Gunnedah Solar Farm - Updated Flood Impact Assessment

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Date:	**29 June 2018** **Rev05**

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Revision History					
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Executive summary

An updated flood impact assessment has been carried out on the proposed Solar Farm located at 765 Orange Grove Road Gunnedah (the Site), NSW for inclusion in the Environmental Impact Statement (EIS), in accordance with the Secretary's Environmental Assessment Requirements (SEARs). The Site is located within the Upper Namoi Management Zone BL of the Draft Floodplain Management Plan for the Upper Namoi Valley Floodplain 2016, and is affected by flooding.

This report presents the results of updated flood modelling undertaken after submission of the EIS to addresses a number of submissions received from the community and government agencies. Flood modelling was undertaken to estimate flood levels for a range of design events, and to estimate the impacts of the Solar Farm. The modelling indicated that the greatest impacts on flood levels would arise from the security fencing and the blockage caused by the accumulation of vegetative debris mats as debris on the fencing. These impacts are assessed in terms of afflux, which is the expected increase in flood level caused by the proposed development. Because of the potential impacts, the security fence has been realigned and designed to reduce afflux.

A preliminary flood model was constructed using ground surface data from the Shuttle Radar Topography Mission (SRTM), which represents the ground surface with a grid of about 30m and a vertical accuracy of about 9.8m across Australia. Though the results demonstrated that the site would be affected by flooding, and the fences were likely to result in small increases to flood levels, the terrain model was considered too coarse to provide an accurate estimation of flood depths and increases at an appropriate scale (less than 1.0 m). This flood model was presented for community consultation in March 2018 and submitted as part of the EIS.

In response to comments received from the community an updated flood model has been prepared. The flood model was revised using much more accurate ground surface data from three sources; LiDAR surveyed in 2000 for the Carroll to Boggabri Flood Study (SMEC, 2003), LiDAR surveyed by drone for Photon in 2017 and the construction drawing for the ring levee around the property at 765 Orange Grove Road (Myalla, or "Lou's Place"). These terrain data were found to be generally consistent with each other, but the 2000 LiDAR showed some inaccuracies of up to about 0.6m between swathes of survey, which appeared to be a survey artefact that did not reflect the real ground surface. **pitt&sherry** has processed the ALS data to smooth the swathe overlap areas as much as possible to avoid 'steps' or sudden jumps in topography in the hydraulic model. The available survey data was combined and processed into a single elevation model. With the new data, the flood model indicated more uniform flow depths across the site, with flood depths and patterns of flow that reflected observed conditions. The revised model was then used to estimate the potential impacts of the proposed solar farm.

For the updated flood model flood flows were also revised following receipt of further information on the flood study carried out for the Carroll to Boggabri Flood Study (SMEC, 2003). Some inconsistencies were found in comparing flows and flood levels for the 1%AEP and 1955 flood floods. The SMEC 1% AEP estimation includes the 1955 flood event which was one of the largest recorded flood events, however this event was prior to the construction of Keepit Dam in 1960. The purpose of Keepit Dam is for flood mitigation among other uses (Water NSW, 2018). The FFA estimated during this study uses gauge data post Keepit Dam and therefore excludes the 1955 event and results in lower design event flow estimates. It appears that the construction of the Keepit Dam has reduced flows. A detailed reconciliation of flows and flood levels was not attempted, and it was assumed that the 1955 flood approximated a 1%AEP flow. Simplified methods were used to estimate 10%AEP, 5%AEP and Probable Maximum Flood (PMF) flows for the purposes of estimating impacts. The updated flood model was calibrated by comparing computed and observed flood levels for the 1955 flood, which resulted in a good fit between the two.

Considering the many comments from the community expressing concern over the security fence and the impacts it may cause when blocked by flood debris. A number of configurations were considered, culminating in a new fence configuration, Fence Configuration 4, which was developed to mitigate potential impacts to flooding. Fence Configuration 4 involves drop-down fencing designed to allow flood water into and through the development site during significant flood events to minimise potential redirection of flood flows due to fence blockage. Fence Configuration 4 was developed and modelled to estimate the additional mitigating benefit of drop-down fencing designed to minimise blockage and redirection of floodwater. The model shows that drop-down fencing further reduces flooding impacts and produces an entirely acceptable outcome whereby the proposed development would have negligible flood impacts on surrounding properties.

