MEMORANDUM

To:	Australian Potash	**Date:**	20 March 2020
Attn:	Stewart McCallion	**Our Ref:**	PE20-00339
		KP File Ref.:	PE801-00354/02-A dss M20001
cc:		**From:**	Dean Sawyer/Brett Stevenson

RE: LAKE WELLS POTASH PROJECT – SURFACE WATER ASSESSMENT

Knight Piésold Pty Limited (KP) is currently providing assistance to Australian Potash Limited (APL) as part of the Feasibility Study of the Lake Wells Sulphate of Potash (SOP) Project near Laverton, Western Australia. The on lake pre-concentration ponds will utilise the natural lake formation to form ponds filled with groundwater abstracted brine.

This document outlines the response to the EPA comments (received from APL on 11th February 2020) regarding hydraulic modelling for the area. The study expands on work already conducted by Golder (Ref. 1) and KP (Ref. 2) with more recent methods and closer examination of water flow through the system.

In general, despite the lack of runoff gauging in the area, with conservative assumptions, the effect of the pre-concentration ponds on flood levels and velocity should be minor. If large events were to occur, flow from west to east can still occur via connected ponds in the northern extent. Small catchments to the south of the ponds will have runoff captured by embankments with water infiltrating into the surrounding dunes.

1. COMMENT 1

EPA Comment:
The hydraulic modelling is consistent with industry standard practice. However, the reliability of the modelling is dependent on the hydrologic assessments.

Response:
Noted, sensitivity assessment is required to cover uncertainty.

2. COMMENT 2

EPA Comment:
There is very little streamflow gauge information available for the Goldfields area of WA. Consequently, broad regional flood estimation methods are required to estimate flood peaks and volumes. The hydrologic assessments undertaken are consistent with industry standard but lack rigour required to overcome the lack of local/regional data. Comparison with aerial imagery and peak flood levels observed during the recent Cyclone Blake event that affected the area last week (January 2020) would validate the assumptions in hydrology and provide additional confidence in model results.

Response:
We acknowledge using observed data provides a more reliable calibration of estimates. We have used the historical satellite images, site rainfall records and site observations to validate the estimate.

Geoscience Australia provides a Water Observations from Space (WOfS) product (Ref. 3). This uses historical satellite imagery to display the frequency of observations for which standing water is observed in an area of interest. Figure 2.1 shows the WOfS data for the southern part of Lake Wells and indicates moderate (~20%) and low (<5%) frequency of flooding regions attributed to runoff.

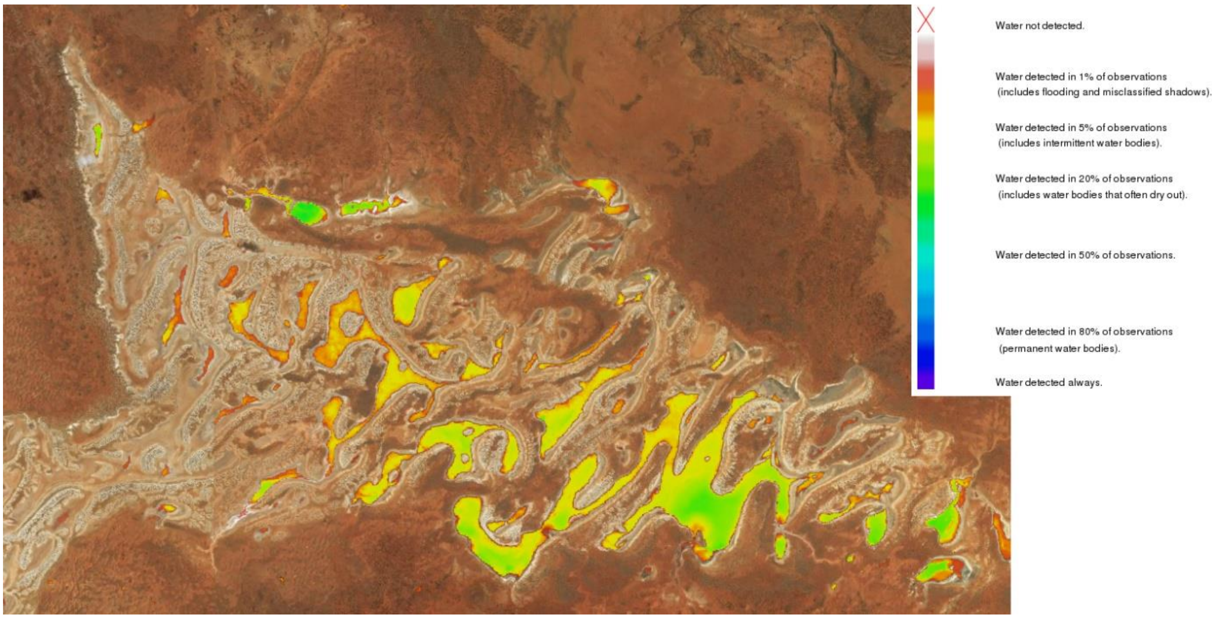


Figure 2.1: Water Observations from Space for Lake Wells

Aerial images also provide a snap shot of ponding water. Examples are provided in Appendix A however the time stamp of the images are not known to correlate with rainfall patterns. The two instances of ponded water however collaborate with the WOfS data that local small catchments produce runoff whereas the larger catchments to the northwest and southwest do not generate substantial runoff into the system.

