25 Years of South Australia's River Murray Salt Interception Schemes

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Mike Hatch (University of Adelaide)
Barry Porter (ex DEWNR)

Where have we come from?

- The main causes of river salinity in South Australia are:
  - Natural saline groundwater flows
  - Irrigation drainage (both direct and through displacement of native groundwater)
- Pre European settlement salt loads in the River in SA were around 800 to 900 tonnes of salt per day and without salinity management were heading for almost 2,500 t/d by 2050.
- The Murray-Darling Basin Commission's 1988 Salinity and Drainage Strategy was the impetus for the Woolpunda (1990) and Waikerie (1992) Salt Interception Schemes
- The 2001-2015 Basin Salinity Management Strategy likewise gave rise to Waikerie Stage 2A (2003), Bookpurnong (2005), Loxton (2007), Waikerie-Lock 2 (2009), Pike River Stage 1 (2011) and Murtho (2014)
- These schemes are now intercepting ~500 tonnes of salt per day.
- In ground, there are now ~250km pipelines, 194 bores, two salt management basins (Stockyard Plain and Noora), replacement cost >$200 Million

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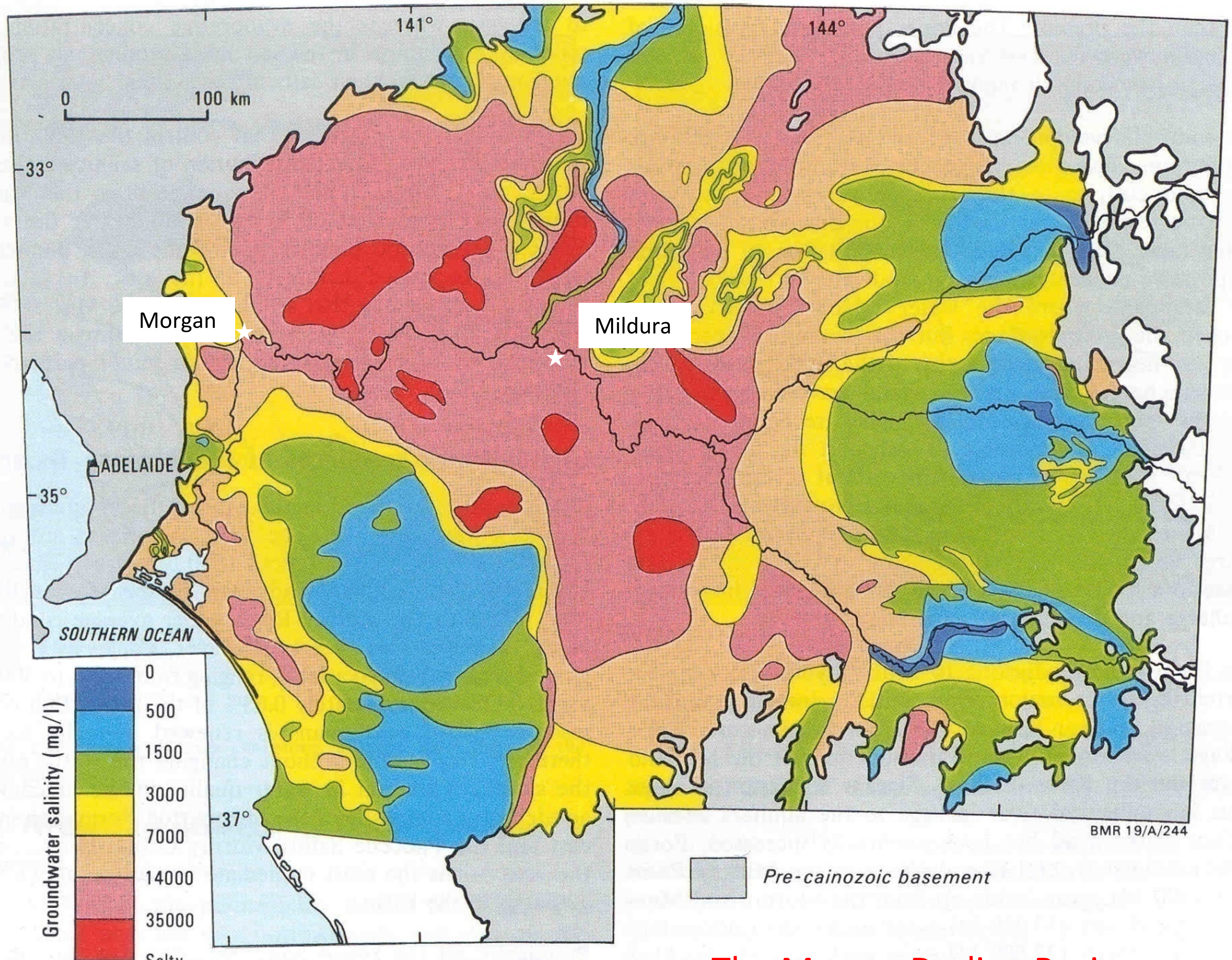
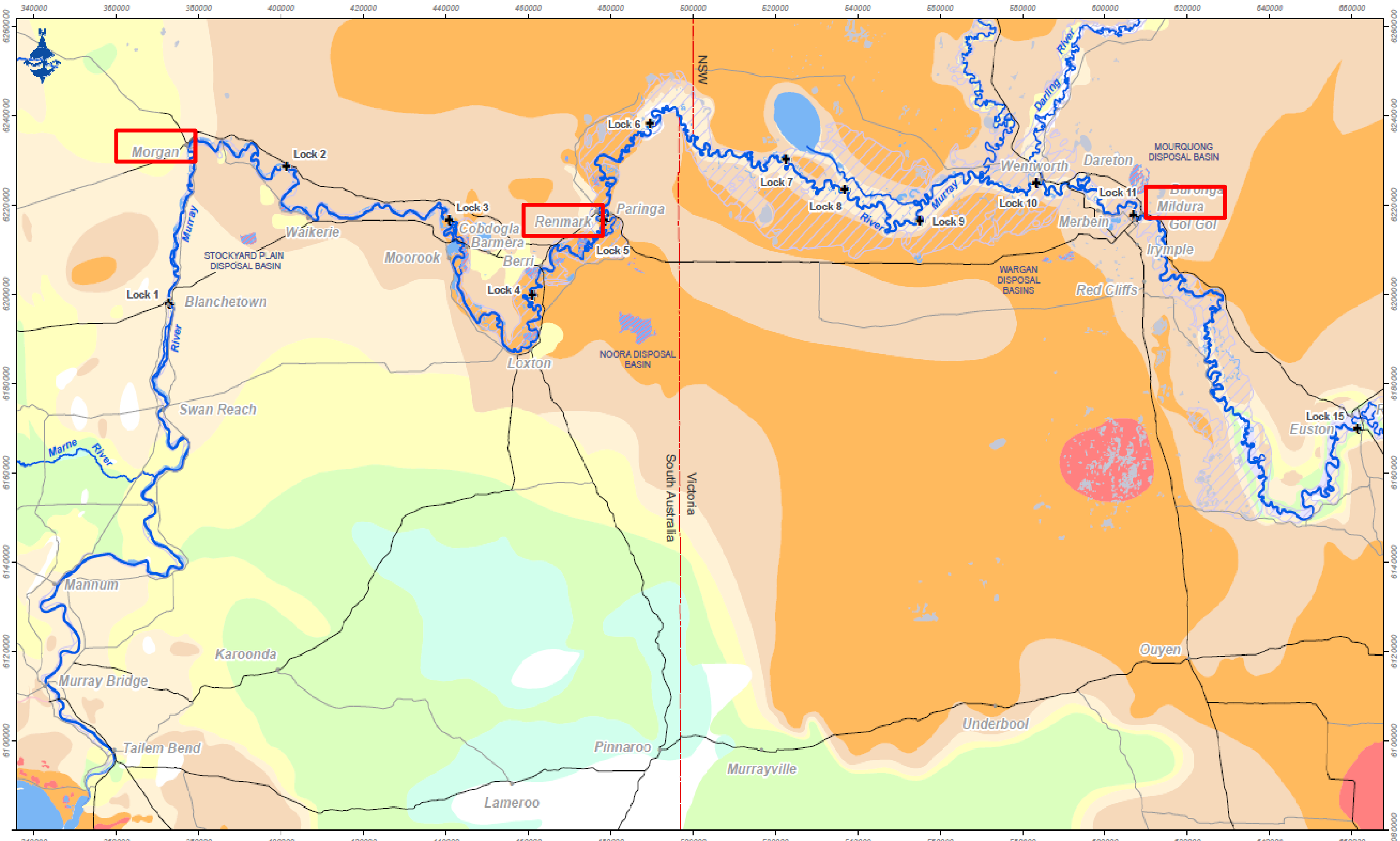
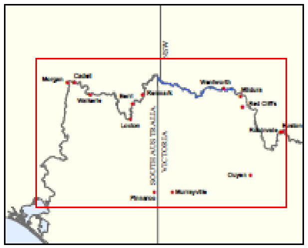


Figure 17. Groundwater salinity map of the shallow unconfined aquifer.

The Murray-Darling Basin groundwaters contain 100,000 Million tonnes of salt





LEGEND

Locks	Disposal Basins	Groundwater Salinity (mg/L):	
State Borders	River Murray	> 100000 mg/L	3000 - 7000 mg/L
Major Watercourse	Lakes:	35000 - 100000 mg/L	1500 - 3000 mg/L
Roads:	Perennial Lake	14000 - 35000 mg/L	1000 - 1500 mg/L
Dual Carriageway	Dry/Intermittent Lake	7000 - 14000 mg/L	500 - 1000 mg/L
Principal Road	River Murray Trench		< 500 mg/L
Secondary Road			

