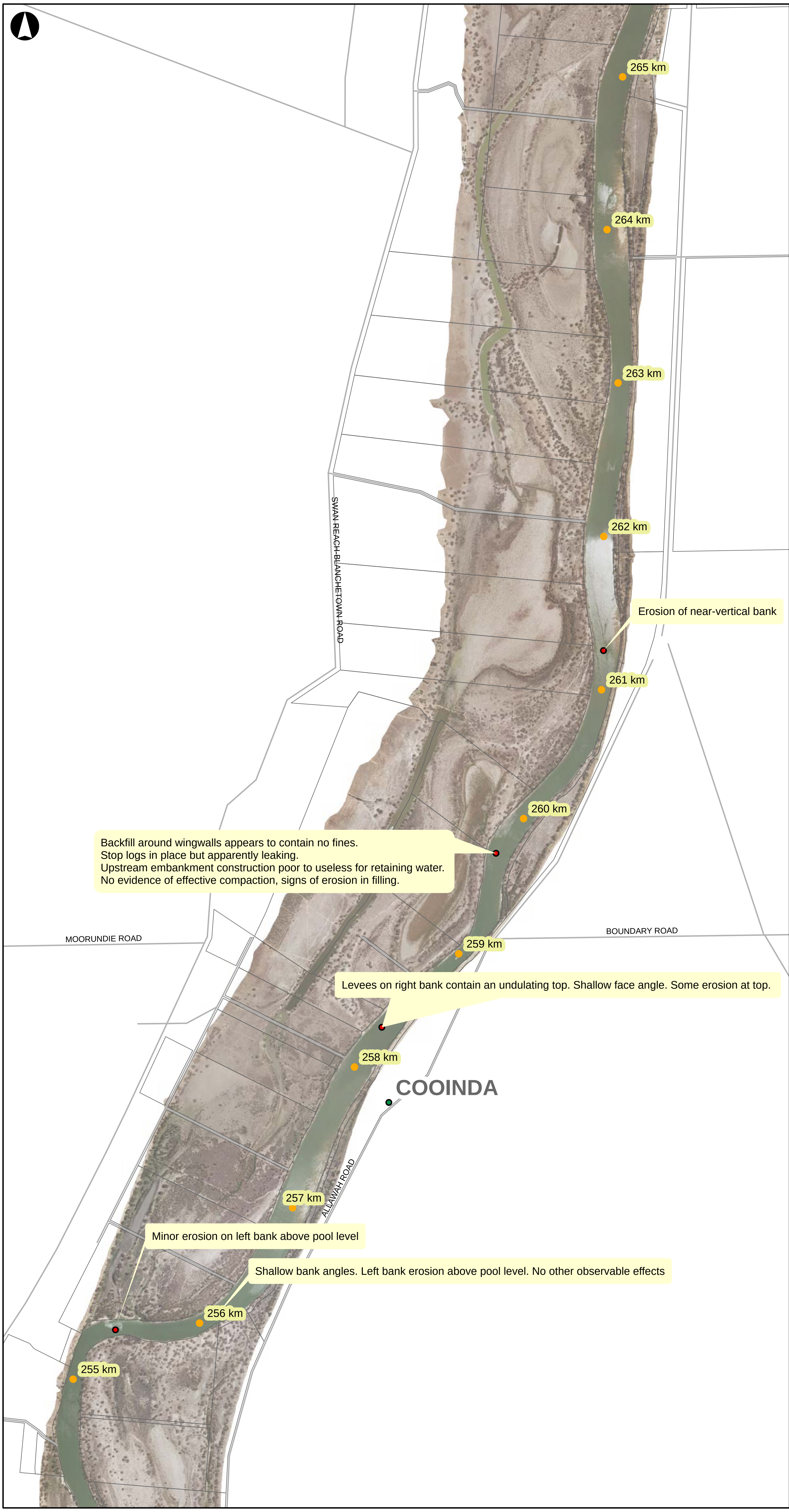
Drawing Title
Sites of Interest

Scale at A3
1:25,000

Drawing Status
For Issue

Job No	Drawing No	Issue
205527	205527-01	F1

\\adfp06\projects$\200000 Series\205527 Soil Cracking Damage in Lower Murray\GIS\Copy of 20081030 Damage Identified.mxd



Legend

- Sites of Interest
- River Chainage, km
- Towns
- Cadastre

Issue	Date	By	Chkd	Appd
F1	2008-11-05	SS	SS	EJS

Metres

0 250 500 1,000

ARUP

Level 2 Optus Centre
431- 439 King William St, Adelaide 5000
Tel +61 8 8413 6500 Fax +61 8 8212 5590
www.arup.com

Client

Department of Water, Land and Biodiversity Conservation

Job Title

Soil Cracking Damage in Lower Murray

Drawing Title

Sites of Interest

Scale at A3

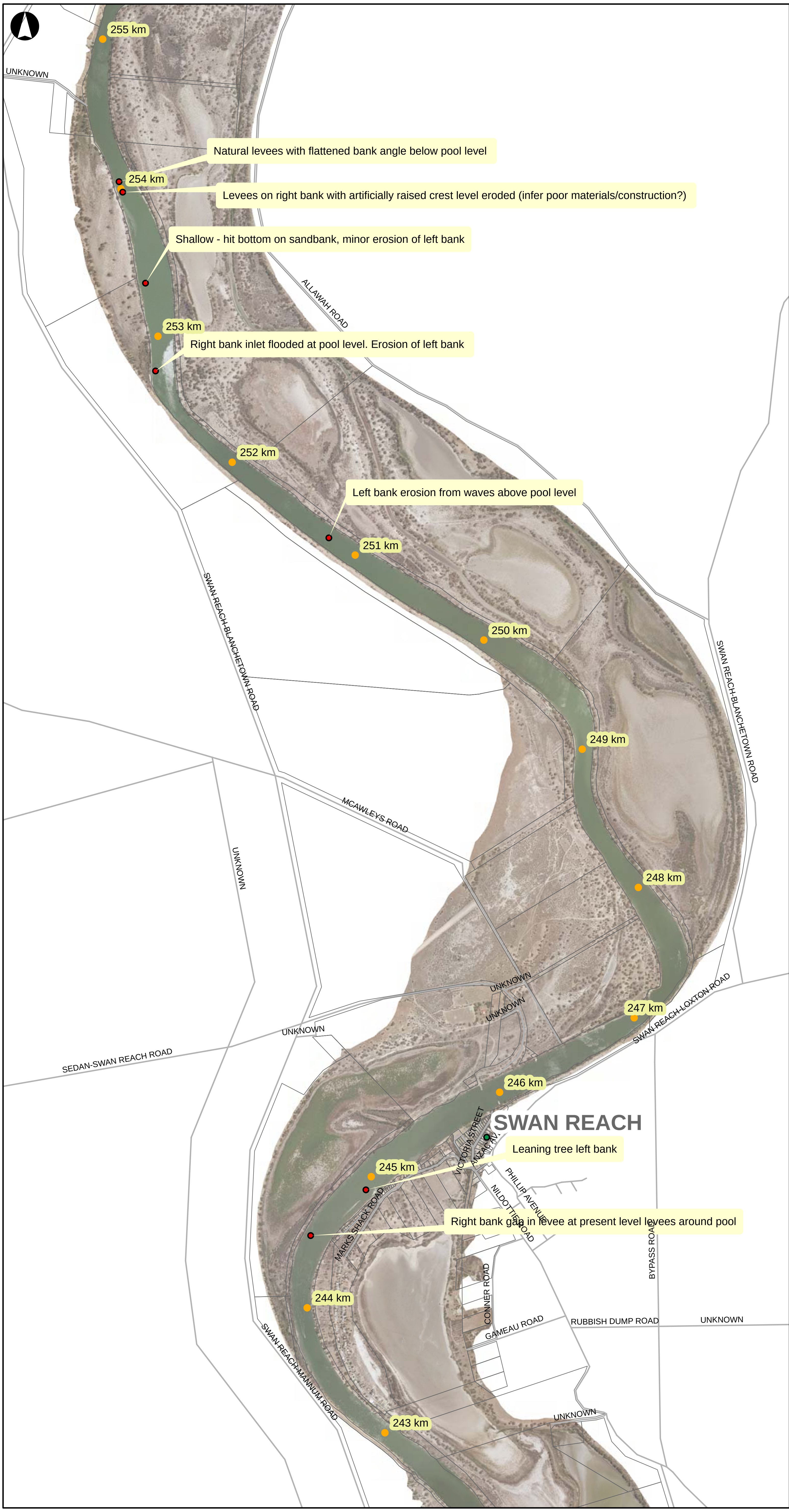
1:25,000

Drawing Status

For Issue

Job No	Drawing No	Issue
205527	**205527-02**	**F1**

\\adlfp06\projects$\200000 Series\205527 Soil Cracking Damage in Lower Murray\GIS\Copy of 20081030 Damage Identified.mxd



Legend

- Sites of Interest
- River Chainage, km
- Towns
- Cadastre

©Copyright Information

F1	2008-11-05	SS	SS	EJS
Issue	Date	By	Chkd	Appd

Metres
0 250 500 1,000

ARUP

Level 2 Optus Centre
431- 439 King William St, Adelaide 5000
Tel +61 8 8413 6500 Fax +61 8 8212 5590
www.arup.com

Client
Department of Water, Land and Biodiversity Conservation

Job Title
Soil Cracking Damage in Lower Murray

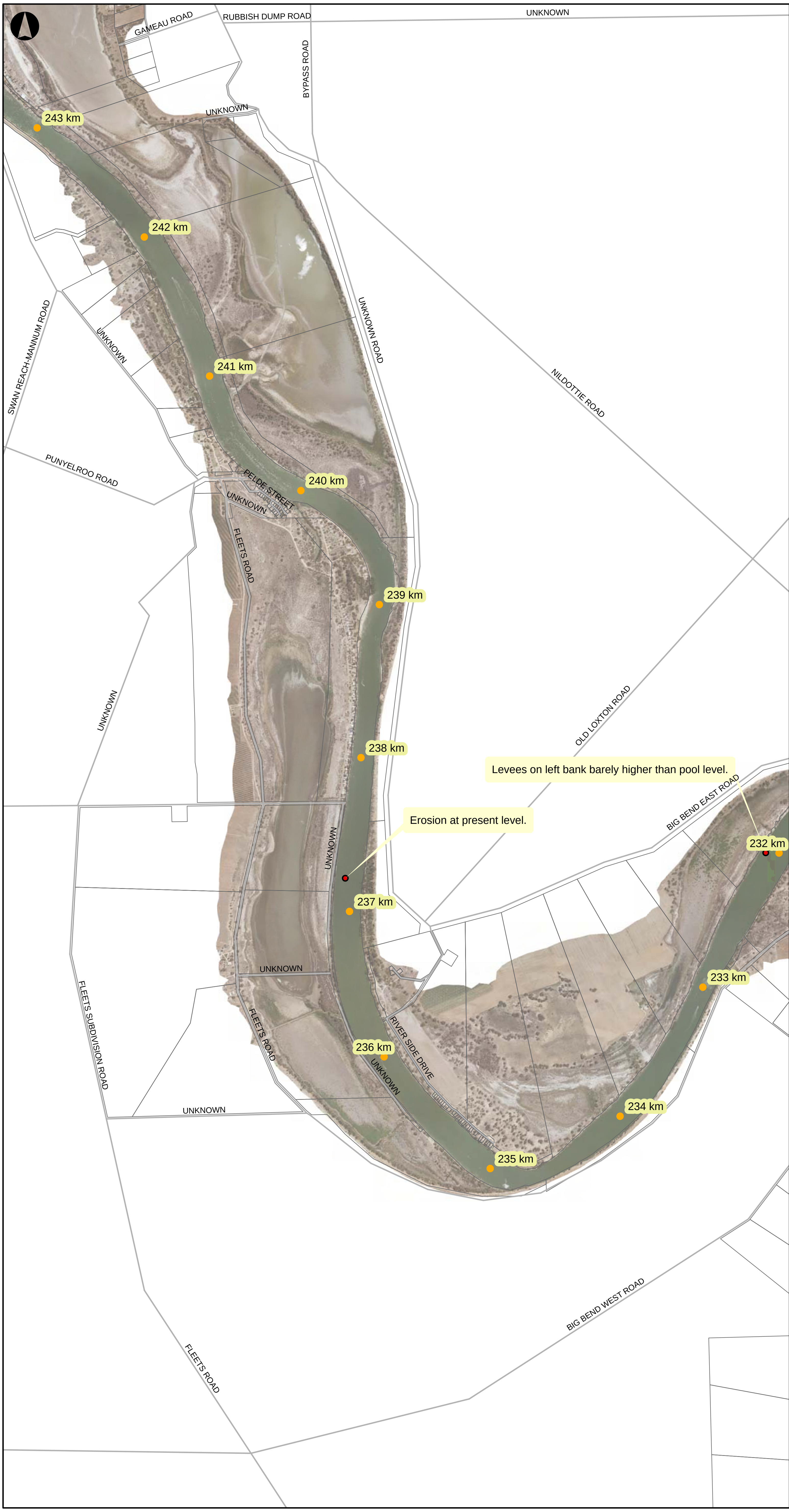
Drawing Title
Sites of Interest

Scale at A3
1:25,000

Drawing Status
For Issue

Job No	Drawing No	Issue
205527	205527-03	F1

\\adfp06\projects\200000 Series\205527 Soil Cracking Damage in Lower Murray\GIS\Copy of 20081030 Damage Identified.mxd



Legend

- Sites of Interest
- River Chainage, km
- Towns
- Cadastre

Issue	Date	By	Chkd	Appd
F1	2008-11-05	SS	SS	EJS

Metres
0 250 500 1,000

ARUP

Level 2 Optus Centre
431- 439 King William St, Adelaide 5000
Tel +61 8 8413 6500 Fax +61 8 8212 5590
www.arup.com