This is also noticeable in the aerial images showing very little creek development entering from the west. This is typical of the area where runoff following rainfall in the higher rocky reliefs is caught in local depressions or infiltrate the sandy surface. Large areas become ineffective catchments, instead reporting to groundwater.

The APL Lake Wells project site has maintained a climate station since September 2016. The daily rainfall is presented in Figure 2.2.

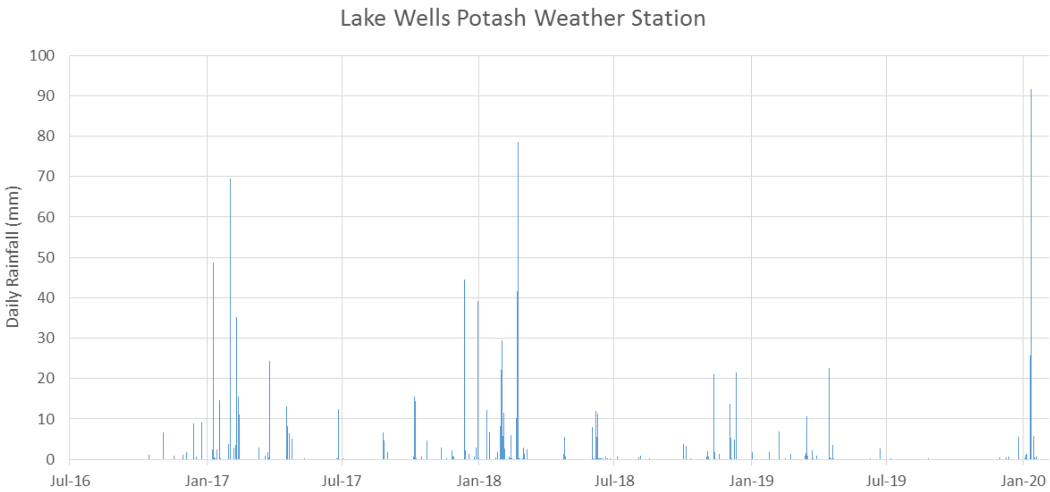


Figure 2.2: Site rainfall measurements

Some key statistics include:

- From October to July, the 2016/2017 rainfall was 334 mm; the 2017/2018 rainfall was 462mm and the 2018/2019 rainfall was 140 mm. The annual average for the site is 192 mm (Ref 2);
- In February 2017, the highest 24 hours rainfall was 69.4 mm. This was not attributed specifically to a cyclone in the region;
- In February 2018, the highest 24 hours rainfall was 78.6 m and 130.4 mm over 72 hours. This was associated with ex-tropical Cyclone Kelvin coming close to 200 km from site (green line in Figure 2.3);
- On the 10th January 2020 the 24 hour rainfall was 91.6 m and 137.8 mm over 72 hours. This was associated with ex-tropical Cyclone Blake;
- The same event recorded 270 mm of rainfall in 24 hours and 308 mm over 72 hours at Carnegie located 160 km to the north. It was reported to be close to the 0.1% Annual Exceedance Probability (AEP) 24 hour rainfall for that site; and
- The same event recorded 148.5 mm of rainfall in 24 hours and 226.3 mm over 72 hours at Prenti Downs 38 km to the north of Lake Wells.

The Lake Wells project site record from Cyclone Blake was equivalent to around a 5% AEP for reference. Site visits to the Lake Wells project site ~2 weeks following the Cyclone Blake event indicated the lakes to the south had residual ponding. This correlates with the WOfS and historical aerial images of ponding in these areas.