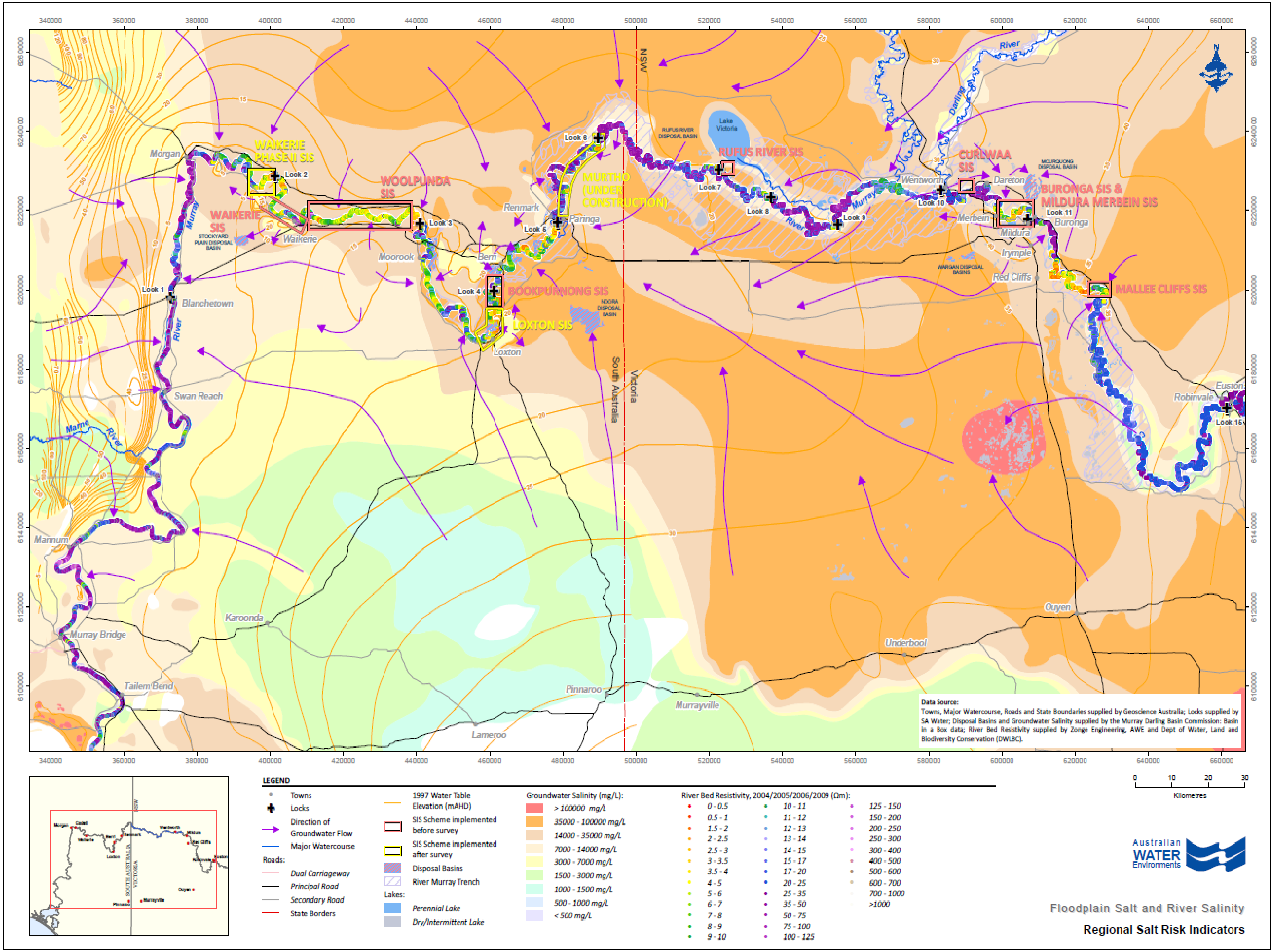
0 10 20 30
Kilometers

Data Source:
Towns, State Borders, Major Watercourses and Roads supplied by Geoscience Australia; Locks supplied by SA Water; Disposal Basins, Lakes and Watertable Salinity supplied by the Murray Darling Basin Commission: Basin in a Box datasets.

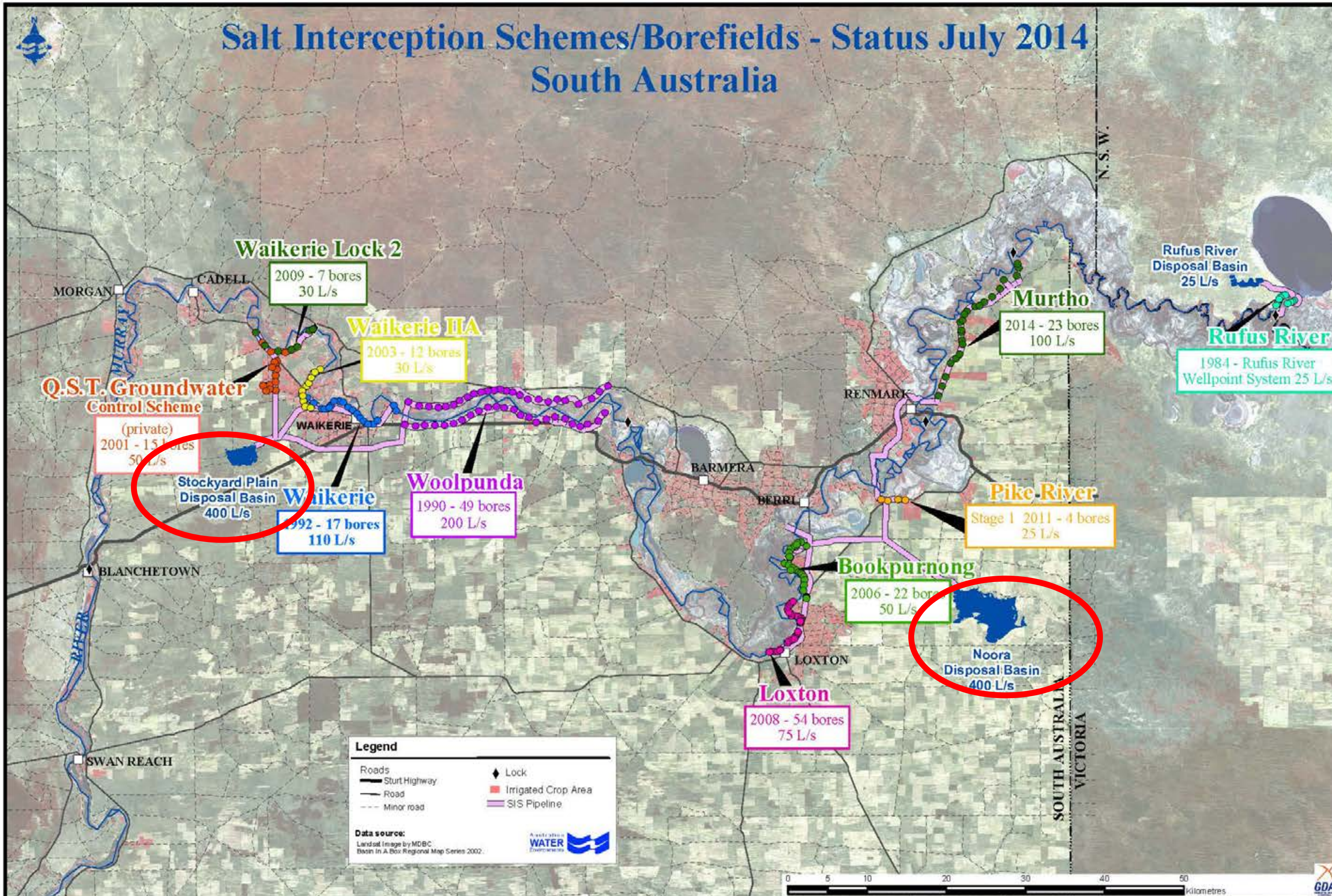
Australian WATER Environments

Floodplain Salt and River Salinity

Regional Groundwater Salinity



Morgan
WAIKERIE PHASE II SIS
Lock 2
WAIKERIE SIS
STOCKYARD PLAIN DISPOSAL BASIN
Waikerie
WOOLPUNDA SIS
Lock 3
Moorook
Renmark
Lock 5
Paringa
Lock 6
MURTHO (UNDER CONSTRUCTION)
Berri
Lock 4
BOOKPURNONG SIS
NOORA DISPOSAL BASIN
LOXTON SIS
Loxton
Lock 1
Blanchetown
Swan Reach
Murray River
Marne River
Mannum
Murray Bridge
Tailem Bend
Karoonda
Lameroo
Pinnaroo
Murrayville
NSW
South Australia
Victoria
RUFUS RIVER DISPOSAL BASIN
Lake Victoria
RUFUS RIVER SIS
Lock 7
Lock 8
Lock 9
Darling River
Wentworth
Lock 10
CURLWAA SIS
Dareton
MOURQUONG DISPOSAL BASIN
BURONGA SIS & MILDURA MERBEIN SIS
Merbein
Mildura
Lock 11
Buronga
Irymple
WARGAN DISPOSAL BASINS
Red Cliffs
MALLEE CLIFFS SIS
Euston
Robinvale
Lock 15
Ouyen
Underbool
Data Source:
Towns, Major Watercourse, Roads and State Boundaries supplied by Geoscience Australia; Locks supplied by SA Water; Disposal Basins and Groundwater Salinity supplied by the Murray Darling Basin Commission; Basin in a Box data; River Bed Resistivity supplied by Zonge Engineering, AWE and Dept of Water, Land and Biodiversity Conservation (DWLBC).
LEGEND
Towns
Locks
Direction of Groundwater Flow
Major Watercourse
Roads:
Dual Carriageway
Principal Road
Secondary Road
State Borders
1997 Water Table Elevation (mAHD)
SIS Scheme implemented before survey
SIS Scheme implemented after survey
Disposal Basins
River Murray Trench
Lakes:
Perennial Lake
Dry/Intermittent Lake
Groundwater Salinity (mg/L):
> 100000 mg/L
35000 - 100000 mg/L
14000 - 35000 mg/L
7000 - 14000 mg/L
3000 - 7000 mg/L
1500 - 3000 mg/L
1000 - 1500 mg/L
500 - 1000 mg/L
< 500 mg/L
River Bed Resistivity, 2004/2005/2006/2009 (Ωm):
0 - 0.5
0.5 - 1
1.5 - 2
2 - 2.5
2.5 - 3
3 - 3.5
3.5 - 4
4 - 5
5 - 6
6 - 7
7 - 8
8 - 9
9 - 10
10 - 11
11 - 12
12 - 13
13 - 14
14 - 15
15 - 17
17 - 20
20 - 25
25 - 35
35 - 50
50 - 75
75 - 100
100 - 125
125 - 150
150 - 200
200 - 250
250 - 300
300 - 400
400 - 500
500 - 600
600 - 700
700 - 1000
>1000
Kilometres
Australian WATER Environments
Floodplain Salt and River Salinity
Regional Salt Risk Indicators