Client
Department of Water, Land and Biodiversity Conservation

Job Title
Soil Cracking Damage in Lower Murray

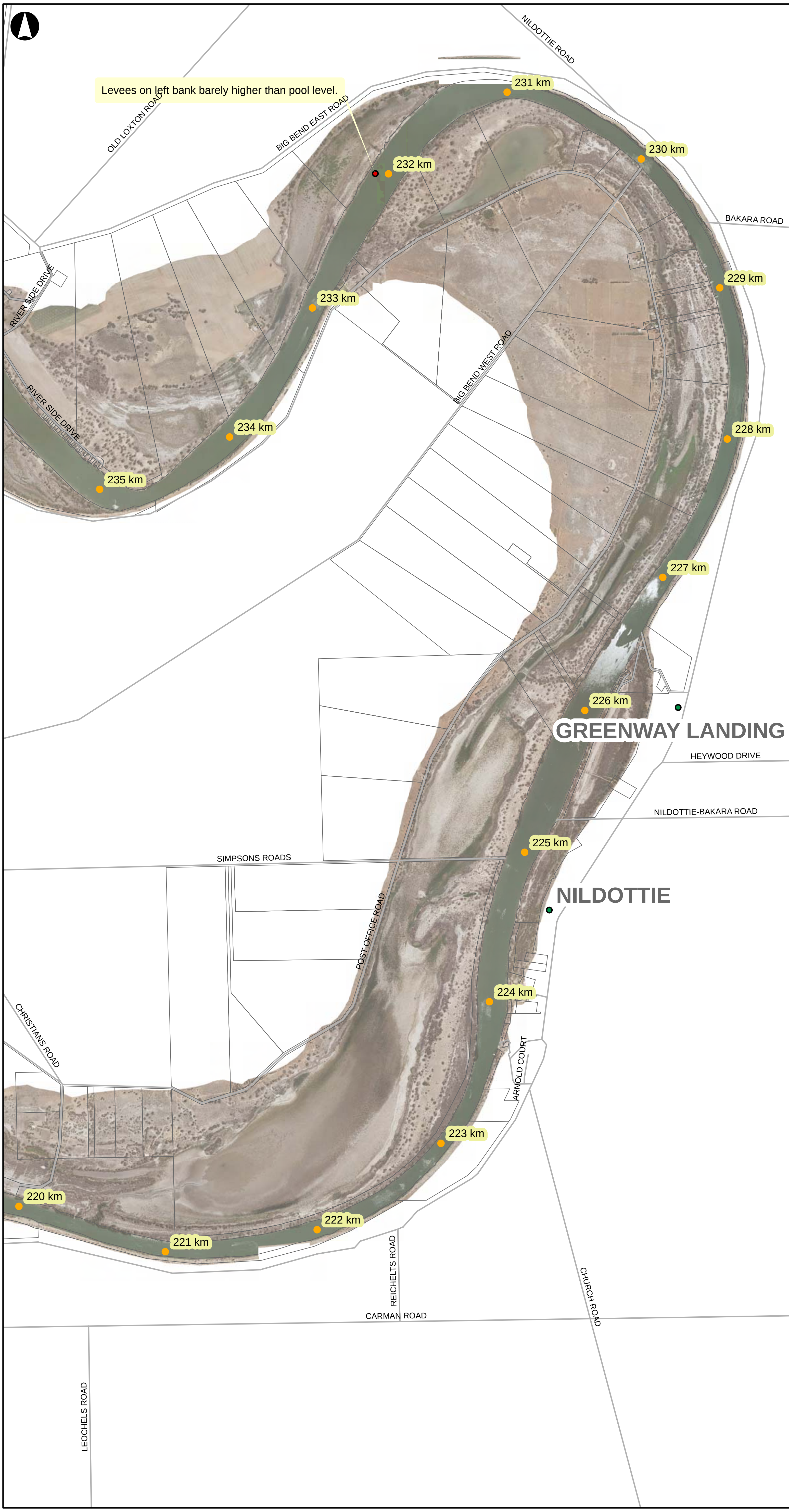
Drawing Title
Sites of Interest

Scale at A3
1:25,000

Drawing Status
For Issue

Job No	Drawing No	Issue
205527	205527-04	F1

\\adlfp06\projects\200000 Series\205527 Soil Cracking Damage in Lower Murray\GIS\Copy of 20081030 Damage Identified.mxd



Legend

- Sites of Interest
- River Chainage, km
- Towns
- Cadastre

Issue	Date	By	Chkd	Appd
F1	2008-11-05	SS	SS	EJS

Metres
0 250 500 1,000

ARUP

Level 2 Optus Centre
431- 439 King William St, Adelaide 5000
Tel +61 8 8413 6500 Fax +61 8 8212 5590
www.arup.com

Client
Department of Water, Land and Biodiversity Conservation

Job Title
Soil Cracking Damage in Lower Murray

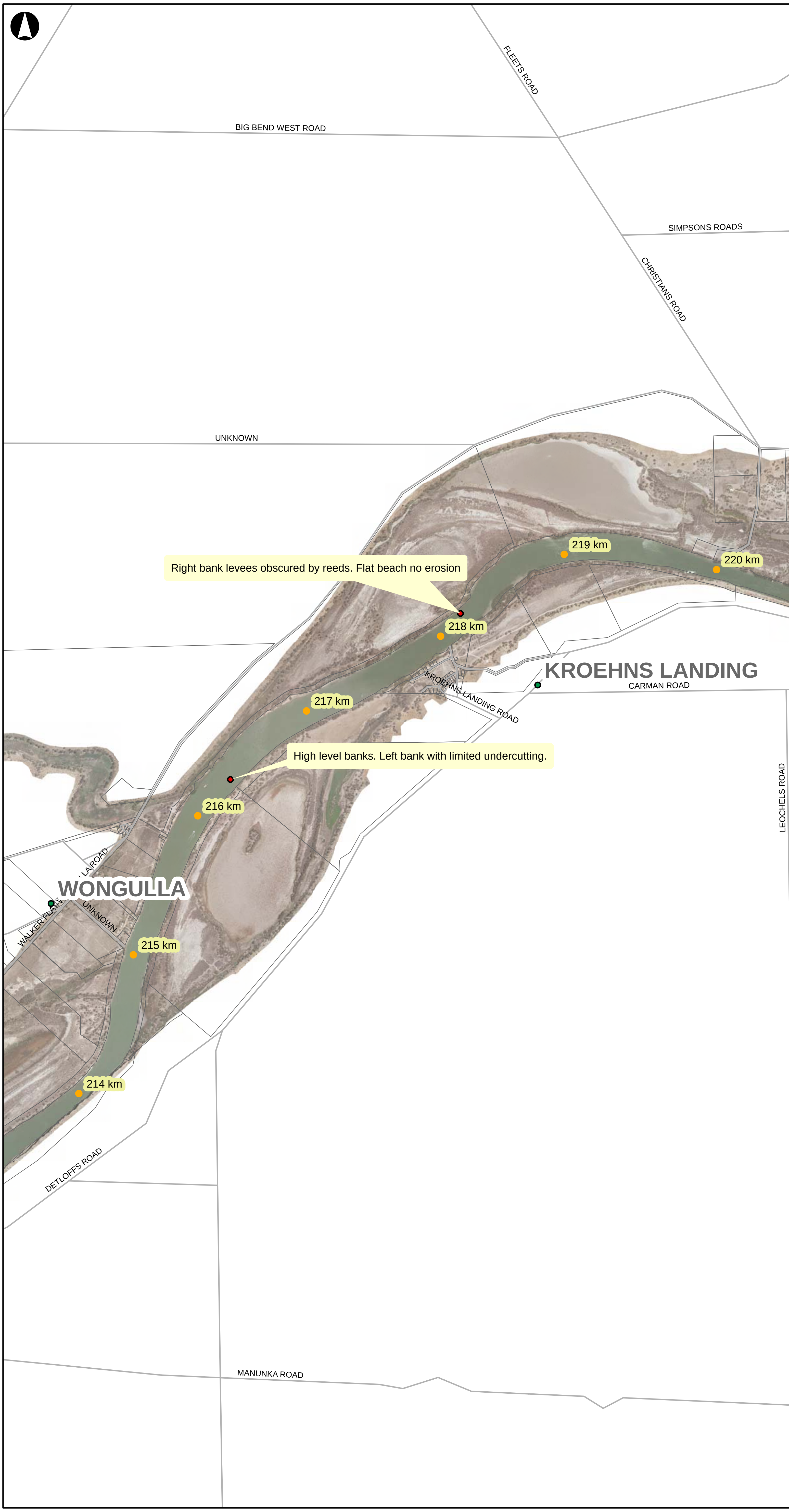
Drawing Title
Sites of Interest

Scale at A3
1:25,000

Drawing Status
For Issue

Job No	Drawing No	Issue
205527	205527-05	F1

\\adfp06\projects\200000 Series\205527 Soil Cracking Damage in Lower Murray\GIS\Copy of 20081030 Damage Identified.mxd



Legend

- Sites of Interest
- River Chainage, km
- Towns
- Cadastre

Issue	Date	By	Chkd	Appd
F1	2008-11-05	SS	SS	EJS

Metres

0 250 500 1,000

ARUP

Level 2 Optus Centre
431- 439 King William St, Adelaide 5000
Tel +61 8 8413 6500 Fax +61 8 8212 5590
www.arup.com

Client

Department of Water, Land and Biodiversity Conservation

Job Title

Soil Cracking Damage in Lower Murray

Drawing Title

Sites of Interest

Scale at A3

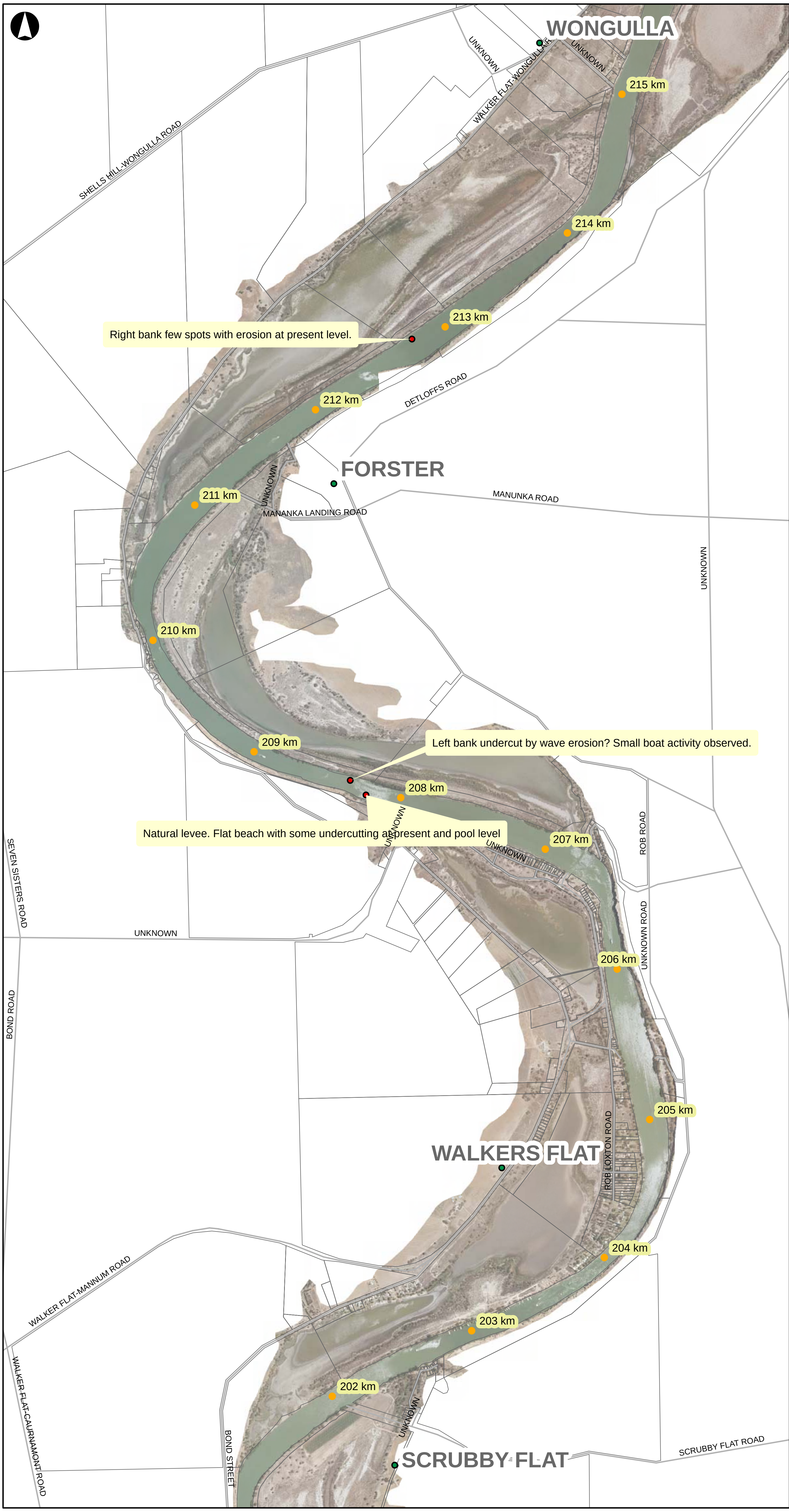
1:25,000

Drawing Status

For Issue

Job No	Drawing No	Issue
205527	205527-06	F1

\\adfp06\projects$\200000 Series\205527 Soil Cracking Damage in Lower Murray\GIS\Copy of 20081030 Damage Identified.mxd



Legend

- Sites of Interest
- River Chainage, km
- Towns
- Cadastre

Issue	Date	By	Chkd	Appd
F1	2008-11-05	SS	SS	EJS

Metres

0 250 500 1,000

ARUP

Level 2 Optus Centre
431- 439 King William St, Adelaide 5000
Tel +61 8 8413 6500 Fax +61 8 8212 5590
www.arup.com