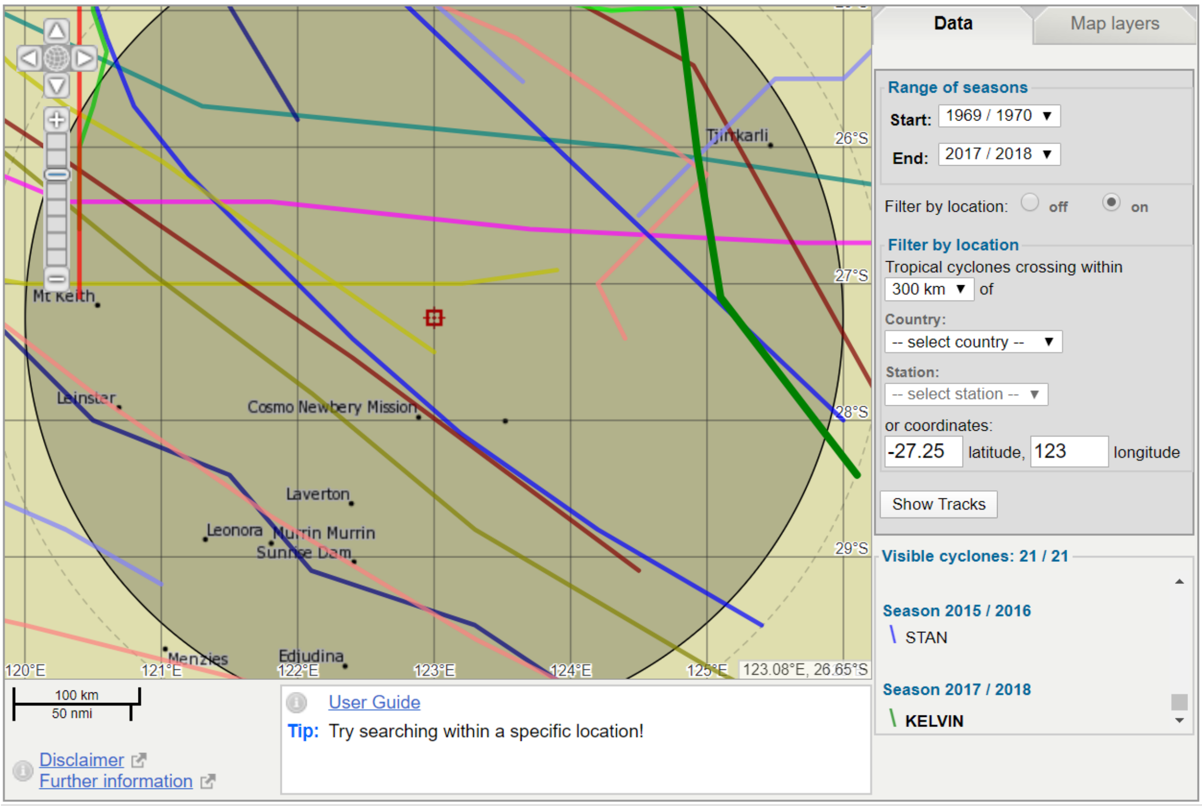


Figure 2.3: Cyclone map history across Lake Wells since 1969 to 2018

In light of the recent extreme rainfall and review of cyclone history above, the Probable Maximum Precipitation (PMP) for the site was calculated from BOM methodologies.

It is noted the PMP values (and other rainfall magnitudes) are influenced by aerial reduction factors as a function of catchment area.

The larger the catchment, the larger the reduction in rainfall is applied as it is unlikely rain can fall evenly across a larger site.

A number of catchments have been delineated to the north and south as well as smaller local catchments for the pond. The catchments from the Golder report were independently verified as reasonably correct. The delineation is provided in Figure 2.4.

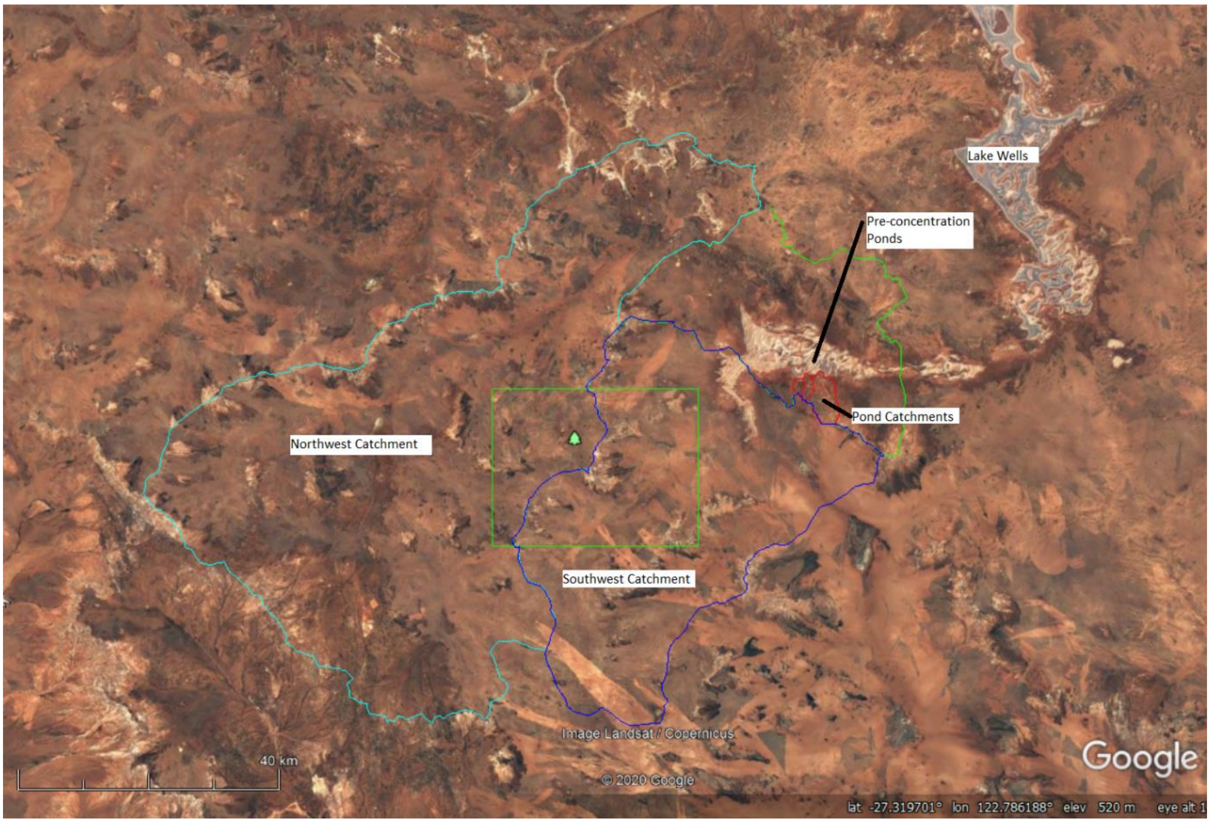


Figure 2.4: Lake Wells catchment areas

The large catchments spread across different PMP estimation zones and various methods were therefore used. These are summarised in Table 2.1.

