Queensland Government

Office of Groundwater Impact Assessment
Department of Regional Development, Manufacturing and Water

Subsidence project update

Landholder Reference Group Meeting # 3

Friday 6th October 2023

Acknowledgement of country

Agenda

Queensland Government

1. Follow-up from last meeting and recap

Subsidence matters

2. Preliminary mapping of susceptibility – *for feedback and input*
3. Mapping of historical subsidence – *for information*
4. Exploring the concept of baseline – *for feedback and input*

Groundwater matters

- Gassy bore
- Airborne survey – an update

Where to from here?

Ground motion vs subsidence

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Subsidence = from CSG depressurisation only

Ground motion = CSG + non-CSG

- **Non-CSG factors**
  - Natural variability: soil shrink/swelling with rainfall etc.
  - Reworking, ground filling, relevelling
  - Groundwater extraction

Key steps and logic

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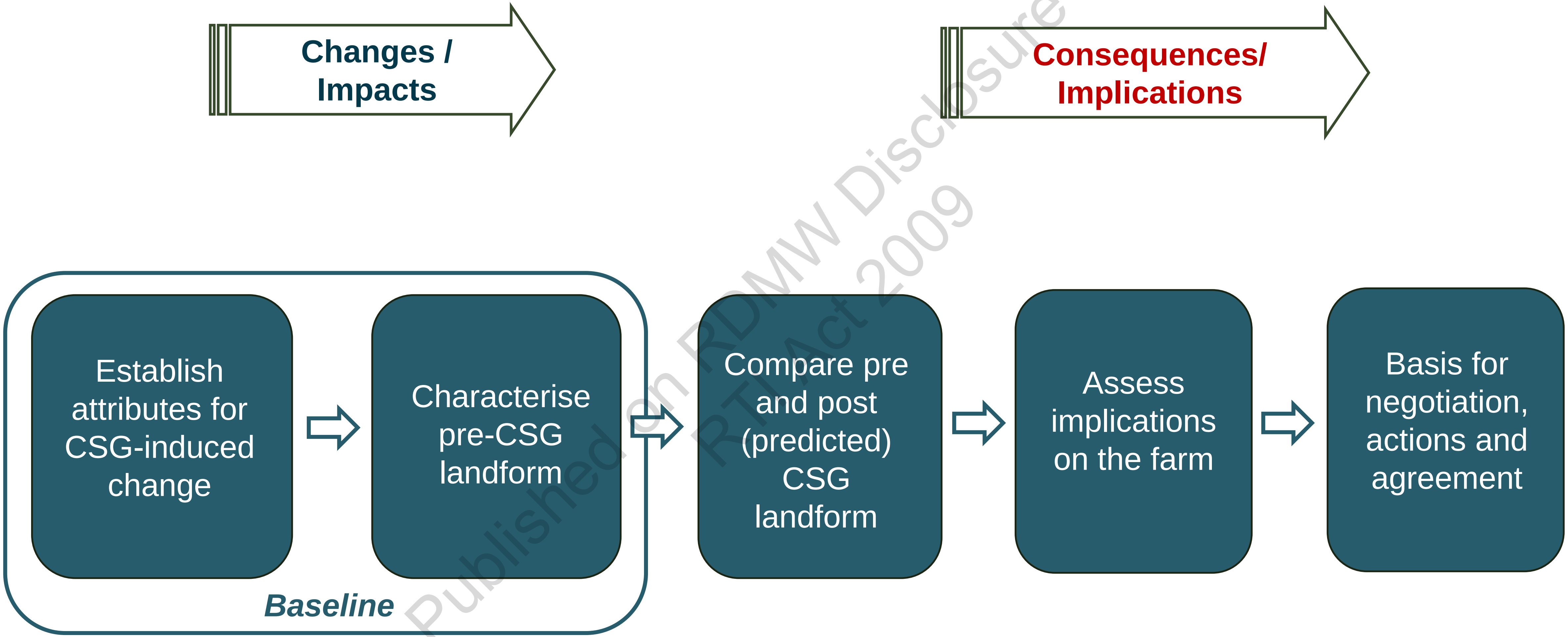

Where are we in the process?

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Govt's announcement to go ahead

May'23

LRG endorsement
- Purpose & scope
- Pilot farms

May'23

Pilot farm: visit
- What matters
- practices

Jul'23

Pilot farm: foundational data
- Lidar
- InSAR

Aug'23

Pilot farm: historical subsidence
- Attributes for measuring change
- Historical subsidence

Oct'23

LRG update

Oct'23

Pilot farm: predictions and changes
- Future predictions
- Mapping changes

Nov ???

Pilot farm scale assessment – selection (Stage 1)

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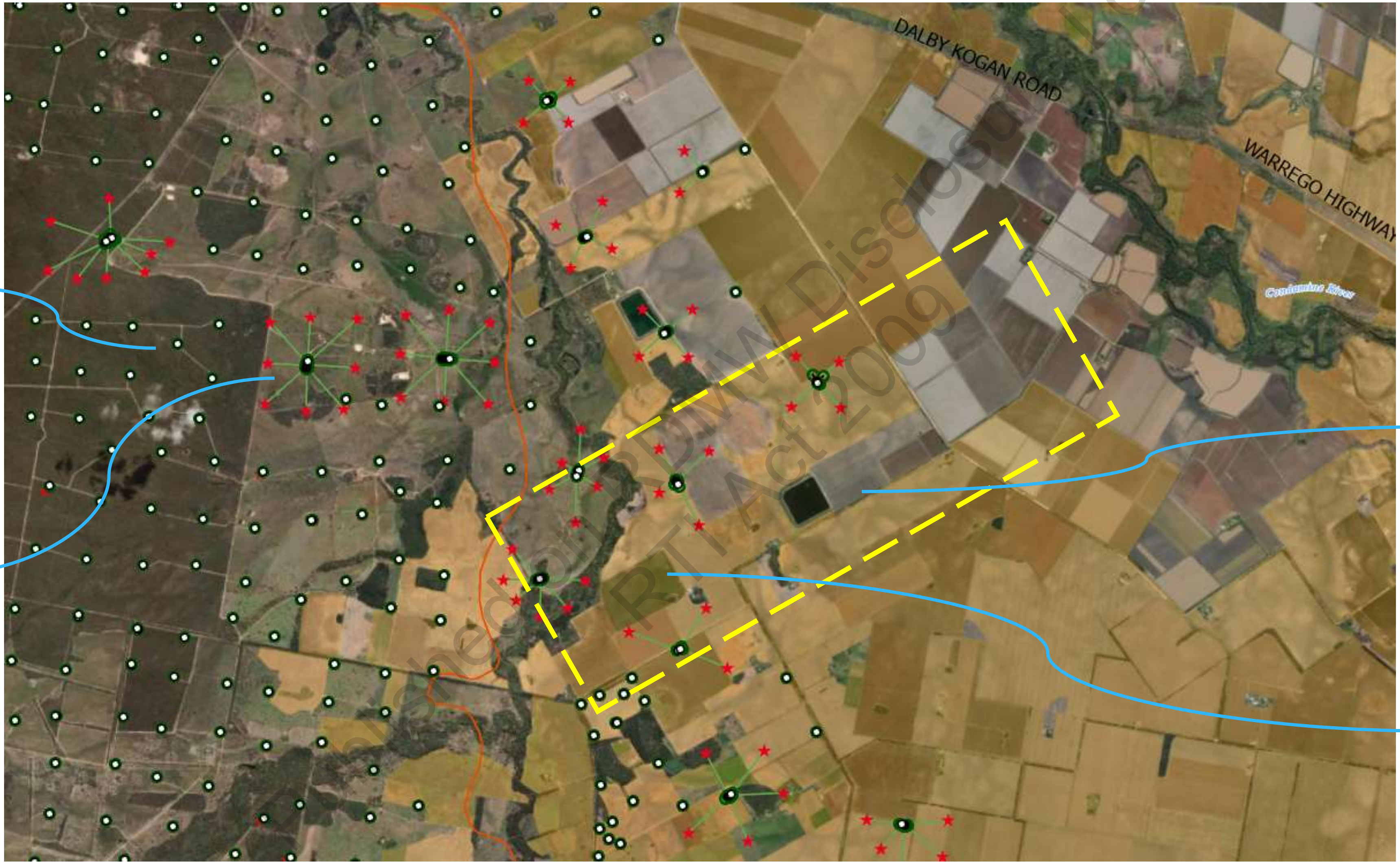
Existing CSG wells

Directional wells



4p4(6) Personal informat
near to CSG wells

h4p4(6) Personal informati
surrounded by CSG wells

Follow-up from the last meetings Meeting No 1

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- Action 2.1 – Re-circulate the ToR to members via the Chairpersons (For OGIA – Attachment 2)
- Action 2.2 – Investigate membership from Toowoomba Regional Council (For OGIA)
- Action 2.3 – Consider appropriateness of GFCQ as an Observer (For Chairpersons and OGIA)
- Action 2.4 – Explore linkages of OGIA work with relevant considerations under the RPI Act (For OGIA)
- Action 2.5 – Consider dissemination of minutes of meetings – e.g. through the OGIA website (For OGIA)

Follow-up from the last meetings Meeting No 1

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- Action 3.1 – Investigate LiDAR anomalies around the 4(6) Personal inform property (For OGIA)
- Action 3.2 – Explore the issue of long-term recharge and recovery during the post-CSG period (For OGIA)
- Action 3.3 – Review terminology and develop approach for establishing baseline in the context of overall objective, i.e. establishing future CSG impacts (For OGIA)

- Action 4.1 – Identify farms as potential sites for the pilot assessment (For OGIA)
- Action 4.1 – Share a draft of the scope of the farm-scale pilot assessment (For OGIA, completed Attachment 3)

Follow-up from the last meetings Meeting No 2

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A special meeting held online on 23 May 2023

Driver

- to discuss viability of the reference group in response to two emails raising questions on the relevance of the group, and the manner they were raised.

Outcome

- The reference group will continue under the terms of engagement agreed upon in the previous meeting.
- Resignation of ch4p4(6) Personal informati from the reference group.

Recap - key observations/feedback so far

- Individual fields are designed to **manage soil moisture** = maximise yield
- Different parts of a farm field are managed differently – **subfields** scale – where some areas are more **susceptible to change** than others
- Susceptibility features vary **between dryland and irrigated fields**
- Slope along the irrigation furrows may vary but slope of **head ditch and tail drain** are critical
- **Dryland farms** are relatively more prone to changes
- Dryland farm areas with slope **as low as 0.01%** are utilised for farming
- Access to **metadata** for LiDAR is essential – time, overlap etc.

2022 LiDAR data issue

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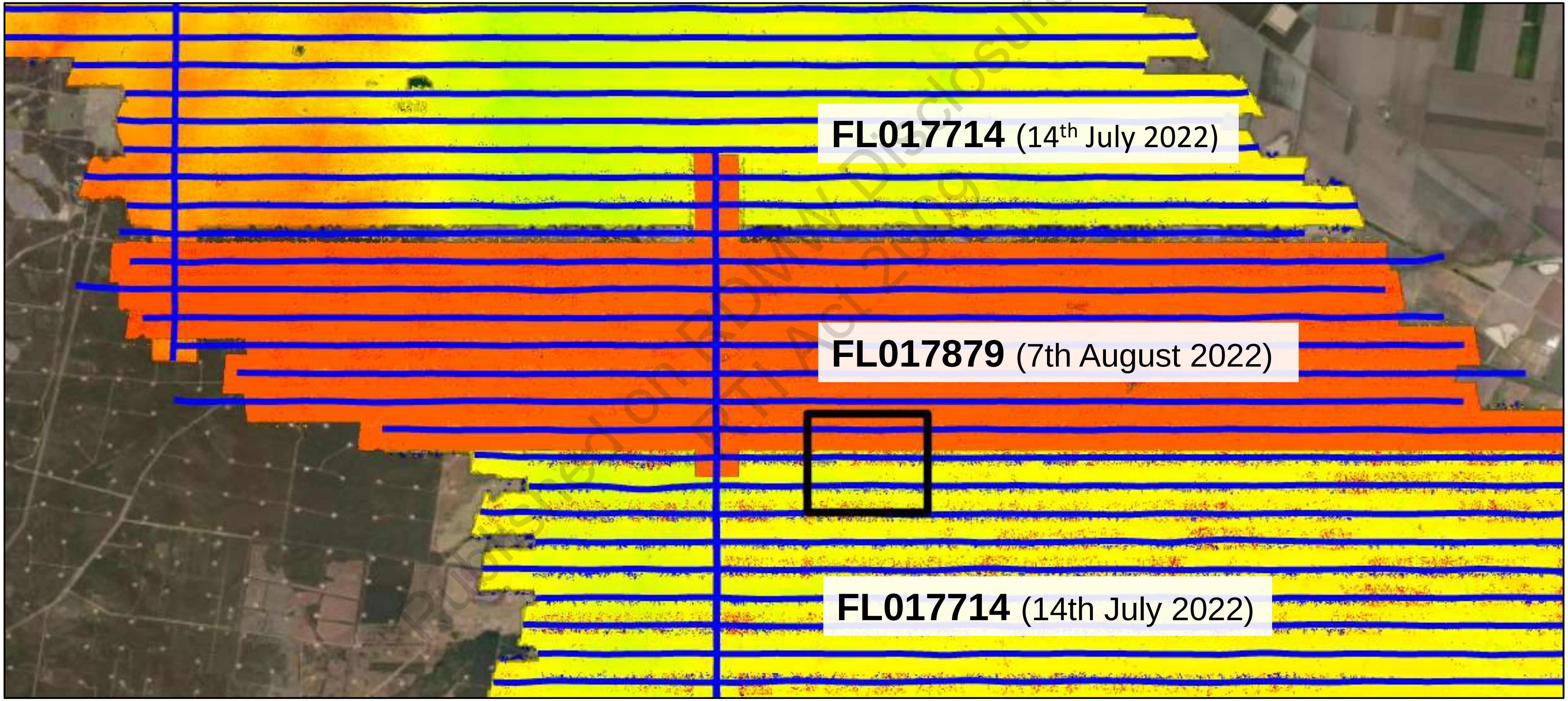
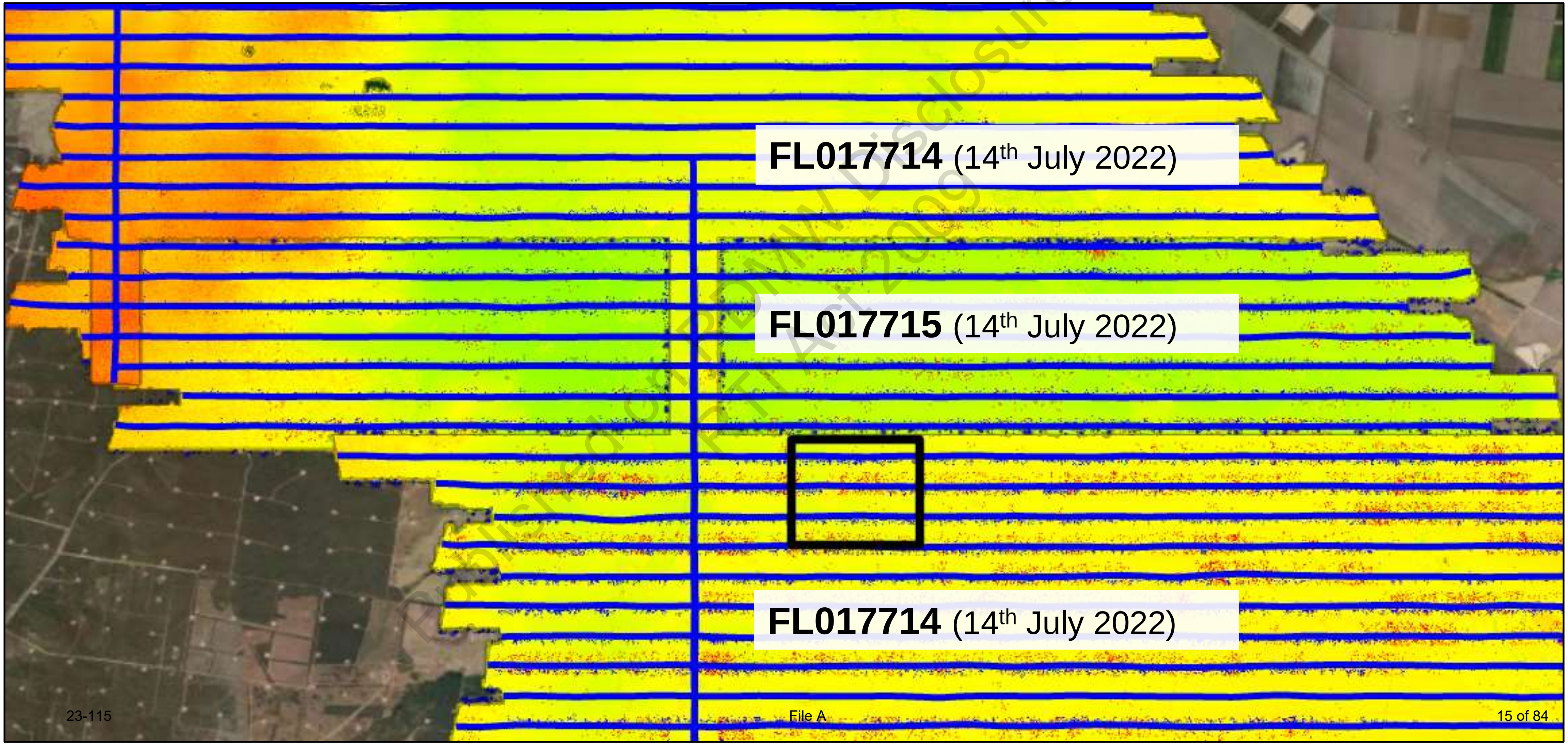
2022 airborne LiDAR data

Original Arrow Energy submission – a composite of FLO17879 and FLO17714



2022 airborne LiDAR data

Updated Arrow Energy submission on 18th August 2023



Data acquisition and processing

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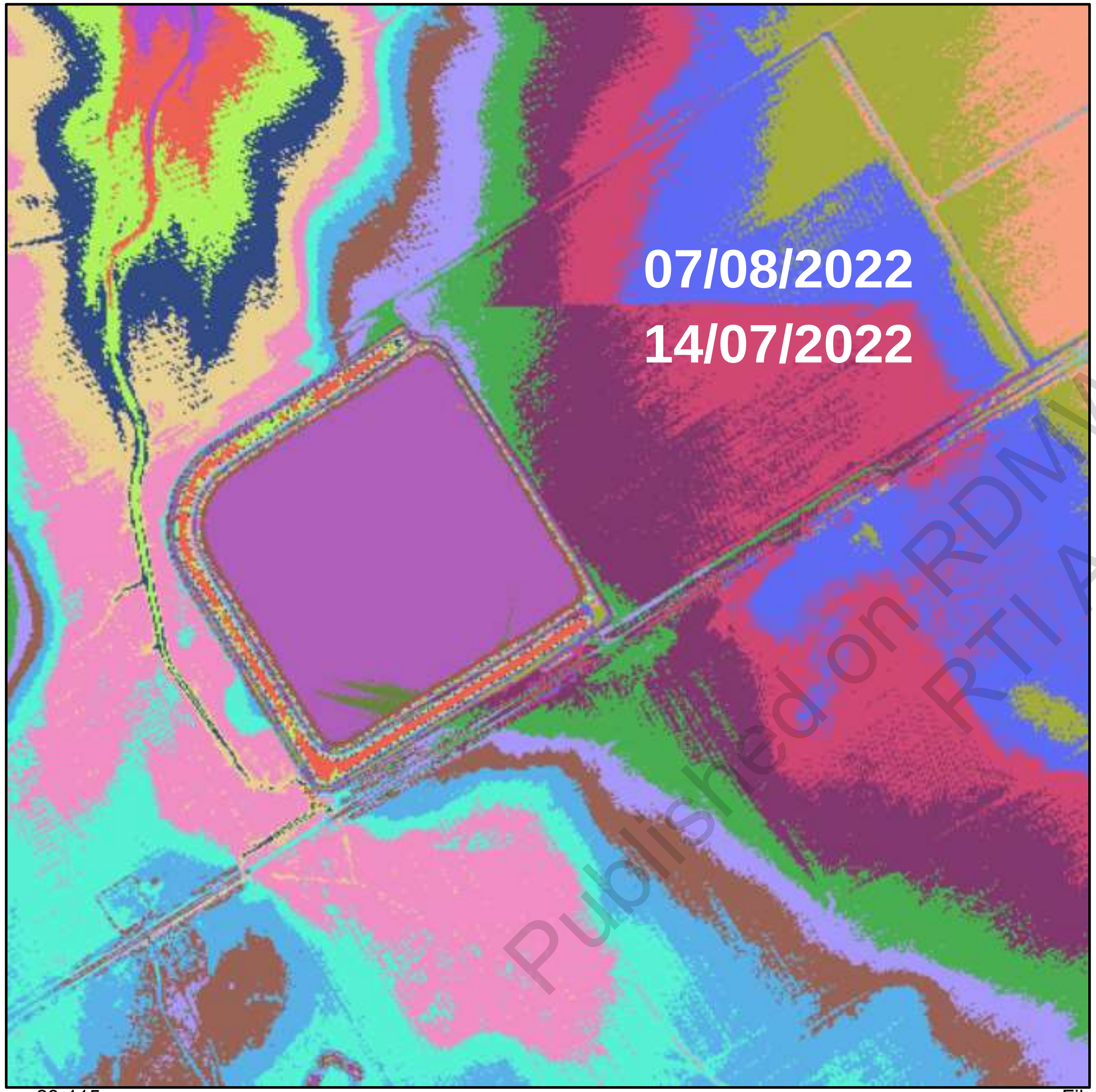
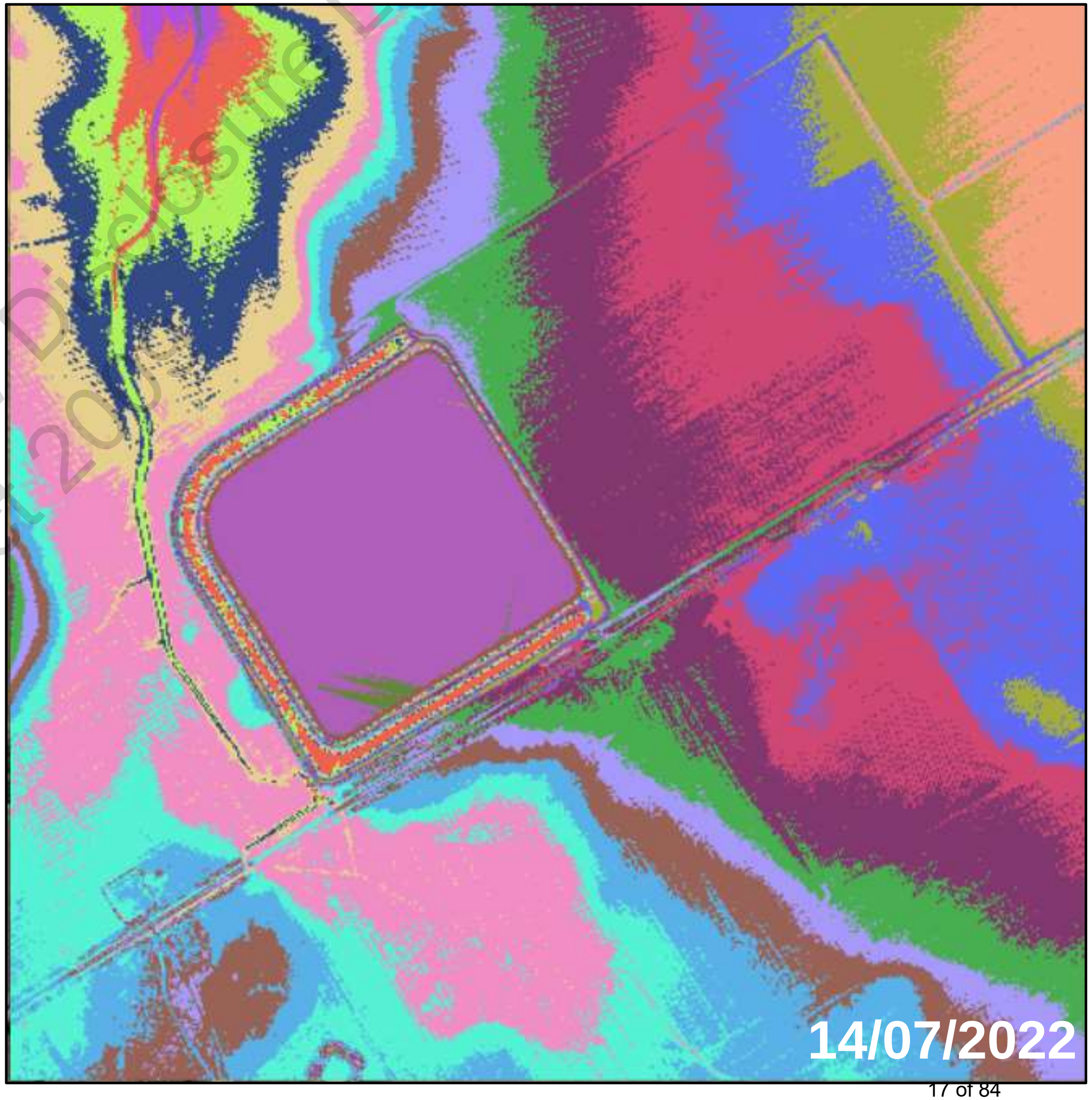
- area surveyed twice
  - 14 July 2022
  - 7 August 2022
- initially submission was a composite of the July & August acquisitions
- latest submission based only on July acquisition