It was found that during the 1955 flood conditions:

- modelling of Fence configuration 4 indicates this option would increase flood levels by a maximum of 0.122 m (122 mm) at the fence, but these impacts are reduced to less than 0.063 m (63 mm) at the eastern property boundary, to about 0.027 m (27 mm) at the northern property boundary, and to about 0.002 m (2 mm) at the worst affected residential receiver.
- under fence configuration 4, the changes in velocity are less than -4% within the fences, up to -1% at the eastern property boundary and up to +4% on the north western property boundary. Localised higher increases to velocity are shown in areas where the water overtops the blocked fence or where water flows around a corner in the fence.

Flood maps have been prepared that show the spatial distribution of the impacts, and tables show how the impacts affect various sensitive receivers (especially residences and farm buildings) and other features (e.g. roads) near the proposed Solar Farm.

1. Context and purpose

Photon Energy Australia Pty Ltd has engaged the services of **pitt&sherry** to undertake a flood impact assessment for the proposed Gunnedah Solar Farm at 765 Orange Grove Road Gunnedah, NSW (the Site). The intent of the flood assessment is to:

- Understand the nature of flooding at the site
- Estimate flood levels
- Estimate the potential impacts of the proposed Solar Farm on flood levels and flow velocity
- Assess the effectiveness of various mitigation strategies designed to reduce potential flood impacts
- Respond to comments received from the community consultation, following the presentation and exhibition of a preliminary flood assessment, which is described in *Gunnedah Solar Farm – Flood Impact Assessment, SY17199B005 REP 31P Rev02*, **pitt&sherry**, 22 March 2018.

2. Location

The Site is located at 765 Orange Grove Road, Gunnedah, New South Wales, and is located on the floodplain of the Namoi River approximately 9km north-east of the town of Gunnedah, as shown in Figure 1. The Lot details of the subject property are summarised in Table 1.

The Site is located within the Upper Namoi Management Zone BL of the *Draft Floodplain Management Plan for the Upper Namoi Valley Floodplain 2016* (Government of NSW, 2016). This zone includes areas of the Lower Liverpool Plains Floodplain (which is the area of the floodplain north of the Binnaway to Werris Creek railway) that are important for the conveyance of floodwaters during the passage of a flood. Its outer boundary is defined by a slope of less than or equal to 0.5%.