Table 2.1: PMP Estimation 2019

Duration (hours)	1% AEP (Ref 2) (mm)	0.1% AEP (Ref 2) (mm)	PMP for Northwest Catchment* (mm)	PMP for Southwest Catchment (mm)	PMP for Pond Catchments (mm)
24	142	218	430 (600)	450	520
48	169	264	520 (790)	550	680
72	183	296	600 (960)	640	820

* Number indicates inland zone whereas brackets indicate coastal zone as the catchment crosses two GSTMR zones. Other catchments are only GSTMR inland zone.

The values indicate a reduction in PMP estimation with increased catchment area.

3. COMMENT 3

EPA Comment:

The peak flows presented in Table 3 include results for an unpublished methodology by Flavell, which have then been increased by 50 % (Table 4) to allow for the uncertainty in the estimates. It is noted that the values in Table 4 for the southern and northern tributaries appear to have been incorrectly labelled (i.e. switched). David Flavell has published a regional flood frequency estimation method for the Leinster area in the "Australian Journal for Water Resources, Vol 16. No. 1 pp, 1 – 20" in 2012.

It is unclear whether it is this published method the consultants have adopted. However, based on the quoted catchment areas for the Northern and Southern Tributaries and Figures 6 to 8 in this journal publication it would appear the published method provides significantly higher peak flows for both the northern and southern tributaries (roughly 3 times higher than the values quoted in Table 4 for the 1 in 100 AEP event). Further justification/confirmation of the appropriateness of adopted peak flows for the Northern and Southern tributaries is recommended.

Response:
The ARR 2019 Regional Flood Frequency Estimation (Ref 4) model is typically used to determine preliminary peak flows from natural catchments. In this arid region, the website does not currently calculate values.

The Flavell paper (Ref 5) was reviewed and applied to the Lake Wells project using the Goldfields – Leinster Area procedure. Both methods in the paper (with and without slope information) were developed using the SRTM topography. The results of the two methods are provided in Table 3.1.

Table 3.1: Flavell peak flow estimation

Catchment	Area (km^2)	Longest Flow Path (km)	Equal Slope (m/km)	Flavell Method 1 (m^3/s)	Flavell Method 2 (m^3/s)
Northwest Catchment	3531	115	0.71	1582	1923
Southwest Catchment	1766	73	1.32	1236	1241
Pond Catchment 1	3.5	3.3	6.21	13.4	14.0
Pond Catchment 2	4.9	4.4	5.71	15.4	16.4
Pond Catchment 3	26.6	10.0	2.42	45.3	56.8

The northwest and southwest catchments are higher than previously quoted by Golder (Ref 2) by about a factor of 4. However we note that the catchments are substantially larger than the 54 km^2 used to calibrate the Flavell methods. Hence the methods may not include aerial reduction factors associated with large catchments.

As discussed above, there is little evidence that substantial runoff occurs from the northwest and southwest catchments. Nonetheless, even with the higher peak inflow estimates, runoff is expected to behave in a similar manner to that modelled previously with the ponds developed i.e. discharge slowly from west to east via the north of the proposed pre-concentration ponds.

In addition, the three small pond catchments to the south of the project were developed in RORB (Ref 6) as single catchment assessments. From the WOfS information, these may need more storm water management during operation than the north and south catchments.

Runoff routing parameters for the RORB modelling used initial loss and constant loss values of 37.5 mm and 2.7 mm/hour respectively for 1% AEP storm events based on the median values recommended in ARR 2019 for the region. The RORB model was run for a range of storm durations and hyetographs to determine the critical duration for the catchment response and routing system. The “ensemble model” option in

RORB was used (average of numerous temporal patterns) to determine peak flows. In addition, the 72 hour event was calculated for total runoff potential. These are presented in Table 3.2.

Table 3.2: Pond catchment peak flows

Catchment	Peak Flow (m^3/s)	Critical Duration (hour)	Runoff from 72 hour event (m^3)
Pond Catchment 1	12.2	4.5	224,000
Pond Catchment 2	13.9	6	307,300
Pond Catchment 3	24.2	12	1,668,000

Peak flows are slightly lower but comparable to the Flavell method noted above.

4. COMMENT 4

EPA Comment:

A triangular shaped hydrograph shape has been adopted based on an assumption that a 18 hour rainfall event would produce the largest inflows (and by assumption water levels in the Lake Wells Playa). A runoff routing approach (such as a RORB model) may provide a better representation of the hydrograph and additional validation of the adopted peak flows. However, it would still be limited by the available local (and regional information)

Response:
For the northwest and southwest catchments, if significant runoff is produced from very rare and extreme events, they may each have varied time to peak inflow and total runoff values. This could also vary depending on the pattern of rainfall across both catchments. However we consider that a runoff routing approach may not provide any increased understanding of the critical duration or associated hydrograph.