Tiles

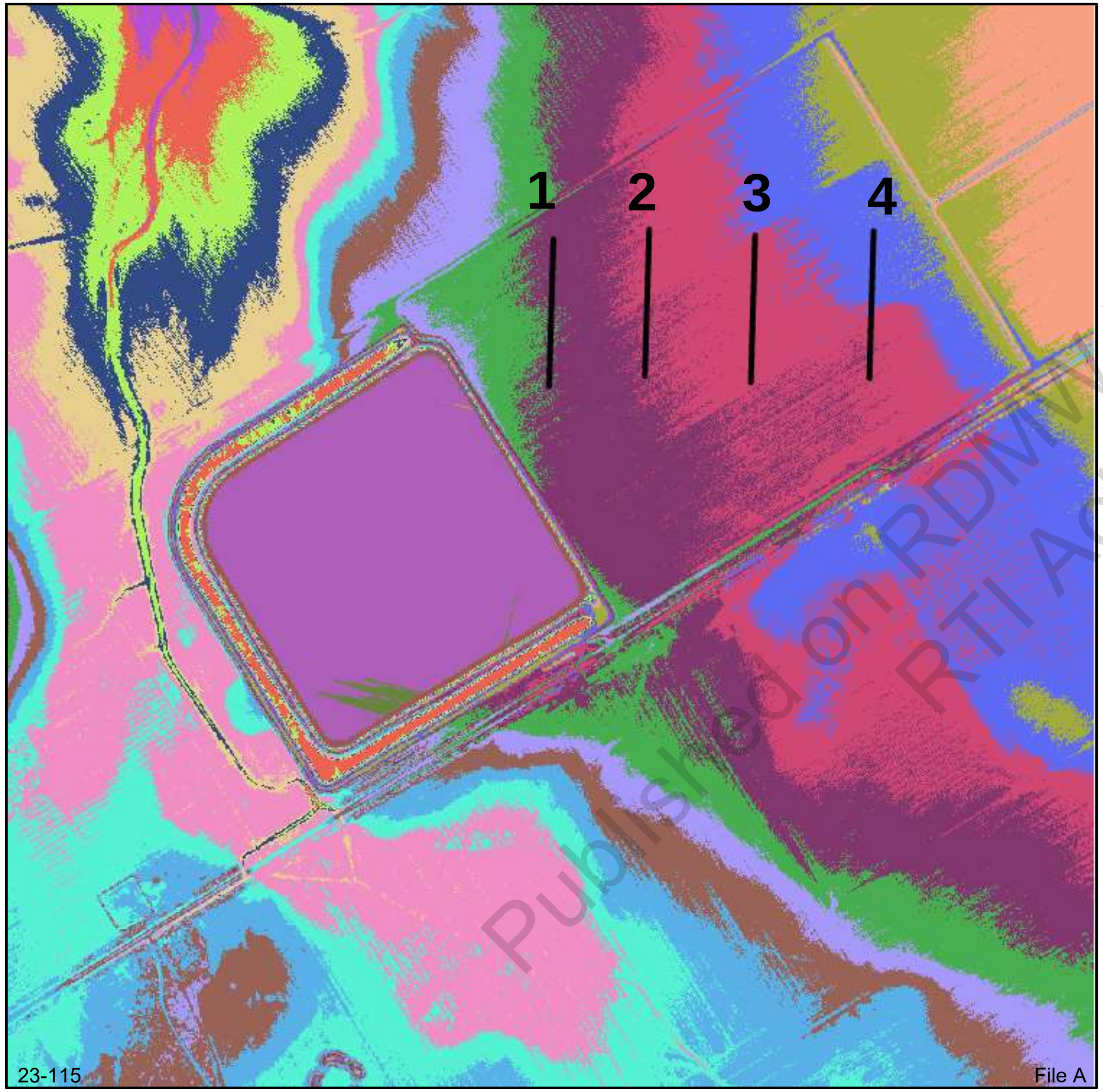
Flight lines

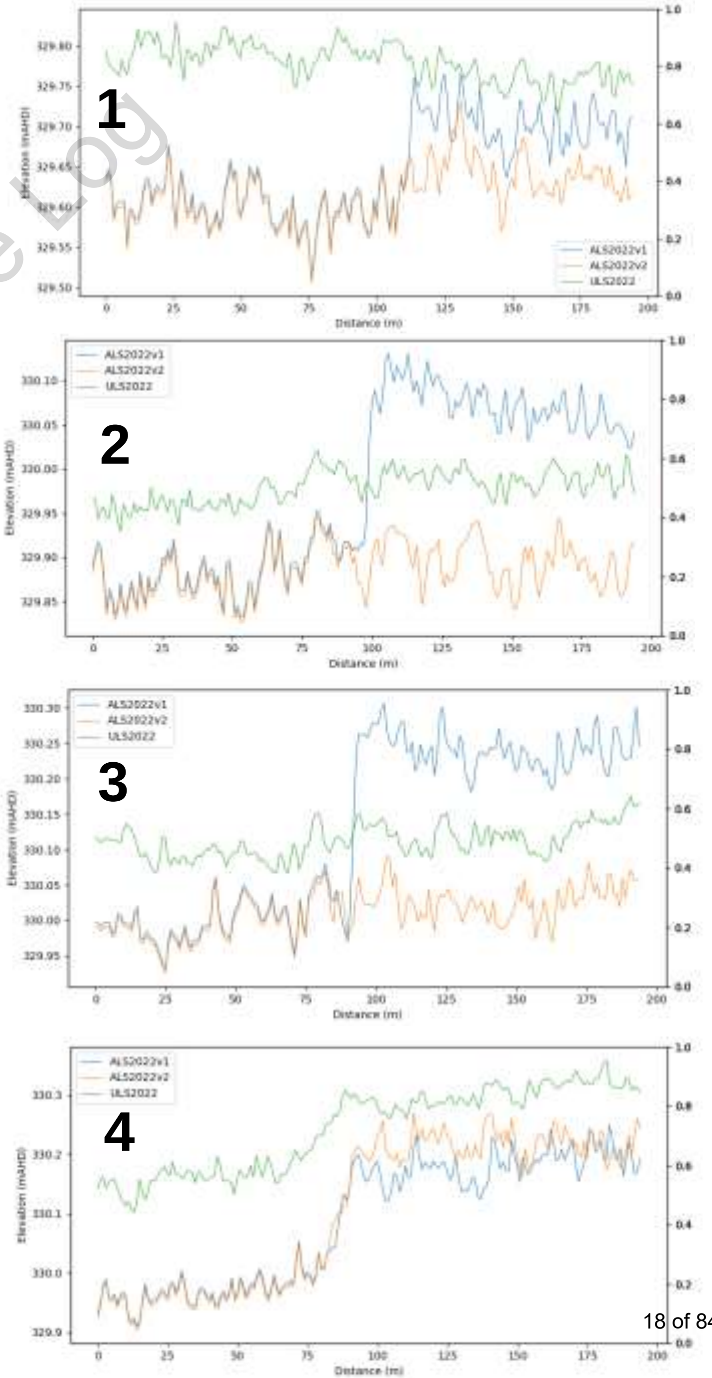
Data submissions





Data submissions + drone





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2. Susceptibility mapping - options

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Context

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Purpose

1. To identify areas that are more susceptible to change

2. Assess changes in the footprint of susceptible areas

Approaches

- Simpler – based on **slope classification**

- Complex – based on **drainage and flow accumulation**

Simple - slope based method

- examples shown are at three different grid scales – 50m, 25m and 10m
- calculated based on elevation difference from surrounding cells
- classes - primarily based on landholder feedback and knowledge

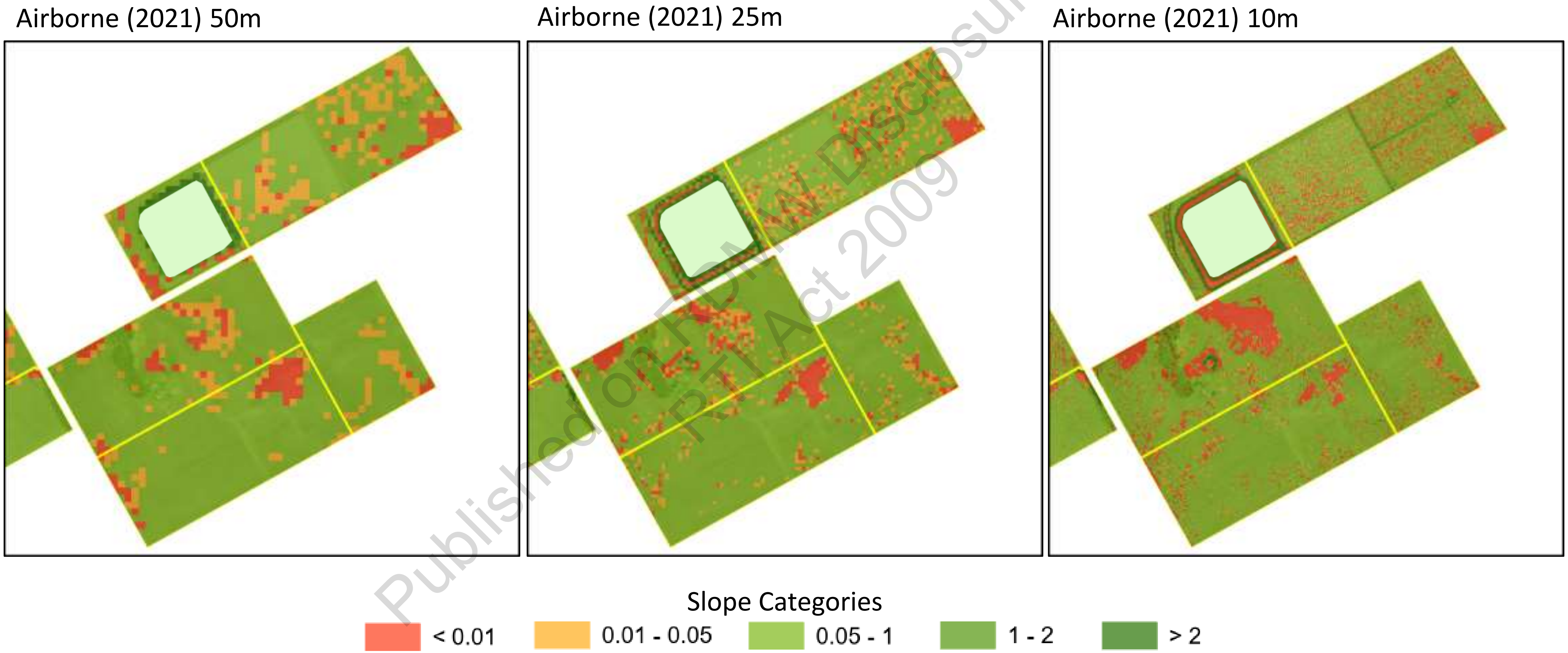
Slope category (%)	mm/km	Rationale	Susceptibility
< 0.01	< 100	Minimum viable dryland slope	Very high
0.01 – 0.05	100 – 500	Minimum viable irrigation slope	High
0.05 – 1	1000	Moderate slope	Moderate
0 – 2	2000	High slope	Low
> 2	> 2000	Very high slope	Very low

Slope based method – example

s4(6) Personal inform - Weroona

Slope based method – example

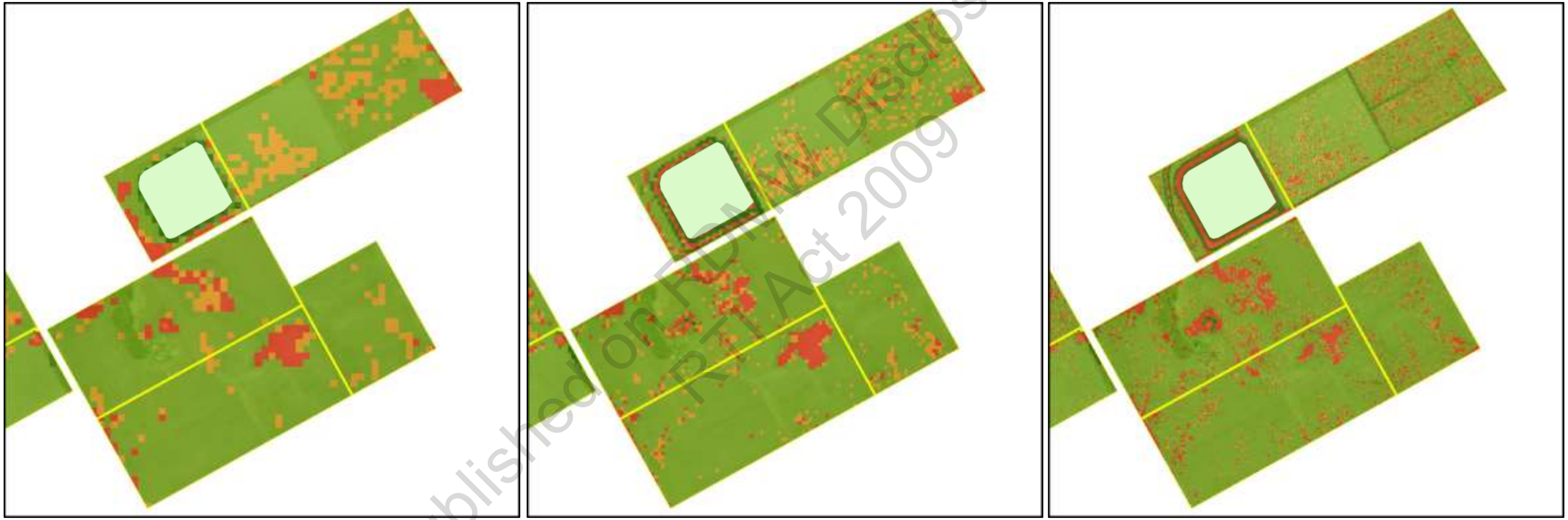
4(6) Personal infor - Weroona



Slope based method – example

4(6) Personal inform - Weroona

Airborne (2020) 50m　　Airborne (2020) 25m　　Airborne (2020) 10m



Slope Categories

< 0.01 | 0.01 - 0.05 | 0.05 - 1 | 1 - 2 | > 2

Slope based method – example

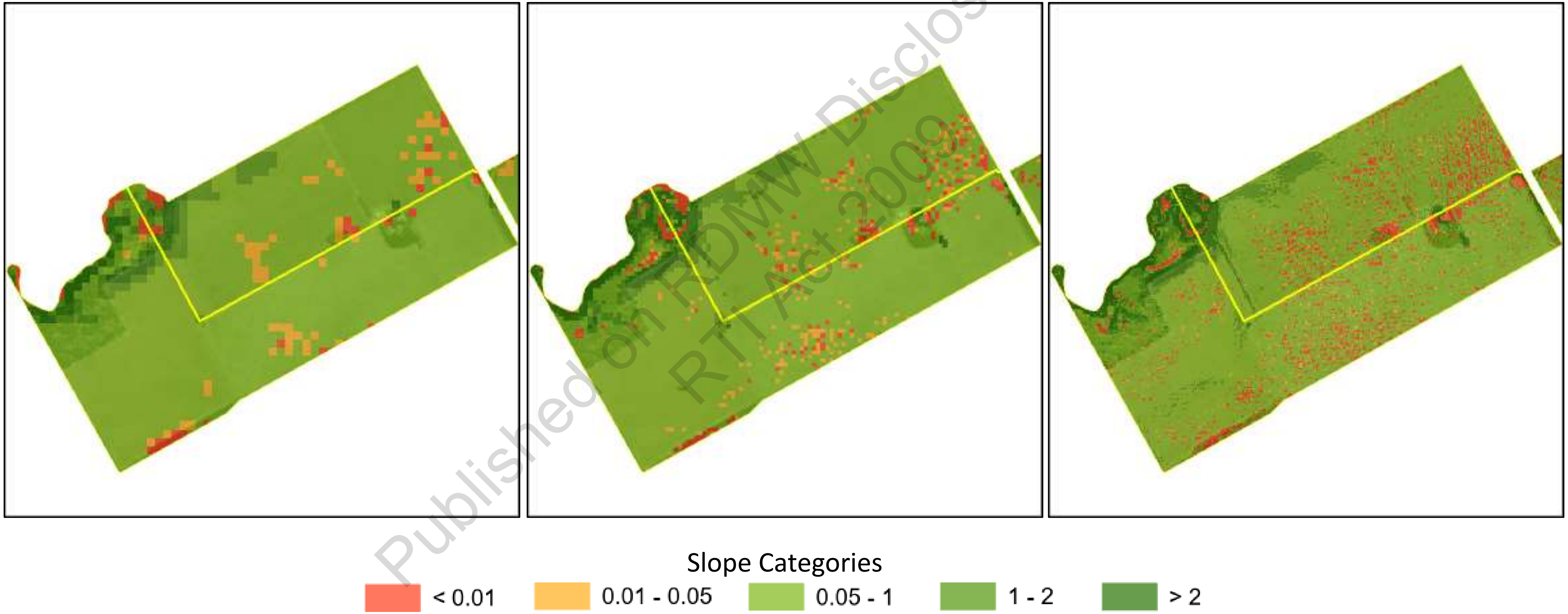
4p4(6) Personal informa - Weemalah

Slope based method – example

4p4(6) Personal informa

Weemalah

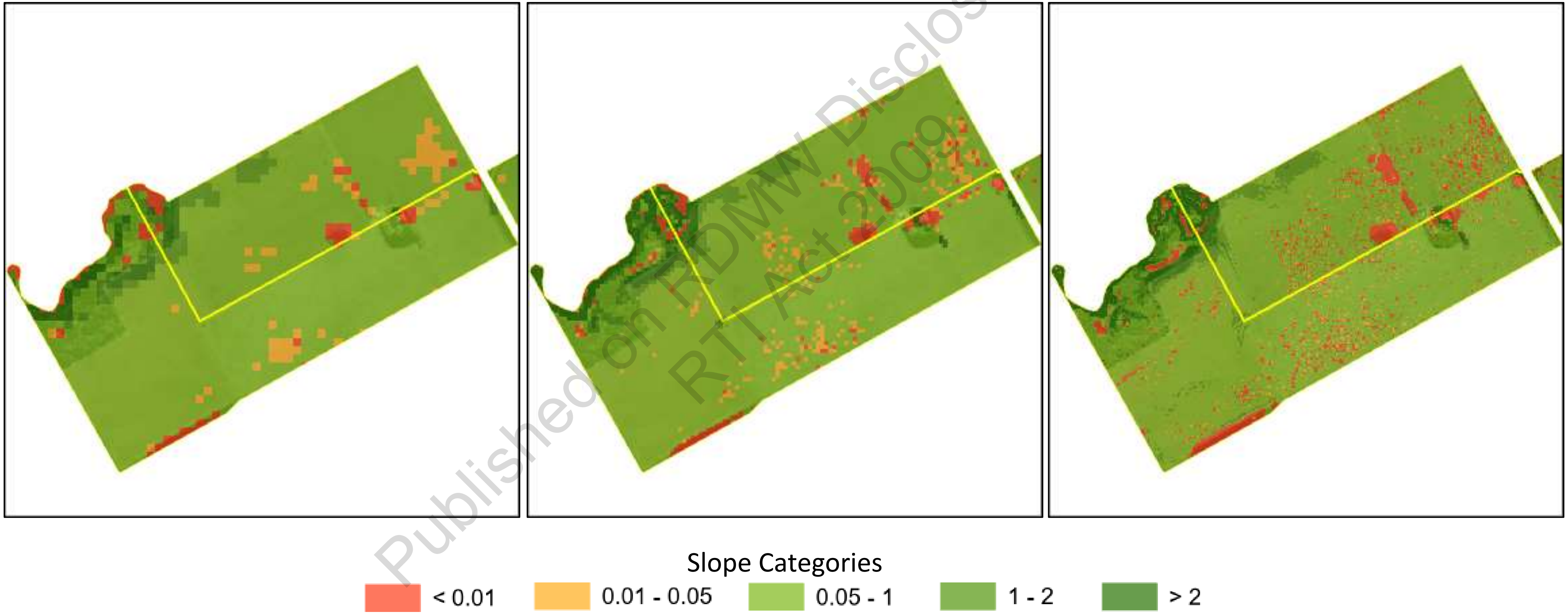
Airborne (2022) 50m | Airborne (2022) 25m | Airborne (2022) 10m



Slope based method – example

4p4(6) Personal informa Weemalah

Airborne (2020) 50m   Airborne (2020) 25m   Airborne (2020) 10m



Slope based method – feedback?

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- are the slope classes reasonable?
- what scale is most useful for the susceptible areas – 50m, 25m or 10m?
- does the mapping highlight key areas of concern for you?

Complex - flow based method

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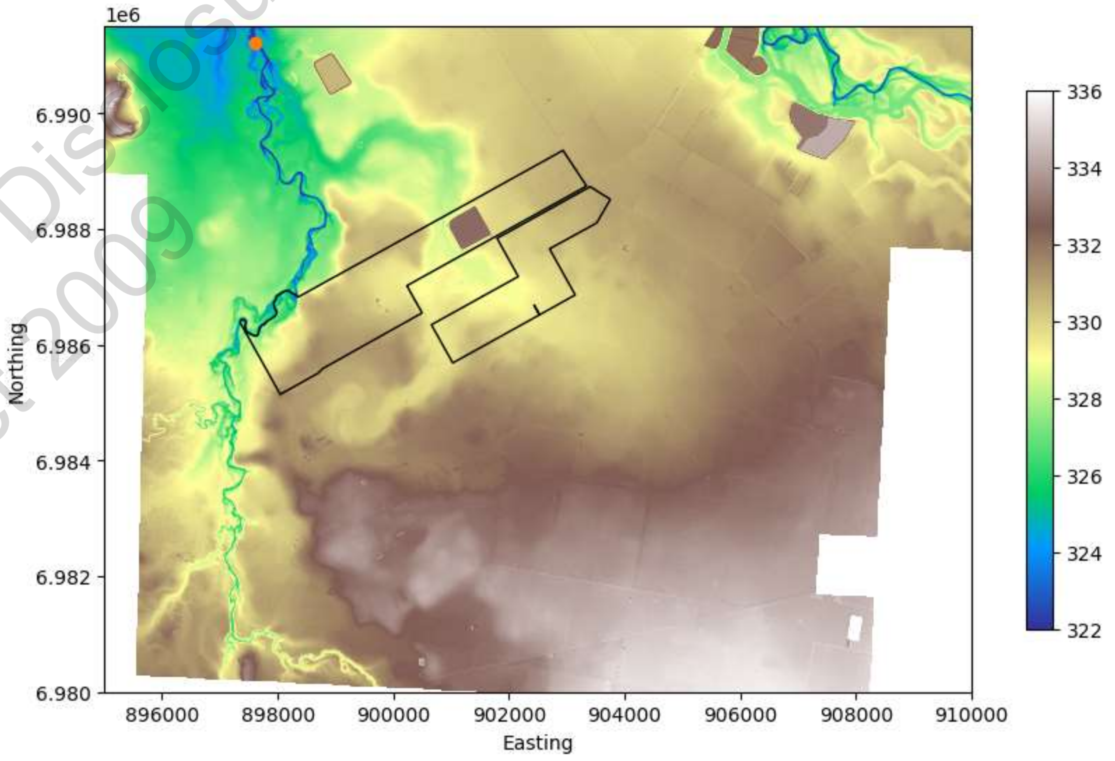
- Flat areas where water can sit for long periods of time are the most sensitive to change
- Changes to the drainage in/around these areas may impact yield/productivity
- Most susceptible during wet periods/after a rainfall event



Inundation model - boundary conditions

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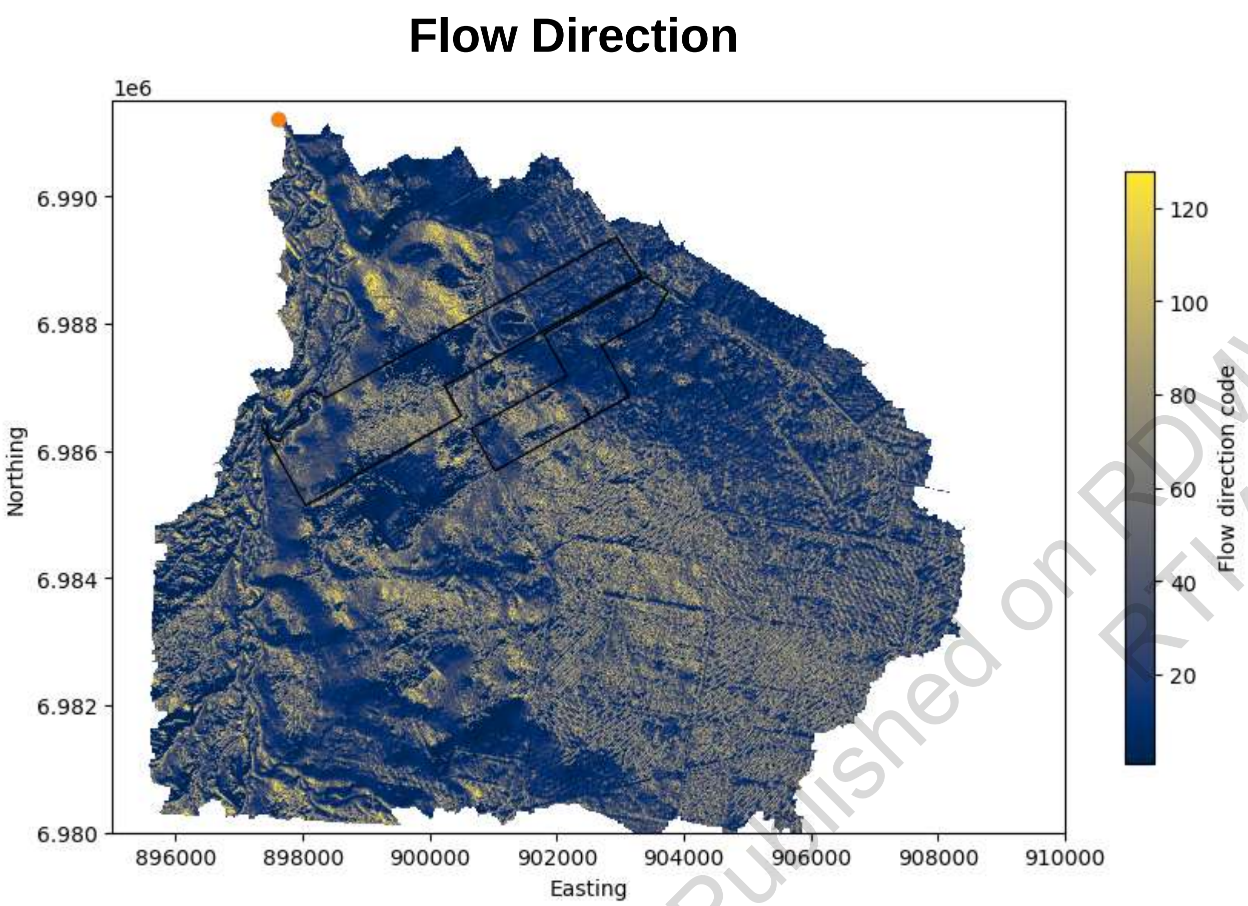