Client

Department of Water, Land and Biodiversity Conservation

Job Title

Soil Cracking Damage in Lower Murray

Drawing Title

Sites of Interest

Scale at A3

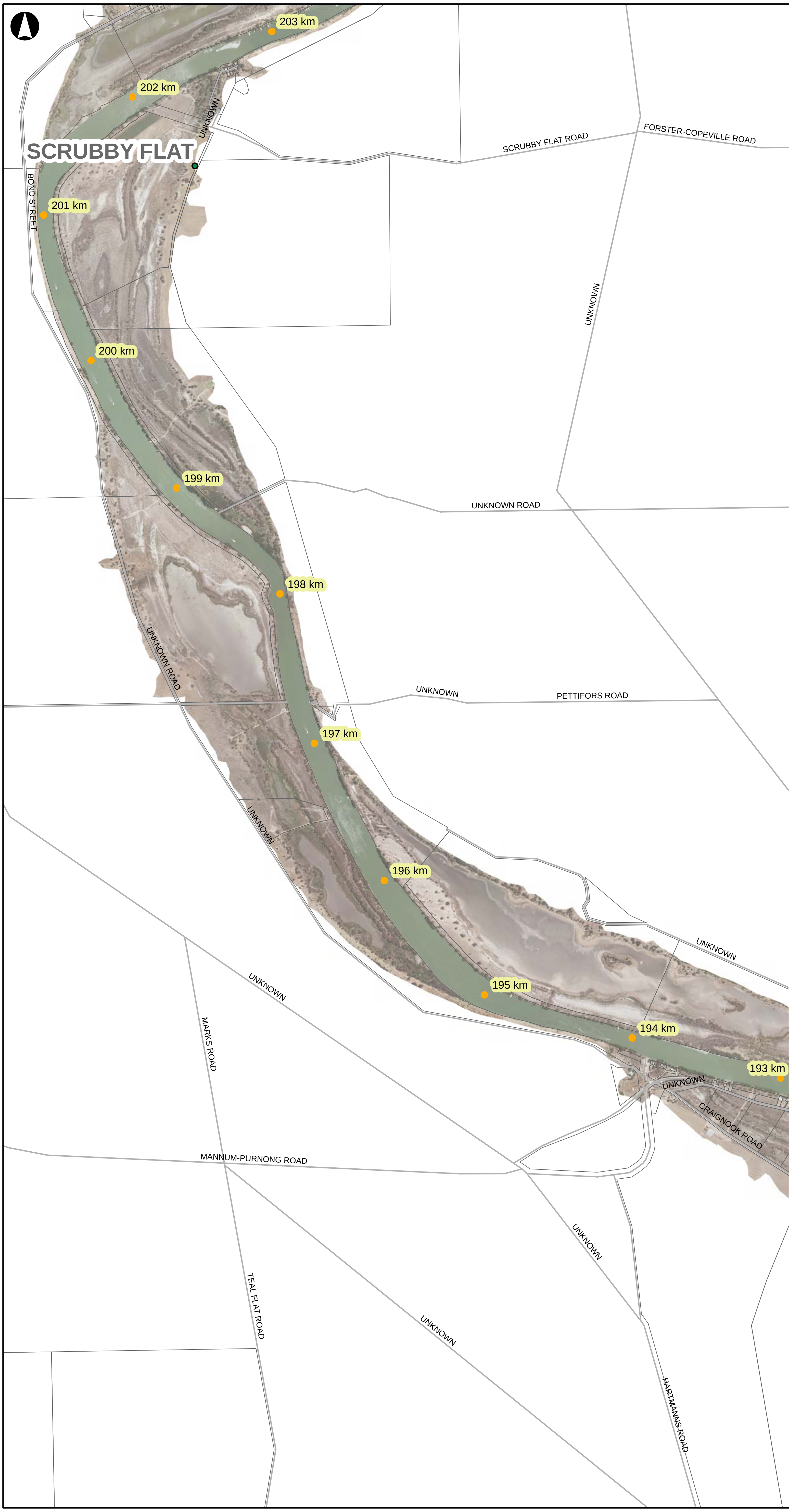
1:25,000

Drawing Status

For Issue

Job No	Drawing No	Issue
205527	205527-07	F1

\\adlfp06\projects$\200000 Series\205527 Soil Cracking Damage in Lower Murray\GIS\Copy of 20081030 Damage Identified.mxd



Legend

- Sites of Interest
- River Chainage, km
- Towns
- Cadastre

Issue	Date	By	Chkd	Appd
F1	2008-11-05	SS	SS	EJS

Metres
0 250 500 1,000

ARUP

Level 2 Optus Centre
431- 439 King William St, Adelaide 5000
Tel +61 8 8413 6500 Fax +61 8 8212 5590
www.arup.com

Client
Department of Water, Land and Biodiversity Conservation

Job Title
Soil Cracking Damage in Lower Murray

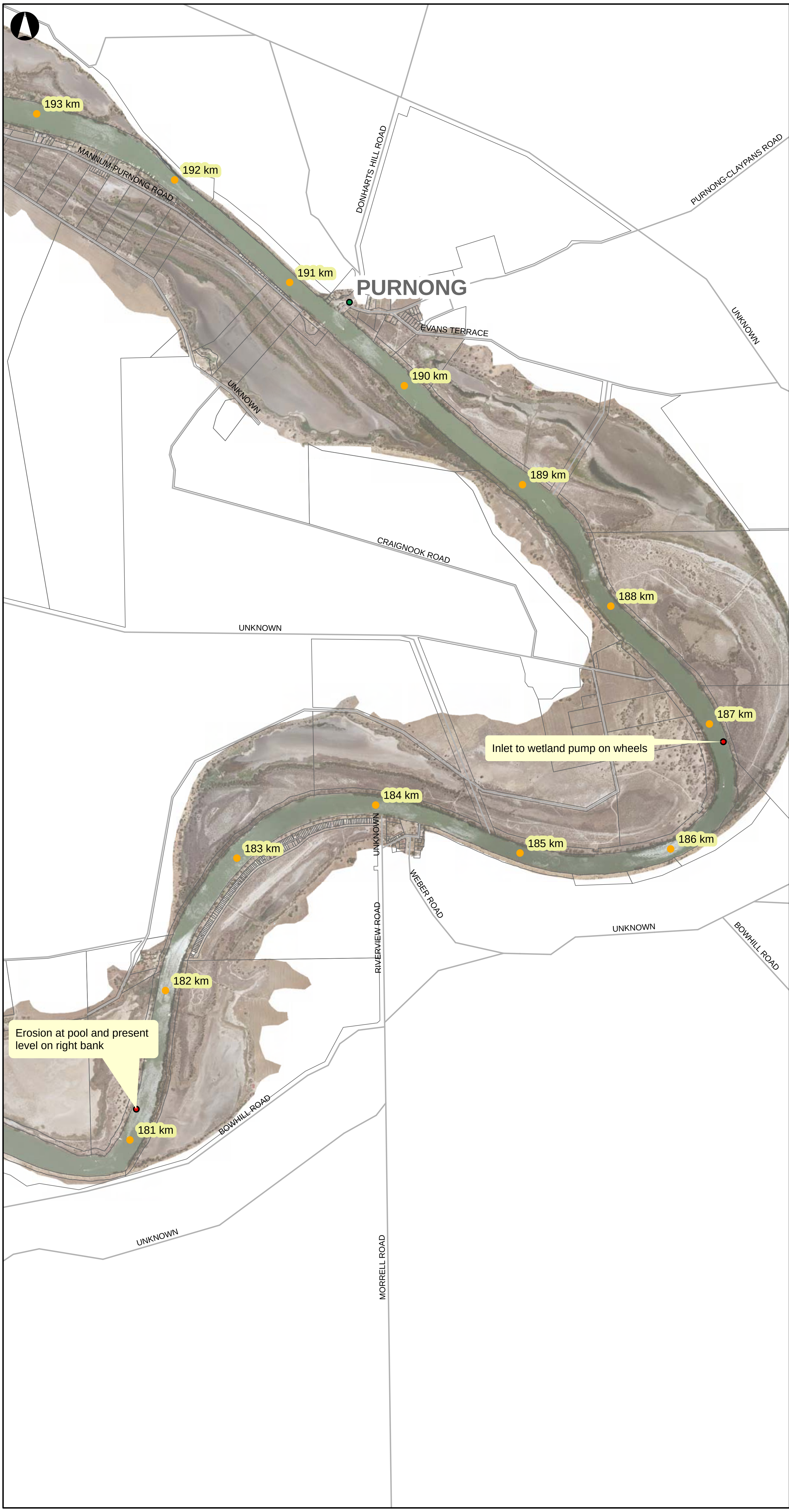
Drawing Title
Sites of Interest

Scale at A3
1:25,000

Drawing Status
For Issue

Job No	Drawing No	Issue
205527	205527-08	F1

\\adlfp06\projects\$\200000 Series\205527 Soil Cracking Damage in Lower Murray\GIS\Copy of 20081030 Damage Identified.mxd



Legend

- Sites of Interest
- River Chainage, km
- Towns
- Cadastre

Issue	Date	By	Chkd	Appd
F1	2008-11-05	SS	SS	EJS

Metres
0 250 500 1,000

ARUP

Level 2 Optus Centre
431- 439 King William St, Adelaide 5000
Tel +61 8 8413 6500 Fax +61 8 8212 5590
www.arup.com

Client
Department of Water, Land and Biodiversity Conservation

Job Title
Soil Cracking Damage in Lower Murray

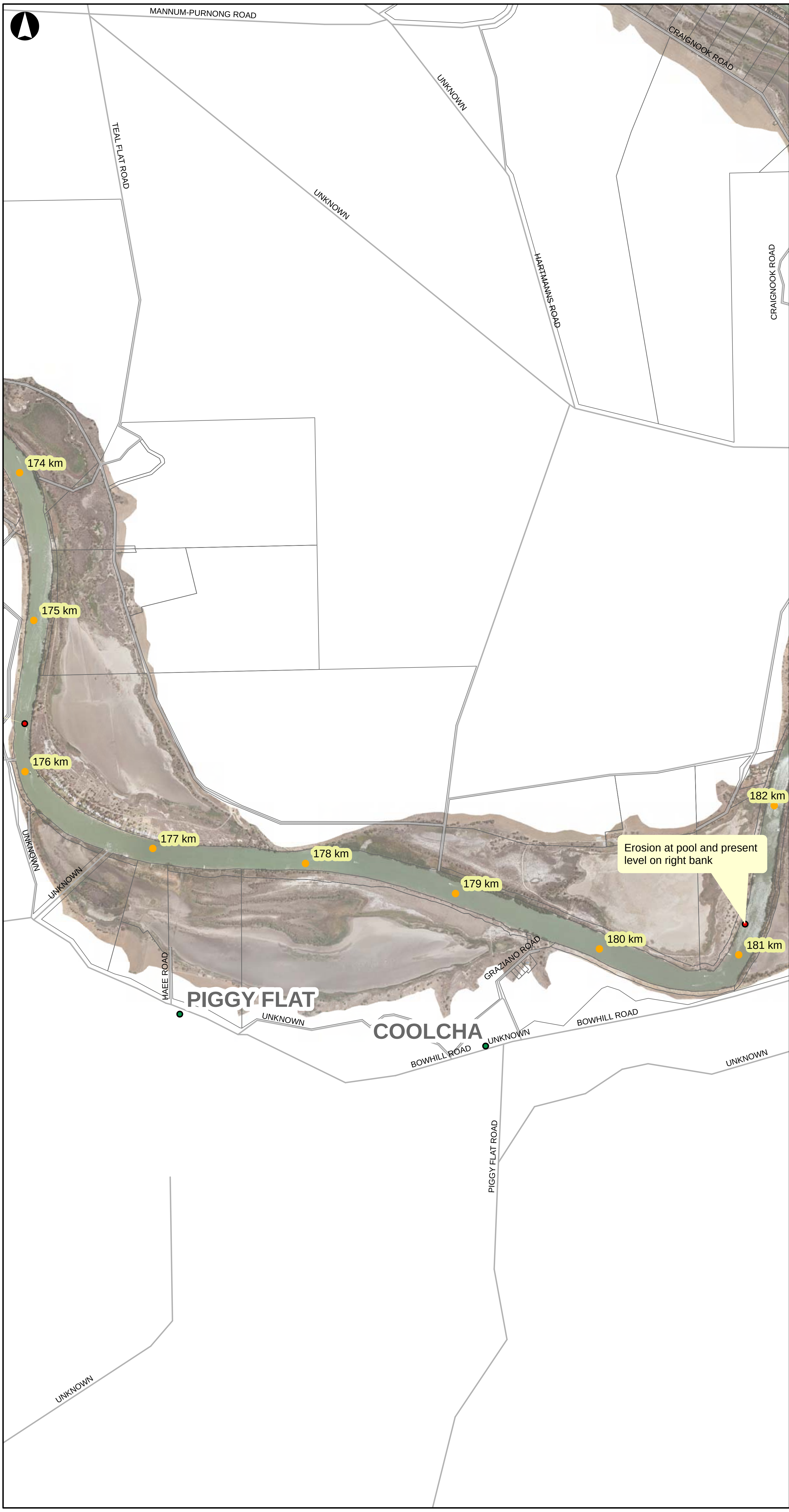
Drawing Title
Sites of Interest

Scale at A3
1:25,000

Drawing Status
For Issue

Job No	Drawing No	Issue
205527	205527-09	F1

\\adlfp06\projects\$\200000 Series\205527 Soil Cracking Damage in Lower Murray\GIS\Copy of 20081030 Damage Identified.mxd



Legend

- Sites of Interest
- River Chainage, km
- Towns
- Cadastre

F1	2008-11-05	SS	SS	EJS
Issue	Date	By	Chkd	Appd

Metres

0 250 500 1,000

ARUP

Level 2 Optus Centre
431- 439 King William St, Adelaide 5000
Tel +61 8 8413 6500 Fax +61 8 8212 5590
www.arup.com