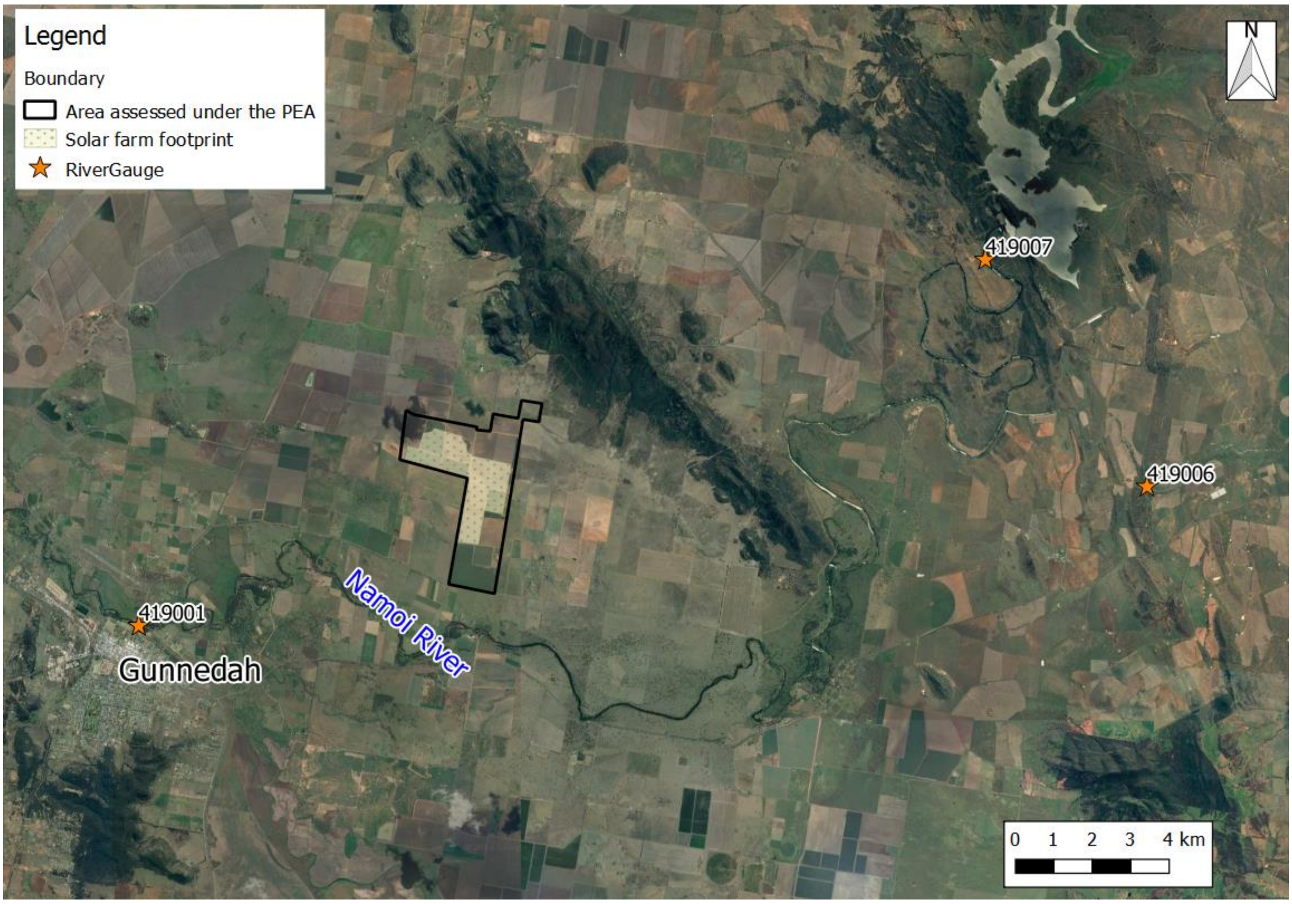


Figure 1: Gunnedah Solar Farm property boundary and nearby river gauges

Table 1: Property details

Location	Address	Lot and DP
Gunnedah	765 Orange Grove Road, Gunnedah, NSW, 2380	Lot 1 DP 186590 Lot 1 DP 1202625, Lot 153 DP 754954, Lot 264 DP 754954, Lot 2 DP 801762, Lot 151 DP 754954

3. Gunnedah SEARs - Flooding and Coastal Erosion

Secretary’s Environmental Assessment Requirements (SEARs) for the proposed Gunnedah Solar Farm were issued on 25 August 2017 from the Office of Environment and Heritage. The SEARs addressed in this document are outlined in Table 2.

Table 2: Relevant SEARs items

Item number	Sub-item	Comments
10. The EIS must **map the following features** relevant to flooding as described in the Floodplain Development Manual 2005 (NSW Government 2005) including:	a. Flood prone land	The site is located within an area that is prone to flooding in events less than 5%AEP
	b. Flood planning area, the area below the flood planning level.	The site is located within the Flood Planning area under the Gunnedah Local Environment Plan (published 26-02-2012)