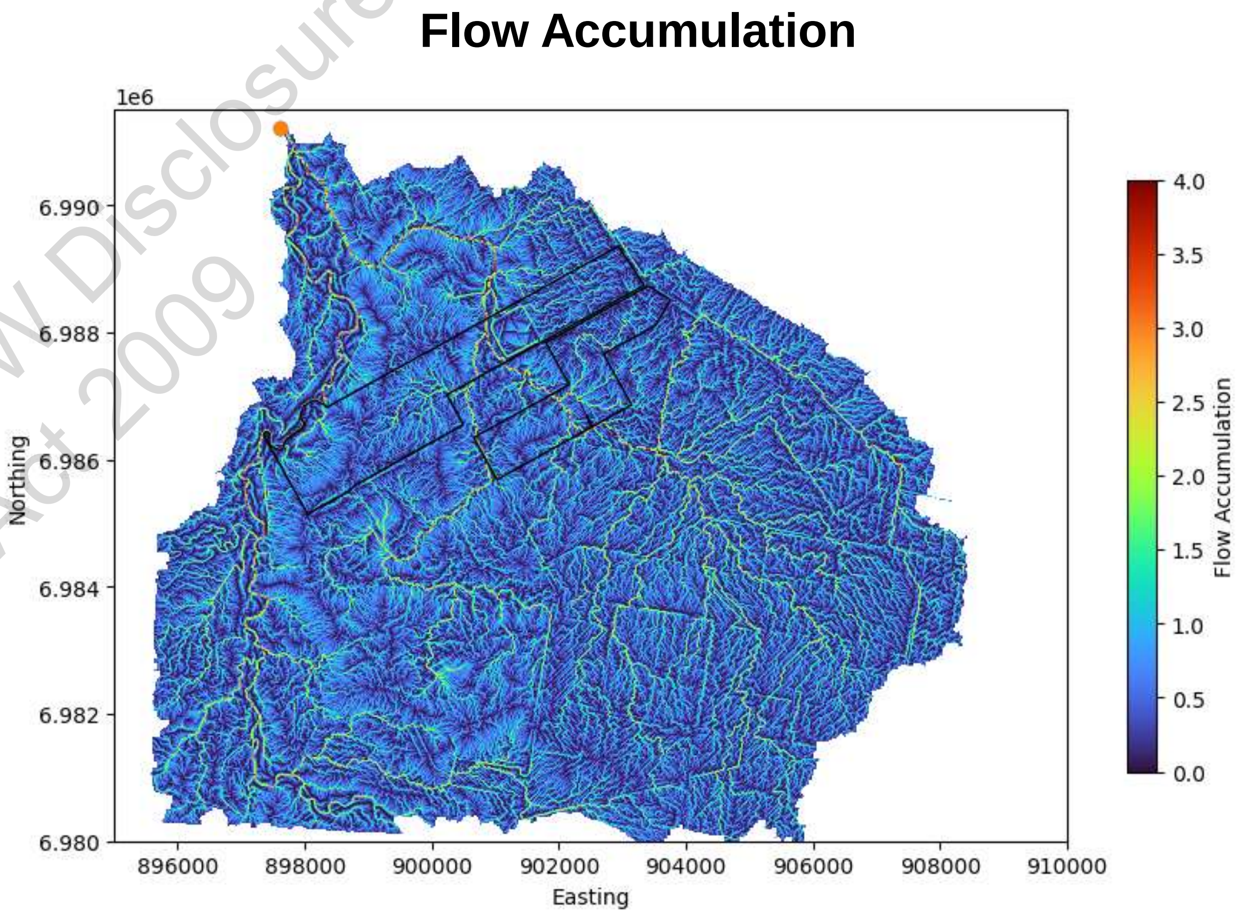

Inundation Model- testing different scenarios

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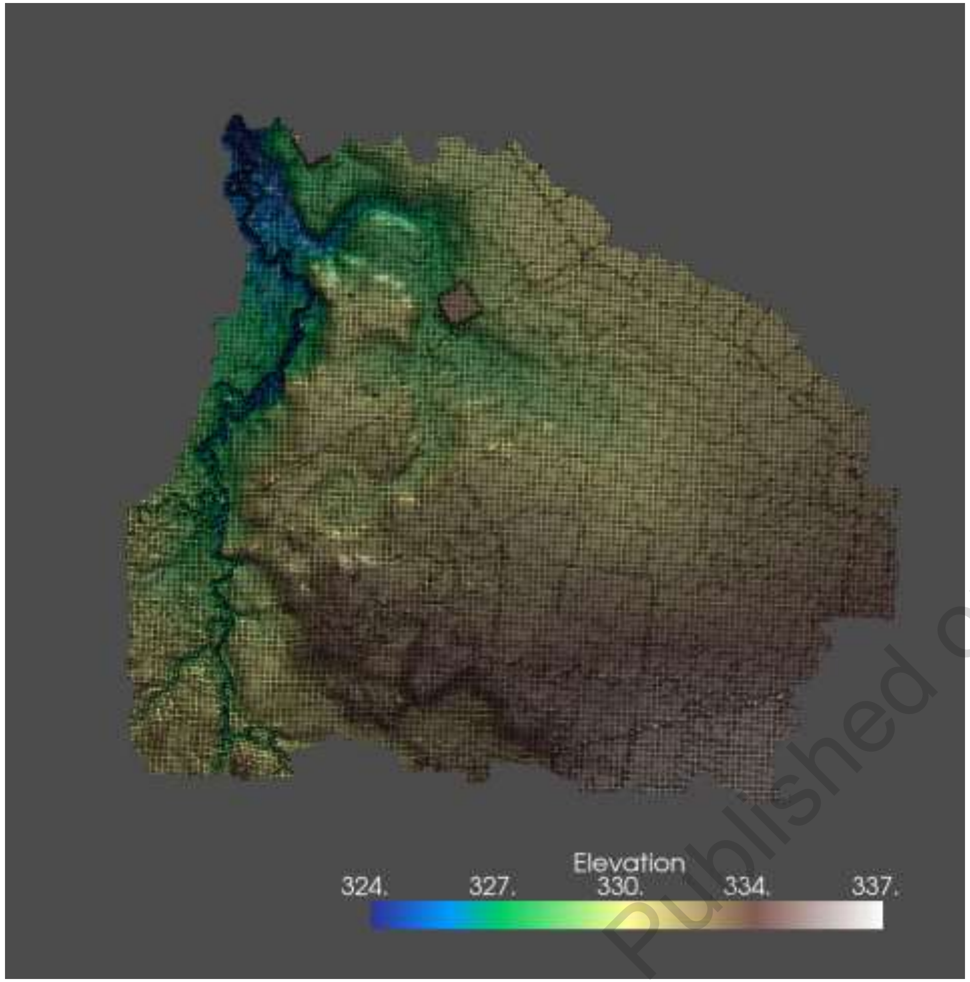

Parameter	Low case	High case
Rainfall intensity	30 mm/h	100 mm/h
Initial soil moisture content	20%	100%
Manning’s n	0.2	0.4
Hydraulic conductivity	1.39E-06 m/day	1.39E-07 m/day

Inundation Model- testing different scenarios (2021 LiDAR)

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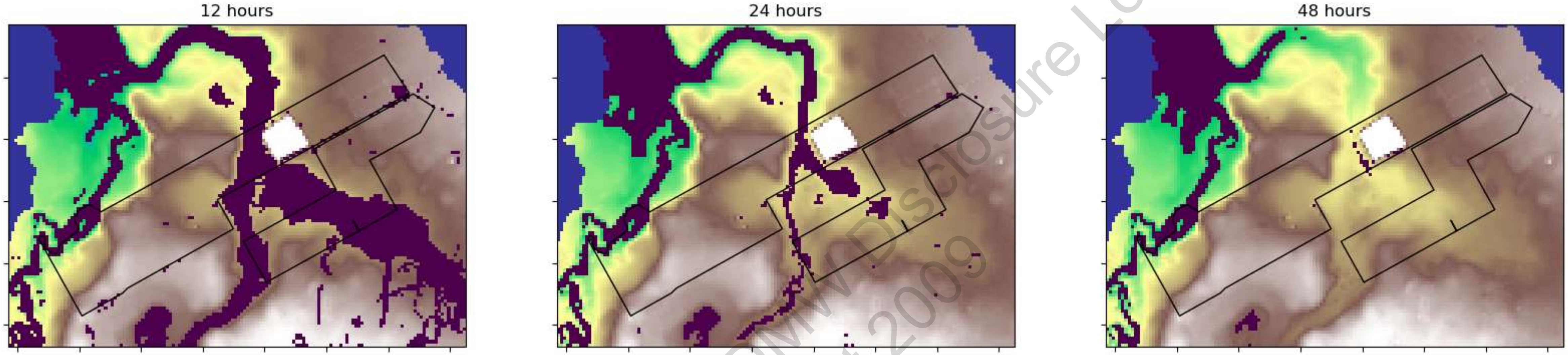
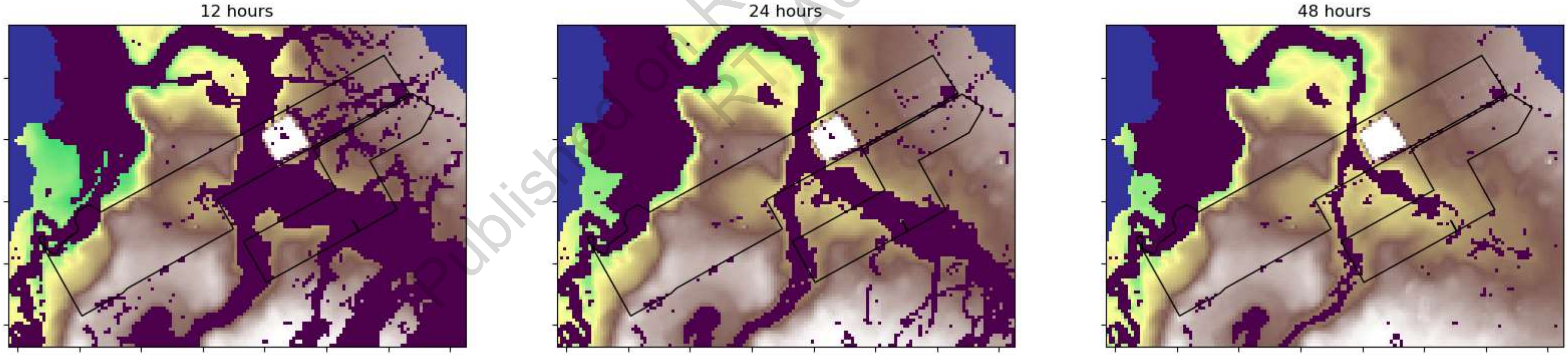
Low Case



High Case



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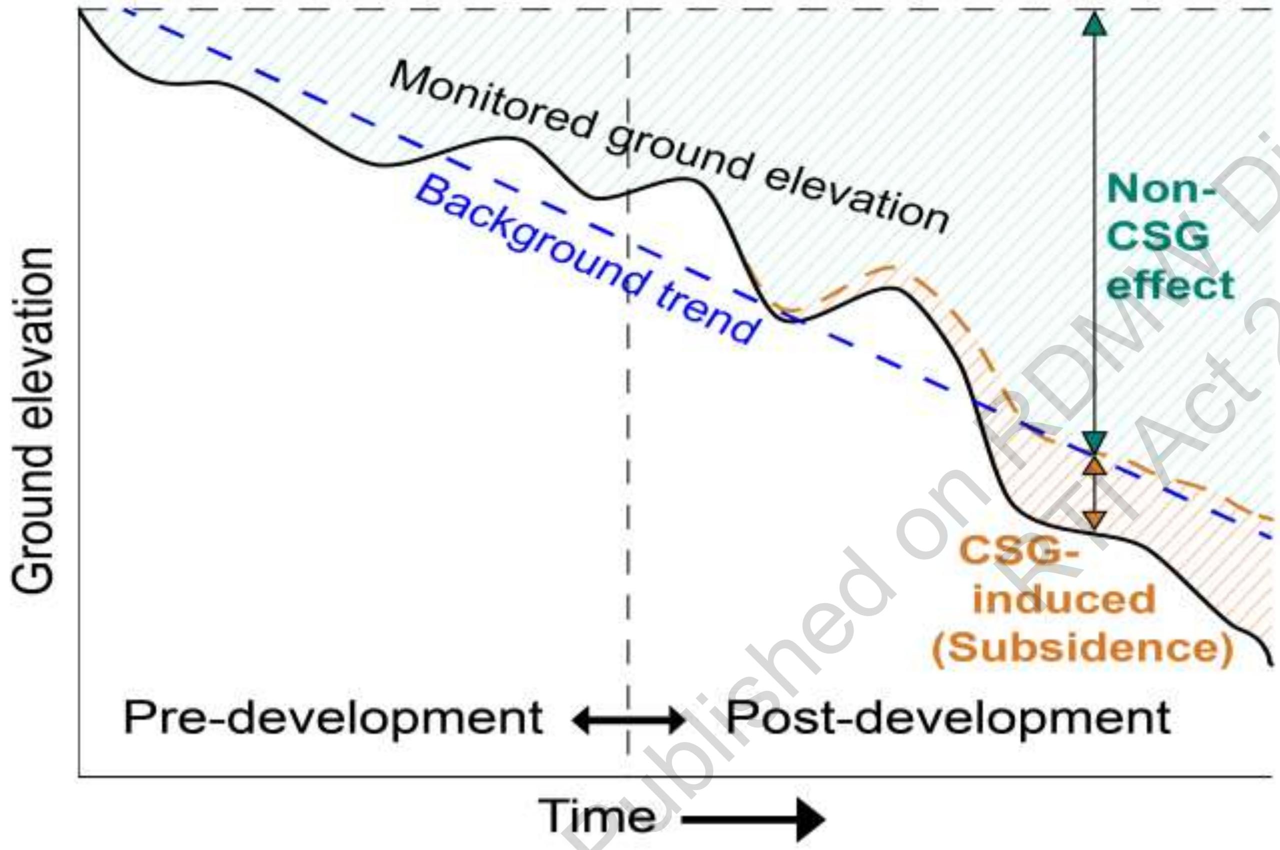
Flow based method – feedback?

- Does the mapping intuitively align with your understanding?
- Any thoughts for improving the method?

And….

- Which is a better method to reflect and measure susceptibility to change?

Ground motion vs subsidence



Ground motion **= CSG + non-CSG**

- **Non-CSG factors**
  - Natural variability: Soil shrink/swelling with rainfall etc
  - Reworking, ground filling, releveling
  - Groundwater extraction

Subsidence **= CSG only**

Exploring ground motion

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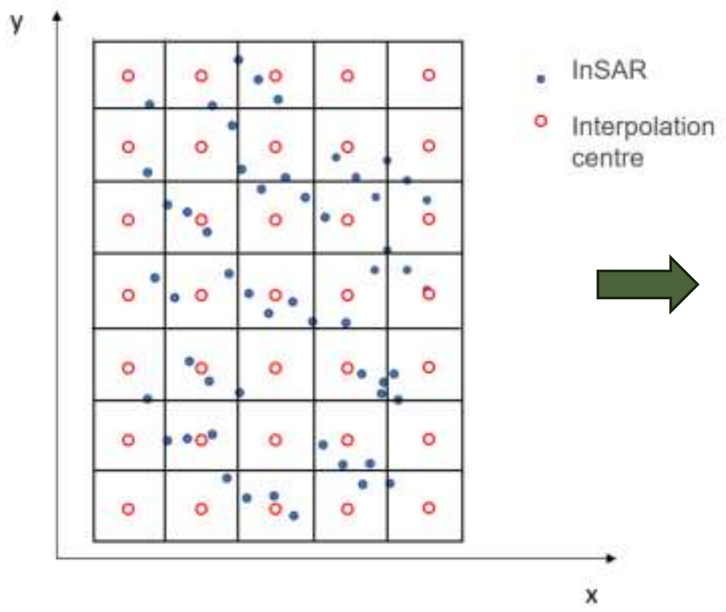

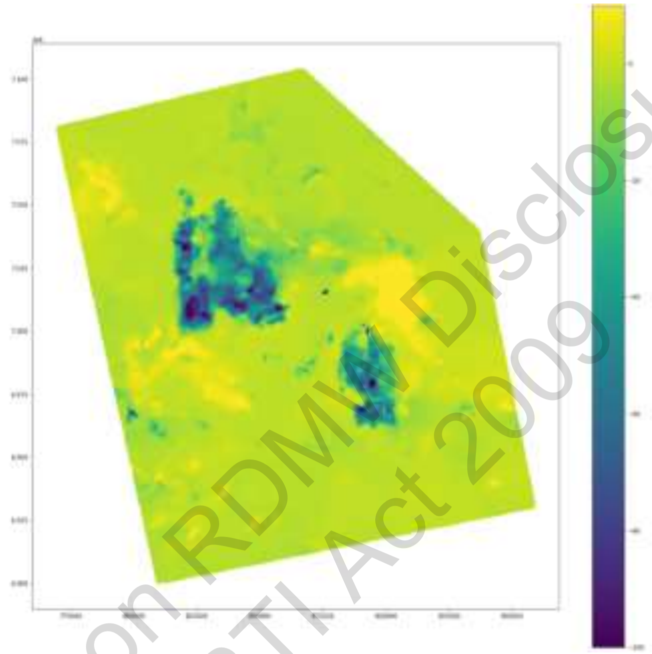

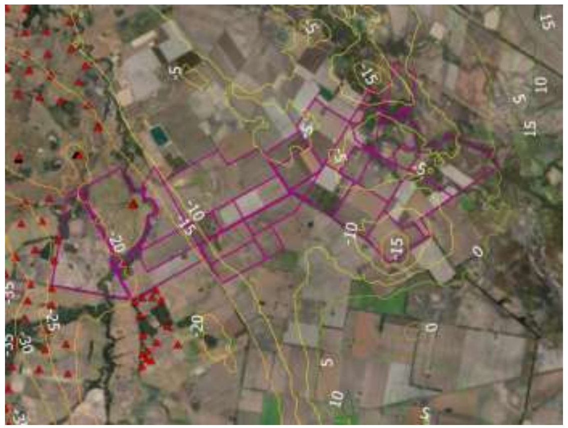

Training

Interpolation model← Input with ground motion and oblique geographic coordinates of InSAR points to machine learning algorithm (extra tree)

Interpolation

Input oblique geographic coordinates of interpolation centres → trained interpolation model → output the interpolated ground motion

Ground motion pattern 09/2015 to...

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Challenges

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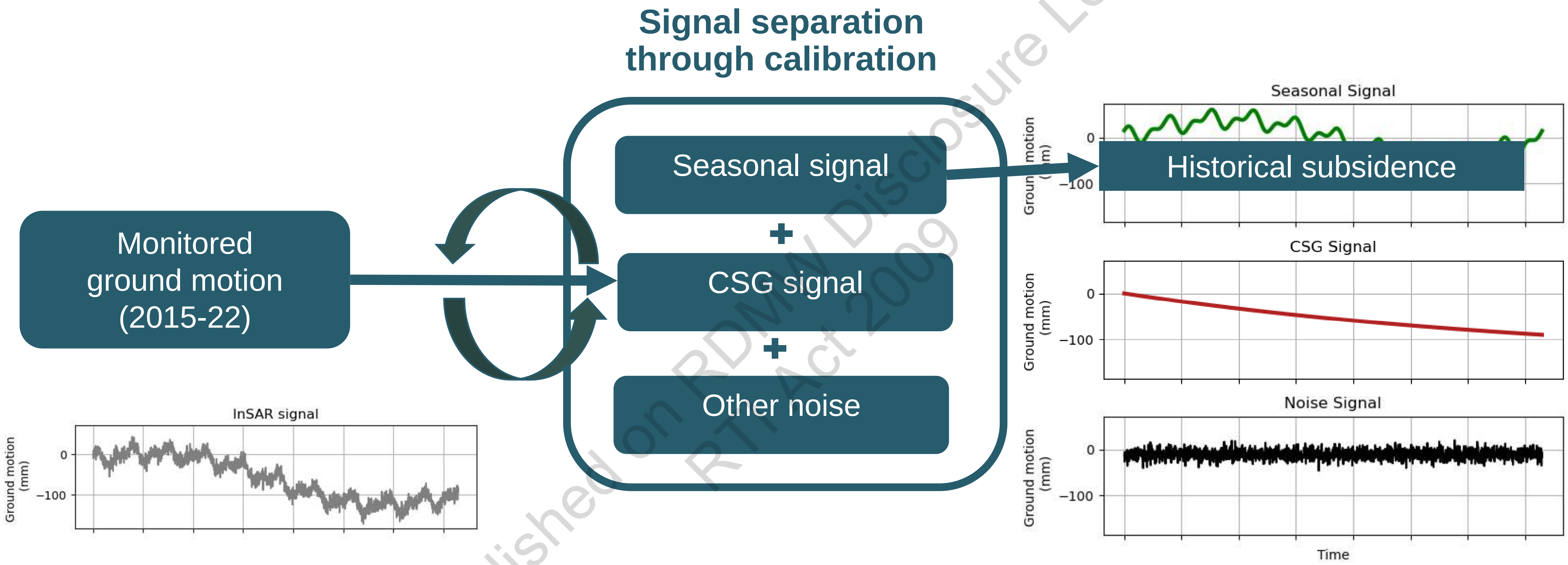
- Only ground motion can be directly monitored/observed and not the subsidence – although in closer to CSG wells subsidence is the dominant cause

- Monitored/observed ground motion is not available everywhere in the Condamine Alluvium

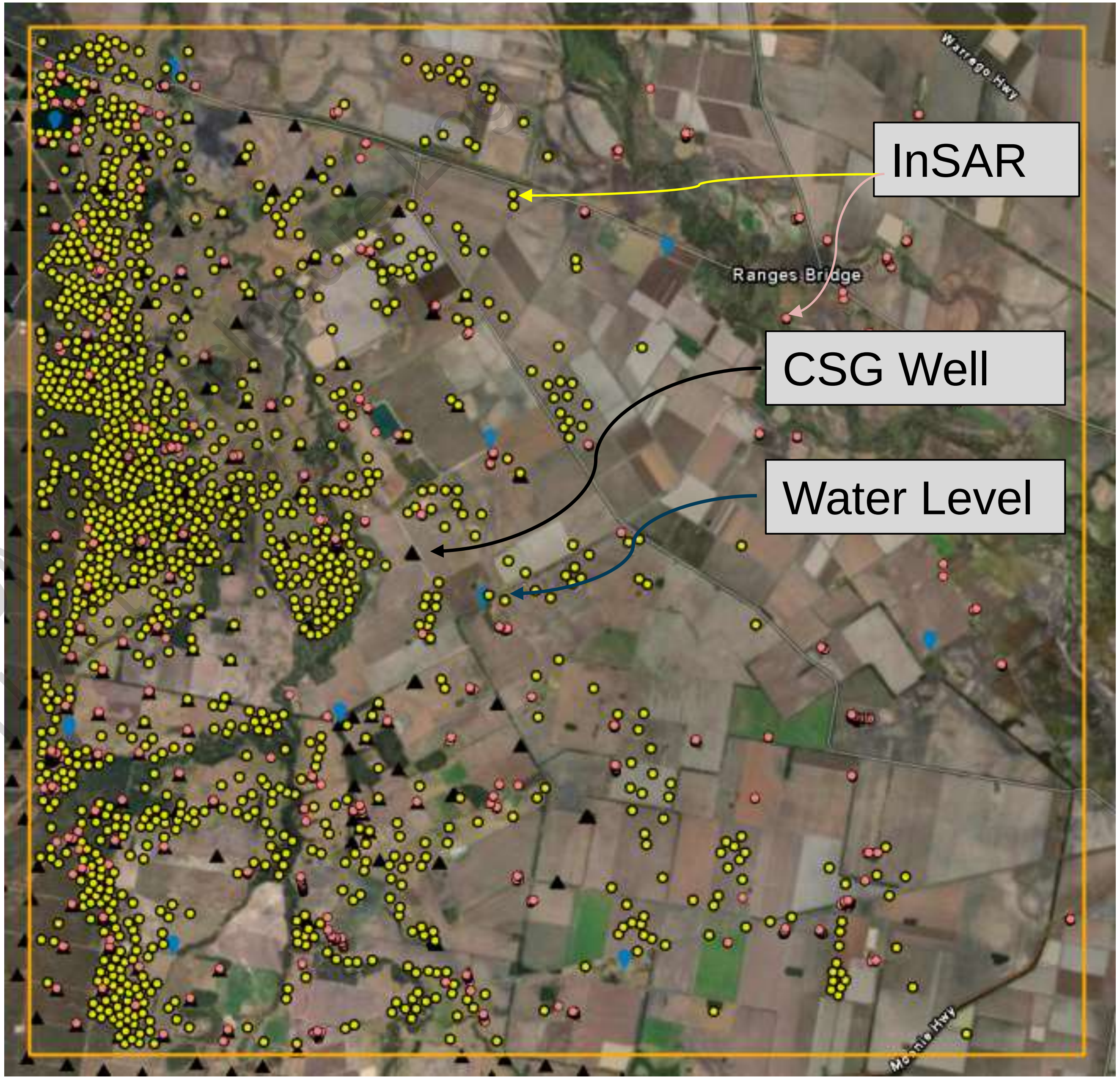
- Monitored or observed ground motion is not available before 2015

So, the way forward…..