In addition, the storm water storage to the west of the proposed pre-concentration ponds will attenuate flows, extending what the critical duration will be of the combined system. Only when flood levels are high enough (regardless of return interval or duration) would flows discharge slowly from west to east via the north of the proposed pre-concentration ponds. This level would be controlled by the topography low points connecting the ponds not being used as pre-concentration ponds.

Hence the previous modelling is considered representative of flows and a focus on downstream erosion protection (HDPE liner proposed) of free standing embankments remains.

5. COMMENT 5

EPA Comment:

The hydraulic model has only been run using the adopted 18 hour event hydrograph. Given the flat terrain and the numerous depression storages, the critical event (largest inundation area and highest water levels) may be caused by a longer event duration, which would have a higher inflow volume but slightly lower peak. –

additional modelling is recommended to test the sensitivity of water levels and extents to the event duration (ie, larger volumes for longer duration events) is recommended.

Response:
As above, a critical duration analysis inclusive of the Playa storage is considered unlikely to provide an increased understanding of the critical event, associated hydrograph or peak levels.

Flows would still discharge slowly from west to east via the north of the proposed pre-concentration ponds. This level would be controlled by the topography low points connecting the ponds not being used as pre-concentration ponds.

6. COMMENT 6

EPA Comment:

The results presented show that the velocities are generally low (<1.0 m/s) during both the existing and proposed scenarios which is expected in areas with such low slopes.

Response:
Given the large scale of the hydraulic modelling, finer resolution velocity plots were not presented. Localised areas of erosion may occur during operation. It is envisaged inspections of standalone embankments (especially to the north) will occur annually and following significant rainfall events.

7. COMMENT 7

EPA Comment:

Proposed development results in a loss in flood storage and changes to flow distributions during major events. This results in increased flood levels upstream and adjacent to the proposal. The differences in modelled levels at the 4 locations reported on in the report show the post development changes reduce as the size of the event gets larger and the flows between the depression downstream of the proposal interconnect (ie, changes in the 0.01 AEP are smaller than the changes in the 0.5 AEP event). – difference maps of the two scenarios (existing and post-development) for each AEP modelled would better illustrate changes across the entire model domain.

Response:
MBS map of “Predicted Changes of Flood Extents” provided in Appendix B represents the increase in flooded areas as a result of the development.

8. COMMENT 8

EPA Comment:

The proposal will reduce the storage available and has the potential to increase downstream flows. – downstream flow rates for the existing runs could be extracted to illustrate the magnitude of changes for each AEP as a result of the proposal.

Response:
Downstream flows (i.e. to the east) were only likely for events 1% AEP and greater in the previous hydraulic model provided the runoff values from the northwest and southwest catchments are realistic. In addition, the lake is essentially a terminal system connected to the other northern parts of Lake Wells.

Direct rainfall will now be captured by the ponds, having limited effect downstream.

9. COMMENT 9

EPA Comment:

The sensitivity of the peak flood levels and downstream discharge for a larger event could further assist the EPA assessment of the risk associated with the proposal. – Hydraulic modelling for an event/s larger than the 0.01 AEP scenarios provided to date is required.

Response:
As discussed in previous comments, larger events may provide unrealistic outputs of runoff estimates and inundation levels. The presented model outputs has all the flooded areas connected hence larger events will result in uniformly higher flood levels across the site with minimal changes in velocity. Larger events have shown to have incrementally smaller impacts on level changes between pre and post project construction.

10. COMMENT 10

EPA Comment:

The modelling does not include loss rates for evaporation and infiltration and cannot directly be used to estimate durations of freshwater inundation.

a. The duration of inundation is expected to be longest at the lowest areas within the system. The presence of similar (or lower) inverts within the depressions outside the affected Playa area would suggest little change in duration. – Some discussion based on the Lidar data comparing existing ground (depression) levels affected by the proposal with the remainder of the Playa to illustrate the relative levels and likelihood of the affected areas being inundated for longer periods.

Response:
Based on the WOfS data, the playa to the southeast is the most often flooded. As this forms part of the pre-concentration ponds, a bund will be constructed at the three main creeks. Using the RORB model total runoff from above, as assessment of storage was conducted.

A minimum storage level for each of the three catchments was determined. An inundation extent is indicated in Figure 10.1.