Client

Department of Water, Land and Biodiversity Conservation

Job Title

Soil Cracking Damage in Lower Murray

Drawing Title

Sites of Interest

Scale at A3

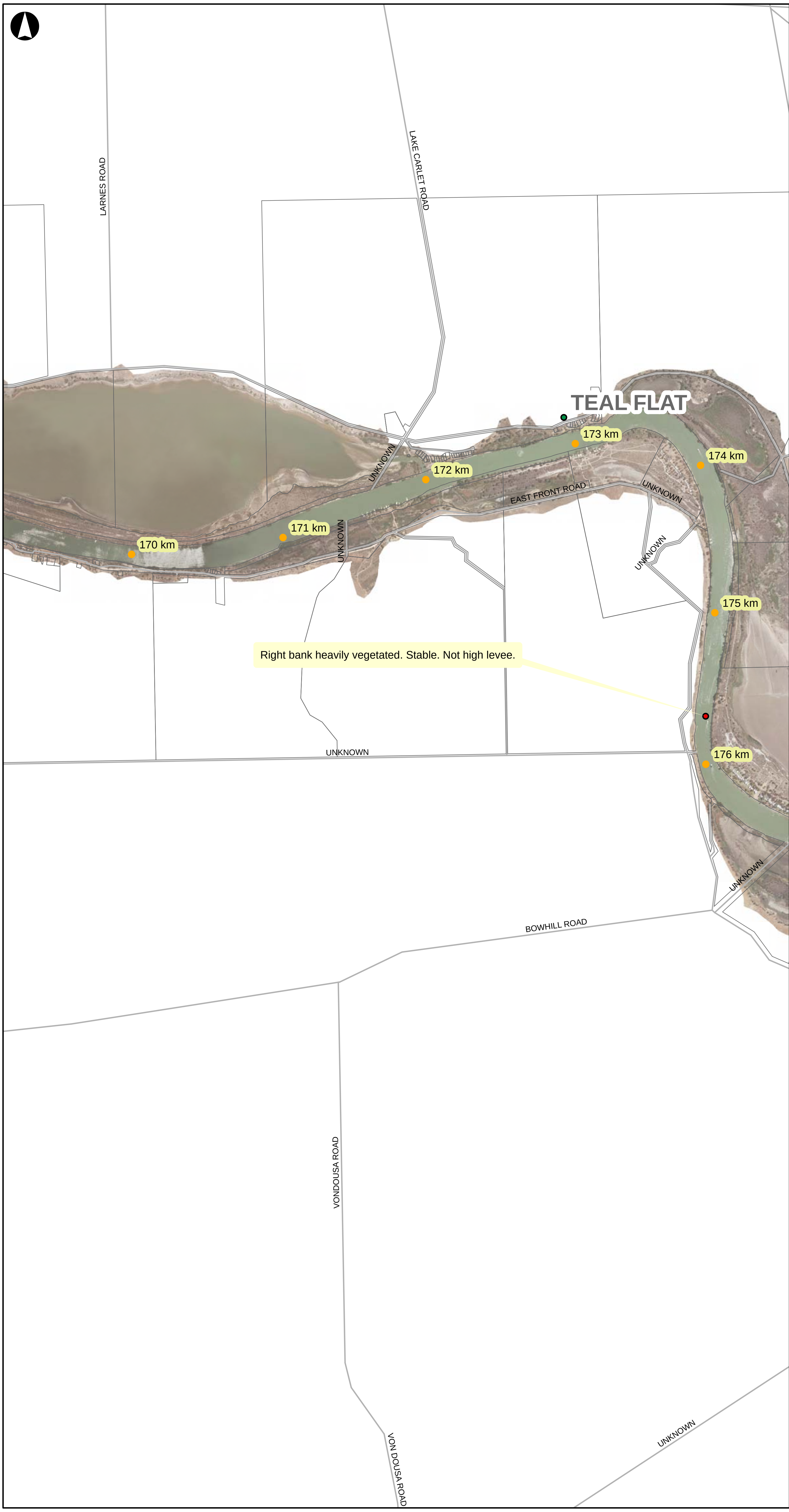
1:25,000

Drawing Status

For Issue

Job No	Drawing No	Issue
205527	205527-10	F1

\\adfp06\projects$\200000 Series\205527 Soil Cracking Damage in Lower Murray\GIS\Copy of 20081030 Damage Identified.mxd



Legend

- Sites of Interest
- River Chainage, km
- Towns
- Cadastre

F1	2008-11-05	SS	SS	EJS
Issue	Date	By	Chkd	Appd

Metres
0 250 500 1,000

ARUP

Level 2 Optus Centre
431- 439 King William St, Adelaide 5000
Tel +61 8 8413 6500 Fax +61 8 8212 5590
www.arup.com

Client
Department of Water, Land and Biodiversity Conservation

Job Title
Soil Cracking Damage in Lower Murray

Drawing Title
Sites of Interest

Scale at A3
1:25,000

Drawing Status
For Issue

Job No	Drawing No	Issue
205527	205527-11	F1

\\adlfp06\projects\s\200000 Series\205527 Soil Cracking Damage in Lower Murray\GIS\Copy of 20081030 Damage Identified.mxd

Legend

- Sites of Interest
- River Chainage, km
- Towns
- Cadastre

Issue	Date	By	Chkd	Appd
F1	2008-11-05	SS	SS	EJS

Metres
0 250 500 1,000

ARUP

Level 2 Optus Centre
431- 439 King William St, Adelaide 5000
Tel +61 8 8413 6500 Fax +61 8 8212 5590
www.arup.com

Client
Department of Water, Land and Biodiversity Conservation

Job Title
Soil Cracking Damage in Lower Murray

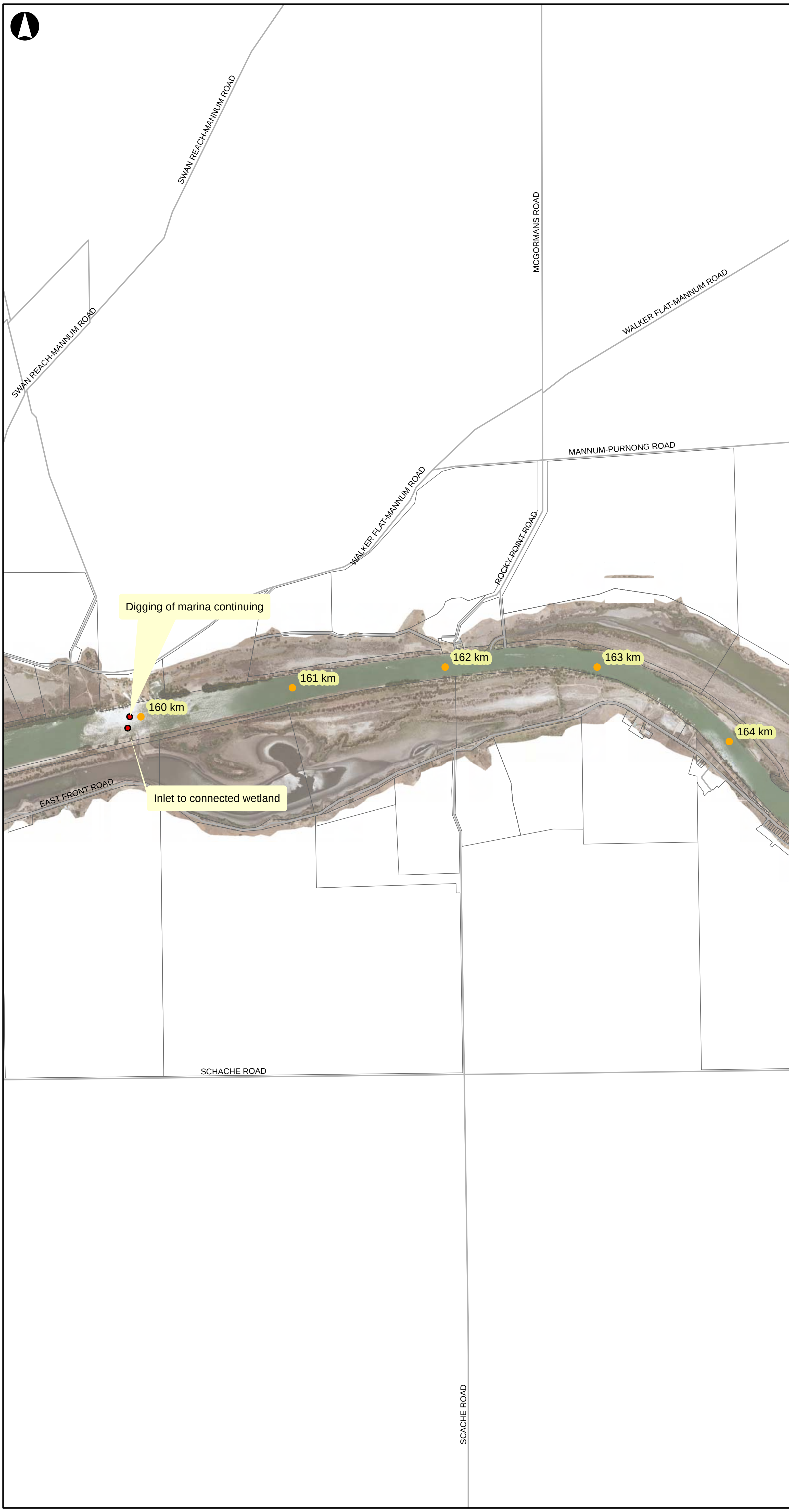
Drawing Title
Sites of Interest

Scale at A3
1:25,000

Drawing Status
For Issue

Job No	Drawing No	Issue
205527	205527-12	F1

\\adlfp06\projects\200000 Series\205527 Soil Cracking Damage in Lower Murray\GIS\Copy of 20081030 Damage Identified.mxd



Legend

- Sites of Interest
- River Chainage, km
- Towns
- Cadastre

Issue	Date	By	Chkd	Appd
F1	05/11/2008	SS	SS	EJS

Metres: 0, 250, 500, 1,000

ARUP

Level 2 Optus Centre
431- 439 King William St, Adelaide 5000
Tel +61 8 8413 6500 Fax +61 8 8212 5590
www.arup.com

Client

Department of Water, Land and Biodiversity Conservation

Job Title

Soil Cracking Damage in Lower Murray

Drawing Title

Sites of Interest

Scale at A3

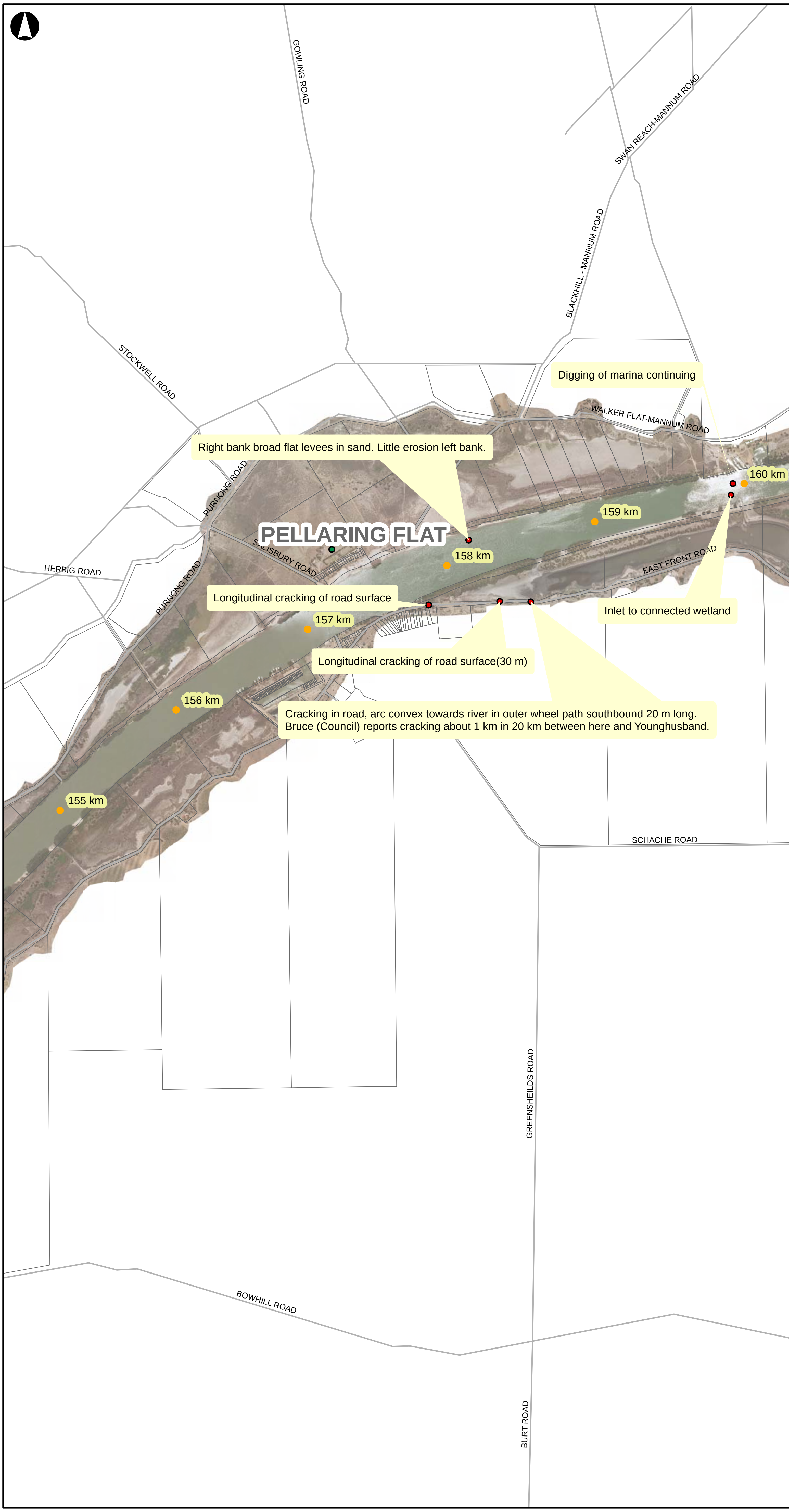
1:25,000

Drawing Status

For Issue

Job No	Drawing No	Issue
205527	205527-13	F1

\\adlfp06\projects\$\200000 Series\205527 Soil Cracking Damage in Lower Murray\GIS\Copy of 20081030 Damage Identified.mxd



Legend

- Sites of Interest
- River Chainage, km
- Towns
- Cadastre

Issue	Date	By	Chkd	Appd
F1	2008-11-05	SS	SS	EJS

Metres
0 250 500 1,000

ARUP

Level 2 Optus Centre
431- 439 King William St, Adelaide 5000
Tel +61 8 8413 6500 Fax +61 8 8212 5590
www.arup.com