Calibration targets

- 3169 InSAR points with timeseries
- 189 Wells with historical monthly water production
- 18 Water Level Monitoring sites with >monthly data
- 213566 observations



History matching

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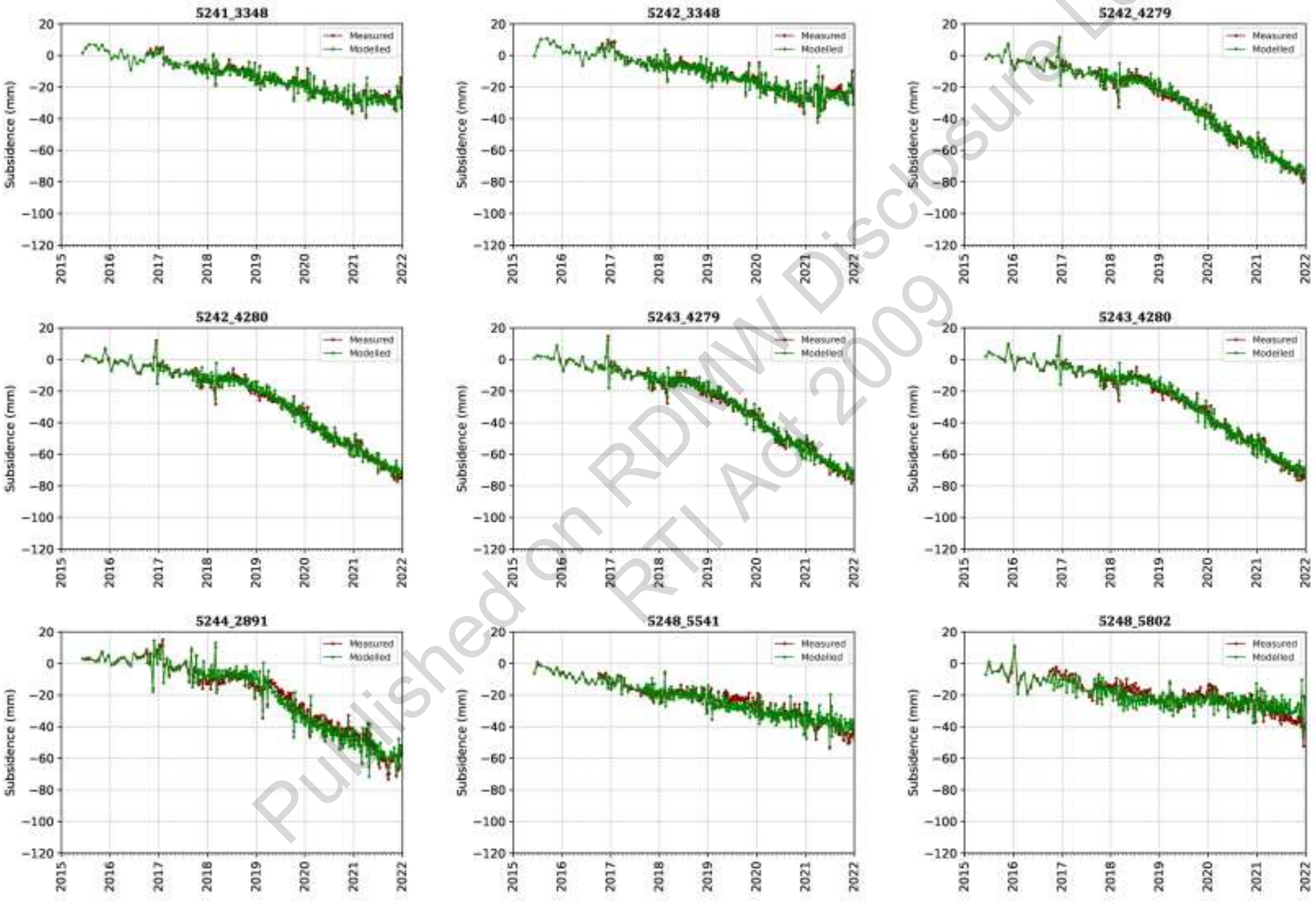

Subsidence pattern (1995 - Current)

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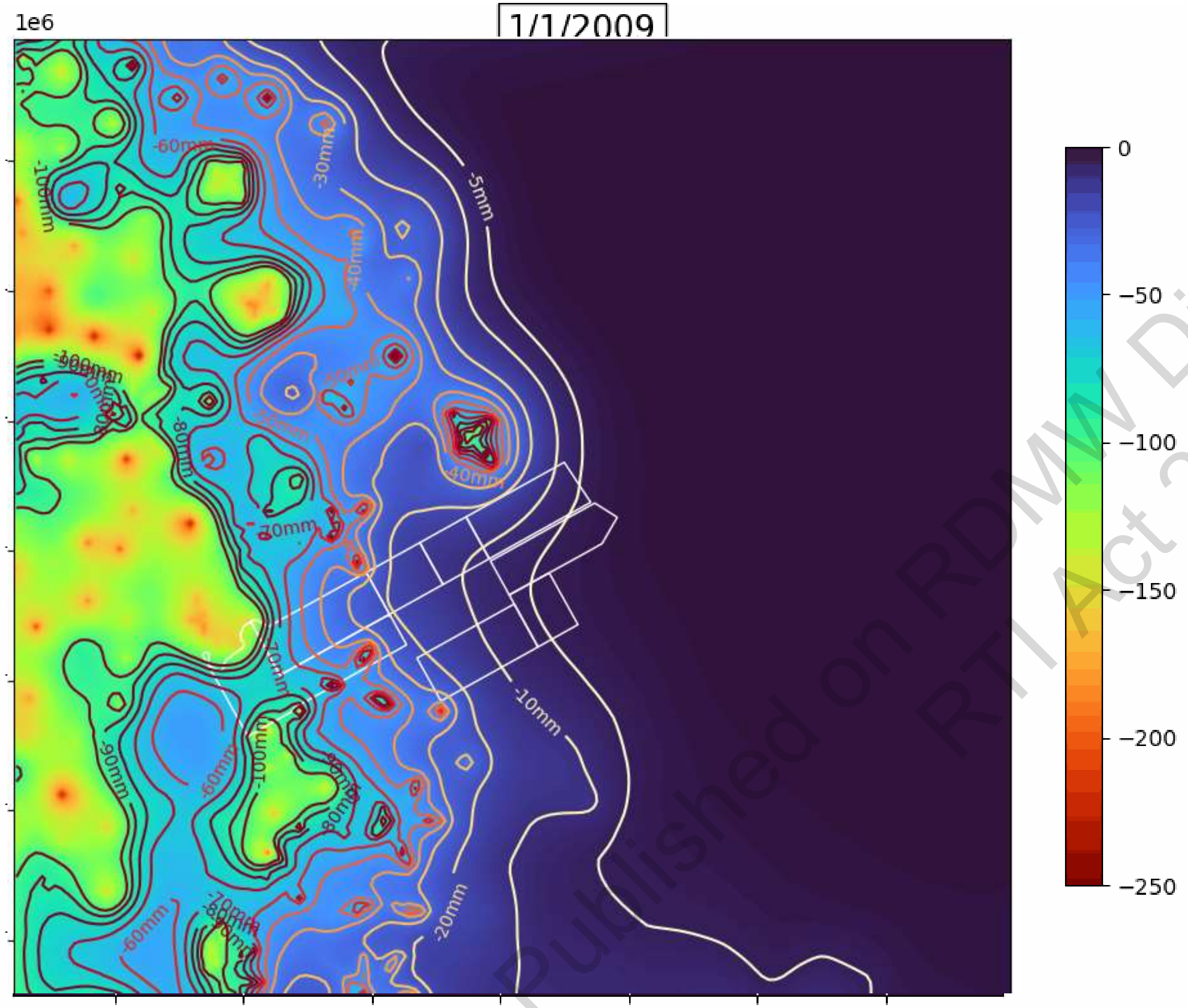
Historical subsidence 2009-2022

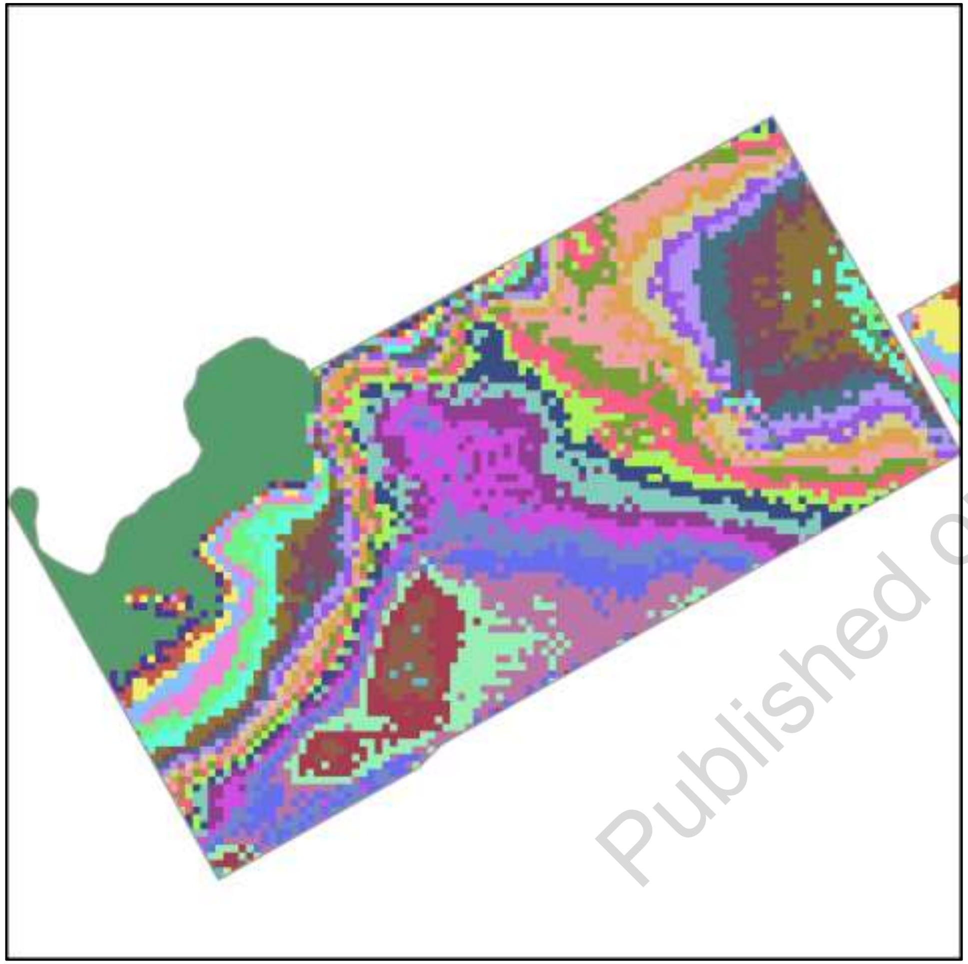


Captures all existing vertical and directional wells

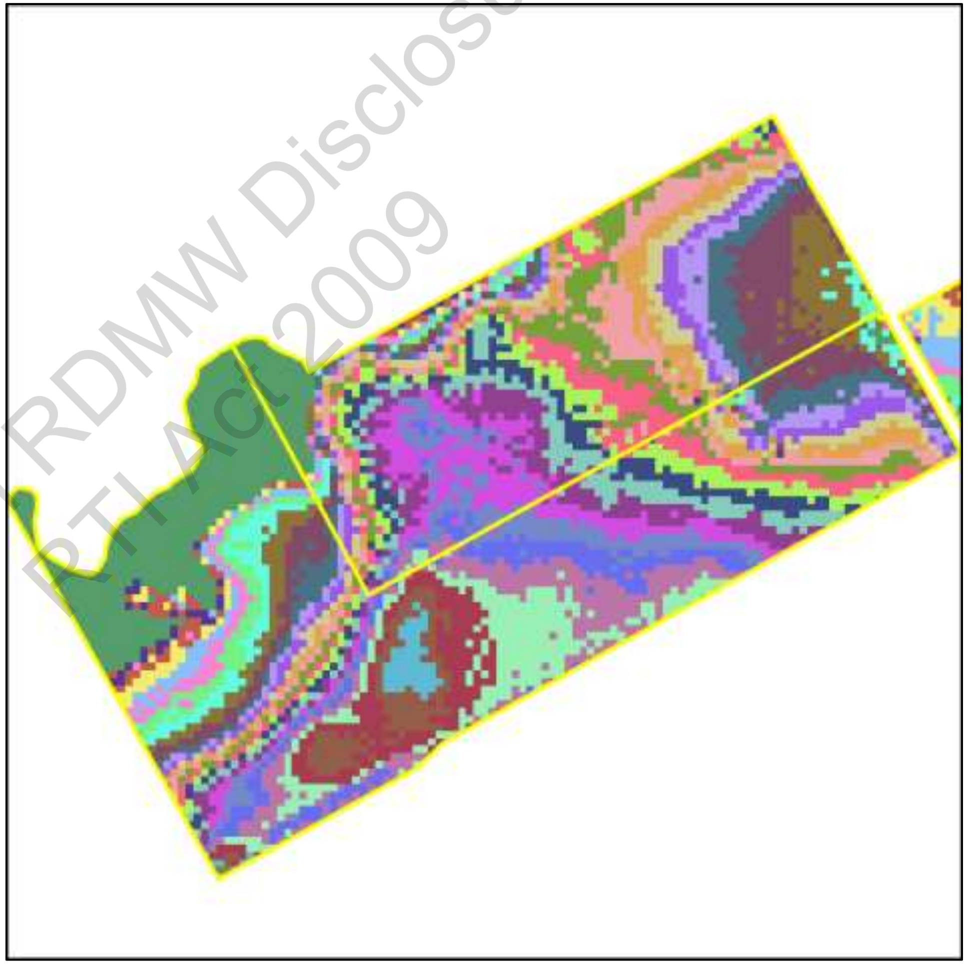
This is only one realisation – we will generate many more to represent uncertainty

Attribute comparison ('Weemalah')

2021 DEM Landform with subsidence



2021 DEM Landform without subsidence



This is only one realisation – we will generate many more to represent uncertainty

Attribute comparison ('Weemalah')

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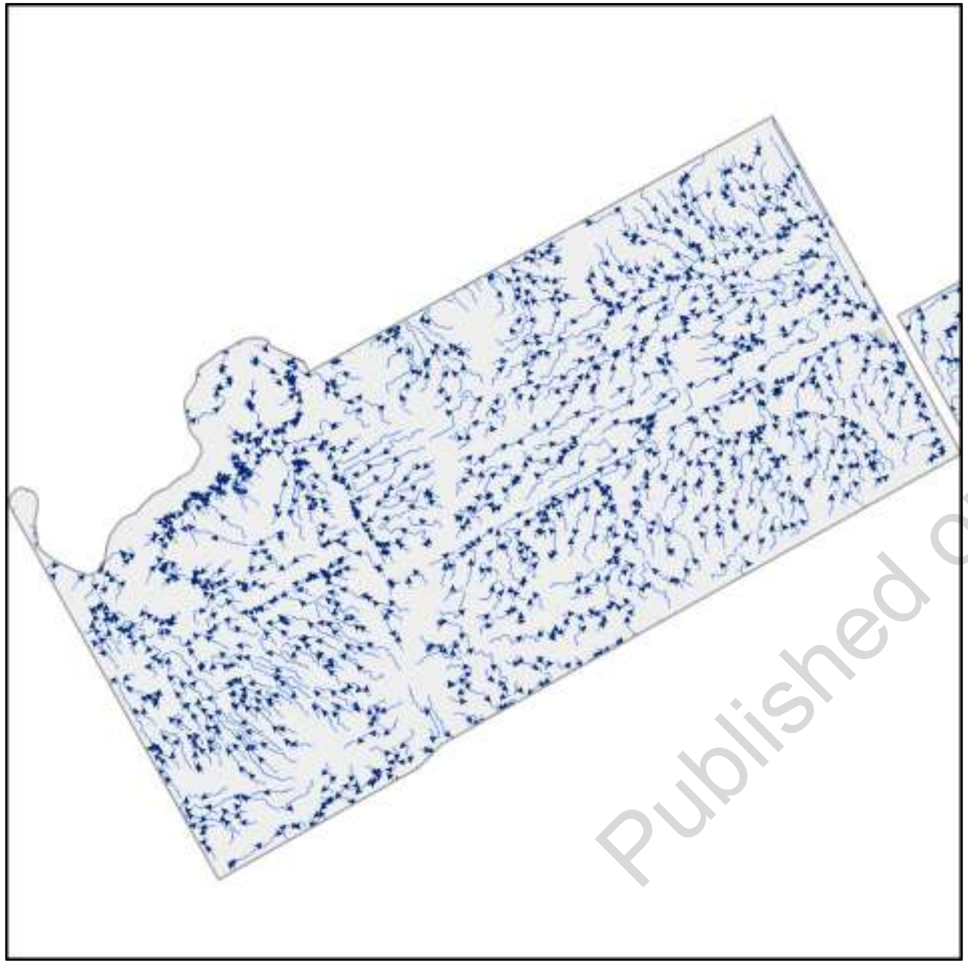
2021 DEM with subsidence - Drainage



2021 DEM without subsidence – Drainage

This is only one realisation – we will generate many more to represent uncertainty

Key learnings and conclusions

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- there is no measured, and reliable, ground motion data from before 2015
- signal separation and modelling is necessary to determine historical subsidence
- ground motion below 5 mm is difficult and impractical to measure directly
- CSG-induced below this is overpowered by other signals
- signal separation can successfully discover the CSG-induced signal InSAR and remove other contributions
- maximum current subsidence around the pilot farms is at the southern edge of the Weemalah – ~ 120mm (from a single realisation) – corresponding to 0.004% change across the farm

4. Exploring the concept of baseline

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Key principles and rationale

1. Core purpose is to establish **reference landform** – to assess change from CSG-induced subsidence

2. Information across **multiple years** is necessary – to establish background conditions

3. **Essential** information at farm scale includes:
   - airborne LiDAR
   - concurrently collected imagery
   - reconfiguration/releveling of farms (where applicable)
   - historical subsidence at the farm

4. **Additional** information – may provide context when assessing implications or cross-verify conclusions
   - soil mapping
   - cropping yield
   - remote sensing products

Steps for baseline assessment

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Step 1: Identify when CSG-subsidence of more than 5 mm first occurs at the farm

'Reference Year'

⇩

Step 2: Determine the baseline period – 3 years prior to CSG-subsidence of 5 mm

'Baseline Period' = **Reference Year - 2 years**

⇩

Step 3: **Characterise** pre-CSG landforms from available data

Example

Year 2019 for Farm XYZ

Example

Year 2019, 2018 and 2017

Step 1: Identify the Reference Year (Options)

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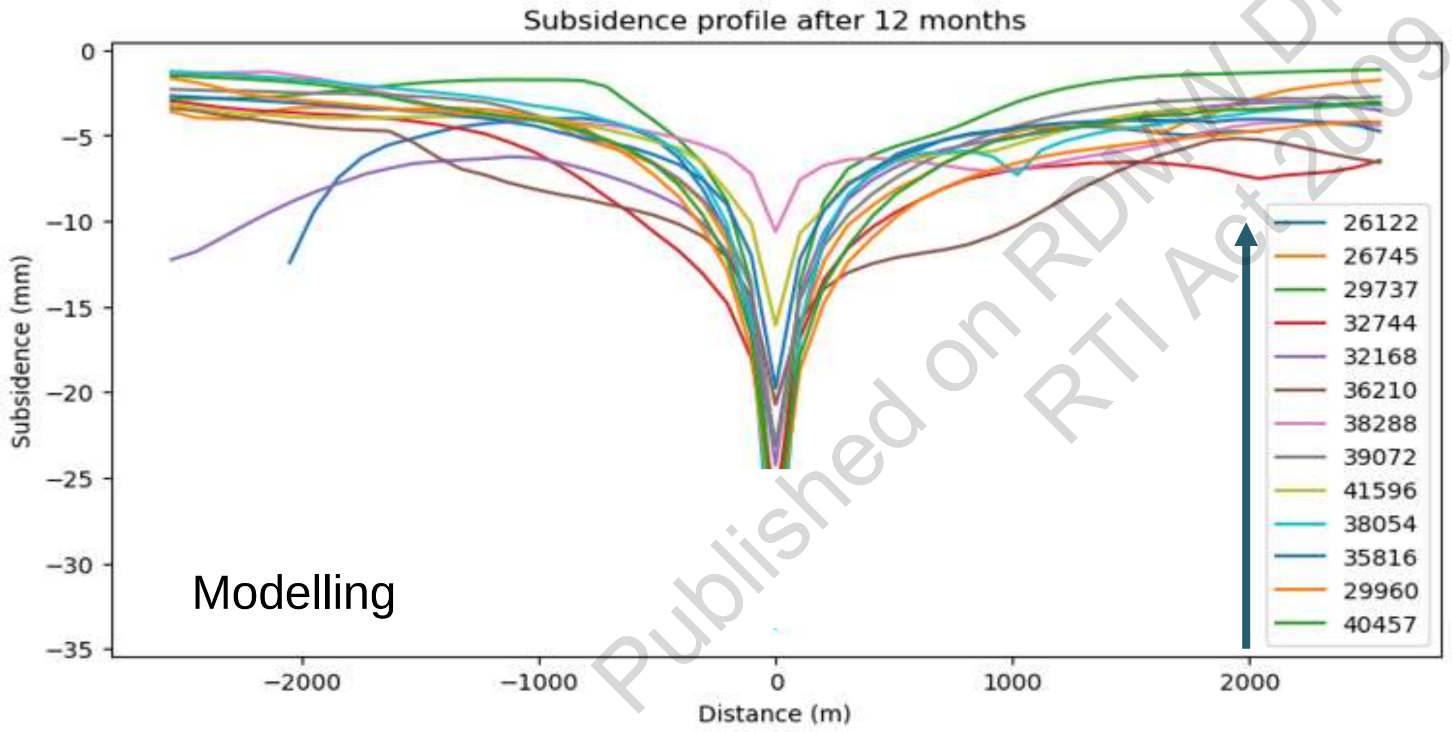
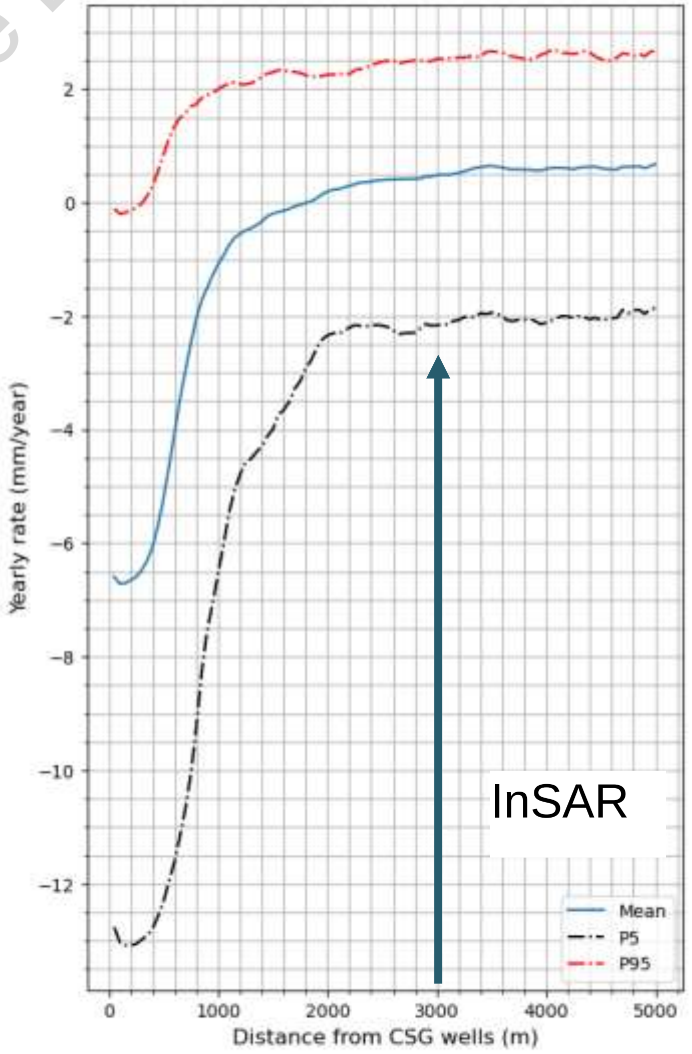
Three options for identifying the '**Reference Year'**

- distance from CSG wells
- monitoring data – InSAR
- modelling of historical subsidence

Distance from CSG wells (option)

- Modelling and monitoring suggests that 5 mm subsidence could reach to about 2-3 km from the CSG wells within 12 months





Distance from CSG wells (option)