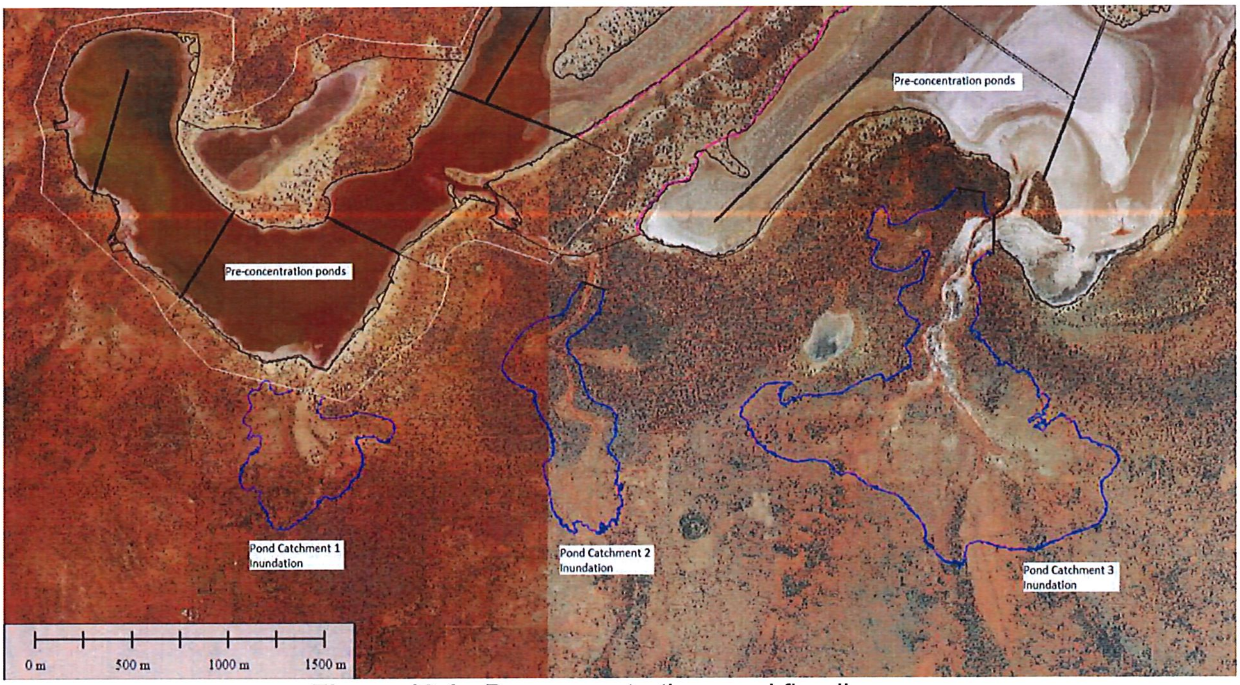


Figure 10.1: Pre-concentration pond flooding

b. The model runs for a 12 day period to allow the water to flow through the system. - A comparison (i.e. difference map) of the existing and post development inundation remaining within the model domain at the final time step may provide a means for quantifying change in inundation area and depths and provide a surrogate measure to assess potential impact on duration of freshwater ponding.

Response:
As per comment 7.

We trust this is sufficient information for your current requirements. Please do not hesitate to contact us should you require any further information.