Client
Department of Water, Land and Biodiversity Conservation

Job Title
Soil Cracking Damage in Lower Murray

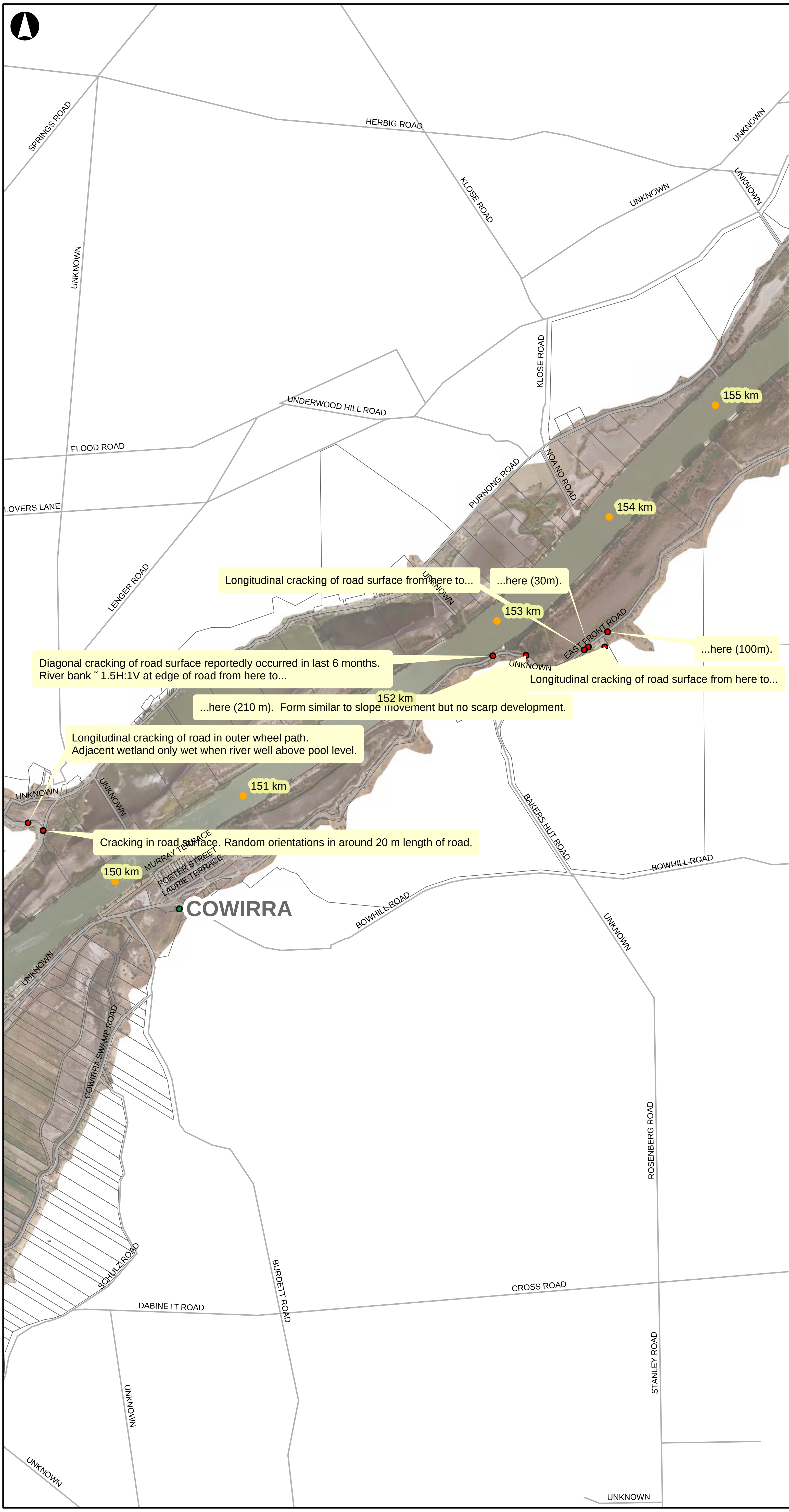
Drawing Title
Sites of Interest

Scale at A3
1:25,000

Drawing Status
For Issue

Job No	Drawing No	Issue
205527	205527-14	F1

\\adfp06\projects$\200000 Series\205527 Soil Cracking Damage in Lower Murray\GIS\Copy of 20081030 Damage Identified.mxd



Legend

- Sites of Interest
- River Chainage, km
- Towns
- Cadastre

Issue	Date	By	Chkd	Appd
F1	2008-11-05	SS	SS	EJS

Metres
0 250 500 1,000

ARUP

Level 2 Optus Centre
431- 439 King William St, Adelaide 5000
Tel +61 8 8413 6500 Fax +61 8 8212 5590
www.arup.com

Client
Department of Water, Land and Biodiversity Conservation

Job Title
Soil Cracking Damage in Lower Murray

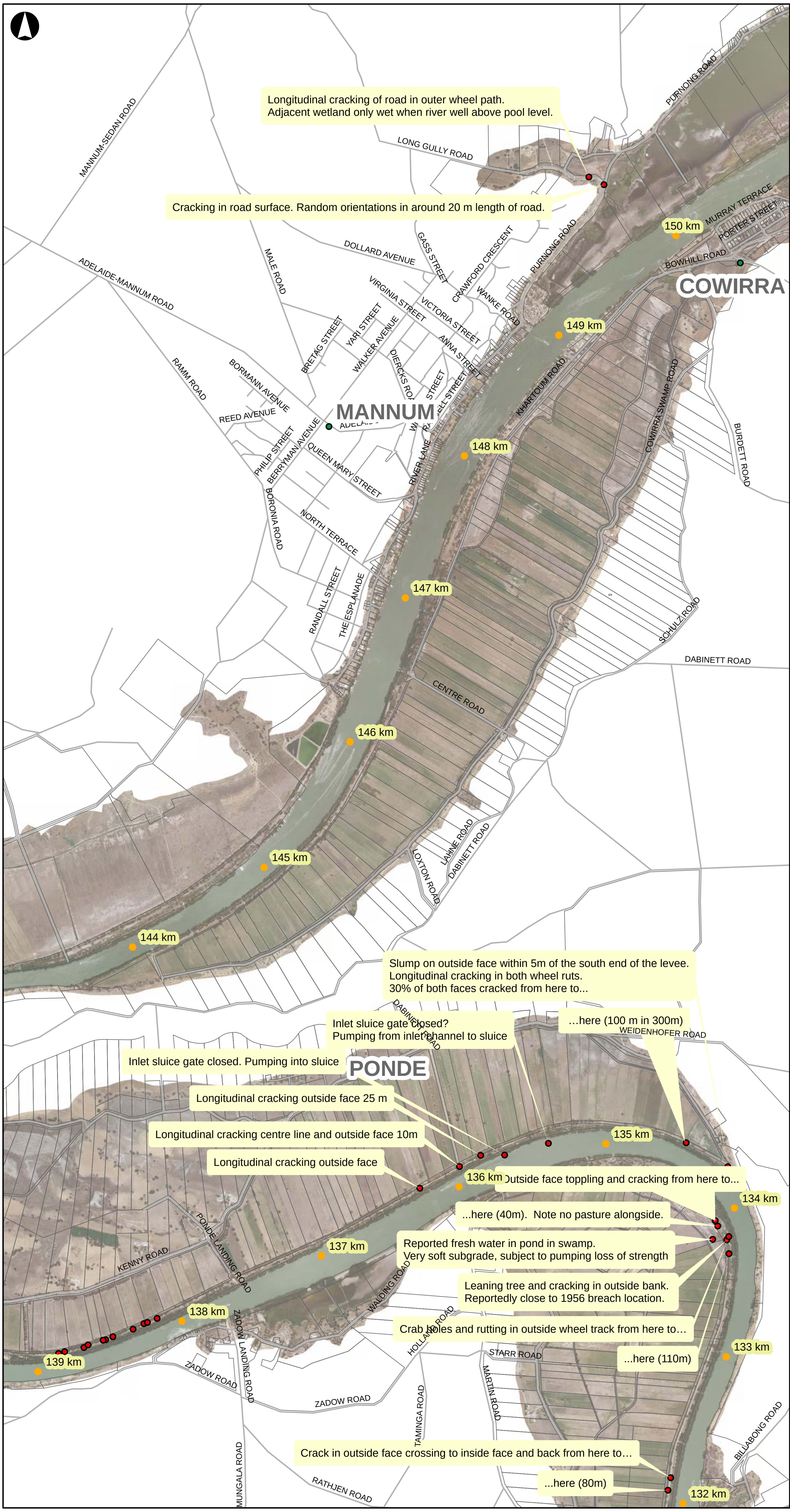
Drawing Title
Sites of Interest

Scale at A3
1:25,000

Drawing Status
For Issue

Job No	Drawing No	Issue
205527	205527-15	F1

\\adfp06\projects\$\200000 Series\205527 Soil Cracking Damage in Lower Murray\GIS\Copy of 20081030 Damage Identified.mxd



Legend

- Sites of Interest
- River Chainage, km
- Towns
- Cadastre

F1	2008-11-05	SS	SS	EJS
Issue	Date	By	Chkd	Appd

Metres
0 250 500 1,000

ARUP

Level 2 Optus Centre
431- 439 King William St, Adelaide 5000
Tel +61 8 8413 6500 Fax +61 8 8212 5590
www.arup.com

Client
Department of Water, Land and Biodiversity Conservation

Job Title
Soil Cracking Damage in Lower Murray

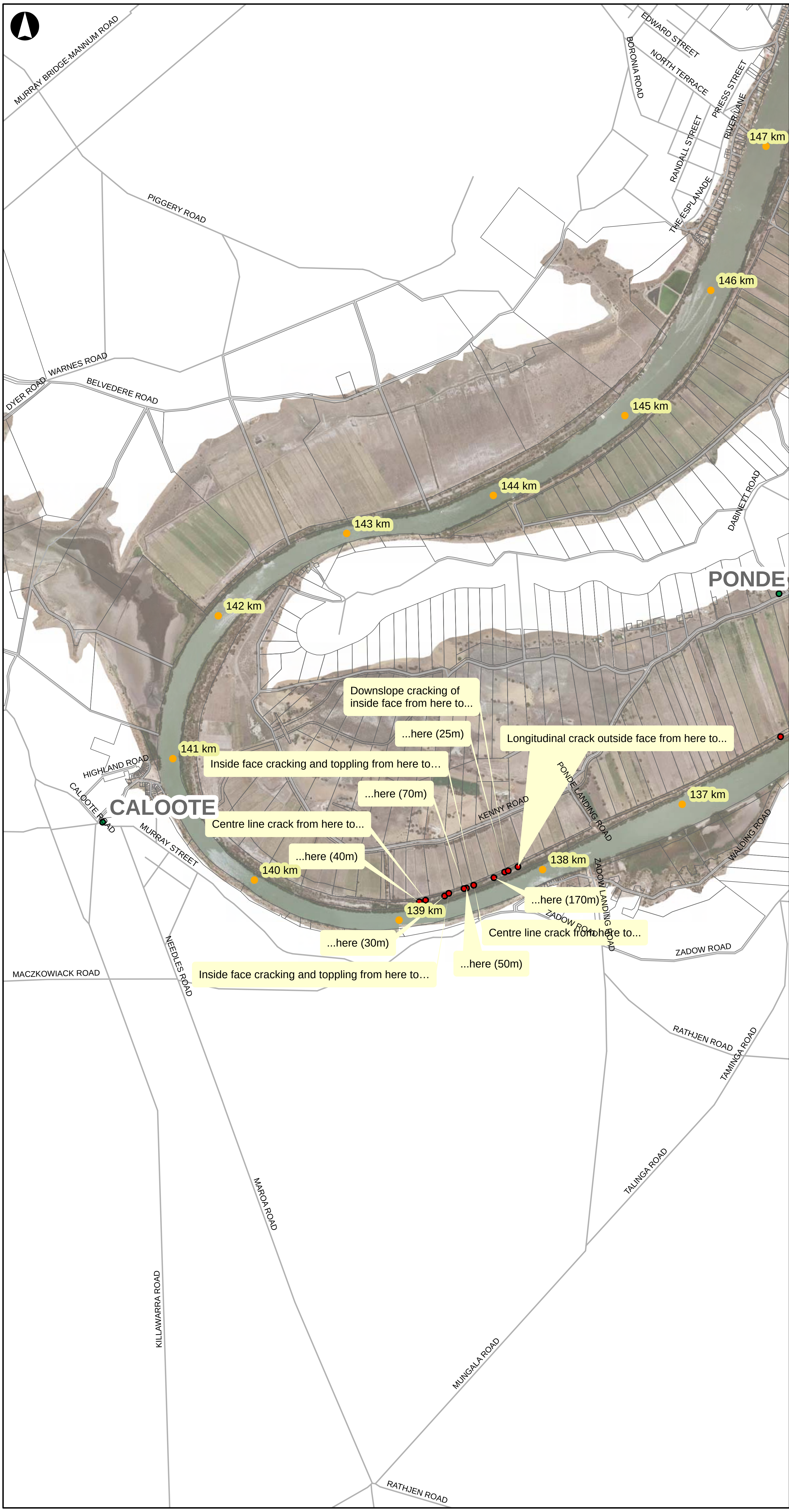
Drawing Title
Sites of Interest

Scale at A3
1:25,000

Drawing Status
For Issue

Job No	Drawing No	Issue
205527	205527-16	F1

\\adfp06\projects\$\200000 Series\205527 Soil Cracking Damage in Lower Murray\GIS\Copy of 20081030 Damage Identified.mxd



Legend

- Sites of Interest
- River Chainage, km
- Towns
- Cadastre

Issue	Date	By	Chkd	Appd
F1	2008-11-05	SS	SS	EJS

Metres

0 250 500 1,000

ARUP

Level 2 Optus Centre
431- 439 King William St, Adelaide 5000
Tel +61 8 8413 6500 Fax +61 8 8212 5590
www.arup.com