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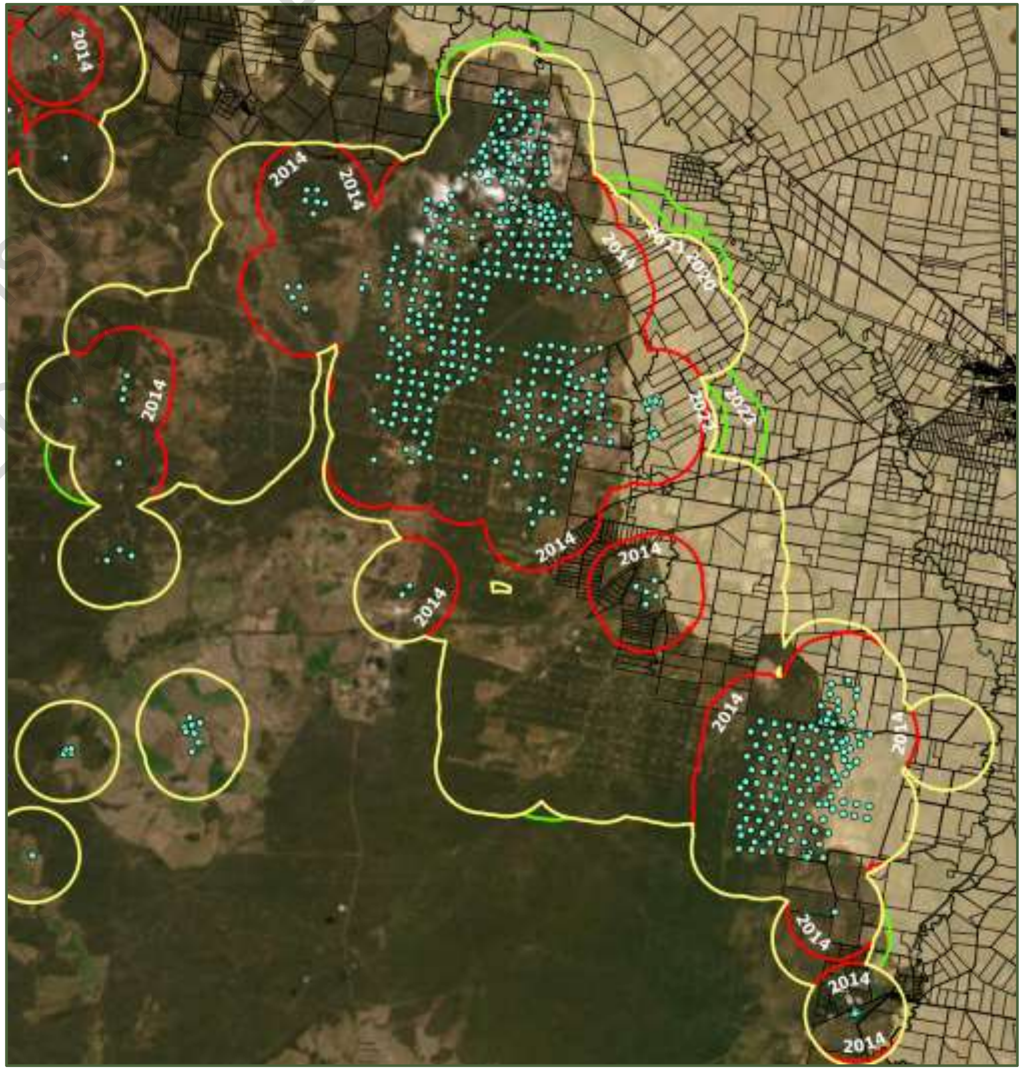
What this might look like…



Advantages

- a simple method
- transparent - all stakeholders can apply
- easy to adjust if well plans change

Disadvantages

- does not consider interference from pre-existing wells

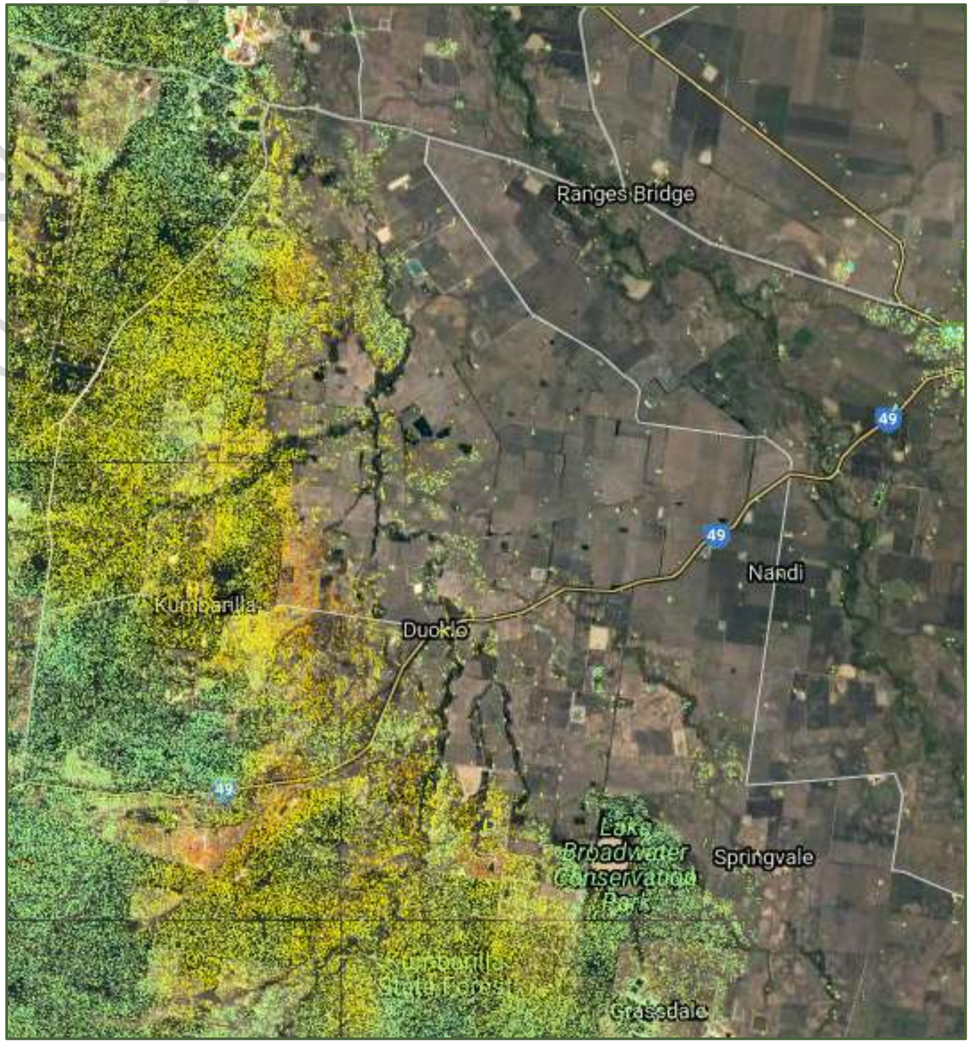
Monitoring data (option)

Advantages

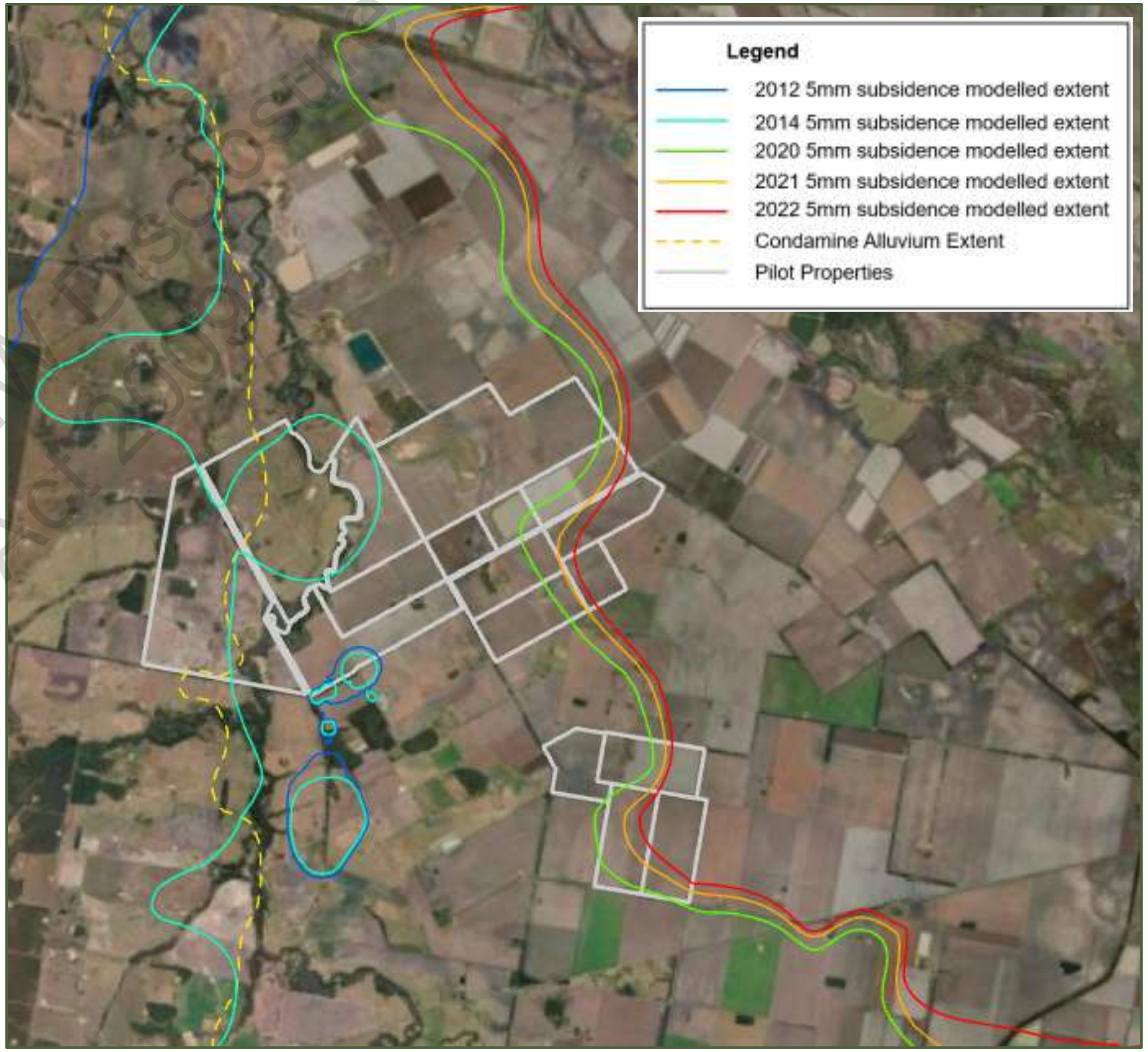
- a simple method
- transparent - data will be available for all

Disadvantages

- includes non-CSG ground motion
- not available prior to 2015



Modelled historical subsidence (option)



Advantages

- considers interference from existing wells
- includes the pre-2015 period
- calibrated to monitoring data (GW/InSAR)

Disadvantages

- a more complex method

Step 2: Which data to use for pre-CSG landforms?

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Is LiDAR available for all three **'Baseline Years'**?

Ex: 2020, 2019 and 2018

No →

Is LiDAR available for any of the years?

2020

No →

Derive all landforms from closest years' LiDAR and historical subsidence

Yes ↓ (from the first question)

Use the LiDAR to characterise landform

Yes ↓ (from the second question)

Use that LiDAR to characterise landform

Landform 1: 2020 LiDAR

↓

Generate 2 more landforms from subsequent years' LiDAR and historical subsidence

Landform 2: (2021 LiDAR) + (historical subsidence up to 2021)
Landform 3: (2022 LiDAR) + (historical subsidence up to 2022)

Reference Year ('Weroona')

Legend

- 2018 5mm subsidence modelled extent
- 2021 5mm subsidence modelled extent
- 2022 5mm subsidence modelled extent
- Pilot Properties

Reference Year: **2018**

Baseline Period: **2016-2018**

Datasets:

- LiDAR not available
- Landforms used for baseline:
- **Landform 1** = 2020 LiDAR + subsidence until 2020
- **Landform 2** = 2021 LiDAR + subsidence until 2021
- **Landform 3** = 2022 LiDAR + subsidence until 2020

Reference Year ('Weemalah')

Reference Year: **2010**

Baseline Period: **2010-2008**

Datasets:

- LiDAR not available
- Landforms used for baseline:
  - **Landform 1** = 2020 LiDAR + subsidence until 2020
  - **Landform 2** = 2021 LiDAR + subsidence until 2021
  - **Landform 3** = 2022 LiDAR + subsidence until 2020

Legend

- 2010 5mm subsidence modelled extent
- 2012 5mm subsidence modelled extent
- 2014 5mm subsidence modelled extent
- Pilot Properties

Step 3: Attributes for measuring change

Dryland fields

- change to susceptible areas – spatial distribution and total area
- change to drainage pattern

Irrigation fields

- change to susceptible areas – spatial distribution and total area
- change to drainage pattern
- change in slope along the furrows
- change in slope along the head ditch and tail drain

Baseline information package

- Identification of the last year when the farm has less than 5 mm of predicted subsidence on the property (‘**Reference Year’**)
- For the three years prior to the Reference Year (***‘Baseline Period’***):
  - LiDAR data – including metadata such as date of capture, etc
  - concurrently collected aerial Imagery
  - 10 cm contours of landform elevation
  - drainage maps
  - susceptibility maps
  - selected cross sections
    - Irrigation – tail drain, head ditch, three along the furrow and three across the furrows
    - Dryland – three along the natural slope and three across
- Historical subsidence – yearly snapshots

Ex: Weroona

Legend

- 2018 5mm subsidence modelled extent
- 2021 5mm subsidence modelled extent
- 2022 5mm subsidence modelled extent
- Pilot Properties

Ex: Aerial imagery ('Weroona')

Landform surface ('Weroona')

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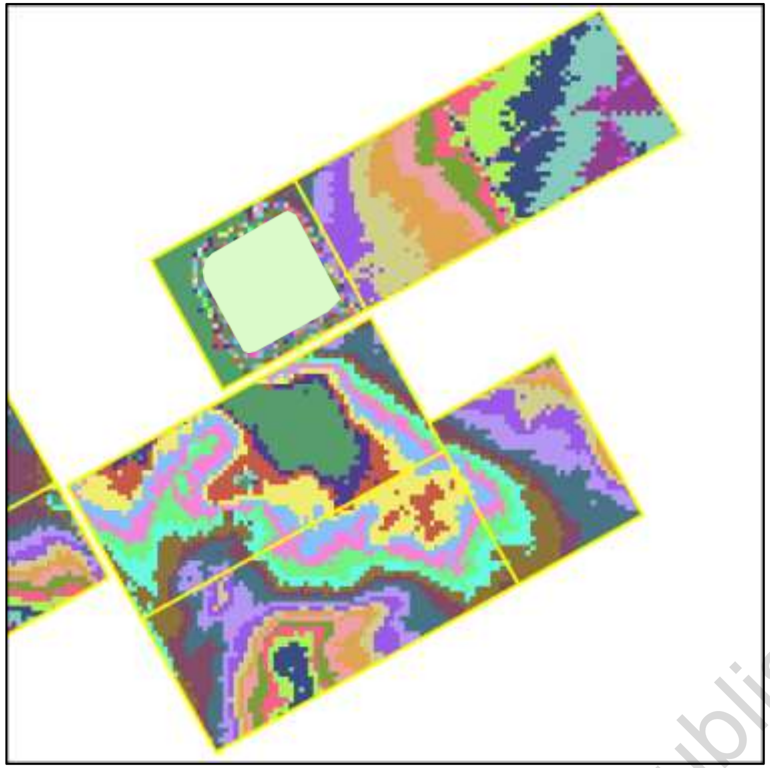
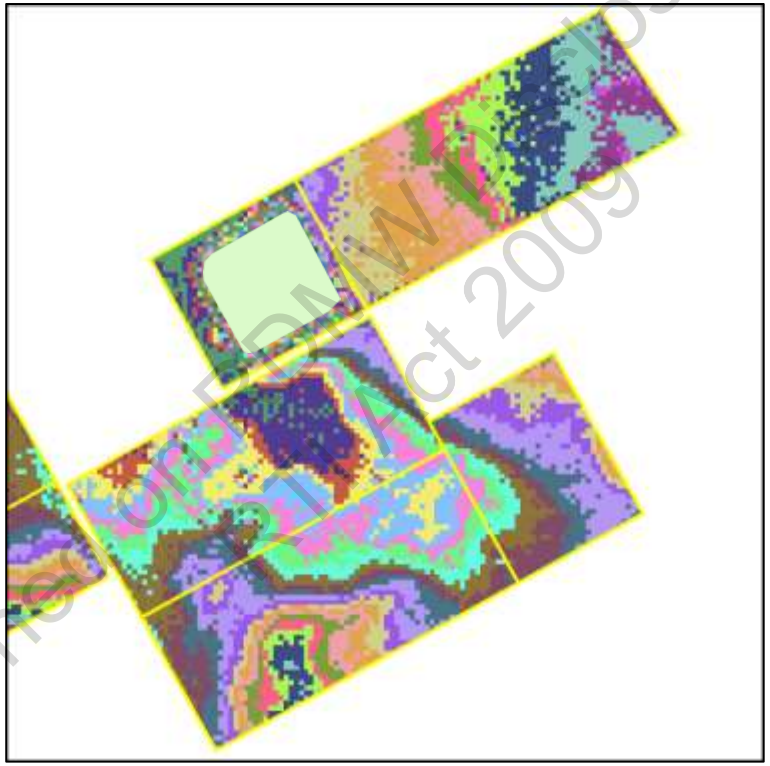
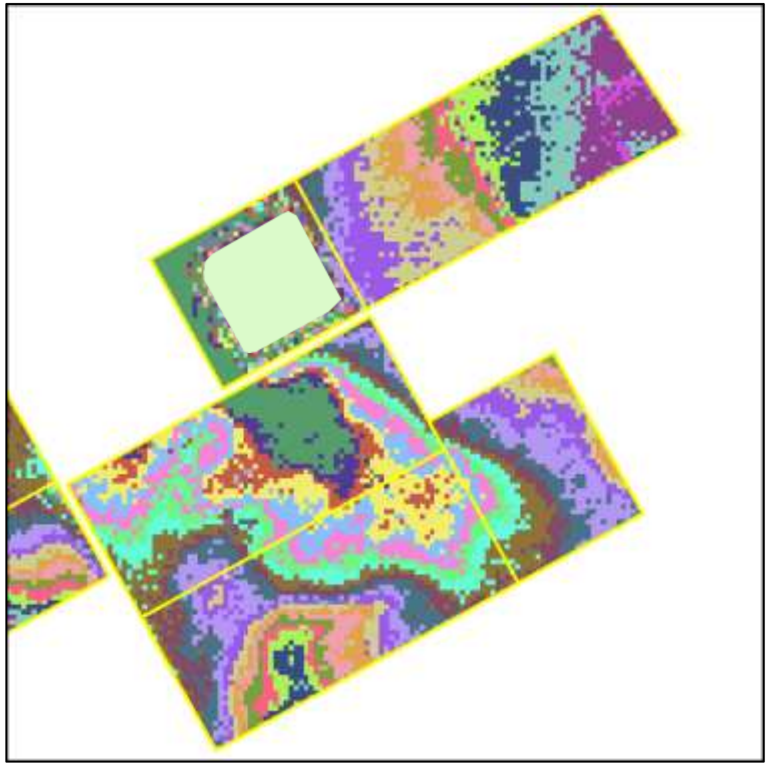
Landform 1 - 25m



Landform 2 - 25m



Landform 3 – 25m



Landform contours ('Weroona')

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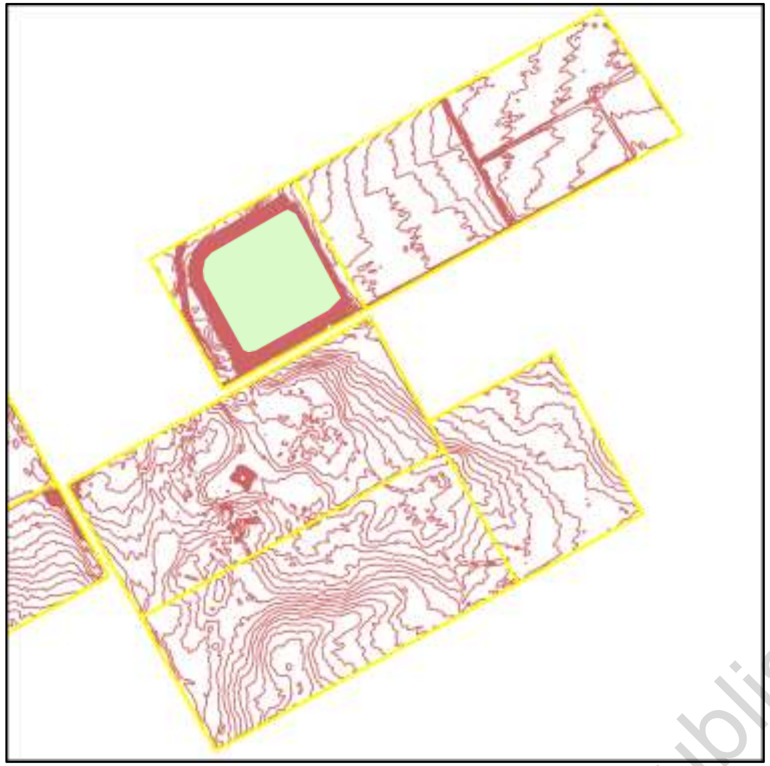
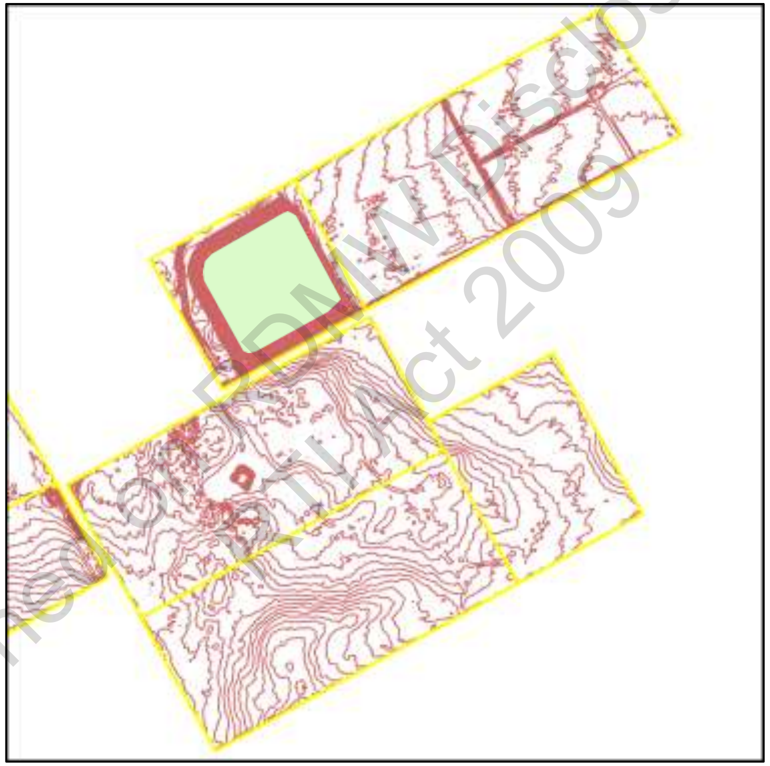
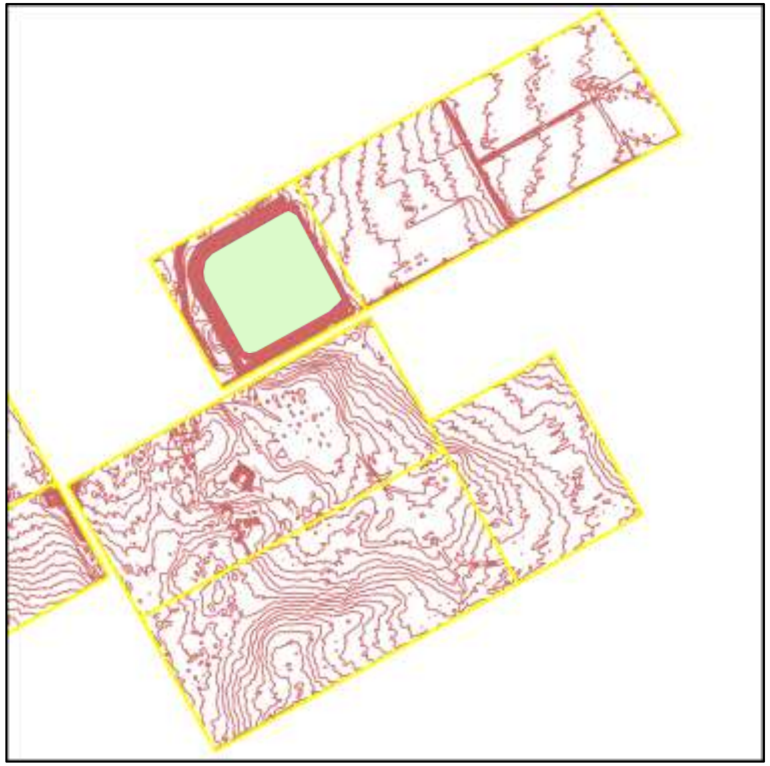
Landform 1 – 10 cm