Yours faithfully
KNIGHT PIÉSOLD PTY LTD

DEAN SAWYER
Senior Engineer

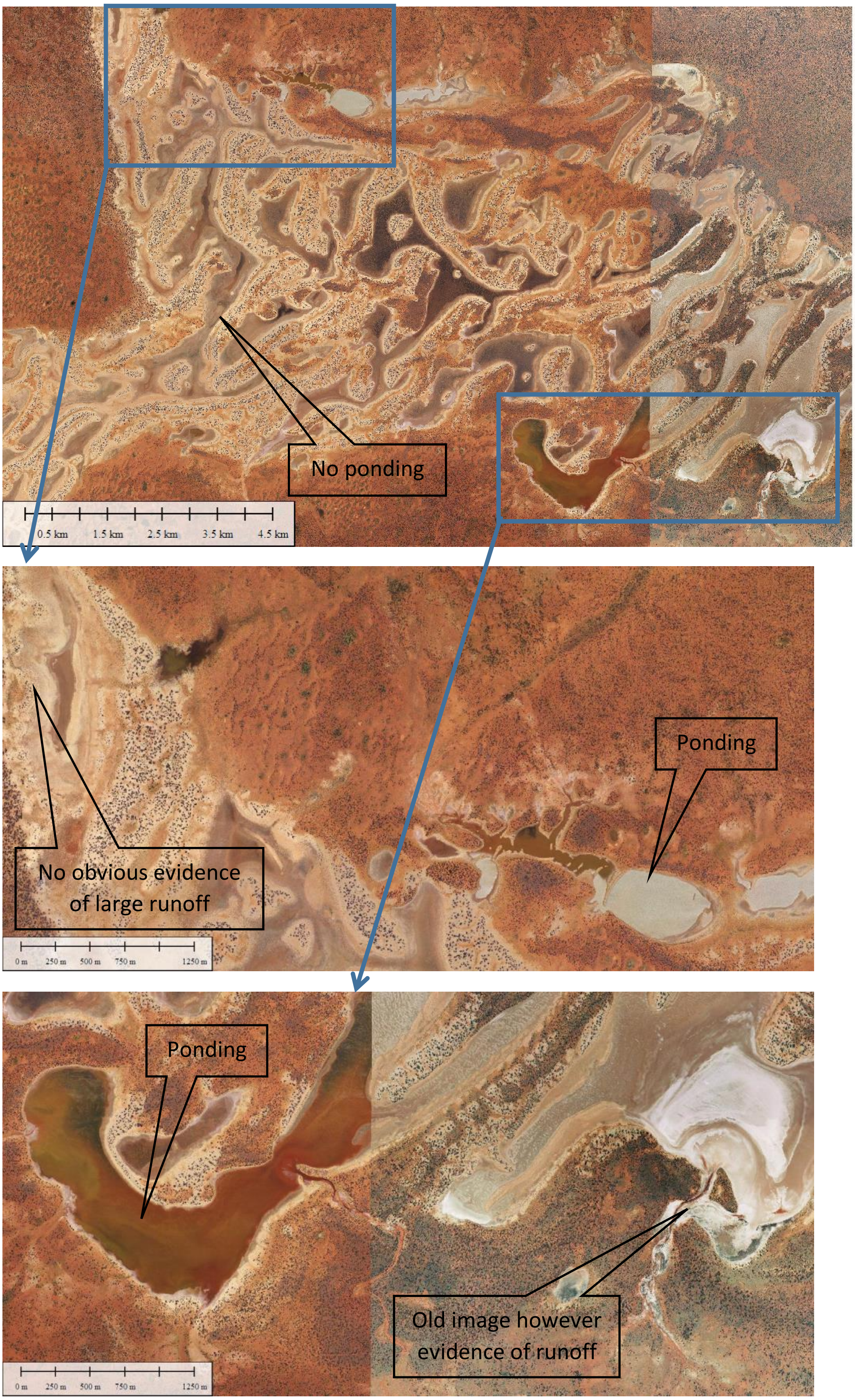
BRETT STEVENSON
Principal Engineer

REFERENCES

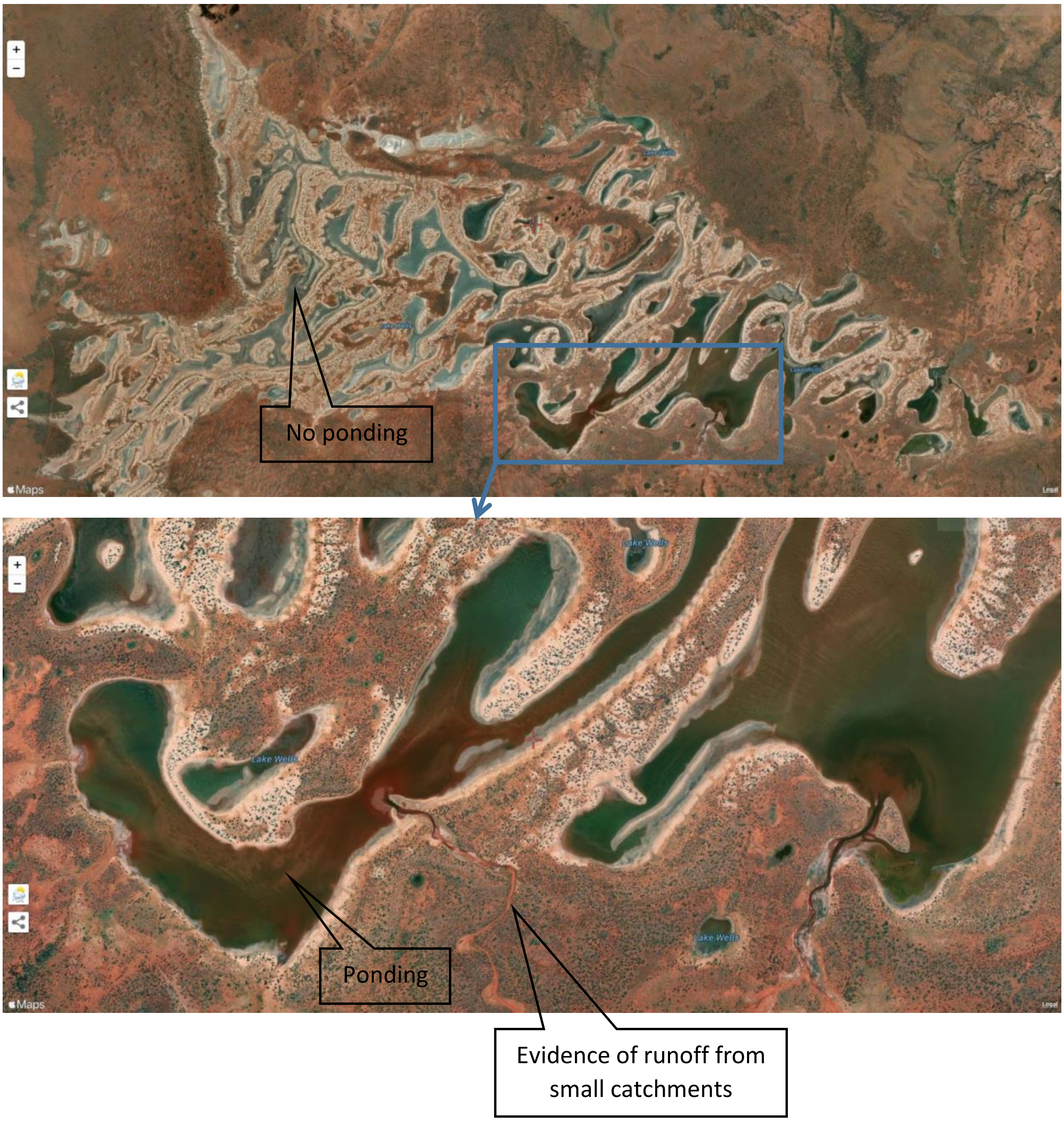
1. Golder Associates "*Lake Wells Potash Project, Hydraulic Study*" Report 1667336-003-R-Rev0, December 2017
2. Knight Piésold "*Lake Wells Potash Project – Baseline Design Climatology*" PE18-00849, September 2018
3. https://www.ga.gov.au/dea/products/wofsARR
4. http://rffe.arr-software.org/
5. D Flavell (2012) "*Design flood estimation in Western Australia*", Australasian Journal of Water Resources, 16:1, 1-20.
6. RORBwin Harc consulting.