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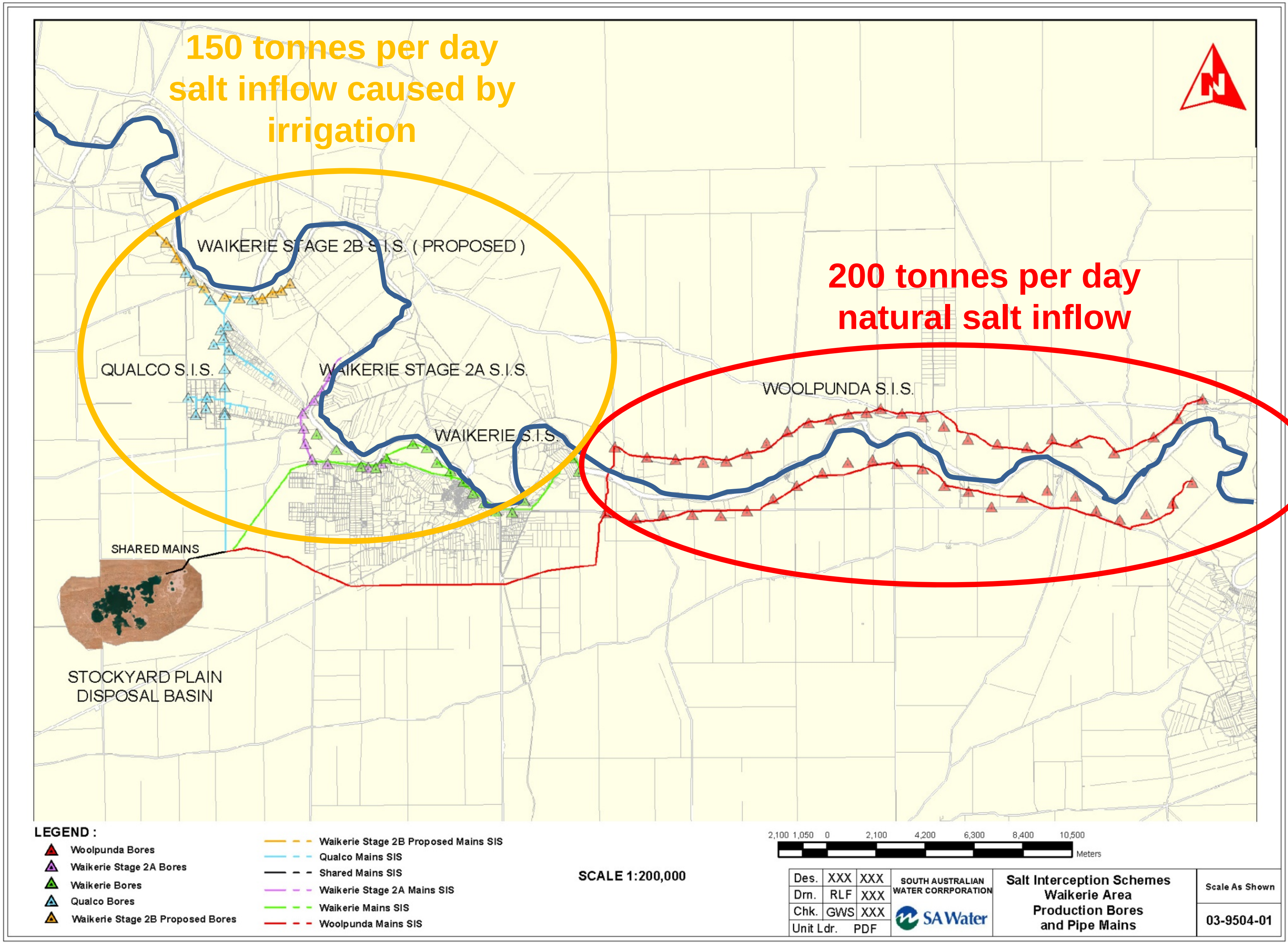
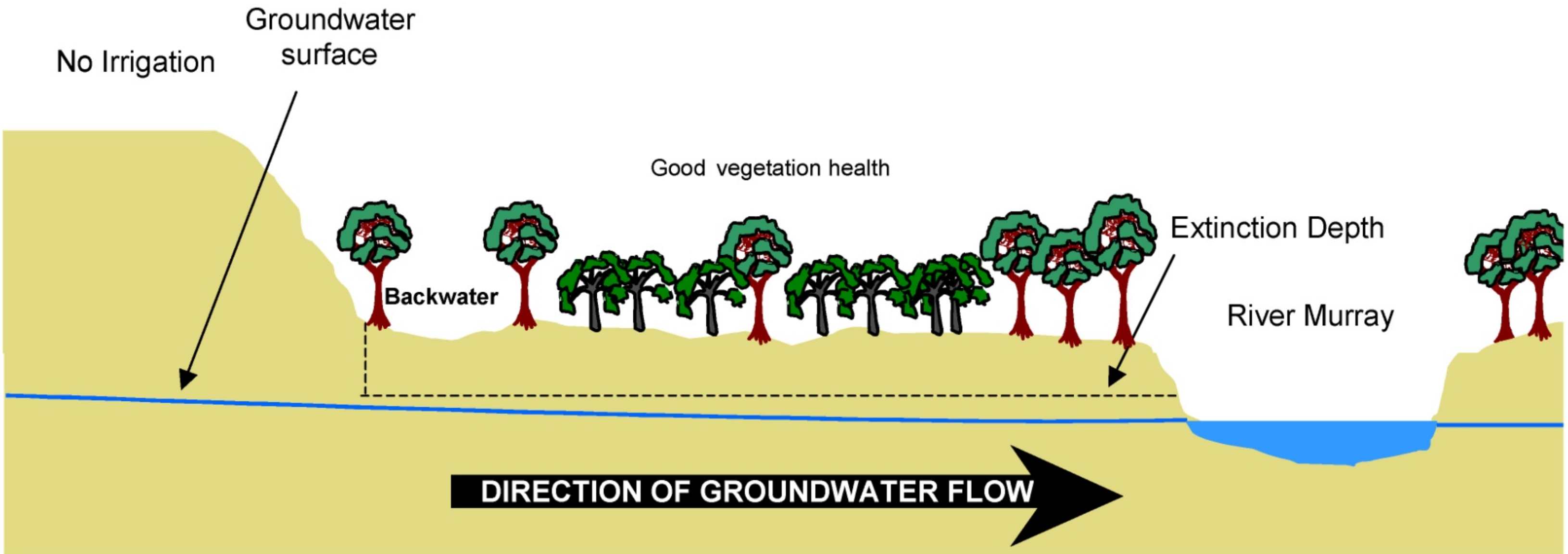


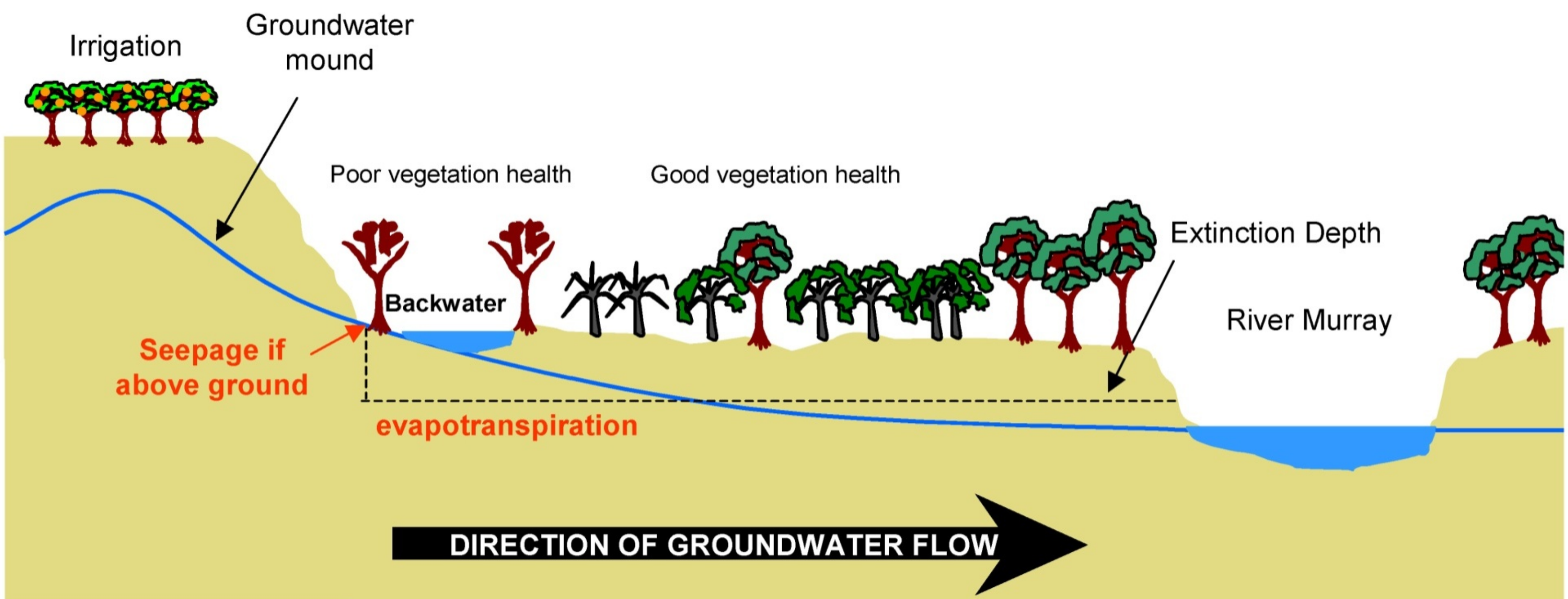
150 tonnes per day salt inflow caused by irrigation
200 tonnes per day natural salt inflow
WAIKERIE STAGE 2B S.I.S. (PROPOSED)
QUALCO S.I.S.
WAIKERIE STAGE 2A S.I.S.
WAIKERIE S.I.S.
WOOLPUNDA S.I.S.
SHARED MAINS
STOCKYARD PLAIN DISPOSAL BASIN
N
LEGEND :
Woolpunda Bores
Waikerie Stage 2A Bores
Waikerie Bores
Qualco Bores
Waikerie Stage 2B Proposed Bores
Waikerie Stage 2B Proposed Mains SIS
Qualco Mains SIS
Shared Mains SIS
Waikerie Stage 2A Mains SIS
Waikerie Mains SIS
Woolpunda Mains SIS
SCALE 1:200,000
2,100 1,050 0 2,100 4,200 6,300 8,400 10,500
Meters
Des. XXX XXX
Drn. RLF XXX
Chk. GWS XXX
Unit Ldr. PDF
SOUTH AUSTRALIAN WATER CORRPORATION
SA Water
Salt Interception Schemes Waikerie Area Production Bores and Pipe Mains
Scale As Shown
03-9504-01

Salt Interception Scheme Basics

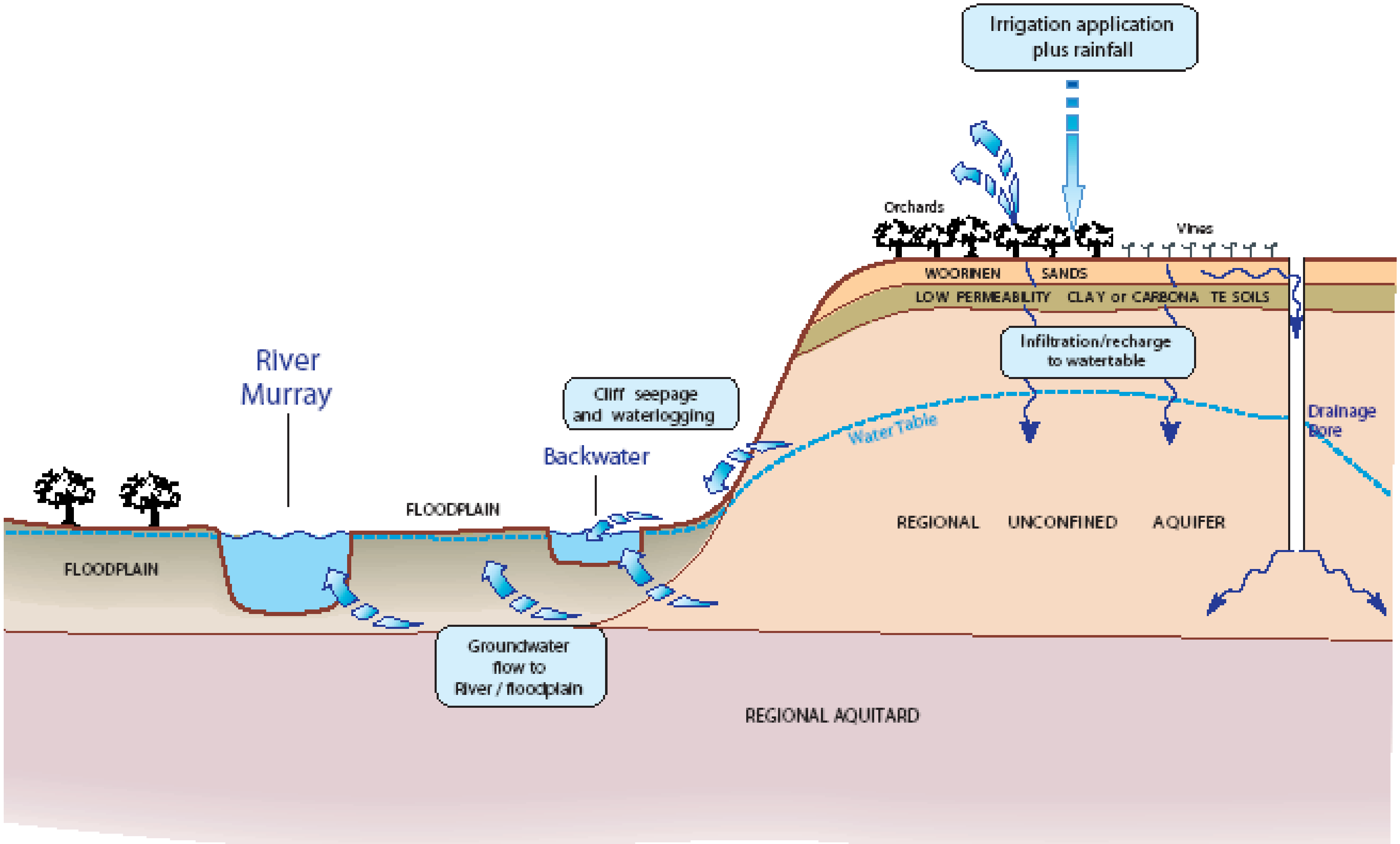
- Problem: Groundwater gradients exist in many reaches, driving saline water into the River
- Solution: Install a line of bore pumps parallel to the river and pump at rates sufficient to lower heads at mid point (between production bores) piezometers to river pool level
- Have the SISs worked? – Midpoint head targets have been reached.
- Other methodologies produce further evidence of significant reductions between pre and post scheme salinities.