Landform 2 – 10 cm



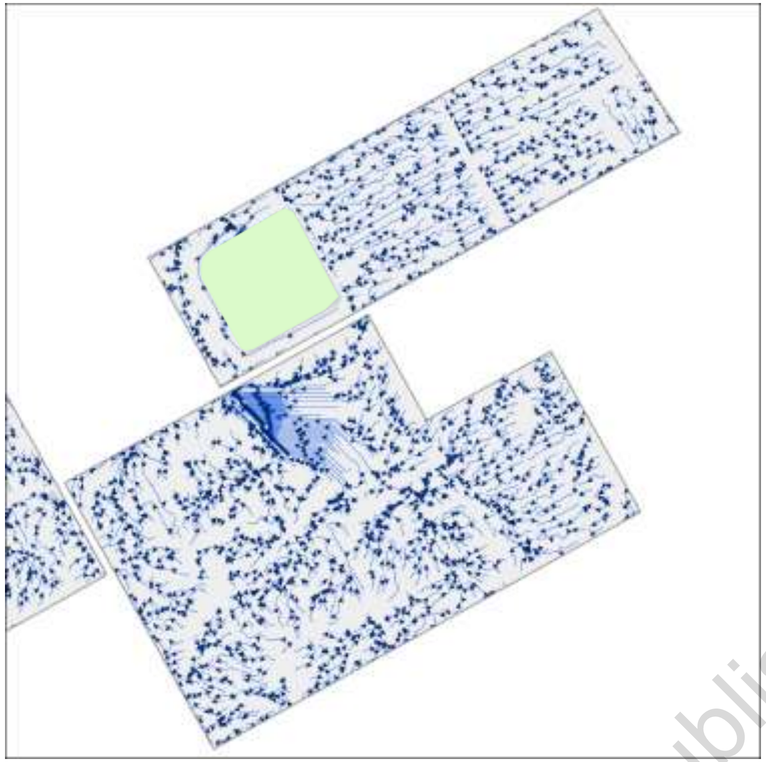
Landform 3 – 10 cm



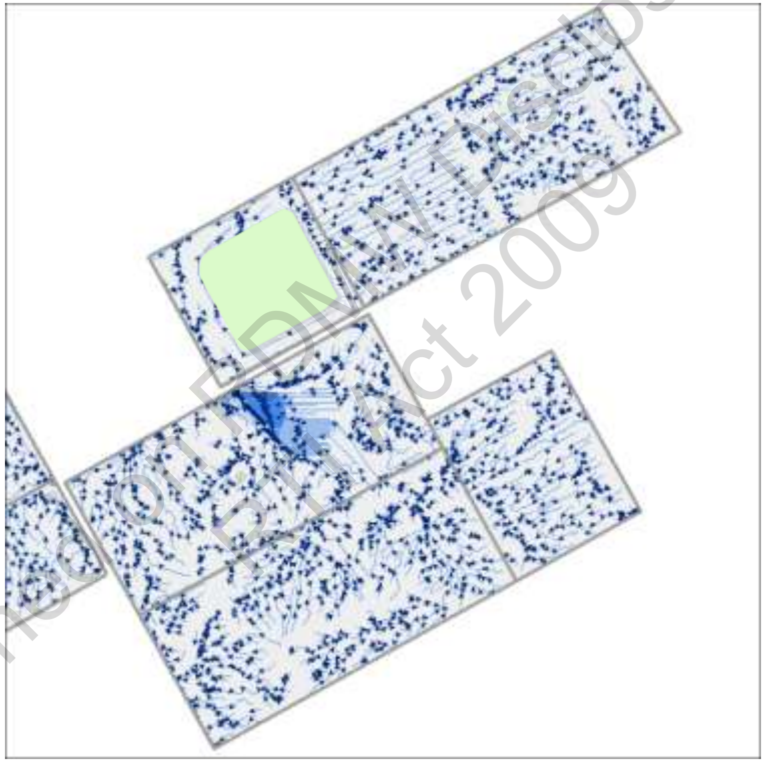
Landform drainage ('Weroona')

Queensland Government

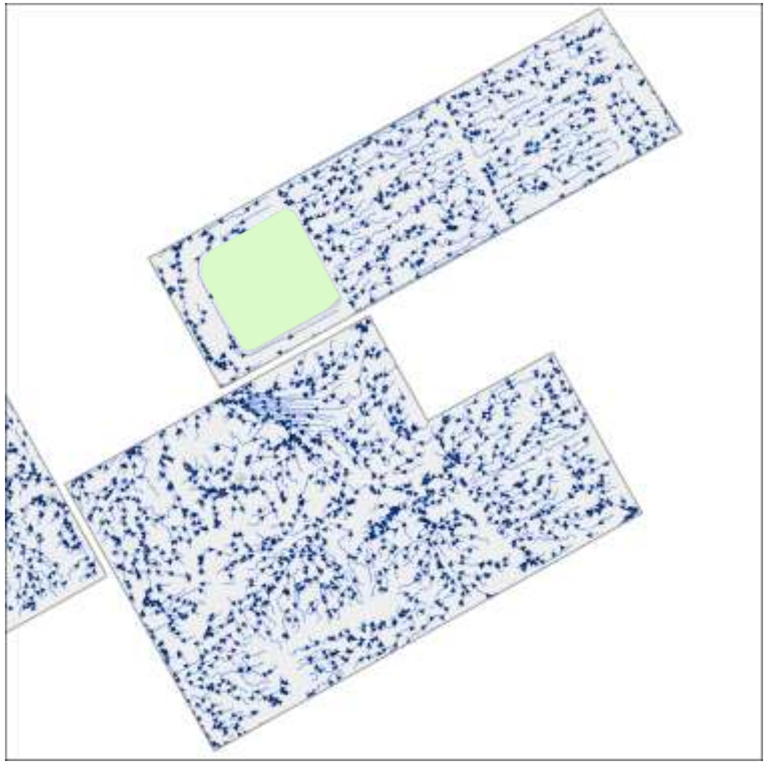
Landform 1 - 5m



Landform 2 - 5m



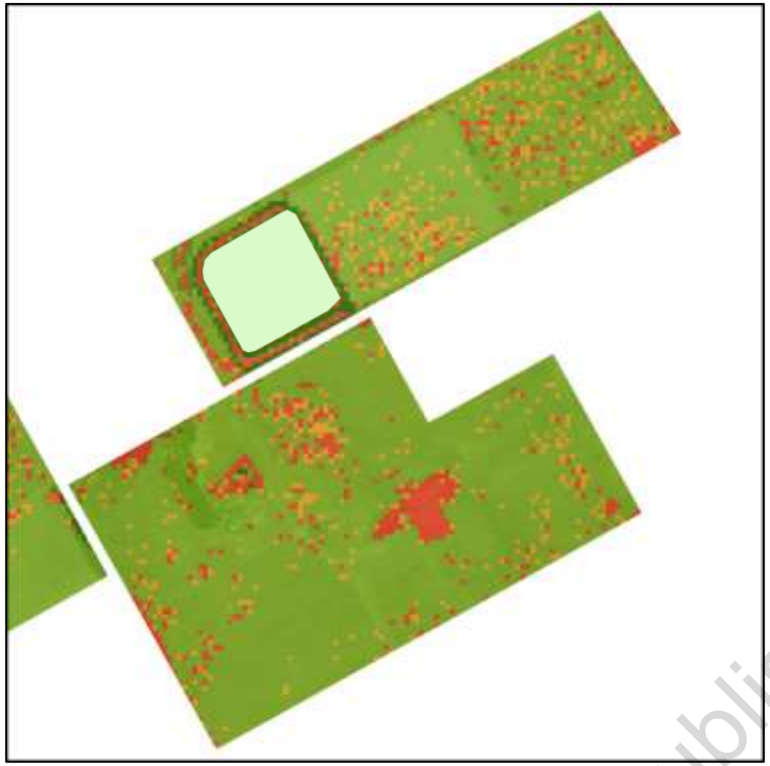
Landform 3 - 5m



Landform slope ('Weroona')

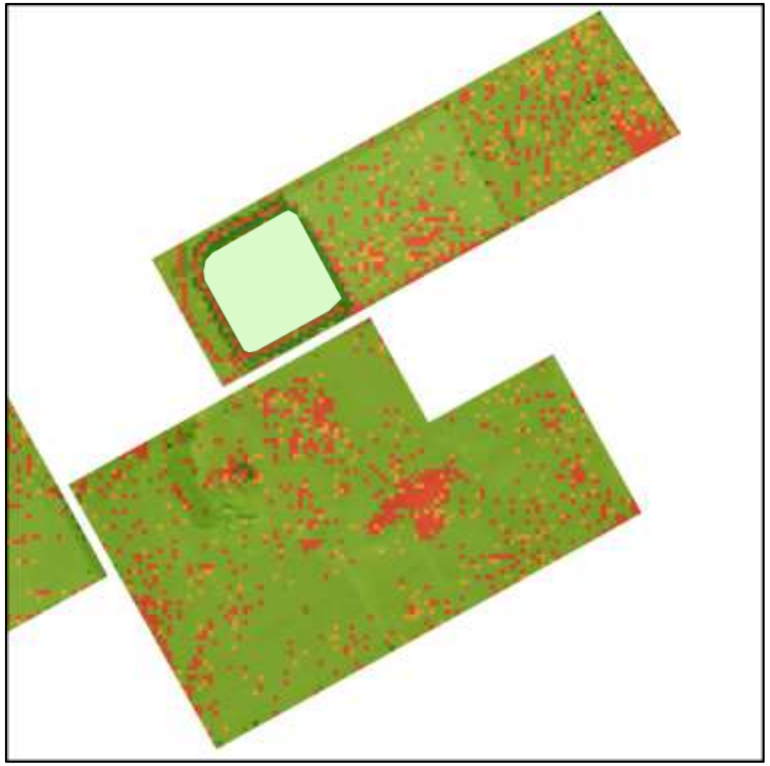
Queensland Government

Landform 1 - 25m



Landform 2 - 25m

Landform 3 - 25m

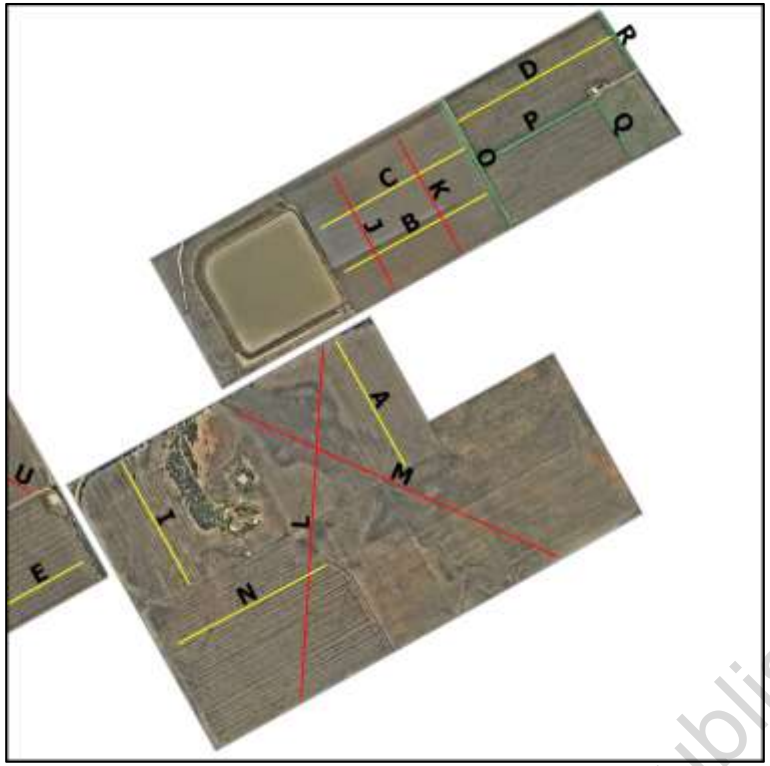


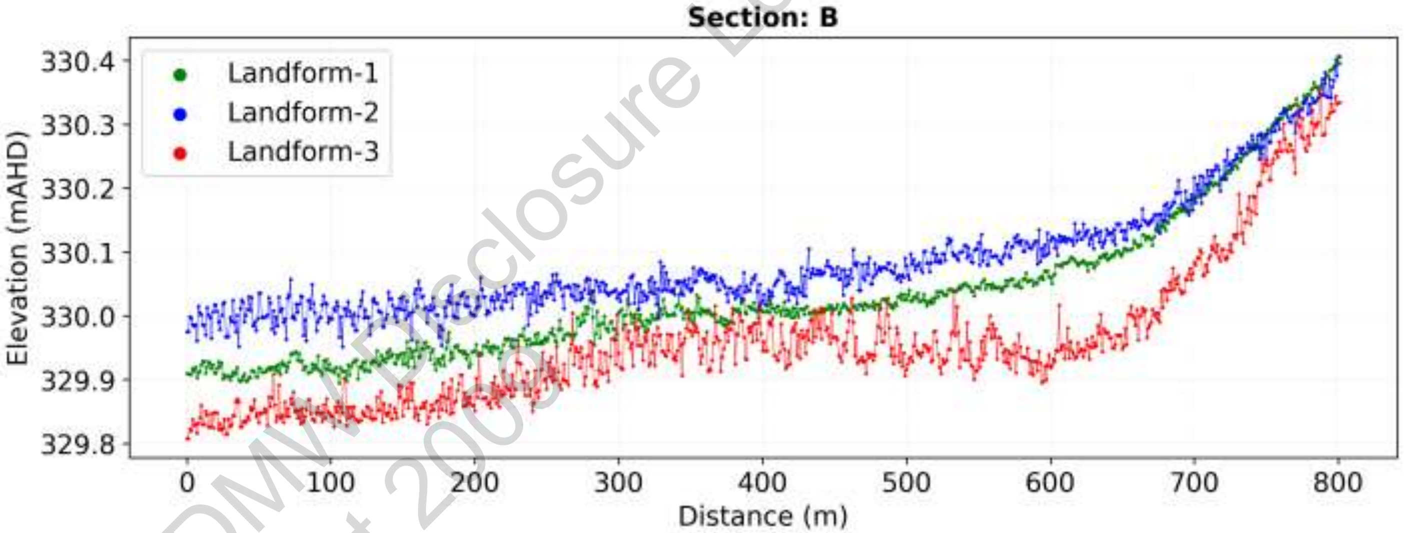
Slope Categories

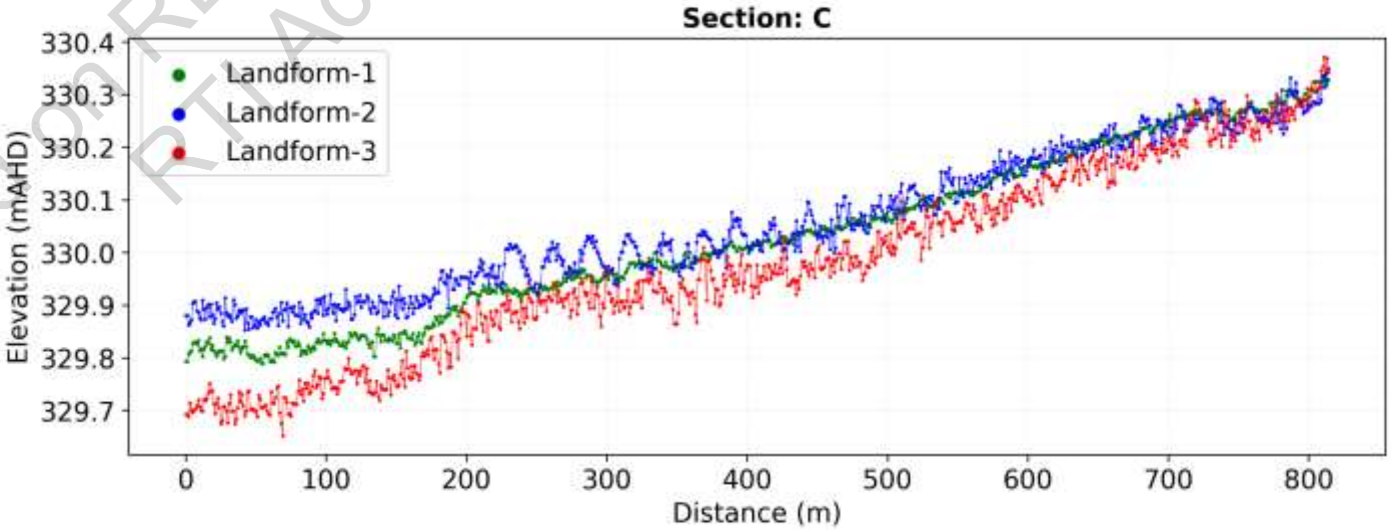
< 0.01 | 0.01 - 0.05 | 0.05 - 1 | 1 - 2 | > 2

Landform sections ('Weroona')

Queensland Government

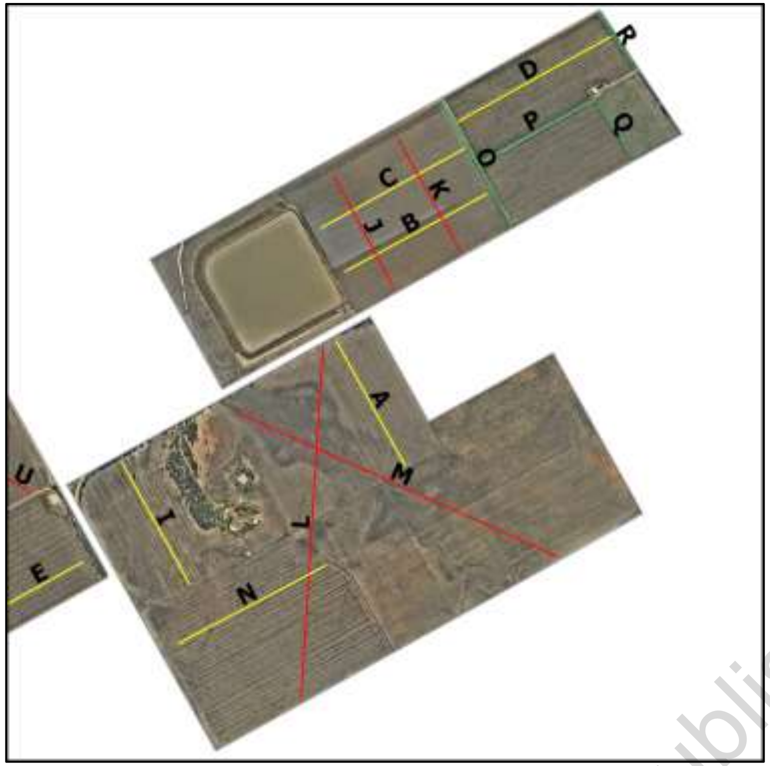


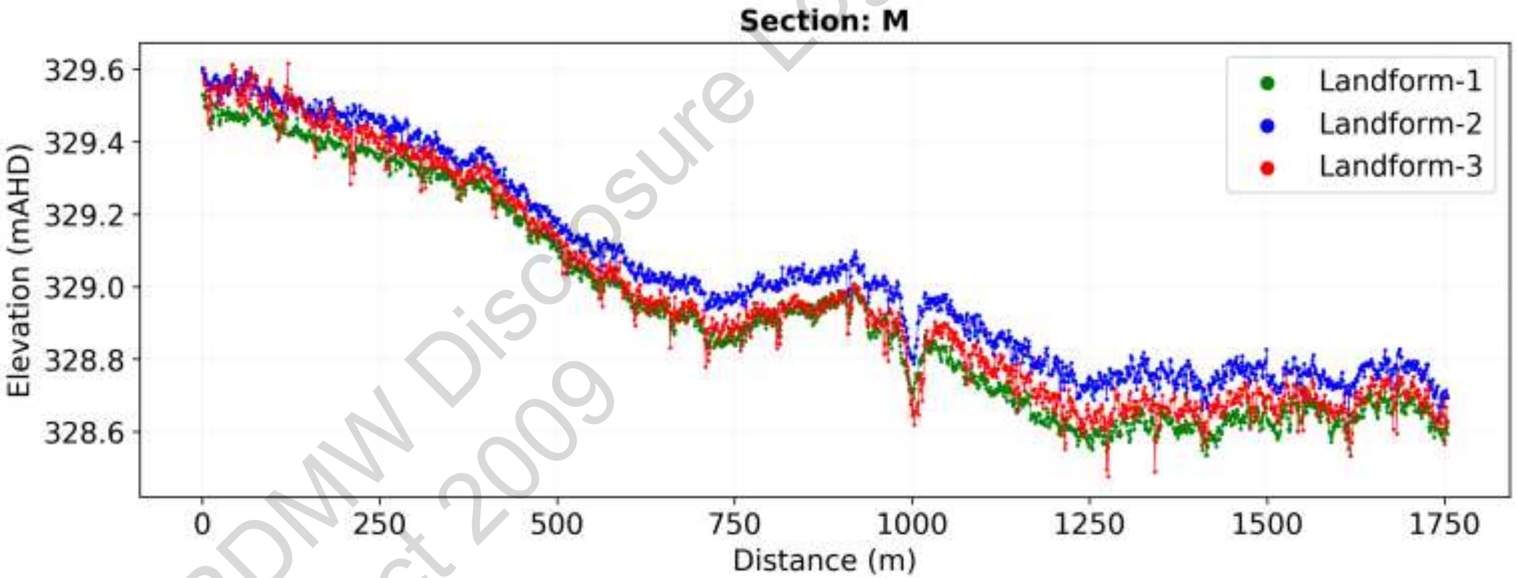


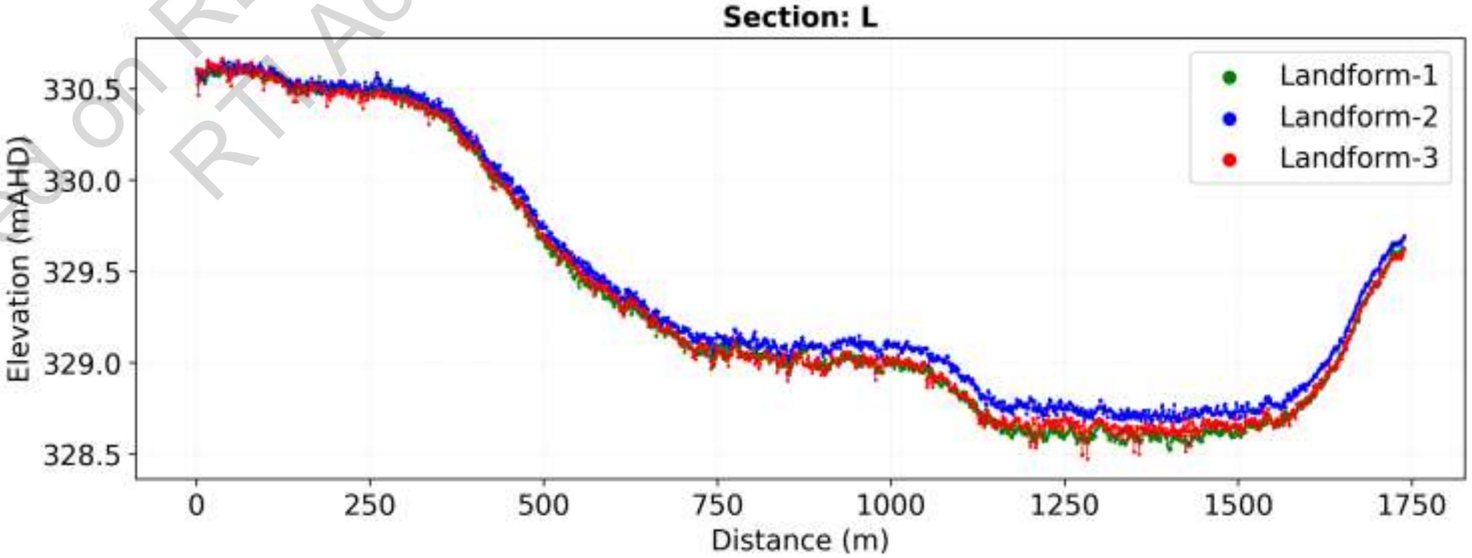


Landform sections ('Weroona')