APPENDIX A
Flooding Aerial Images

Client Supplied *0356.ecw* provided August 2012, undated capture.

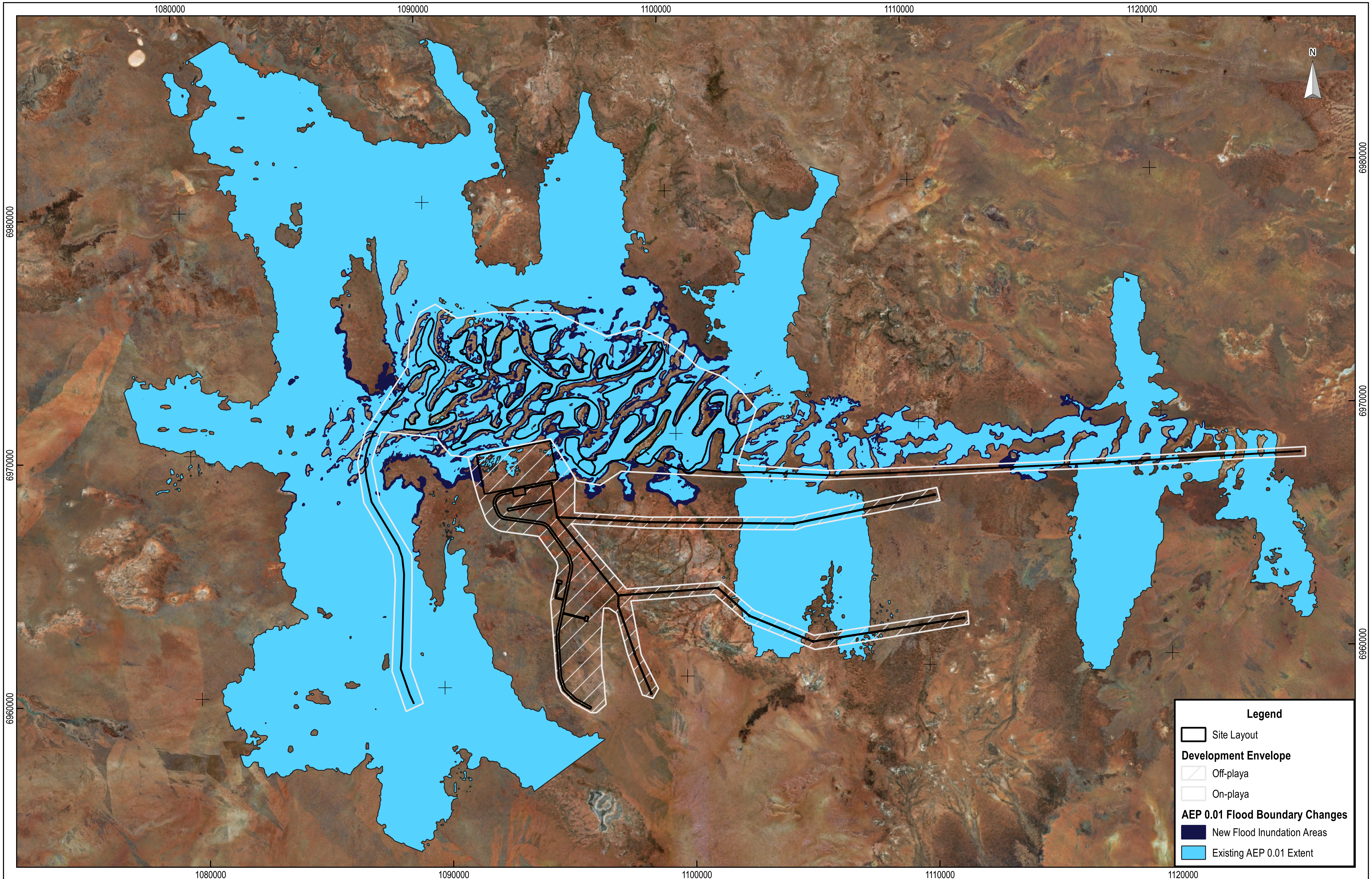


Unknown date: Apple Maps https://satellites.pro/Australia_map#-27.256462,123.039322,13



APPENDIX B

Predicted Changes to Flood Extents (from MBS Environmental)



Scale: 1:140000
Original Size: A3
Aerial Photo: ESRI Satellite
Grid: GDA94 / MGA zone 51 (EPSG:28351)

Australian Potash
Lake Wells Project
Environmental Review Document

Figure

Predicted Changes to Flood Extents

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