Client

Department of Water, Land and Biodiversity Conservation

Job Title

Soil Cracking Damage in Lower Murray

Drawing Title

Sites of Interest

Scale at A3

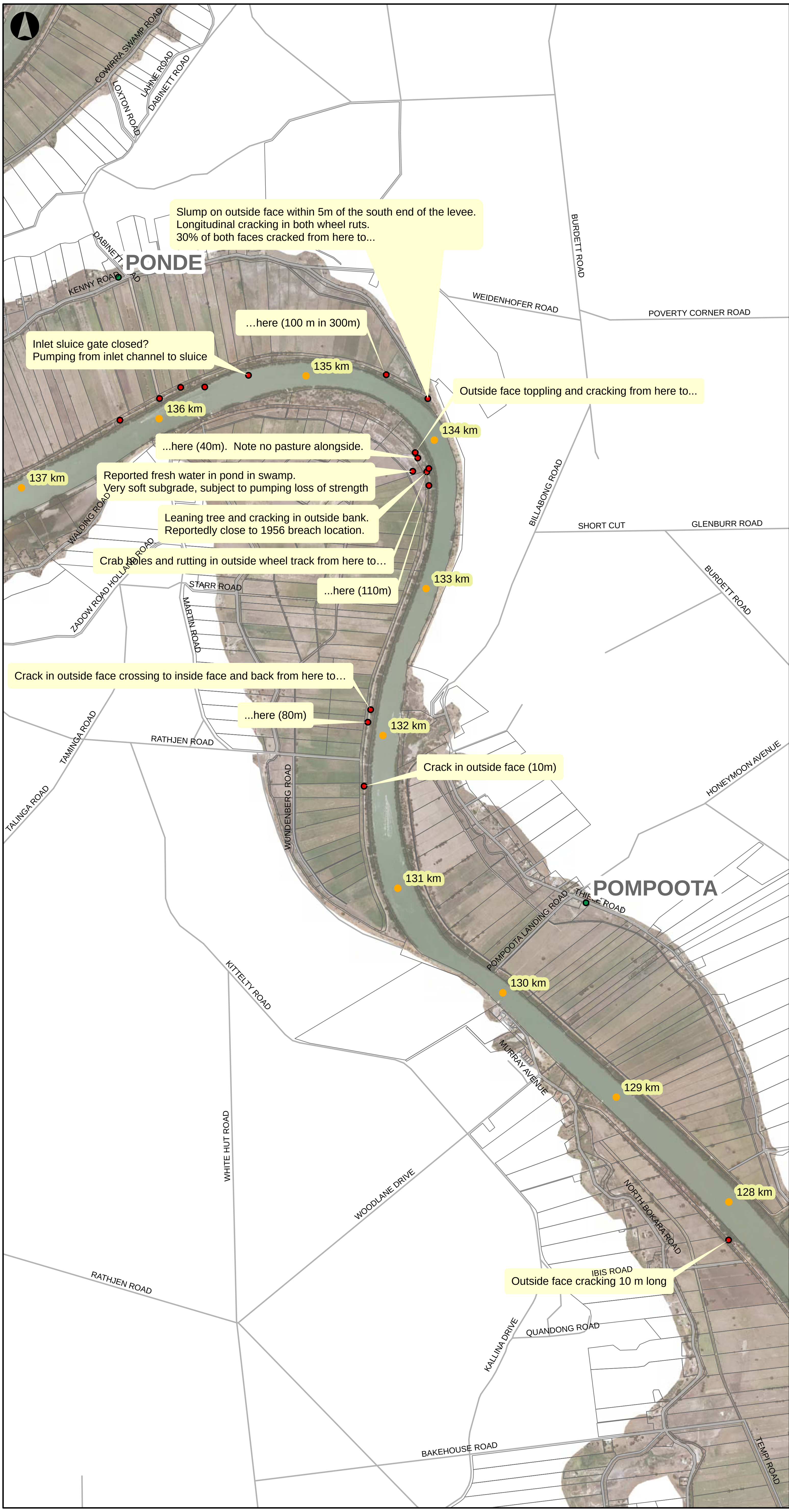
1:25,000

Drawing Status

For Issue

Job No	Drawing No	Issue
205527	205527-17	F1

\\adfp06\projects\$\200000 Series\205527 Soil Cracking Damage in Lower Murray\GIS\Copy of 20081030 Damage Identified.mxd



Legend

- Sites of Interest
- River Chainage, km
- Towns
- Cadastre

Issue	Date	By	Chkd	Appd
F1	2008-11-05	SS	SS	EJS

Metres
0 250 500 1,000

ARUP

Level 2 Optus Centre
431- 439 King William St, Adelaide 5000
Tel +61 8 8413 6500 Fax +61 8 8212 5590
www.arup.com

Client
Department of Water, Land and Biodiversity Conservation

Job Title
Soil Cracking Damage in Lower Murray

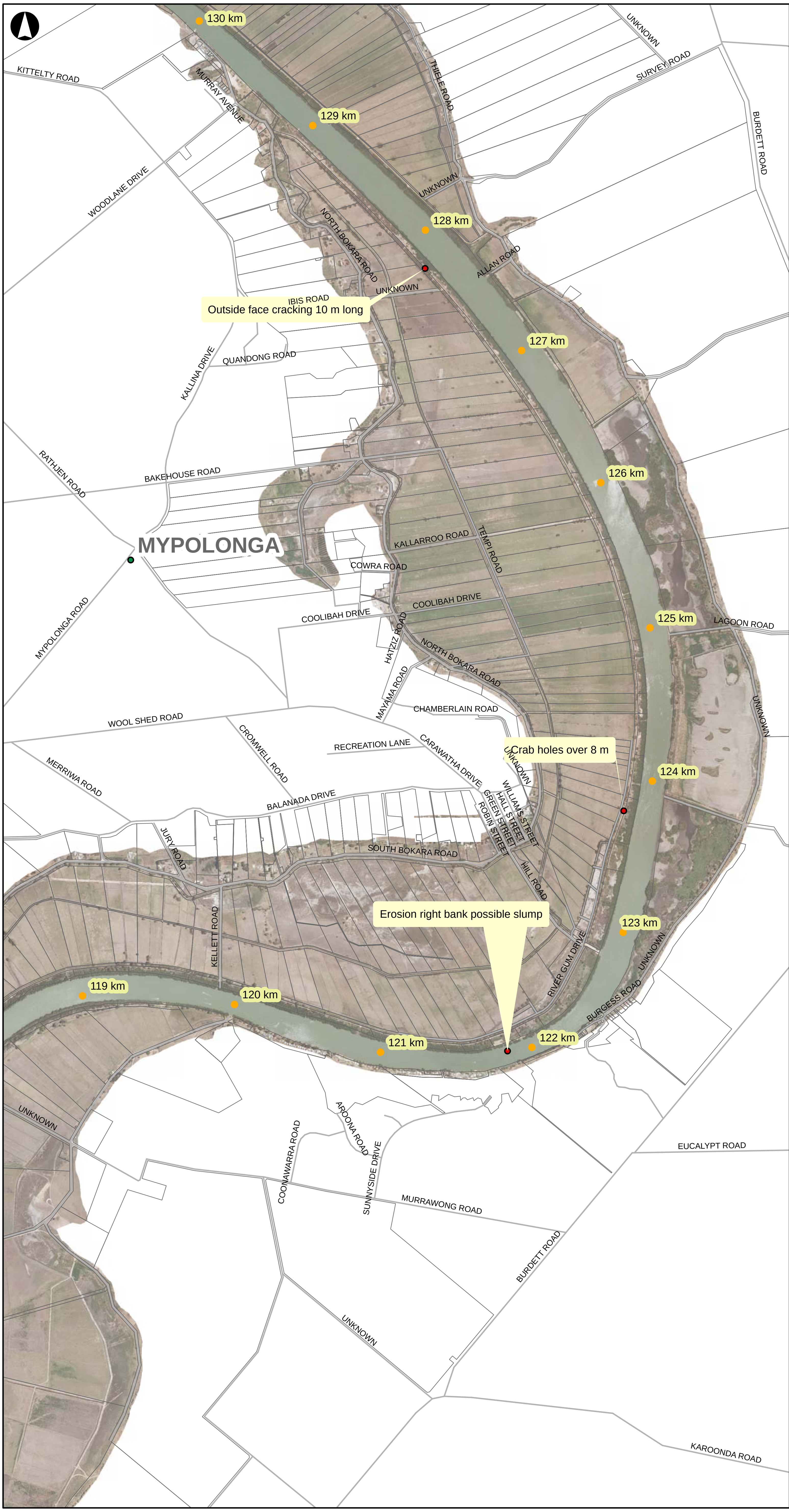
Drawing Title
Sites of Interest

Scale at A3
1:25,000

Drawing Status
For Issue

Job No	Drawing No	Issue
205527	205527-18	F1

\\adfp06\projects\$\200000 Series\205527 Soil Cracking Damage in Lower Murray\GIS\Copy of 20081030 Damage Identified.mxd



Legend

- Sites of Interest
- River Chainage, km
- Towns
- Cadastre

Issue	Date	By	Chkd	Appd
F1	2008-11-05	SS	SS	EJS

Metres
0 250 500 1,000

ARUP

Level 2 Optus Centre
431- 439 King William St, Adelaide 5000
Tel +61 8 8413 6500 Fax +61 8 8212 5590
www.arup.com

Client
Department of Water, Land and Biodiversity Conservation

Job Title
Soil Cracking Damage in Lower Murray

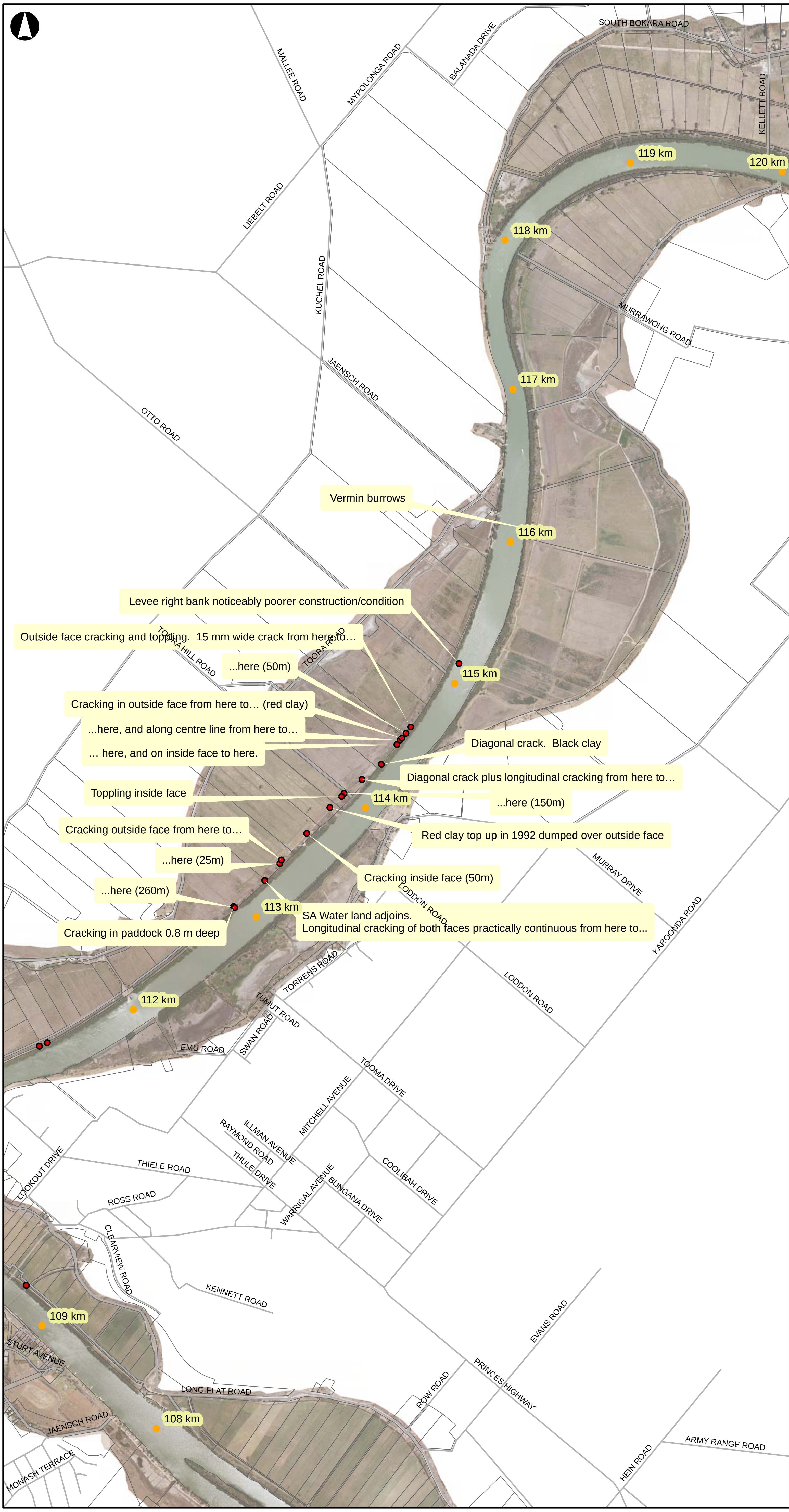
Drawing Title
Sites of Interest

Scale at A3
1:25,000

Drawing Status
For Issue

Job No	Drawing No	Issue
205527	205527-19	F1

\\adlfp06\projects\$\200000 Series\205527 Soil Cracking Damage in Lower Murray\GIS\Copy of 20081030 Damage Identified.mxd



Legend

- Sites of Interest
- River Chainage, km
- Towns
- Cadastre

Issue	Date	By	Chkd	Appd
F1	2008-11-05	SS	SS	EJS

Metres

0 250 500 1,000

ARUP

Level 2 Optus Centre
431- 439 King William St, Adelaide 5000
Tel +61 8 8413 6500 Fax +61 8 8212 5590
www.arup.com