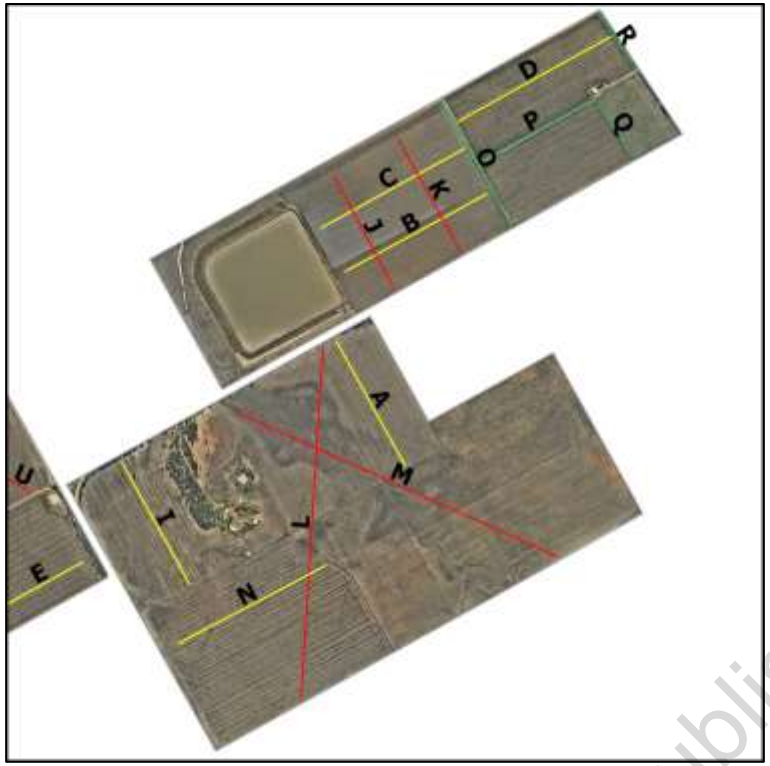
Queensland Government

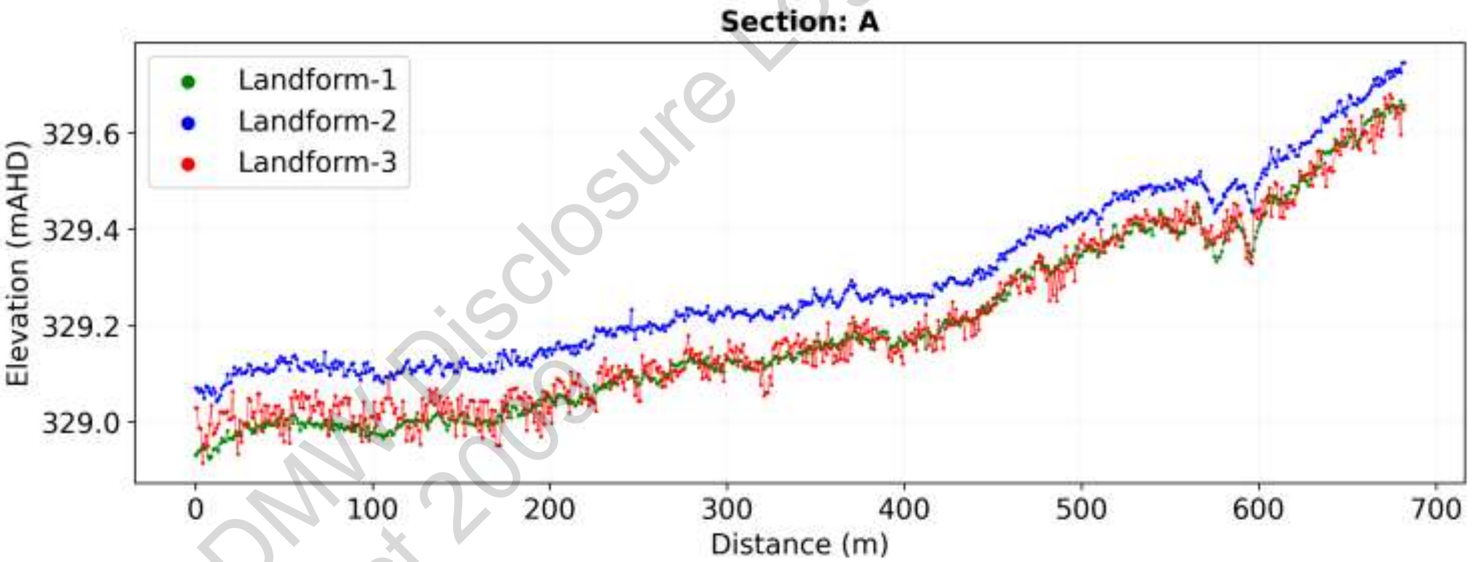


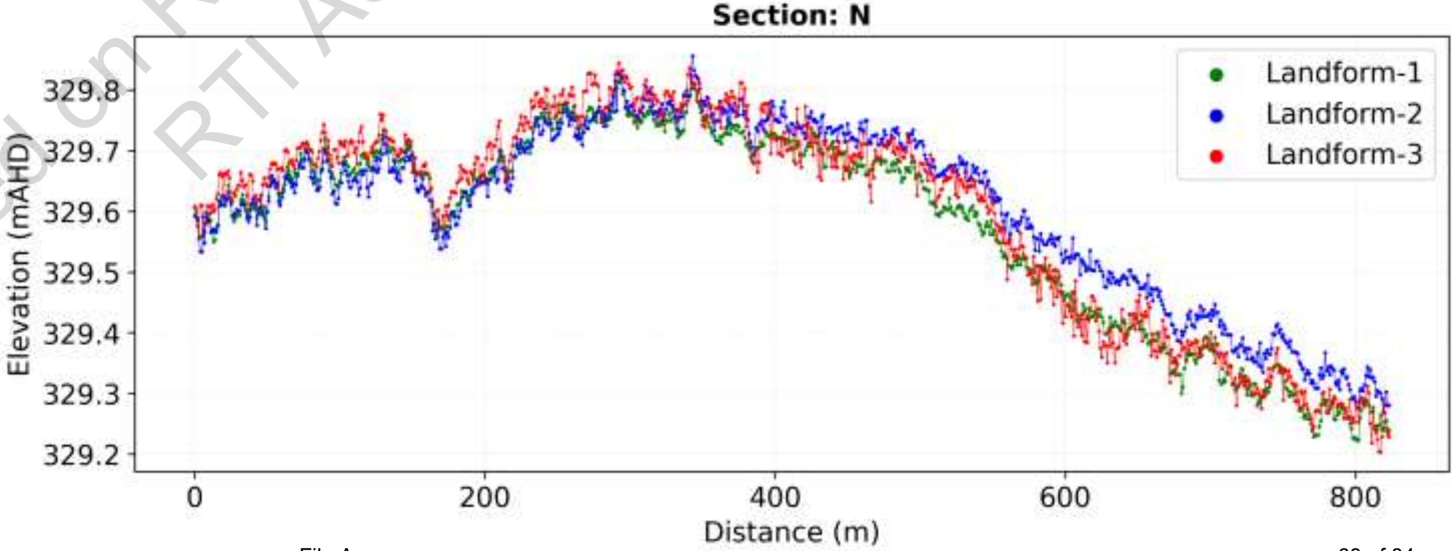




Landform sections ('Weroona')







Reference Year ('Weemalah')

Reference Year: **2010**

Baseline Period: **2010-2008**

Datasets:

- LiDAR not available
- Landforms used for baseline:
  - **Landform 1** = 2020 LiDAR + subsidence until 2020
  - **Landform 2** = 2021 LiDAR + subsidence until 2021
  - **Landform 3** = 2022 LiDAR + subsidence until 2020

Legend

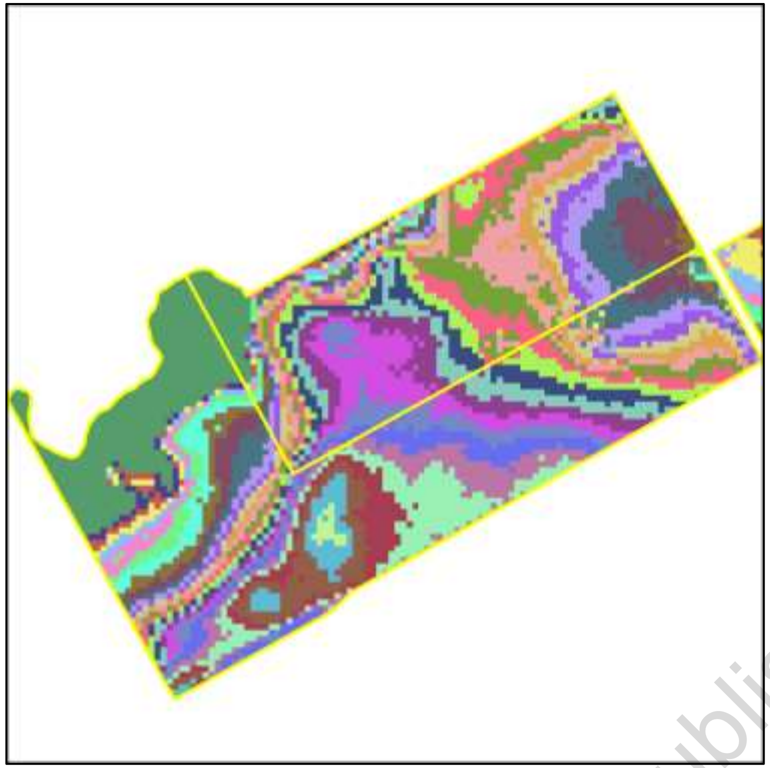
- 2010 5mm subsidence modelled extent
- 2012 5mm subsidence modelled extent
- 2014 5mm subsidence modelled extent
- Pilot Properties

Aerial imagery ('Weemalah')

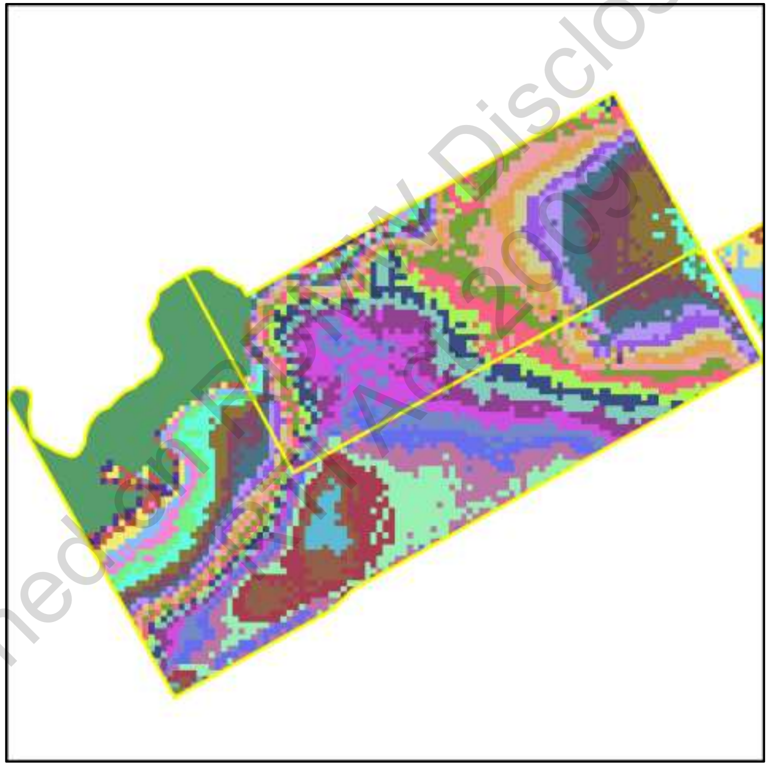
Confidential and Interim. Not for public release. Does not represent definitive conclusions or opinion from OGIA

Landform surface ('Weemalah')

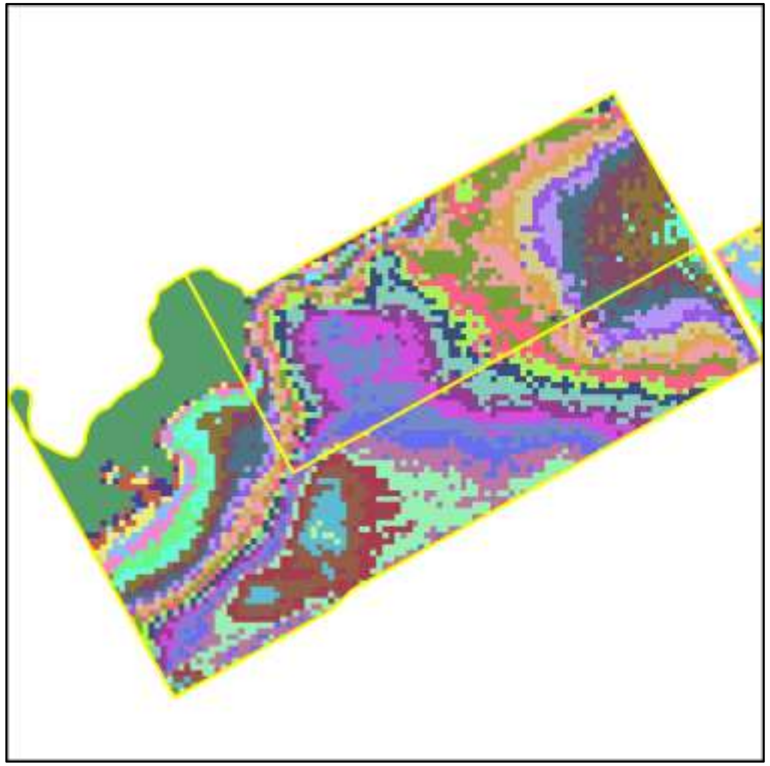
Landform 1 - 25m



Landform 2 - 25m



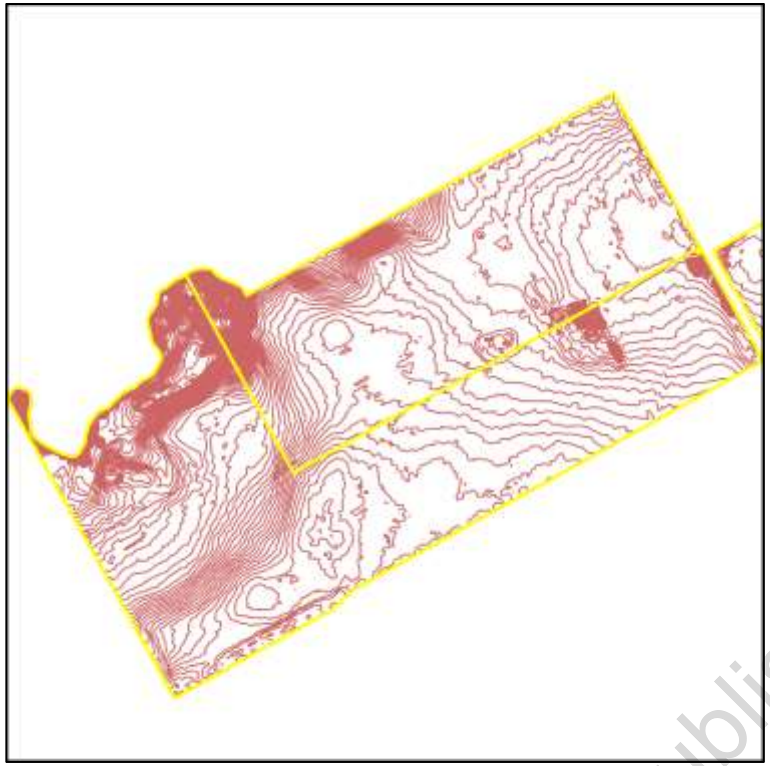
Landform 3 - 25m



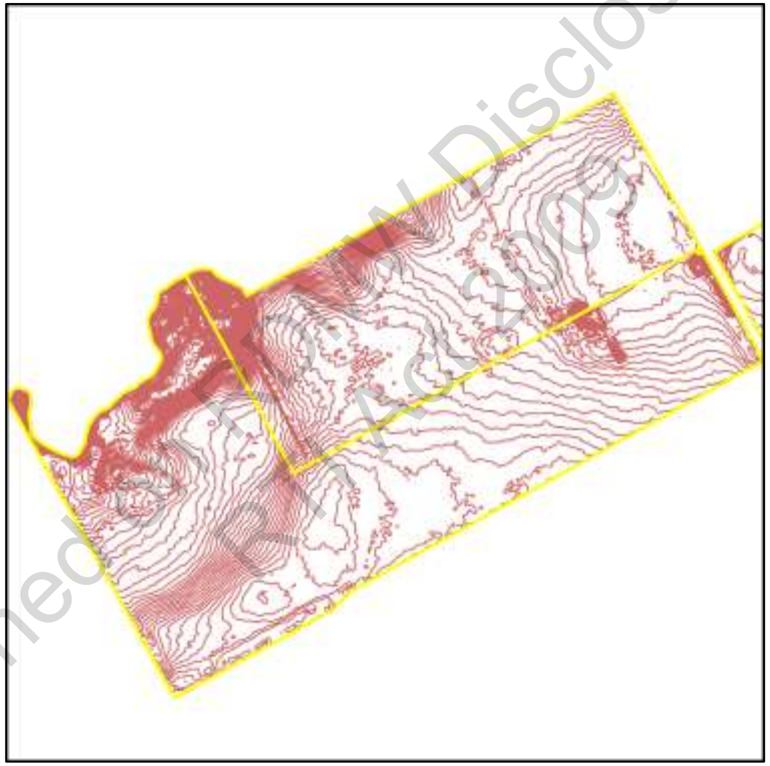
Landform contours ('Weemalah')

Queensland Government

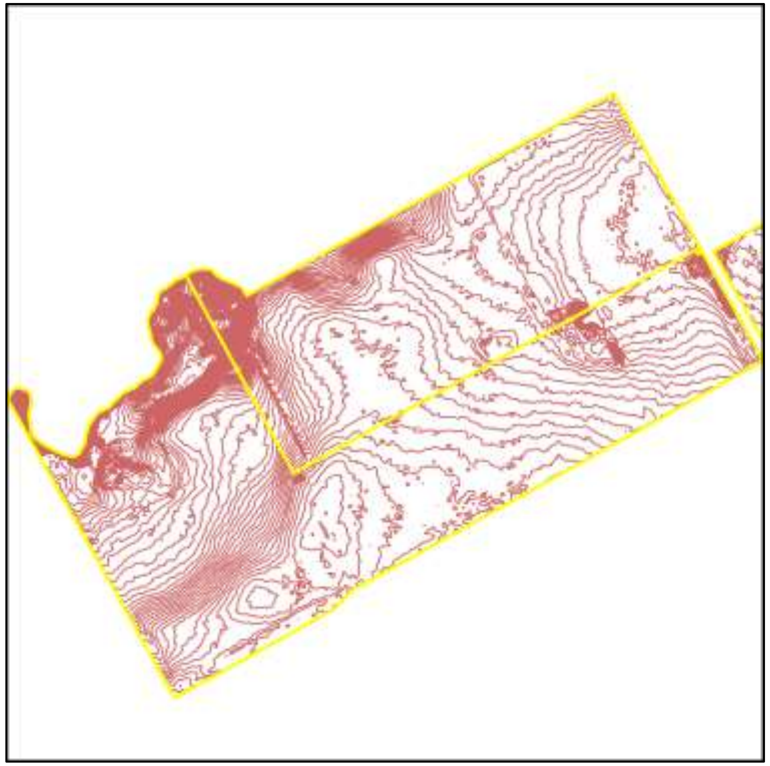
Landform 1 - 10 cm contours



Landform 2 – 10 cm contours

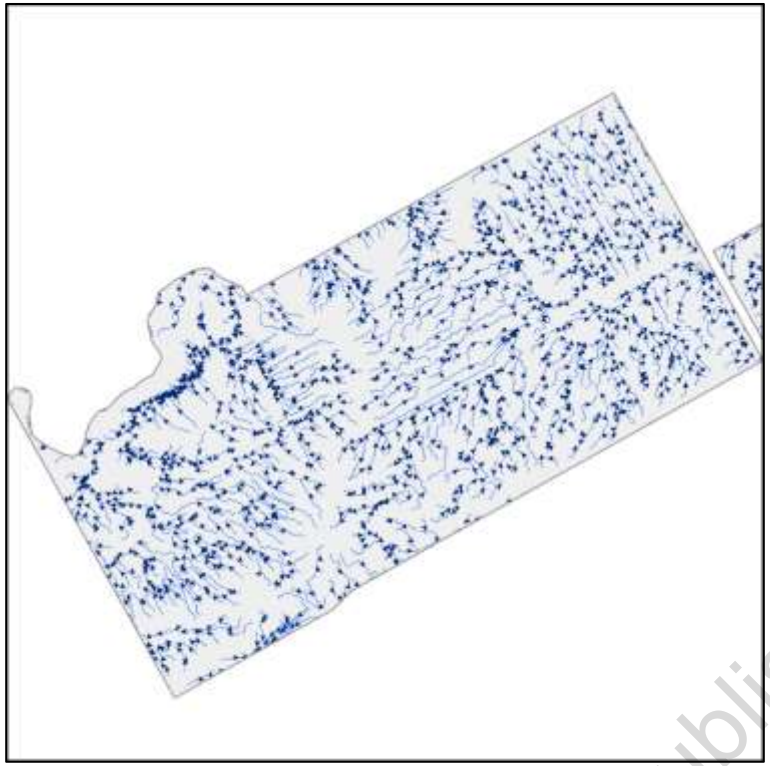


Landform 3 – 10 cm contours

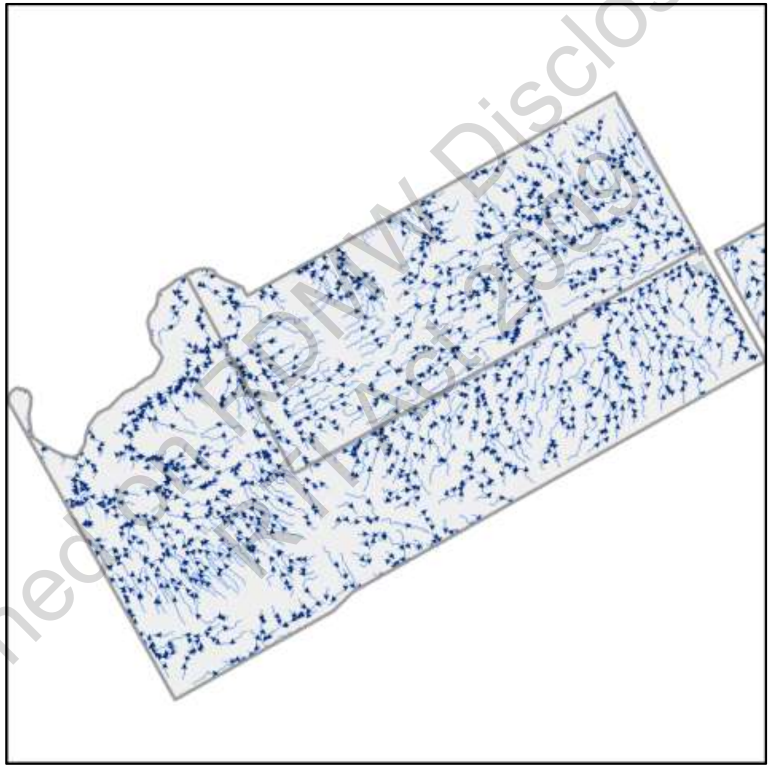


Landform drainage (‘Weroona’)