Before irrigation



After irrigation



DIAGRAMMATIC - NOT TO SCALE

Bookpurnong LWMP

GROUNDWATER PROCESS

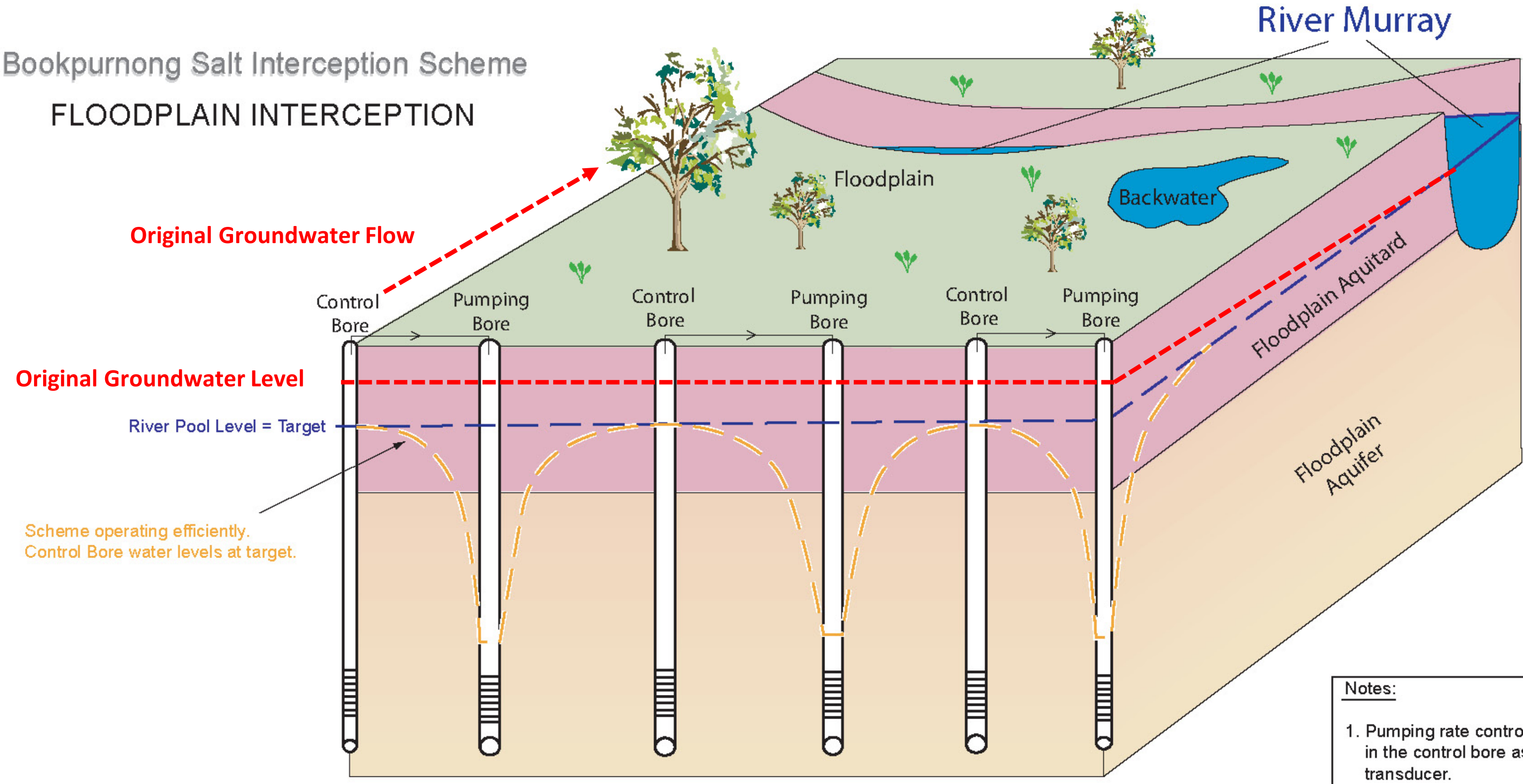
Figure 7

Job No. - 44818 - 009

Clark's floodplain - Bookpurnong

Bookpurnong Salt Interception Scheme

FLOODPLAIN INTERCEPTION



Legend:

- Feedback loop
- Bore + screen

DIAGRAMMATIC - NOT TO SCALE

Notes:

1. Pumping rate controlled by water level in the control bore as measured by a transducer.
2. Control Bore Target
   = 10.0mAHD downstream Lock 4
   = 13.0mAHD upstream Lock 4
3. When water level in control bore is above target, pump will speed up.
4. When water level in control bore is below target, pump will slow down.

Australian WATER Environments

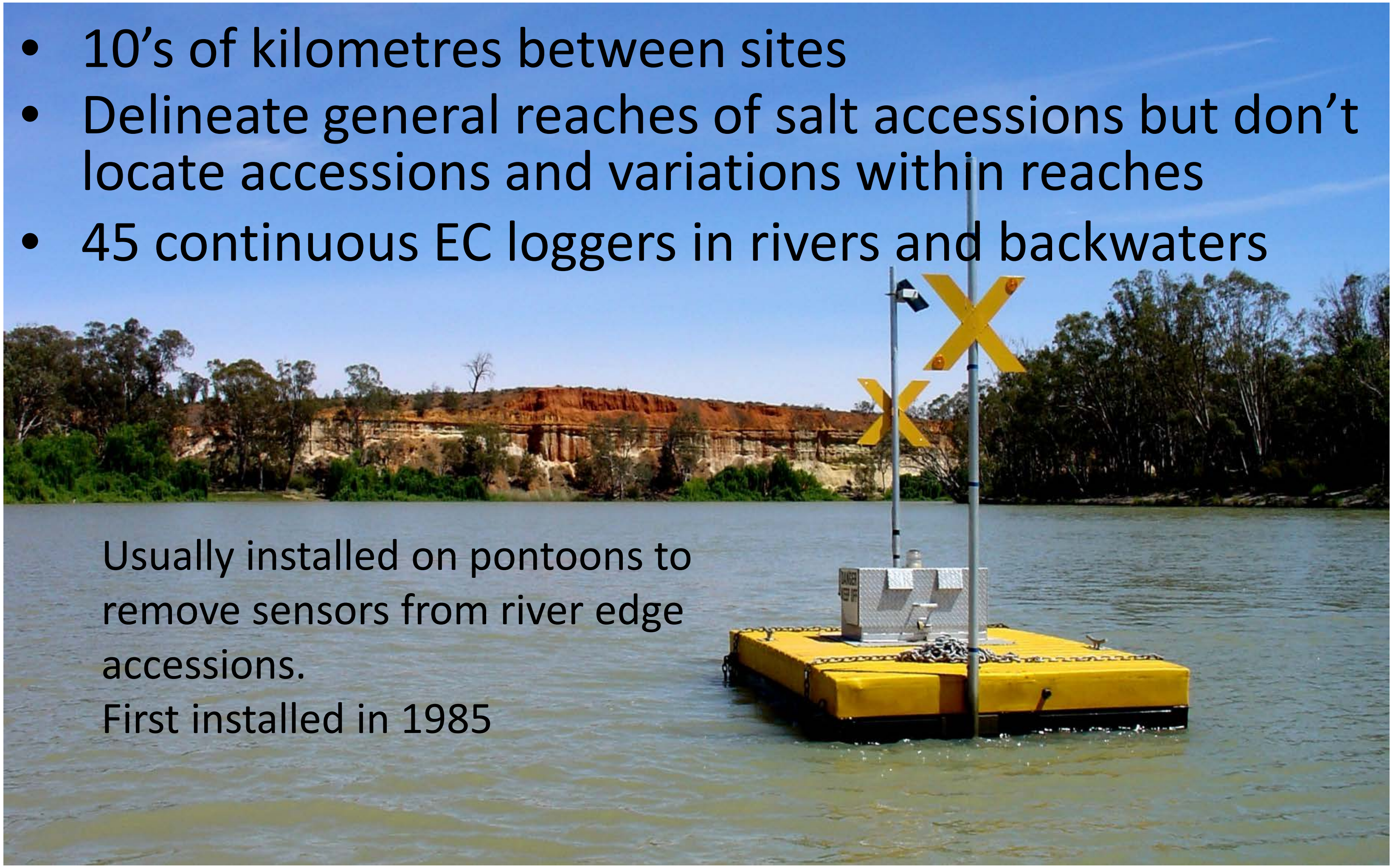
Figure 2

Tools used for SIS investigations and performance assessment – what have they given us?