Client

Department of Water, Land and Biodiversity Conservation

Job Title

Soil Cracking Damage in Lower Murray

Drawing Title

Sites of Interest

Scale at A3

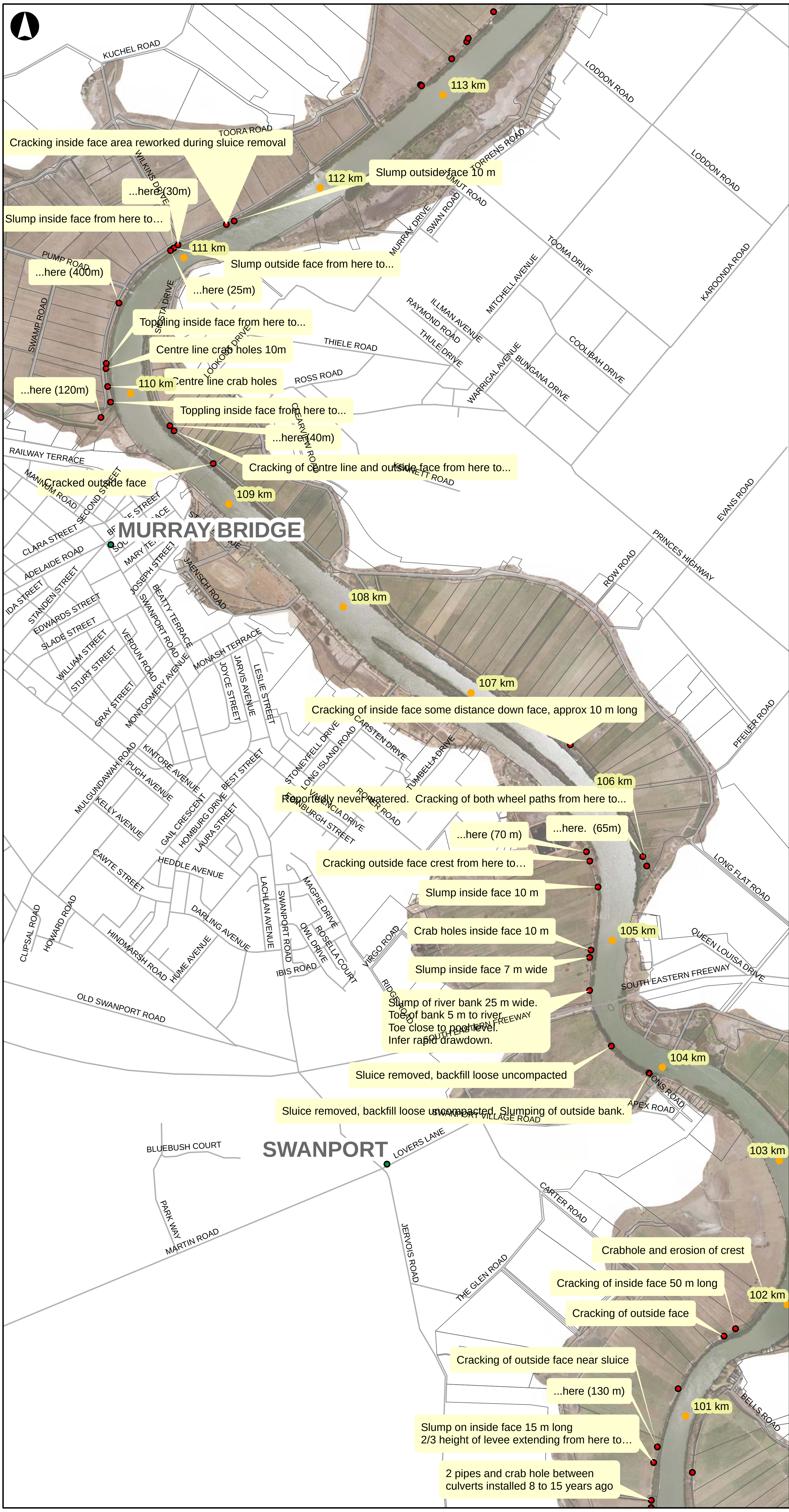
1:25,000

Drawing Status

For Issue

Job No	Drawing No	Issue
205527	205527-20	F1

\\adlfp06\projects\$\200000 Series\205527 Soil Cracking Damage in Lower Murray\GIS\Copy of 20081030 Damage Identified.mxd



Legend

- Sites of Interest
- River Chainage, km
- Towns
- Cadastre

F1	2008-11-05	SS	SS	EJS
Issue	Date	By	Chkd	Appd

Metres

0 250 500 1,000

ARUP

Level 2 Optus Centre
431- 439 King William St, Adelaide 5000
Tel +61 8 8413 6500 Fax +61 8 8212 5590
www.arup.com

Client

Department of Water, Land and Biodiversity Conservation

Job Title

Soil Cracking Damage in Lower Murray

Drawing Title

Sites of Interest

Scale at A3

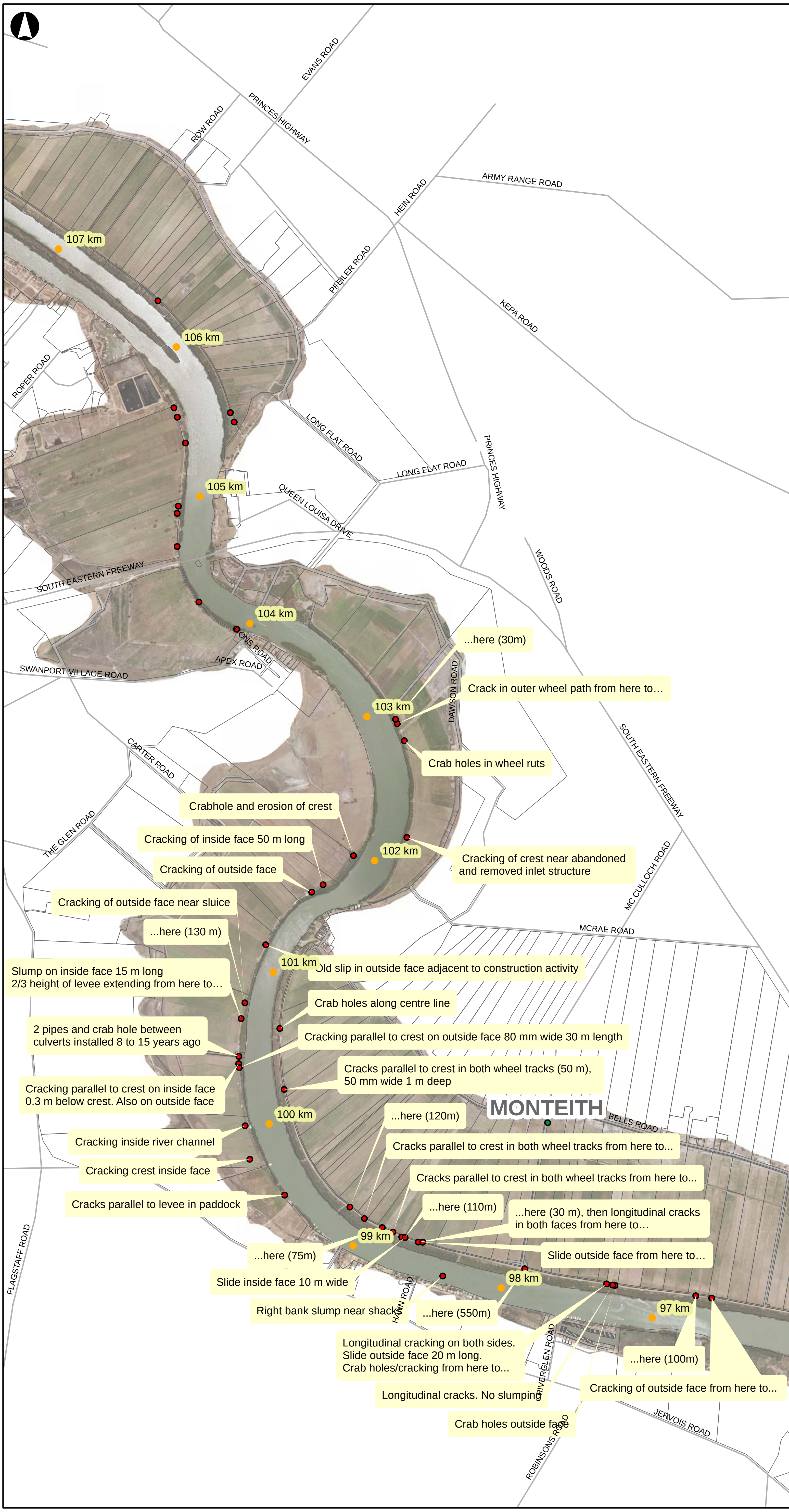
1:25,000

Drawing Status

For Issue

Job No	Drawing No	Issue
205527	**205527-21**	**F1**

\\adfp06\projects\$\200000 Series\205527 Soil Cracking Damage in Lower Murray\GIS\Copy of 20081030 Damage Identified.mxd



Legend

- Sites of Interest
- River Chainage, km
- Towns
- Cadastre

F1	2008-11-05	SS	SS	EJS
Issue	Date	By	Chkd	Appd

Metres
0 250 500 1,000

ARUP

Level 2 Optus Centre
431- 439 King William St, Adelaide 5000
Tel +61 8 8413 6500 Fax +61 8 8212 5590
www.arup.com

Client
Department of Water, Land and Biodiversity Conservation

Job Title
Soil Cracking Damage in Lower Murray

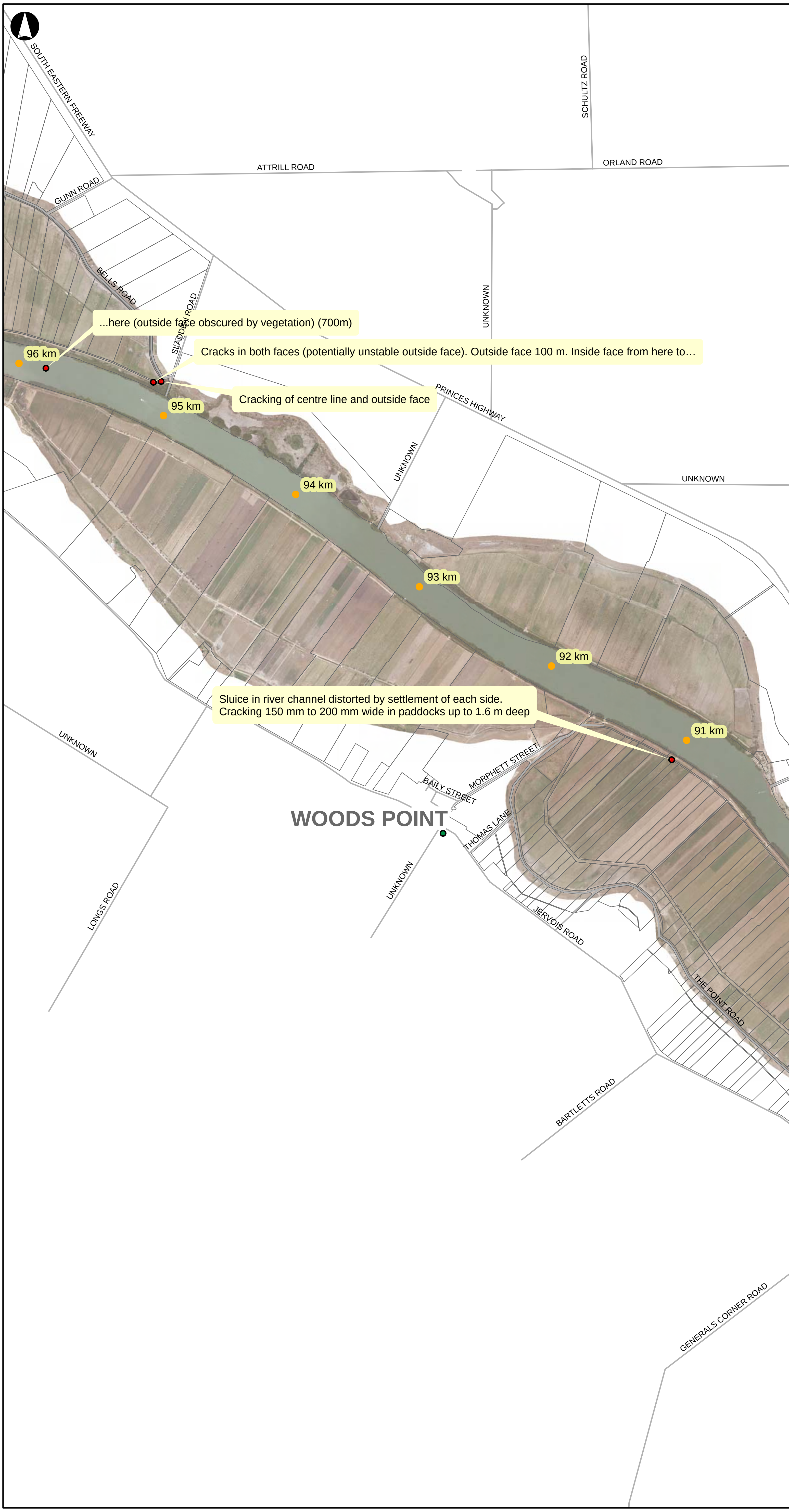
Drawing Title
Sites of Interest

Scale at A3
1:25,000

Drawing Status
For Issue

Job No	Drawing No	Issue
205527	205527-22	F1

\\adfp06\projects\$\200000 Series\205527 Soil Cracking Damage in Lower Murray\GIS\Copy of 20081030 Damage Identified.mxd



Legend

- Sites of Interest
- River Chainage, km
- Towns
- Cadastre

Issue	Date	By	Chkd	Appd
F1	2008-11-05	SS	SS	EJS

Metres
0 250 500 1,000

ARUP

Level 2 Optus Centre
431- 439 King William St, Adelaide 5000
Tel +61 8 8413 6500 Fax +61 8 8212 5590
www.arup.com