Item number	Sub-item	Comments
	c. Hydraulic categorisation (floodways and flood storage areas).	The site is located in the floodplain of the Namoi River and functions principally as flood storage. The Site is located within the Upper Namoi Management Zone BL of the *Draft Floodplain Management Plan for the Upper Namoi Valley Floodplain 2016*
11. The EIS must **describe flood assessment and modelling undertaken** in determining the design flood levels for events, including a minimum of the 1 in 10 year, 1 in 100 year flood levels and the probable maximum flood, or an equivalent extreme event.		See Sections 4 and 6
12. The EIS must model the effect of the proposed development (including fill) on the flood behaviour under the following scenarios:	a. Current flood behaviour for a range of design events as identified in item 11 above. This includes the 1 in 200 and 1 in 500 year flood events as proxies for assessing sensitivity to an increase in rainfall intensity of flood producing rainfall events due to climate change.	See Section 4 The Probable Maximum Flood (PMF) has been included as a proxy for the 200 year ARI and 500 year ARI floods.
13. Modelling in the EIS must consider and document:	a. The impact on existing flood behaviour for a full range of flood events including up to the probable maximum flood.	See Sections 4 and 6 The range of flood events comprises 10%AEP, 5%AEP, 1%AEP and PMF
	b. Impacts of the development on flood behaviour resulting in detrimental changes in potential flood affection of other developments or land. This may include redirection of flow, flow velocities, flood levels, hazards and hydraulic categories.	Changes to flood levels and velocities are shown in the flood maps in Appendix A, and the tables of changes at sensitive receivers in Section 0
	c. Relevant provisions of the NSW Floodplain Development Manual 2005.	The NSW Floodplain Development Manual has been addressed where practical in the model preparation for this assessment.
14. The EIS must assess the impacts of the proposed development on flood behaviour, including:	a. Whether there will be detrimental increases in the potential flood affectation of other properties, assets and infrastructure.	Changes to flood levels are shown in the flood maps in Appendix A, and the tables of changes at sensitive receivers in Section 0
	b. Consistency with Council floodplain risk management plans.	Council's floodplain risk management plans have been consulted during this Flood Impact Assessment

Item number	Sub-item	Comments
	c. Compatibility with the flood hazard of the land.	Council's floodplain risk management plans have been consulted during this Flood Impact Assessment
	d. Compatibility with the hydraulic functions of flow conveyance in floodways and storage in flood storage areas of the land.	It is considered that the proposed development is compatible with the hydraulic functions of flow conveyance and flood storage in the vicinity.
	e. Whether there will be adverse effect to beneficial inundation of the floodplain environment, on, adjacent to or downstream of the site.	It is considered that the development will not appreciably change the beneficial effects of inundation in the vicinity.
	f. Whether there will be direct or indirect increase in erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses.	The site is not located close to the Namoi River, and will not affect the river's erosion, siltation, vegetation, and bank stability
	g. Any impacts the development may have upon existing community emergency management arrangements for flooding. These matters are to be discussed with the SES and Council.	It is considered that the development will not affect community emergency management arrangements.
	h. Whether the proposal incorporates specific measures to manage risk to life from flood. These matters are to be discussed with the SES and Council.	It is considered that the development will not change risks to life from flooding.
	i. Emergency management, evacuation and access, and contingency measures for the development considering the full range or flood risk (based upon the probable maximum flood or an equivalent extreme flood event). These matters are to be discussed with and have the support of Council and the SES.	It is considered that the development will not change emergency evacuation and access.

Item number	Sub-item	Comments
	j. Any impacts the development may have on the social and economic costs to the community as consequence of flooding.	It is considered that the development will not change social costs to the community. The economic costs relate to changes in flooding, which are mapped in Appendix A. There are economic benefits associated with the development of the proposed Solar Farm, but a comprehensive economic assessment is beyond the scope of the current study.

4. Key comments received from the community

Following exhibition of the EIS in May 2018, 52 submissions were received from the community. Most of these raised concerns about flood impacts and the accuracy of the previous flood modelling. The key themes expressed in community submissions related to flooding, are summarised as follows:

- Concerns were expressed over the location of the solar farm on a floodplain and potential impacts on flood conditions and impacts to neighbouring properties. Particular concerns relate to the security fence which would likely become blocked by debris in a flood, causing redirection of flows and worsening of flood effects on surrounding properties.
- Questions were raised over the accuracy of the flood model and data inputs, including:
  - terrain data (SRTM). Would have been better to use more accurate LiDAR data
  - doesn't reflect key landscape features (eg major irrigation channels)
  - use of 1984 flood data as a template. Why not use the 1955 flood?
  - reference to river gauges for historic data
  - effect of Mooki River and other local waterways including Rangari Creek
  - whether landholder records of flood observations were checked
  - how the model addresses the unpredictability of flooding
  - Inconsistencies between P&S flood model and actual observations of dry land vs inundated areas
- Concerns were expressed over lack of reference to the Carroll to Boggabri Flood Management Plan (2006) and apparent inconsistencies between the P&S flood modelling and data in the FMP from SMEC modelling (eg flood depths, velocities).
- Disagreement with the security fence blockage assessment and predicted impact on flooding. Respondents felt blockage would be 100% and a flood would flatten the fence. Suggested redesign or remove the fence.
- Some respondents suggested lowering/removing channel banks to reduce flood impacts; and provided support for the development without a security fence, or with reconfigured fence or drop-down fence and designed floodways.