- Toroidal Coil Continuous EC Recorders (since 1985)
- Run of River Salinity Surveys (from early 1980's)
- Close-spaced, 3D Salinity Mapping (since 2006)
- NanoTEM – electromagnetic salinity surveying (since 2002)
- Made possible by advances in computing power, GPS and GIS technologies
- There are some very encouraging correlations between these tools with respect to:
  - Salt loads and the reductions achieved by the SIS's
  - The location and quantum of salt inflows to the river
  - Evidence of the modification of groundwater flow patterns caused by SIS pumping including the development of freshwater lenses adjacent the river

Continuous EC Recorders

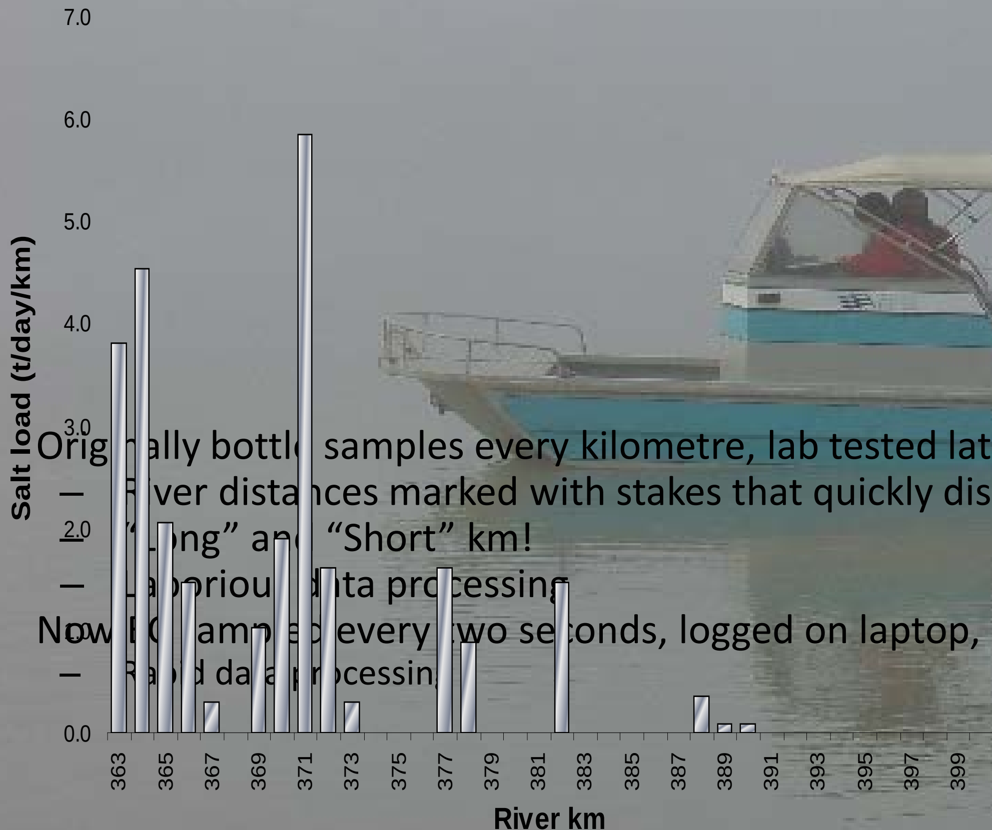
- 10’s of kilometres between sites
- Delineate general reaches of salt accessions but don’t locate accessions and variations within reaches
- 45 continuous EC loggers in rivers and backwaters



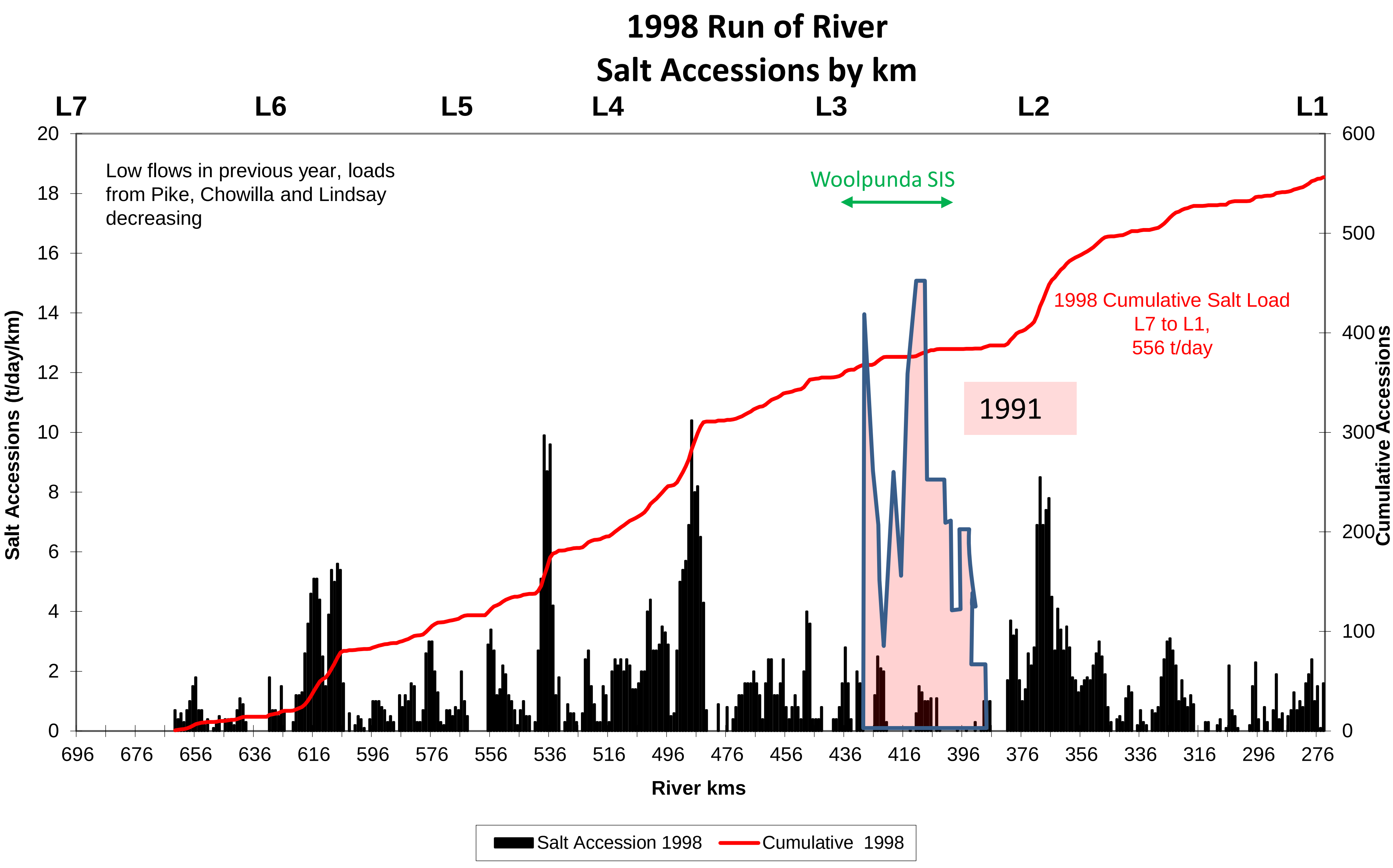
Usually installed on pontoons to remove sensors from river edge accessions.
First installed in 1985

Run of River Salinity Surveys

- Salt load accessions related to location
- In South Australia since 1985
- Change in salinity of water as it traverses each river km is calculated
- Originally used to determine salt load in 1km intervals, expressed as tonnes/day/km
- More recent analysis methodologies enable much more precise location of accessions to within a few 100m



- Originally bottle samples every kilometre, lab tested later.
  – River distances marked with stakes that quickly disappeared
  – “Long” and “Short” km!
  – Laborious data processing
- Now EC sampled every two seconds, logged on laptop, GPS positioned
  – Rapid data processing



1998 Run of River
Salt Accessions by km
L7
L6
L5
L4
L3
L2
L1
Low flows in previous year, loads from Pike, Chowilla and Lindsay decreasing
Woolpunda SIS
1998 Cumulative Salt Load L7 to L1, 556 t/day
1991
Salt Accessions (t/day/km)
Cumulative Accessions
River kms
0
2
4
6
8
10
12
14
16
18
20
0
100
200
300
400
500
600
696
676
656
636
616
596
576
556
536
516
496
476
456
436
416
396
376
356
336
316
296
276
Salt Accession 1998
Cumulative 1998