Client
Department of Water, Land and Biodiversity Conservation

Job Title
Soil Cracking Damage in Lower Murray

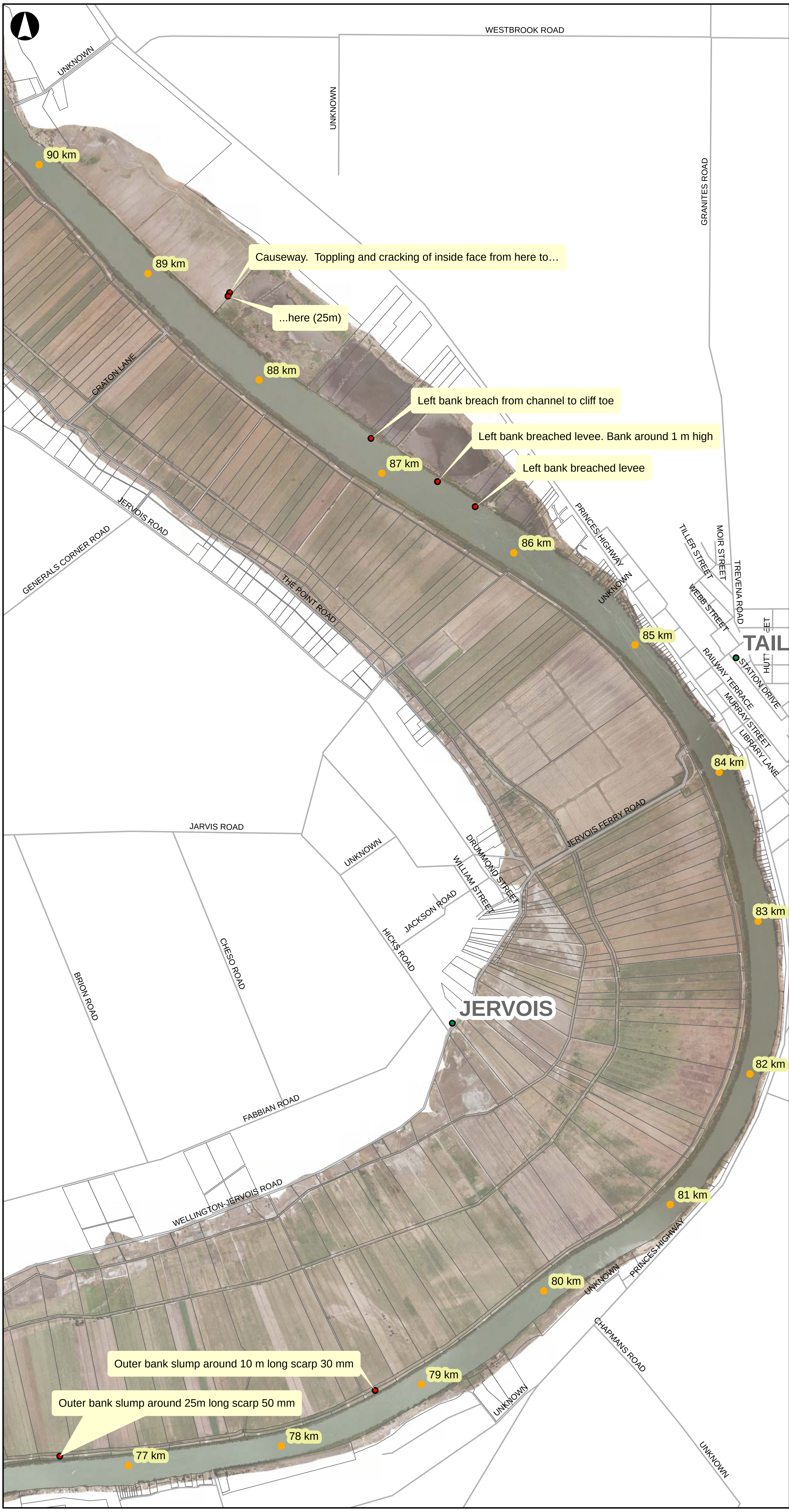
Drawing Title
Sites of Interest

Scale at A3
1:25,000

Drawing Status
For Issue

Job No	Drawing No	Issue
205527	205527-23	F1

\\adfp06\projects\200000 Series\205527 Soil Cracking Damage in Lower Murray\GIS\Copy of 20081030 Damage Identified.mxd



Legend

- Sites of Interest
- River Chainage, km
- Towns
- Cadastre

F1	2008-11-05	SS	SS	EJS
Issue	Date	By	Chkd	Appd

Metres
0 250 500 1,000

ARUP

Level 2 Optus Centre
431- 439 King William St, Adelaide 5000
Tel +61 8 8413 6500 Fax +61 8 8212 5590
www.arup.com

Client
Department of Water, Land and Biodiversity Conservation

Job Title
Soil Cracking Damage in Lower Murray

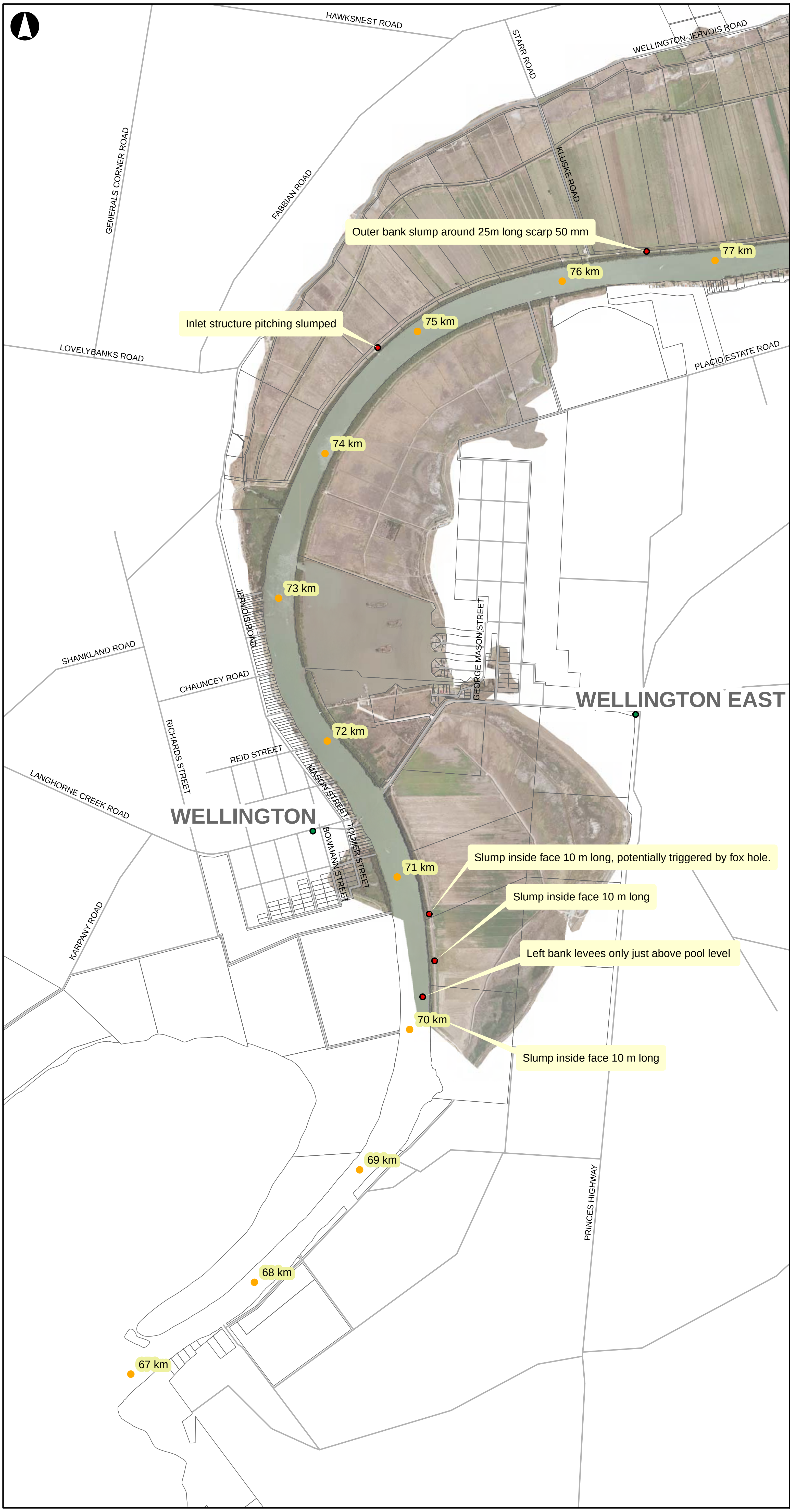
Drawing Title
Sites of Interest

Scale at A3
1:25,000

Drawing Status
For Issue

Job No	Drawing No	Issue
205527	205527-24	F1

\\adfp06\projects\$\200000 Series\205527 Soil Cracking Damage in Lower Murray\GIS\Copy of 20081030 Damage Identified.mxd



Legend

- Sites of Interest
- River Chainage, km
- Towns
- Cadastre

©Copyright Information

Issue	Date	By	Chkd	Appd
F1	2008-11-05	SS	SS	EJS

Metres
0 250 500 1,000

ARUP

Level 2 Optus Centre
431- 439 King William St, Adelaide 5000
Tel +61 8 8413 6500 Fax +61 8 8212 5590
www.arup.com

Client
Department of Water, Land and Biodiversity Conservation

Job Title
Soil Cracking Damage in Lower Murray

Drawing Title
Sites of Interest

Scale at A3
1:25,000

Drawing Status
For Issue

Job No	Drawing No	Issue
205527	205527-25	F1

\\adfp06\projects\$\200000 Series\205527 Soil Cracking Damage in Lower Murray\GIS\Copy of 20081030 Damage Identified.mxd

Appendix D

Levee Observations

Irrigation Area	Description
Right Bank	
Baseby	Unknown construction date. Vehicle access over parts of the levee, not on others. Black clay; 2m high outside face variable slope 1H:1V to 2H:1V, 4 m high inside face variable slope 2H:1V to 5H:1V. Not watered 1 or 2 years. Measurements by Tony Baulderstone suggest up to around 0.3 m settlement of levee since mid-1970's. Generally good condition.
Wall Flat	Original construction 1917. Vehicle access. Original construction used red clay core from local quarry with black clay from swamps for shoulder embankments. Topped up in 1950's and 1970's. 1970 top up included road pavement on crest. Outside face around 2 m high face slope 2.5H:1V. Inside face around 4 m high face slope 4H:1V. Generally good condition.
Mypolonga	Unknown construction date. Vehicle access. Red clay. Outside face around 2m high face slope around 2H:1V, inside face around 4 m high face slope around 1H:1V. Generally good condition but has had rework within last 6 weeks.
Toora	Unknown construction date. Vehicle access over parts of the levee, not on others. Black clay core, apparently from broad swale now present near toe of inside bank. River channel some distance from inside bank toe. Red clay in places possibly from topping up (1992?). 2m high outside face variable slope 1H:1V to 2H:1V, 4 m high inside face variable slope 2H:1V to 5H:1V.
Mobilong	Unknown construction date. Vehicle access. Red clay; 2m high outside face slope around 1H:1V, 4 m high inside face slope around 2H:1V. Not watered 3 or 4 years. At least 50% of the banks cracked on one side or the other.
Long Island	Unknown construction date. No vehicle access. Red clay; 2m high outside face slope around 1H:1V, 4 m high inside face slope 2H;1V slightly rounded crest. Not watered 2008. Generally good condition.
River Glen	Unknown construction date. No vehicle access. Levee 5 to 6 m from River bank. Red clay north end black clay south end.. 2m high outside face, slope around 1H:1V, 4 m high inside face slope around 1H:1V. Very poor condition.
Woods Point	Unknown construction date. No vehicle access along levees. Red clay. Outside face around 2 m high slope around 1H:1V, inside face around 4 m high slope around 1H:1V.
Jervois	Unknown construction date. Vehicle access along levee. Red clay. Outside face around 2 m high face slope around 2H:1V. Inside face around 4 m high face slope around 2H:1V. Generally OK condition.
Left Bank	
Cowirra	Unknown construction date (early - similar Neeta North?). Limited vehicle access. Red sandy clay, possibly over black clay core; 2m high outside face slope around 1H:1V, 3 to 4 m high inside face slope around 2H:1V. Generally good condition.
Neeta North	Unknown construction date (early?). Vehicle access along crest. Red sandy clay, possibly over black clay core; 2m high outside face slope around 1H:1V, 3 to 4 m high inside face slope around 2H:1V. Generally good condition.

Neeta	Unknown construction date. Vehicle access. Red clay, possibly top-up over original black clay core; 2m high outside face slope around 1H:1V, 4 m high inside face slope around 1H:1V.
Pompoota	Unknown construction date (pre-1956). Vehicle access along crest, but only in dry conditions. Red sandy clay possibly placed 1956, over black clay core; 2m to 3 m high outside face slope around 2H:1V, 3 to 4 m high inside face slope around 2.5H:1V. Not all levee traversed and viewed. Not watered in 2 years.
Burbridge	Unknown construction date. Vehicle access along crest. Red clay; 3m high outside face slope around 1H:1V, 3 to 4 m high inside face slope around 2H:1V. Generally good condition. No observed defects
Glen Lossie	Construction started 1914 and proceeded for several years. Levees have been topped up periodically since. Cowan lost sole ownership 1952. No vehicle access. North end black clay; 2m high outside face slope around 1H:1V, 3 to 4 m high inside face slope around 5H:1V. Generally good condition although inside face generally bare dry granular cloddy clay, outside face vegetated. No defects observed. South End red clay probably with black clay core (spoil from vermin burrows) 2m high outside face slope around 1H:1V, 3 to 4 m high inside face slope around 2H:1V. Vermin burrows may affect integrity/stability
Burdett	Unknown construction date. Vehicle access. Red clay; 2m high outside face, 4 m high inside face slope around 1H:1V. Generally good condition but has had rework recently.
Long Flat	Unknown construction date. Vehicle access. Red clay; 2m high outside face. No defects observed, 4 m high inside face slope around 1H:1V. Generally good condition but has had rework recently .
Yddinga	Levees built 1970 topped up 1974/1975/1976. Poor vehicle access. Red clay; 2m high outside face slope around 1H:1V, 4 m high inside face slope around 1H:1V, narrow rounded crest. Generally good condition
Monteith	Unknown construction date. Vehicle access. Red clay; 2m high outside face slope around 1H:1V, 4 m high inside face slope around 1H:1V rounded crest. Generally poor condition.
Kilsby	Unknown construction date. No vehicle access. Red clay; 2m to 3 m high outside face, 3 to 4 m high inside face. Outside face around 1.5H:1V, inside face around 2H:1V. Swamp retired; not watered many years. Only southern part of levee viewed - atrocious weather and access difficulties prevented viewing north.
Westbrook	Unknown construction date. Difficult vehicle access, best in dry conditions. Red clay; 2m to 3 m high outside face slope around 1.5H:1V, 3 to 4 m high inside face slope around 2H:1V. Generally good condition except causeway at southern end.
Placid	Unknown construction date. Black clay. No vehicle access in wet weather. Outside bank around 1.5 m high slope 1H:1V. Inside bank around 3 m high slope 2H:1V. Retired swamp not watered since 1991 at least.
McFarlane	Swamp flooded 1917. Vehicle access. Levee constructed 1950's 1960's; topped up 1967. Red clay. Outside bank around 2 m high 2H:1V, inside bank around 4 m high 4H:1V