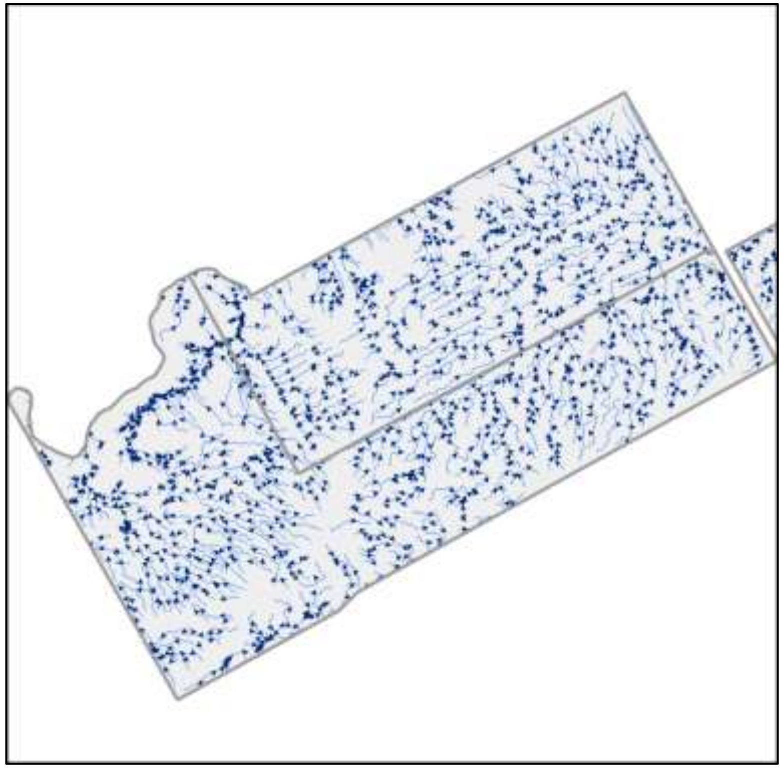
Landform 1 - 5m



Landform 2 - 5m

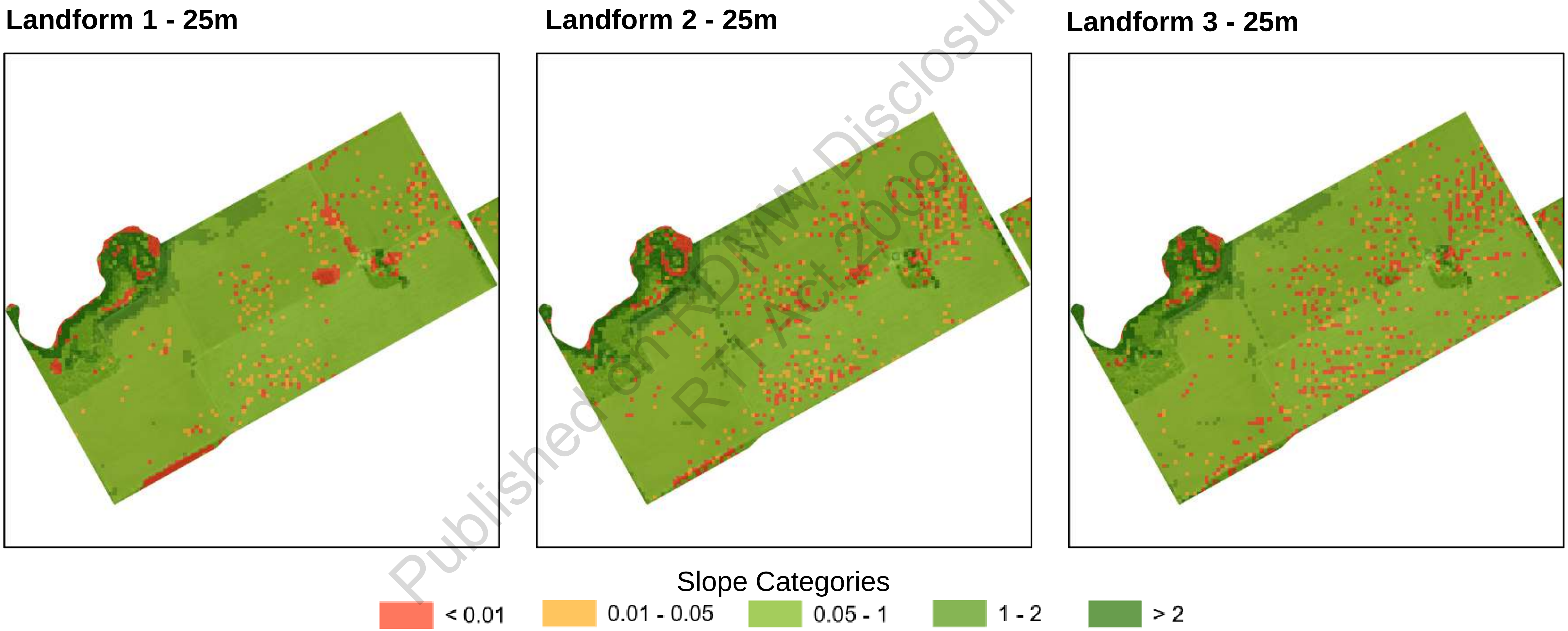


Landform 3 - 5m

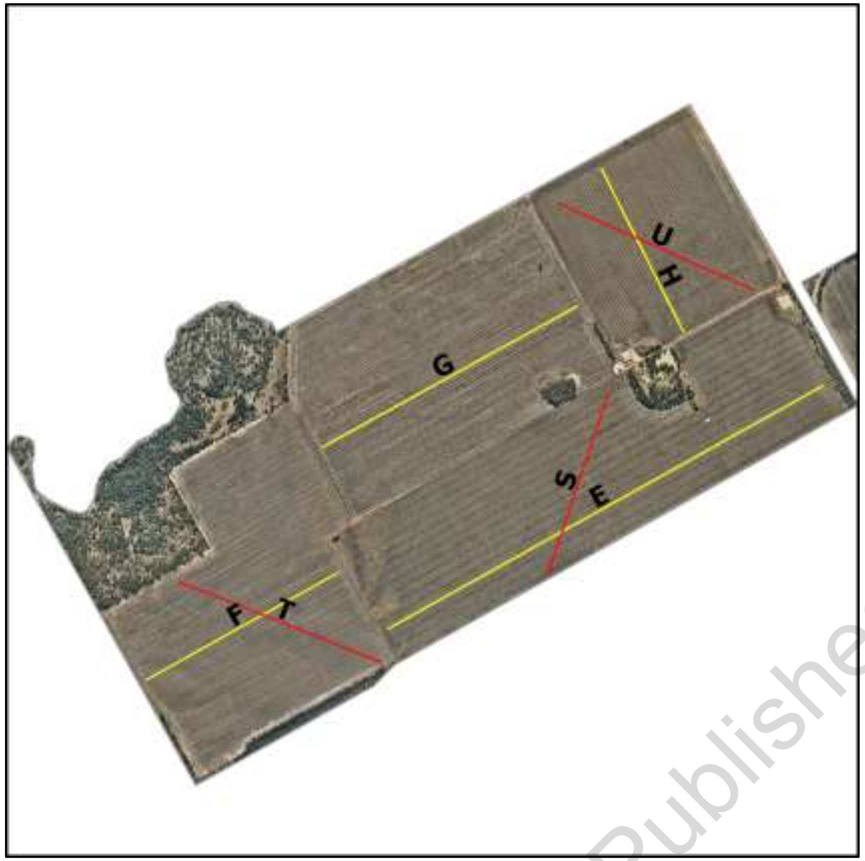


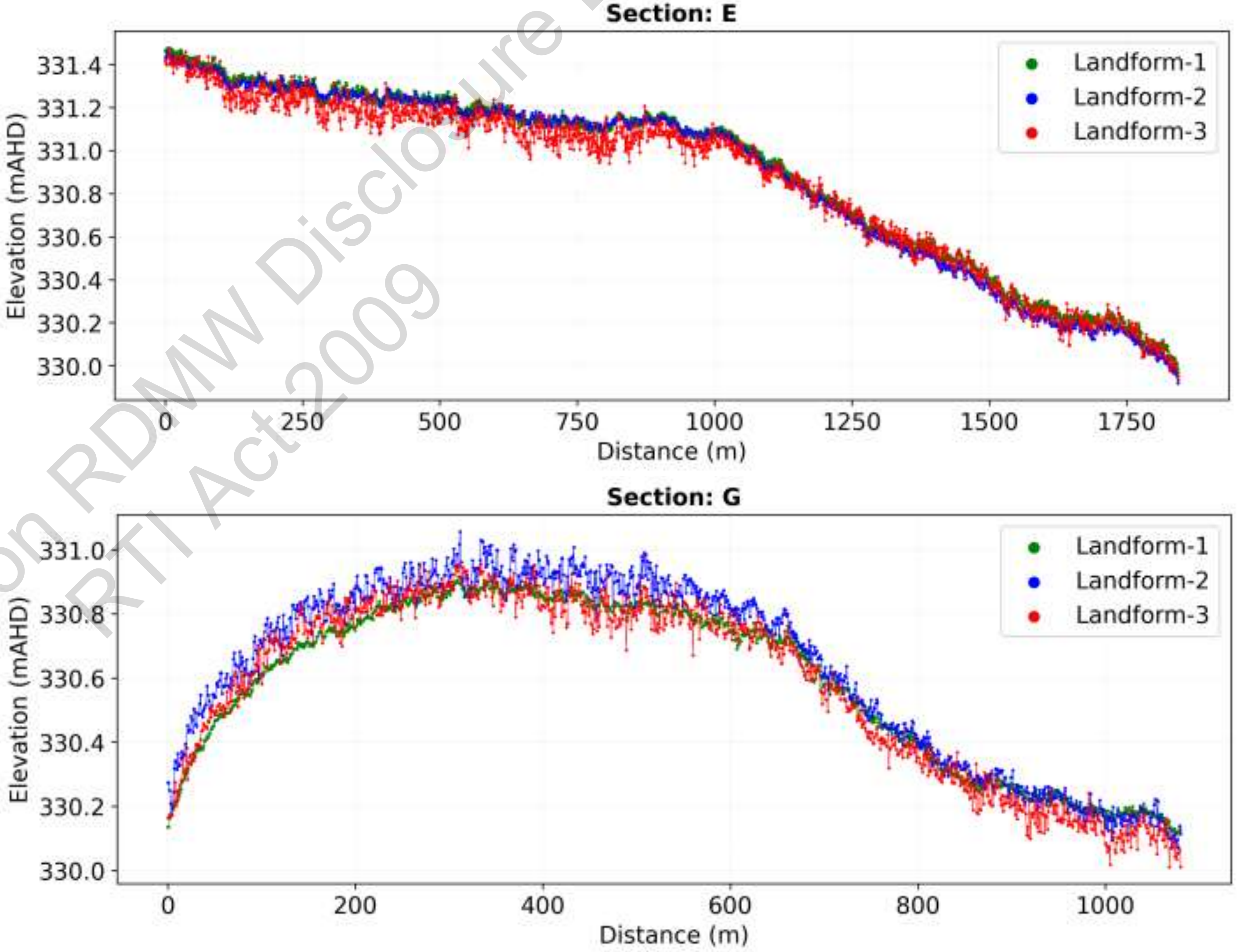
Landform slope ('Weemalah')

Queensland Government

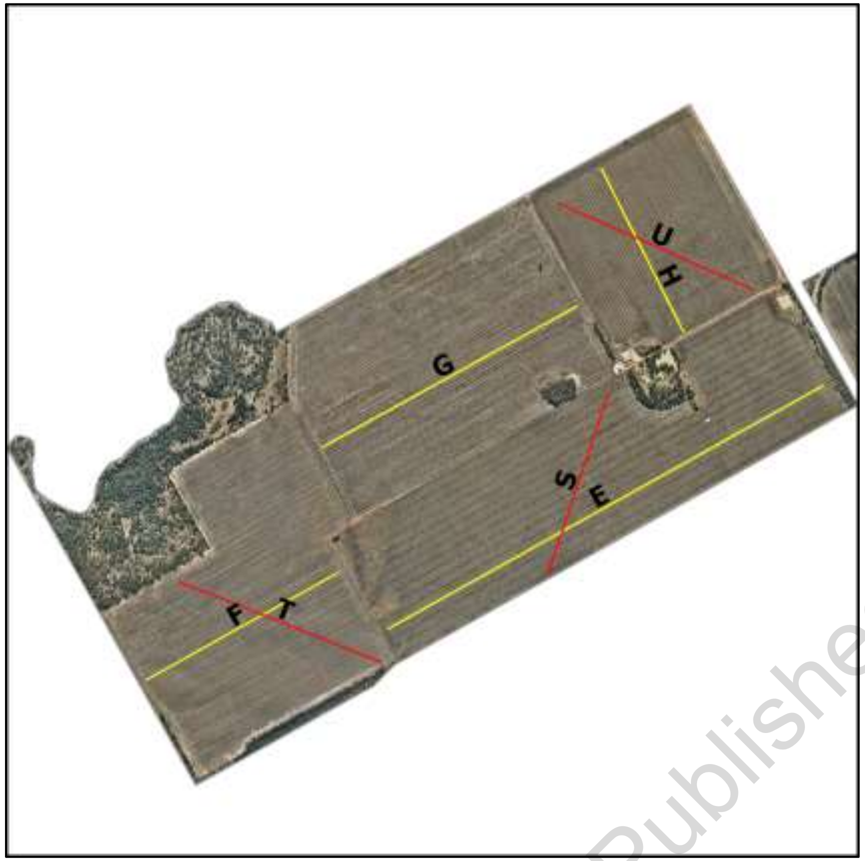


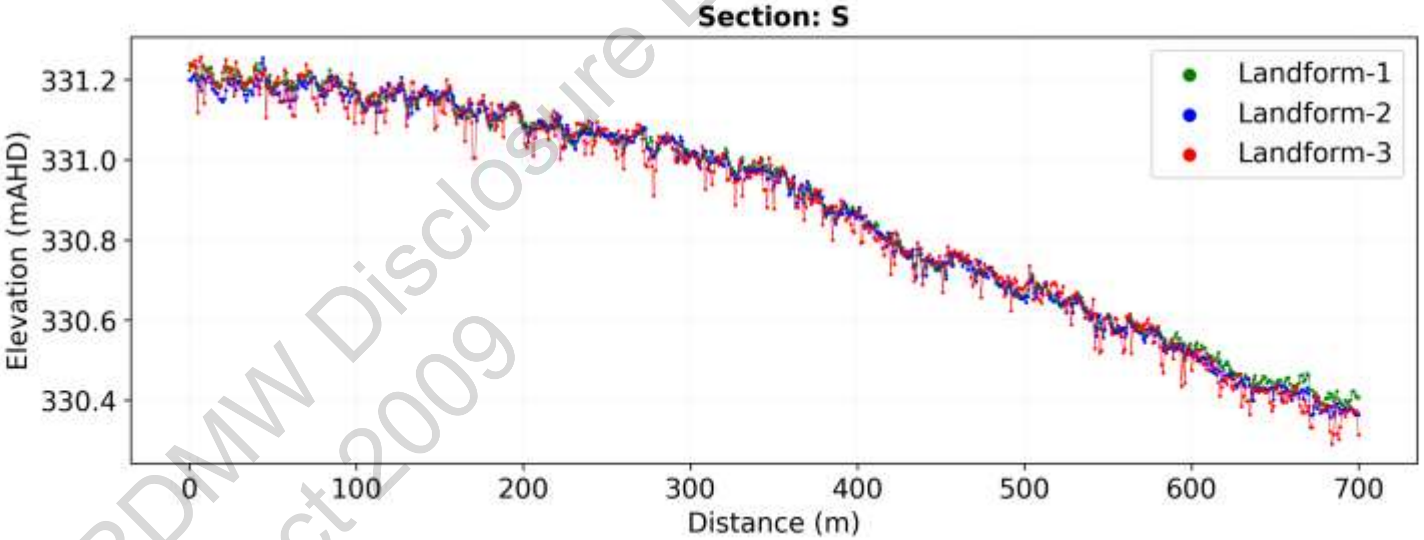
Landform sections ('Weemalah')

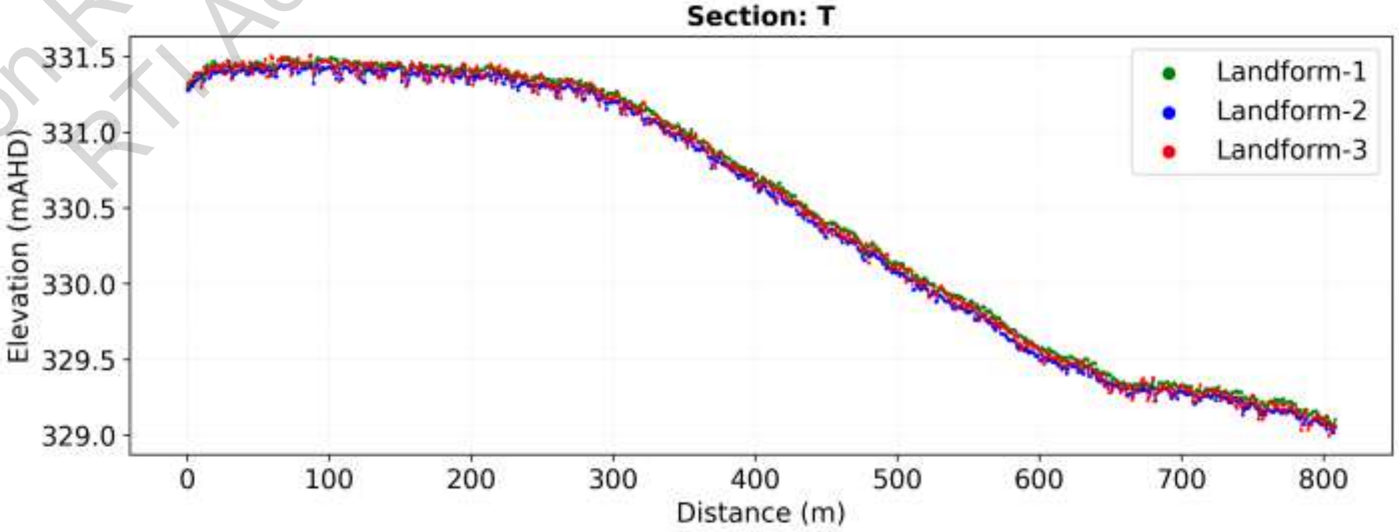




Landform sections ('Weemalah')







Gassy bore investigation (RN107607)

Office of Groundwater Impact Assessment

Thursday 5th October

Queensland Government

Office of Groundwater Impact Assessment

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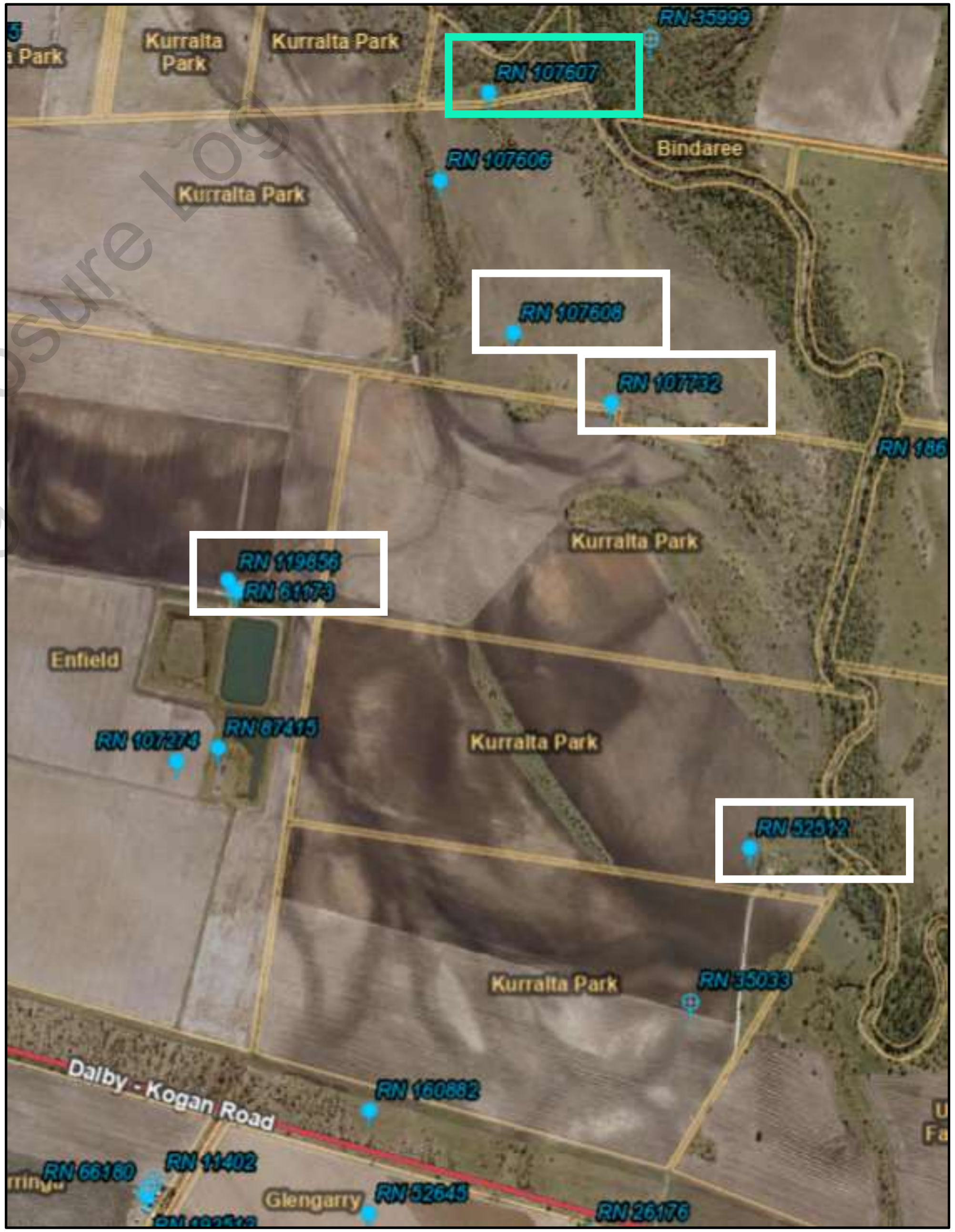
Thursday 5th October

- recorded landholder observations
- construction details
- water level measurement
- water chemistry samples (including dissolved gas)
- free gas measurements



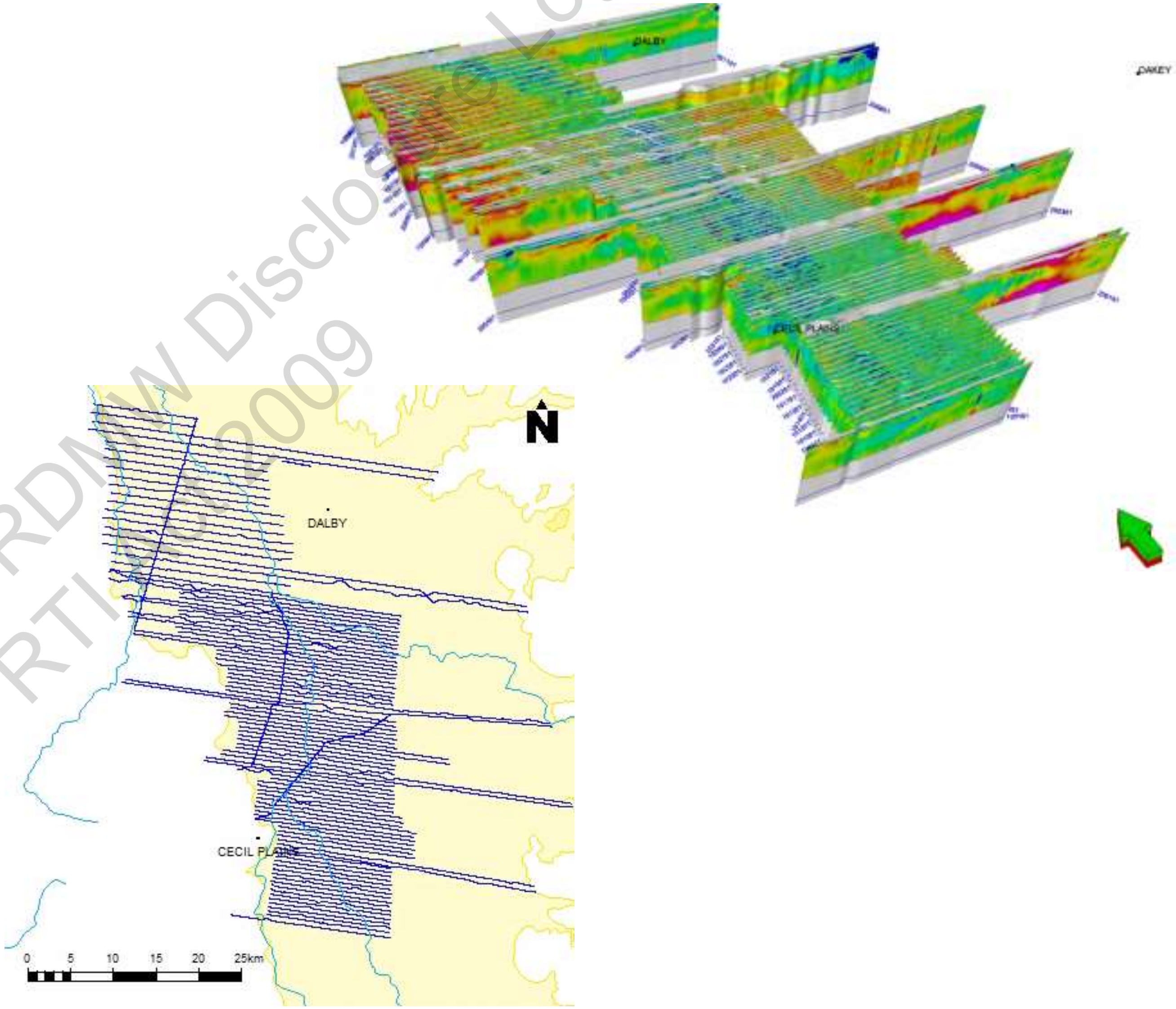
Project scope

Queensland Government

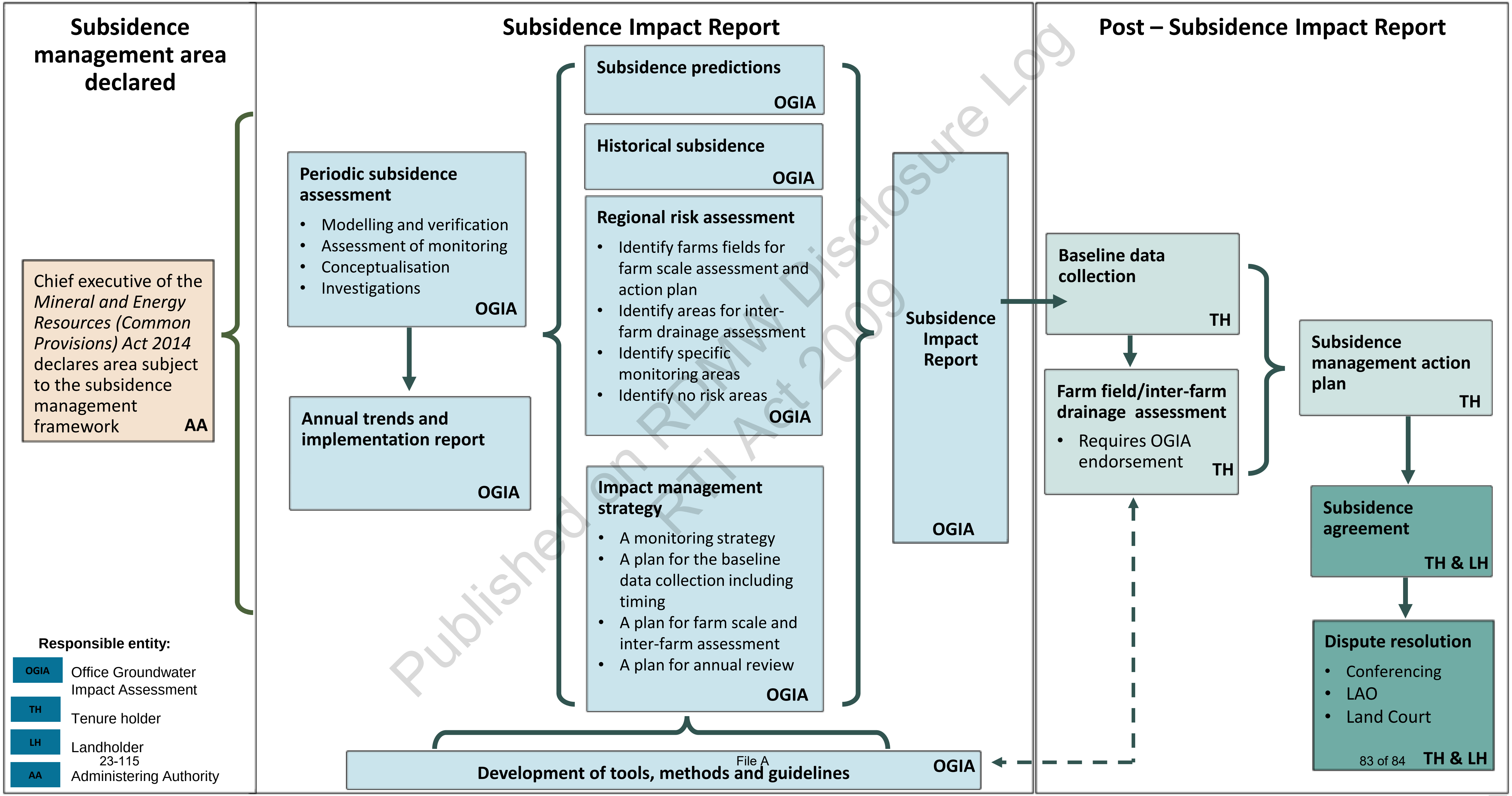
- OGIA commissioned in May 2023
- approximately 2,000 km of lines
- to understand the shallow geology and groundwater system, including improving conceptualisation of the Horrane Fault
- data and basic products from SkyTEM

Next steps

- geologically constrained inversions
- interpretation with other data



Subsidence management framework process



End

Office of Groundwater Impact Assessment