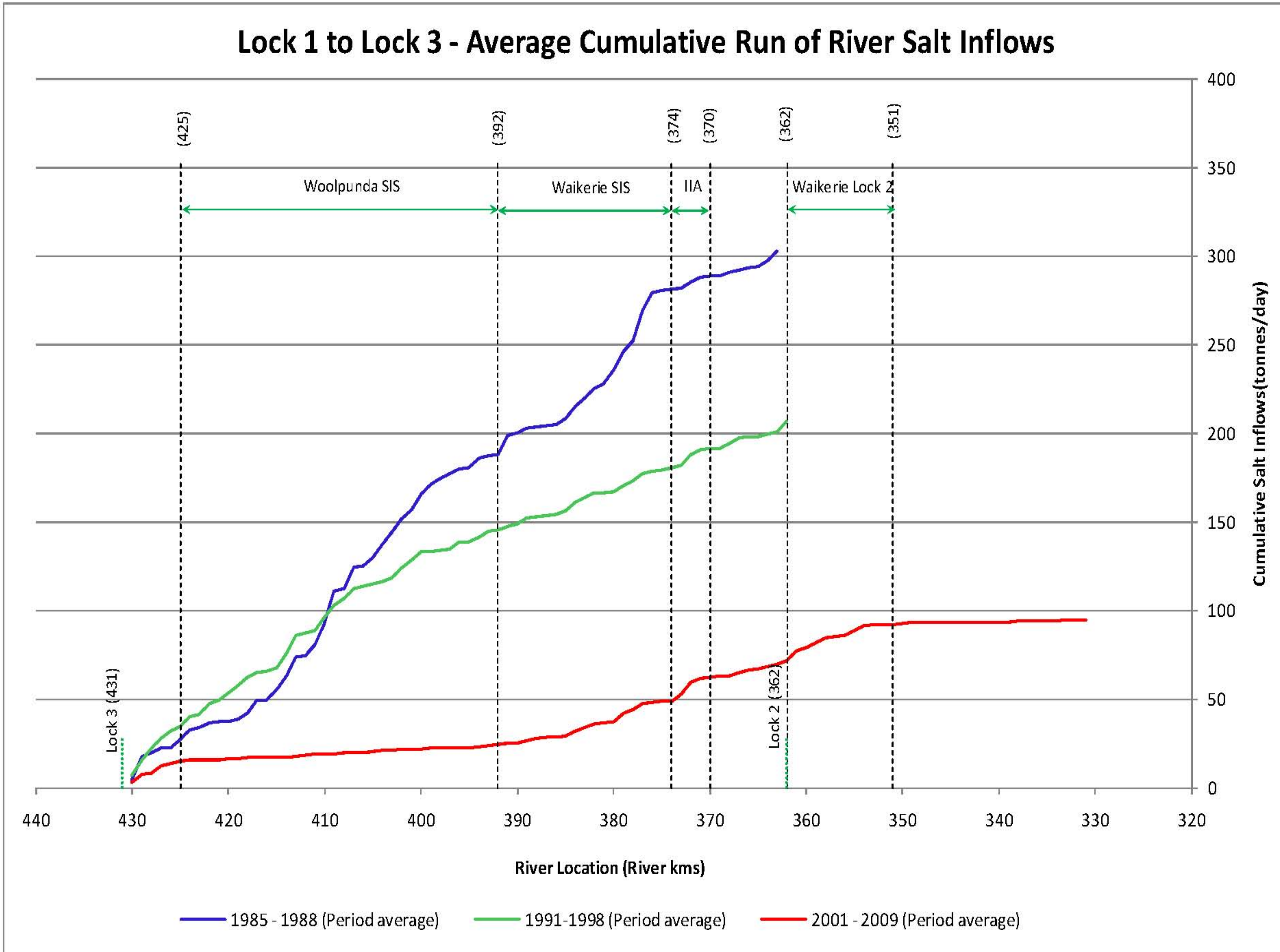


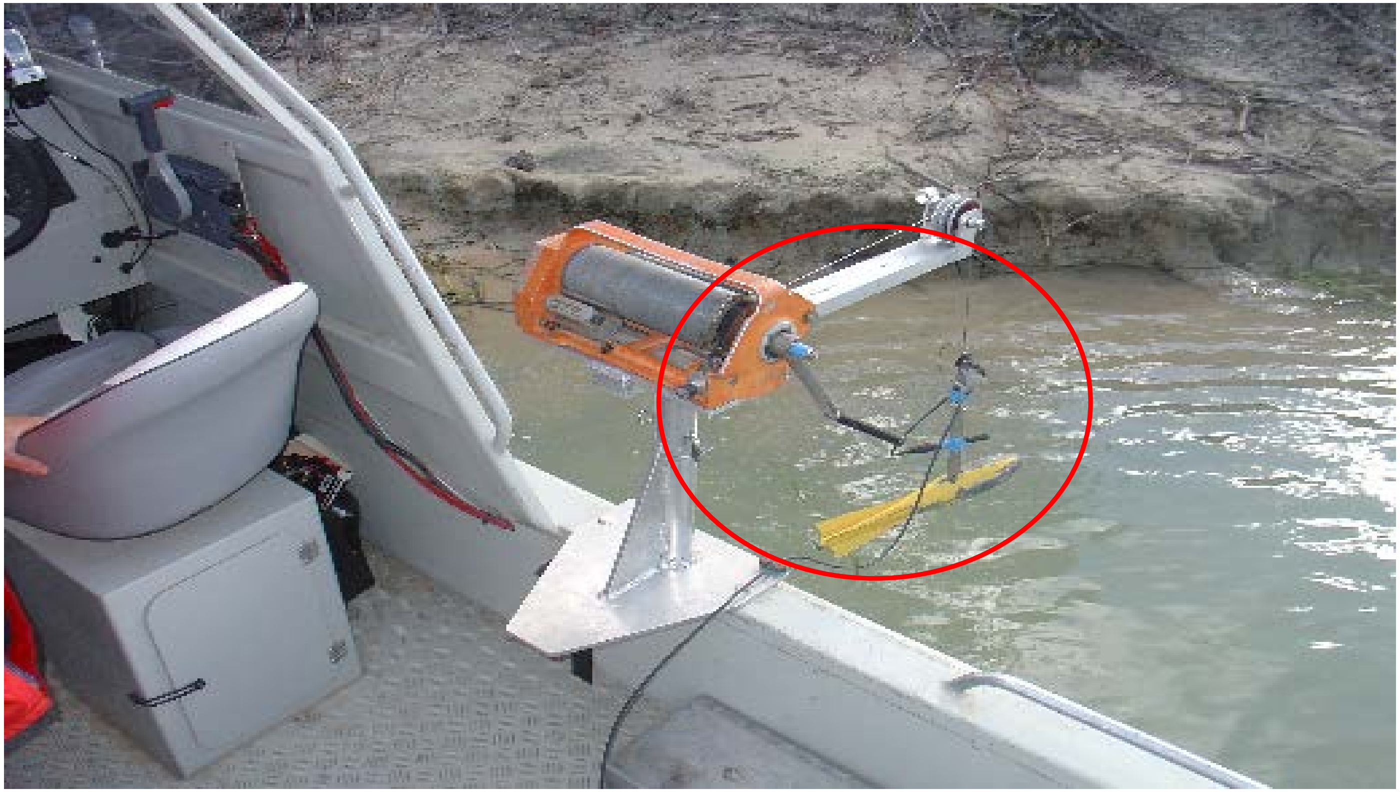
FIGURE 4.2 LOCK 1 TO LOCK 3 – AVERAGE SALT INFLOWS PER DECADE

3D In-stream EC

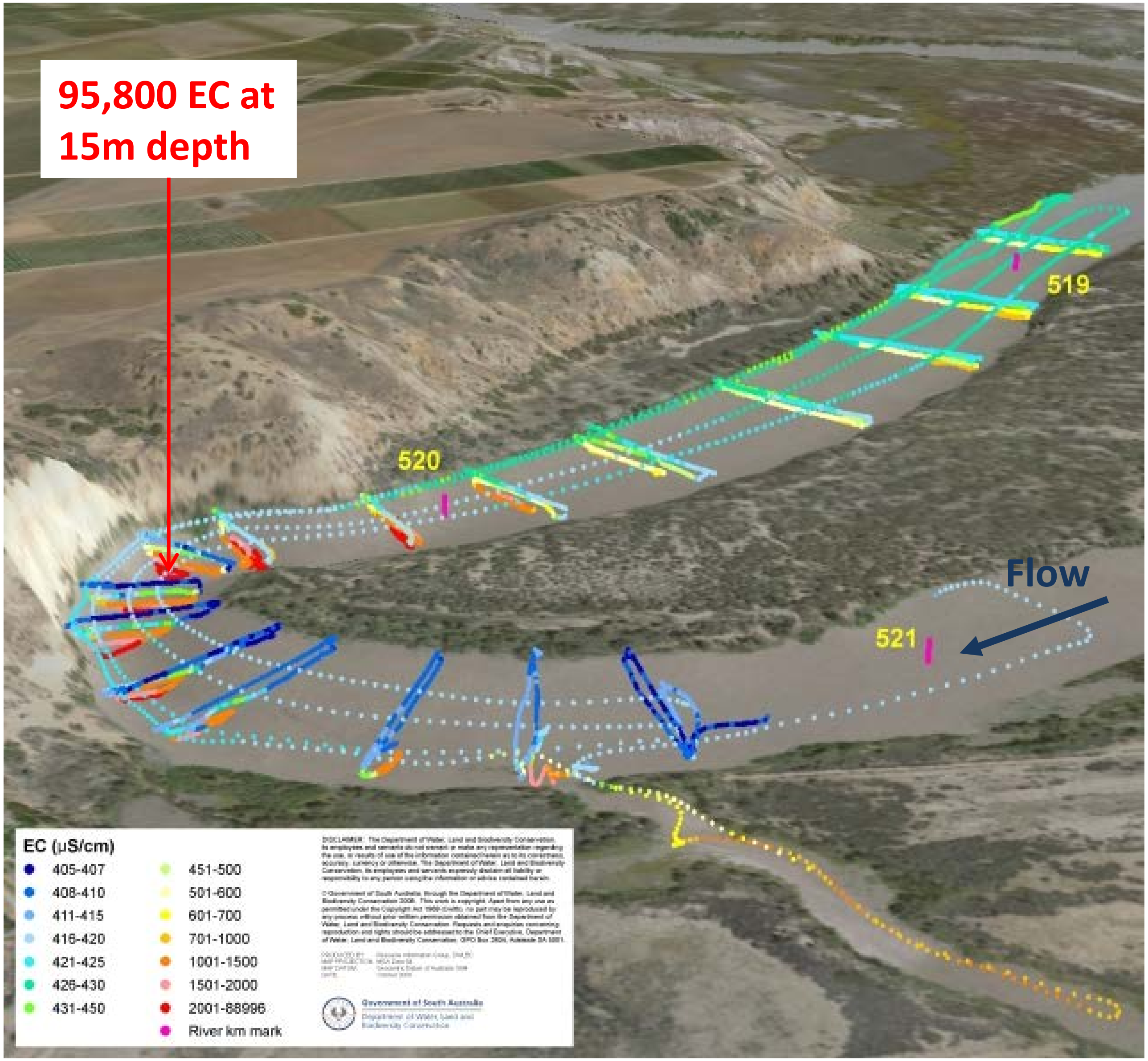
EC probe attached to weight on depth calibrated winch

Lowered to depth while boat is moving

GPS, EC, temperature and depth readings taken every 2 seconds



Bookpurnong Cliffs 3D Instream EC



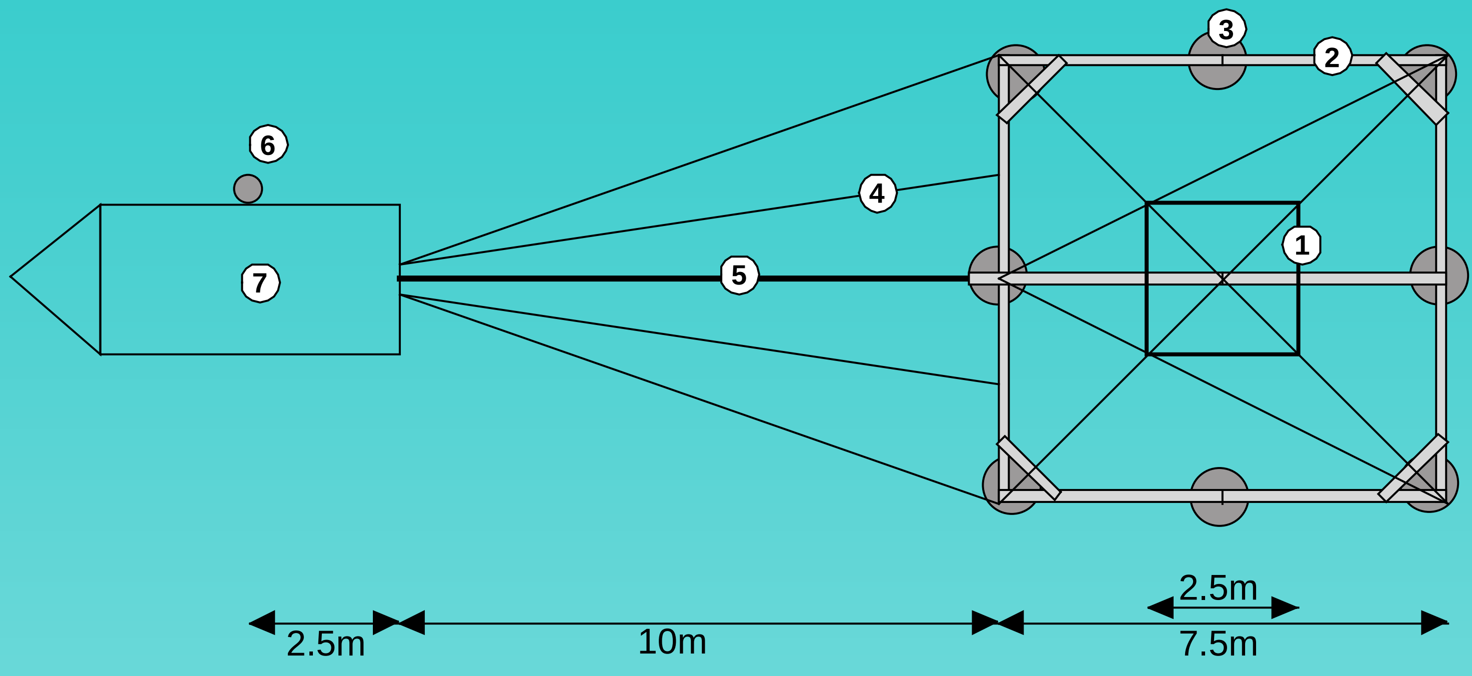
NanoTEM – Instream Electromagnetic Salinity Surveying

- Measures the resistivity of saturated geological materials which is affected by:
  - Material properties (clays are more conductive than sand)
  - Porosity and saturation of the material
  - Water salinity
- Instream NanoTEM will be influenced by:
  - Gaining and losing stream conditions, generating lower or higher resistivities respectively
  - Groundwater salinity, generating lower resistivities with increasing salinity
  - Riverbed geology, with clays generating lower resistivities than sands and limestones

Potential Benefits of NanoTEM

- Identifying where gaining and losing stream conditions occur
- Identify the locations of regional clay aquitards beneath the river
- Illustrate where Salt Interception Schemes have been effective in preventing saline groundwater inflows (before and after SIS comparisons)
- Assist with SIS investigations and scheme design through identifying potential areas of salt inflow (although NanoTEM can’t quantify flux)
- Identify where freshwater lenses may have been created adjacent the river by SIS over pumping
- Optimisation of SIS’s by identifying areas of over or under pumping

Concept Data Acquisition – Floating NanoTEM



- 1 – Receiver loop: 2.5 m x 2.5 m
- 2 – Transmitter loop: 7.5 m x 7.5 m
- 3 – Tyre inner tubes
- 4 – Tow ropes
- 5 – Transmitter/Receiver cable return
- 6 – Boat
- 7 – GPS Antennae and depth sounder

First Generation NanoTEM

Practical Data Collection

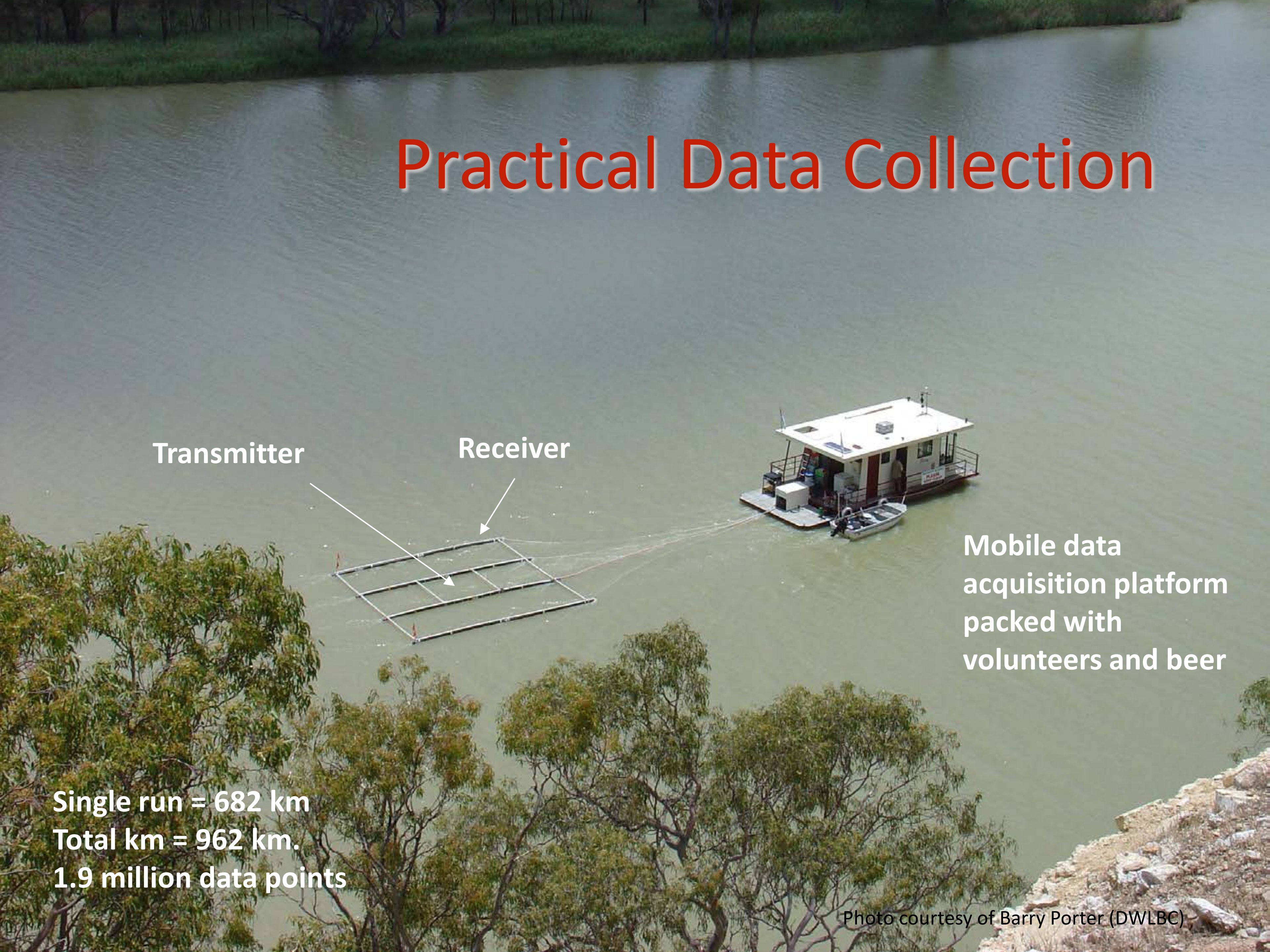
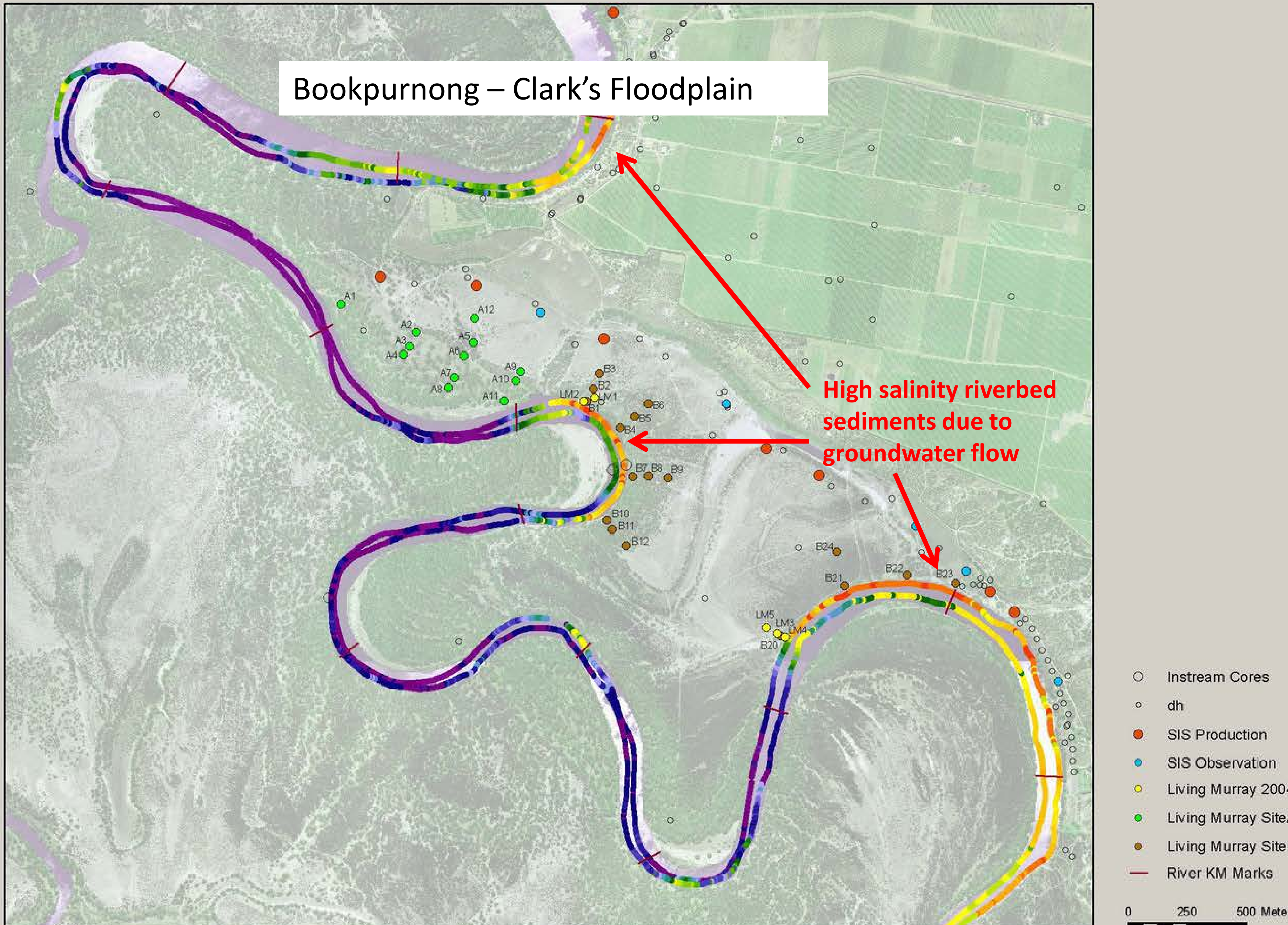
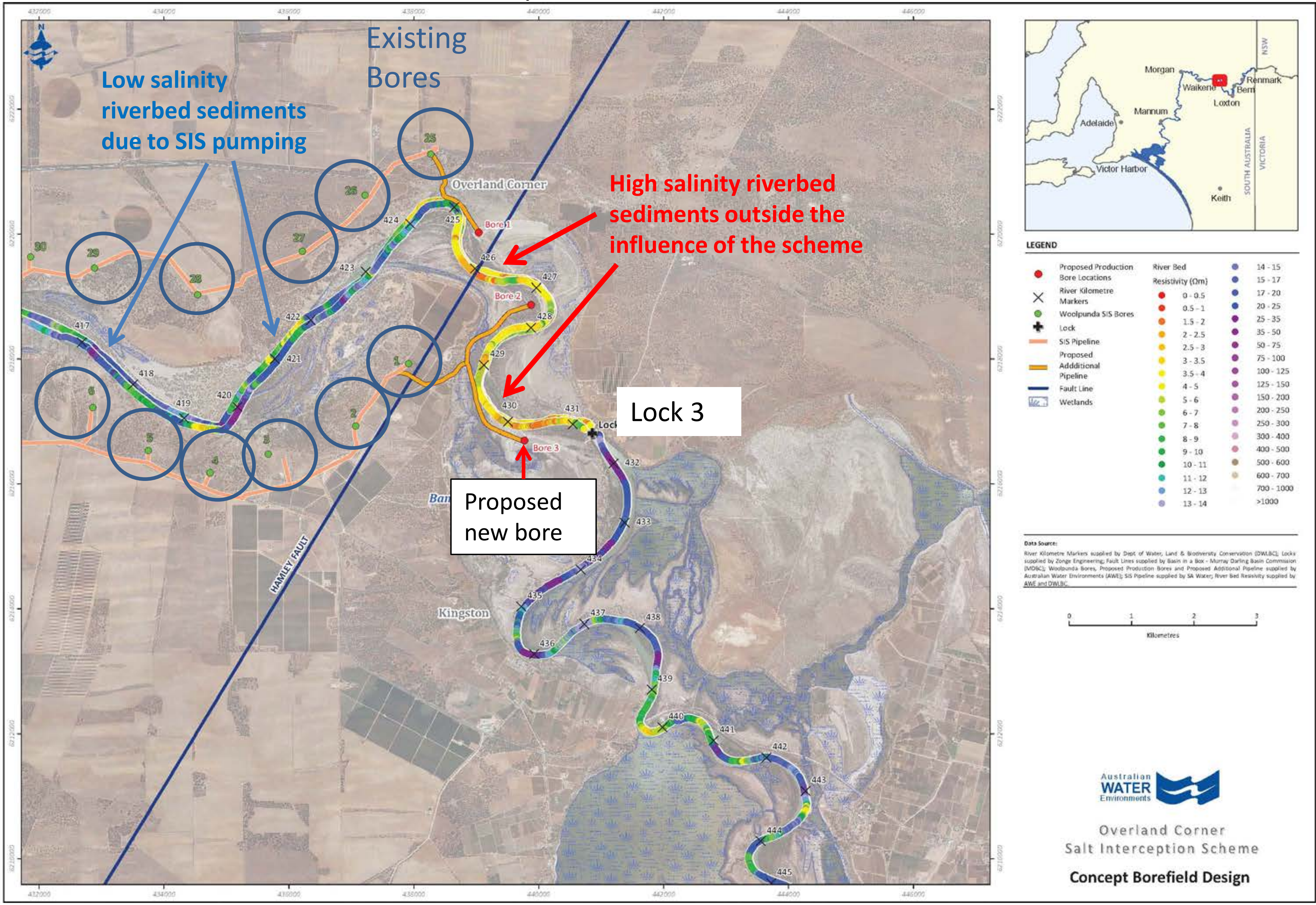


Photo courtesy of Barry Porter (DWLBC)


Bookpurnong – Clark's Floodplain
High salinity riverbed sediments due to groundwater flow
A1
A2
A3
A4
A5
A6
A7
A8
A9
A10
A11
A12
B1
B2
B3
B4
B5
B6
B7
B8
B9
B10
B11
B12
B20
B21
B22
B23
B24
LM1
LM2
LM3
LM4
LM5
Instream Cores
dh
SIS Production
SIS Observation
Living Murray 2004
Living Murray SiteA
Living Murray SiteB
River KM Marks
0
250
500 Meters

Woolpunda SIS – Eastern End



The Challenges

- Complex hydrogeology
- Large scale engineering of dynamic groundwater systems
- High capital costs
- Corrosive saline water
- Locating suitable disposal sites (NIMBY)
- Potential high maintenance and power costs
- Biofouling of pumps and pipelines by “iron bacteria”

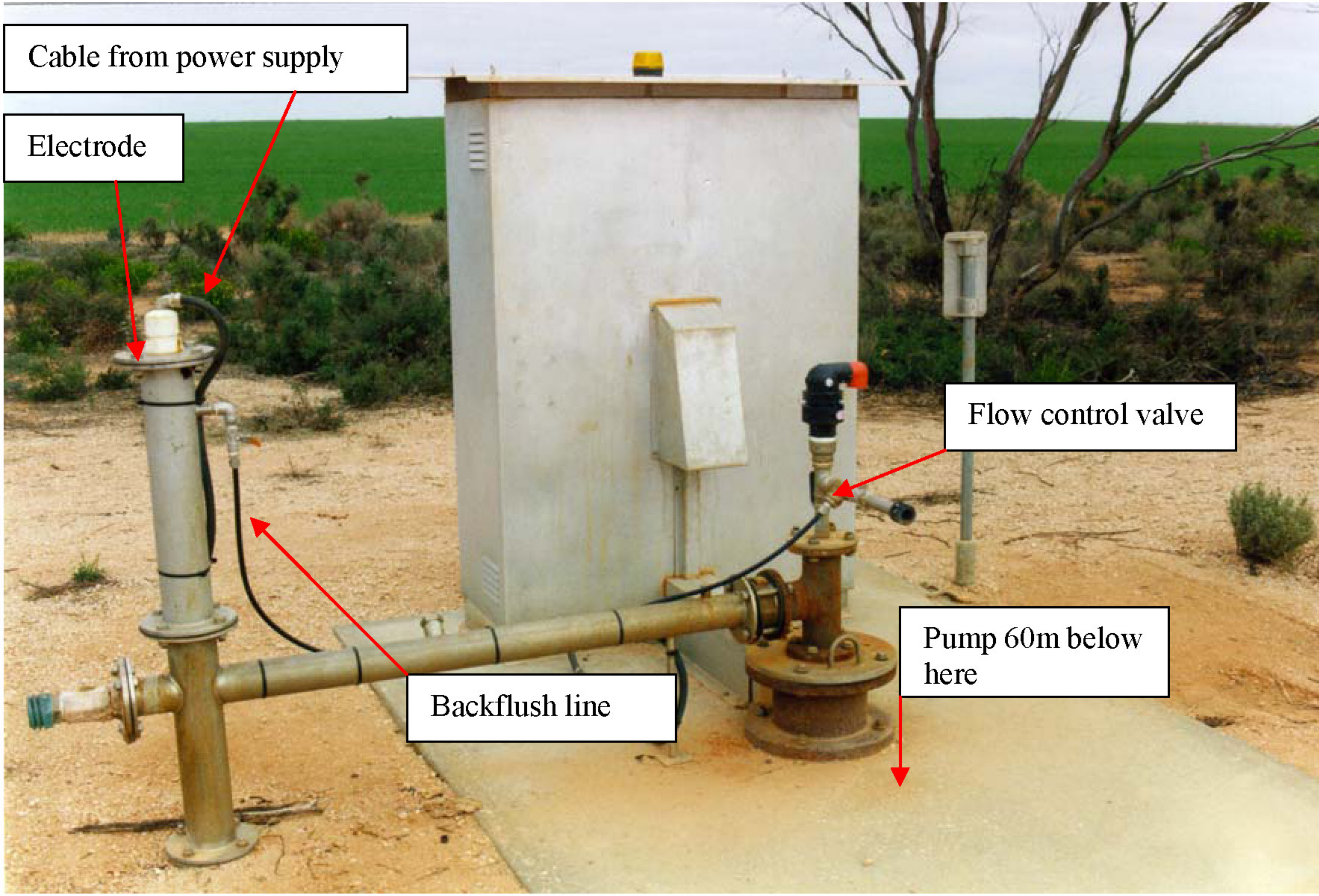
The Hazards of Groundwater Pumping

Iron Bacteria **Aluminium Oxide**

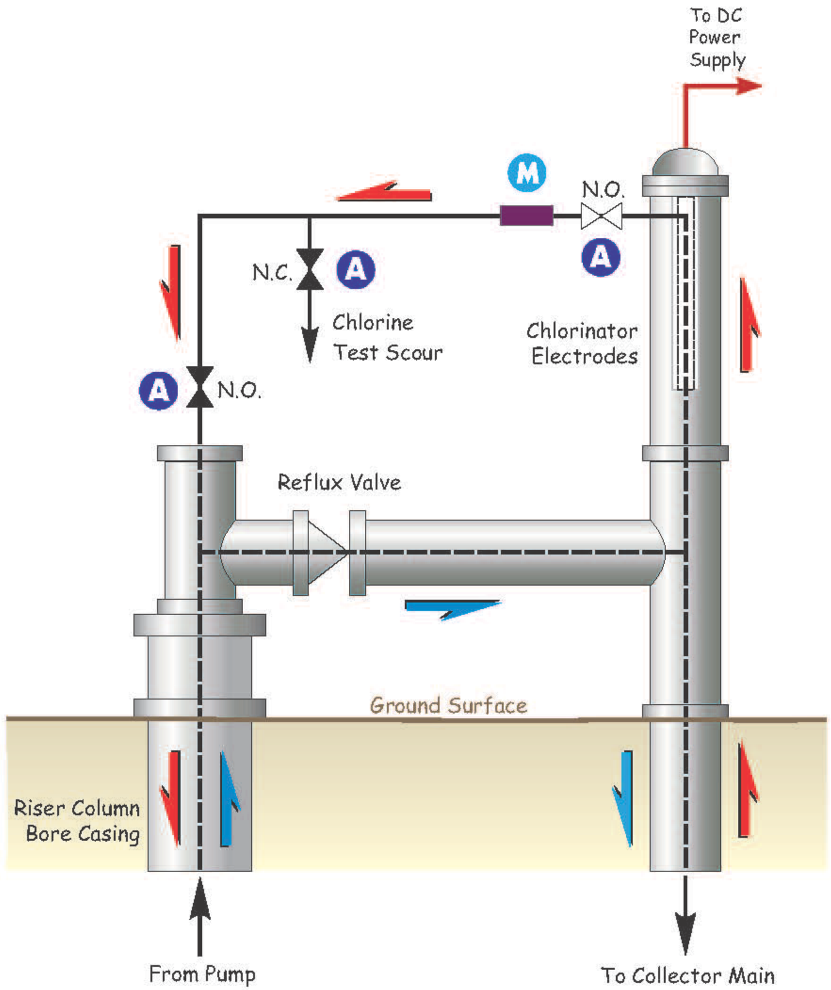
Woolpunda SIS - Iron Bacteria Covered Pump Being Removed

Iron Bacteria

- Naturally occurring bacteria in groundwater derive energy from oxidising soluble ferrous iron (Fe^{++}) to insoluble ferric iron (Fe^{+++})
- The resultant gelatinous sludge rapidly blocks pumps, pipelines and bore screens, reducing flows and increasing hydraulic lossess.
- In the worst case, a new pump would lose 45% of its flow within 50 days.
- Pumps now kept clean by electrolytic chlorinators, pipelines by periodic pigging and bores by chemical dosing.



Woolpunda SIS Chlorination System



A	1/2" SS ball valves
N.O.	Normally open
N.C.	Normally closed
M	Maric flow controller (9 L/min)
(blue arrow)	Water flow while pumping
(red arrow)	Water flow while chlorinating

Australian WATER ENVIRONMENTS
GeoTech Graphics 505-2261
Job No. 41275

Chlorination System Operation

Figure ?

Salt Interception – Future Directions and Challenges

- Pike River – (~$25 Million, ~30 bores) has been accepted by MDBA as a technically viable scheme but has not provided funding. In 2011 SA received $2M towards funding Pike with 2km pipeline and 4 bores
- No more large scale SISs are anticipated, the remaining sources of salt are too diffuse and scattered to be economically intercepted
- Optimisation, enhancement, augmentation of existing SIS's
- Challenges of aging infrastructure and higher maintenance requirements, harsh operating environments, increasing electricity costs, budget pressures from SA, Vic and NSW who fund SIS operations

Conclusions

- The >$200M investment in SIS's has paid off
- Salt loads have been significantly reduced by about 500t/d
- SIS effectiveness has been proven by a range of techniques:
  - Run of River
  - Continuous EC Recorders
  - Close-spaced, 3D Salinity Mapping
  - NanoTEM
- There are opportunities to use SIS's for purposes other than just salt load reductions by the deliberate creation of fresh water lenses adjacent the river channel to:
  - Reduce post flood salt loads from floodplains
  - Improve floodplain vegetation health