It is acknowledged that the previous modelling depended on the SRTM DEM-H terrain data (which has a vertical accuracy of about ±9.8m against 90% of tested heights across Australia), and approximated flows approaching the site from the Namoi River. The intent of the previous modelling was to carry out a preliminary assessment that focused more on modelling changes due to the solar farm. It demonstrated that:

- the site is flood affected

- the security fencing could cause impacts in terms of increased flood levels and changed velocities
- the security fence should be designed in a way that reduces flood impacts.

The SRTM DEM-H data were used in the previous assessment because better terrain data were not available at the time. Better data have now been acquired in the form of LiDAR from OEH and other sources as described in Section 5.2, which also notes their limitations. The flood modelling based on these terrain data yields more credible results in terms of the distribution and depths of flooding around the site, which agree better with observed flood levels. In the previous model, the terrain was much more 'lumpy', falsely creating a network of channels and islands, which yielded over-estimates of velocities and impacts. In the current model, the terrain is much flatter and is criss-crossed with farm drains and levees, yielding more uniform flow distribution with lower velocities and lower potential impacts due to the solar farm.

Whereas the previous model only addressed flows approaching the site from the Namoi River, the current model includes a distribution of flows between the Namoi and Mooki rivers, based on further information obtained from the *Gunnedah and Carroll Floodplain Management Plan* 1999 (SMEC Study, updated 2014). As illustrated in the flood maps, the site is located where the flows from the two river systems merge over the flood plain, and the current model includes this mechanism by its representation of the terrain surface of the channels and flood plains. Inflows from the Rangari Creek were included in the Namoi and Mooki total flow, and were not modelled explicitly, because of the lack of flow data. Flows from the Rangari Creek merge with Namoi and Mooki flows on the flood plain over a wide area generally downstream of the site. Modelled flood levels and depths for the 1955 flood also agree well with observed flood levels and depths.

It is considered that the current model improves the representation of flood behaviour around the proposed solar farm, and hence provides a more accurate assessment of potential impacts compared with the previous (March 2018) flood assessment.

Photon has been investigating drop-down fencing options and is now committed to installing a suitable drop-down fence so as to minimise potential impacts due to fence blockage and redirection of flows. The drop-down fence would be designed to permit relatively unimpeded flow of floodwaters through the solar farm site. Modelling of a drop-down fence configuration has been undertaken. Detailed design of the drop-down fence would be undertaken post approval.

5. Construction of updated flood model

5.1 General approach

A flood model was constructed using the program HEC-RAS 5.0.4 in 2D mode. The model was calibrated by adjusting roughness parameters to yield flood levels consistent with observed flood levels for the 1955 flood event.

The flood model has been constructed from available rainfall and terrain data and has been verified by comparing flood levels with historic records and other flood studies, especially river gauge records and the *Gunnedah and Carroll Floodplain Management Plan* 1999 (SMEC Study, updated 2014).

5.2 Terrain data

The terrain data used were acquired from three sources:

- Aerial laser survey (ALS) carried out in 2000 for the Carroll to Boggabri Flood Study (SMEC, 1999, updated 2003), as illustrated in Figure 2. These data have a vertical accuracy of about 0.05 m. The surveyor notes that in some swathe overlap areas the vertical accuracy decreases by up to 0.60 m due to excessive turbulence. **pitt&sherry** has processed the ALS data to smooth the swathe overlap areas as much as possible to avoid artificial 'steps' or sudden jumps in topography in the hydraulic model, which will provide a more realistic representation of flow across the flood plain. The ALS data was compared against current aerial imagery to ensure that key hydraulic features are included.

- Drone survey data of the proposed solar farm site, which was carried out in 2017 for Photon Energy, as illustrated in Figure 3. This survey includes the current irrigation channels and flood levee banks on the site.
- The construction drawing for a ring levee at 765 Orange Grove Road (Myalla, or "Lou's Place") as illustrated in Figure 5. This drawing was developed by Stewart Surveys and shows spot levels on the existing ground and design levels for the levee.

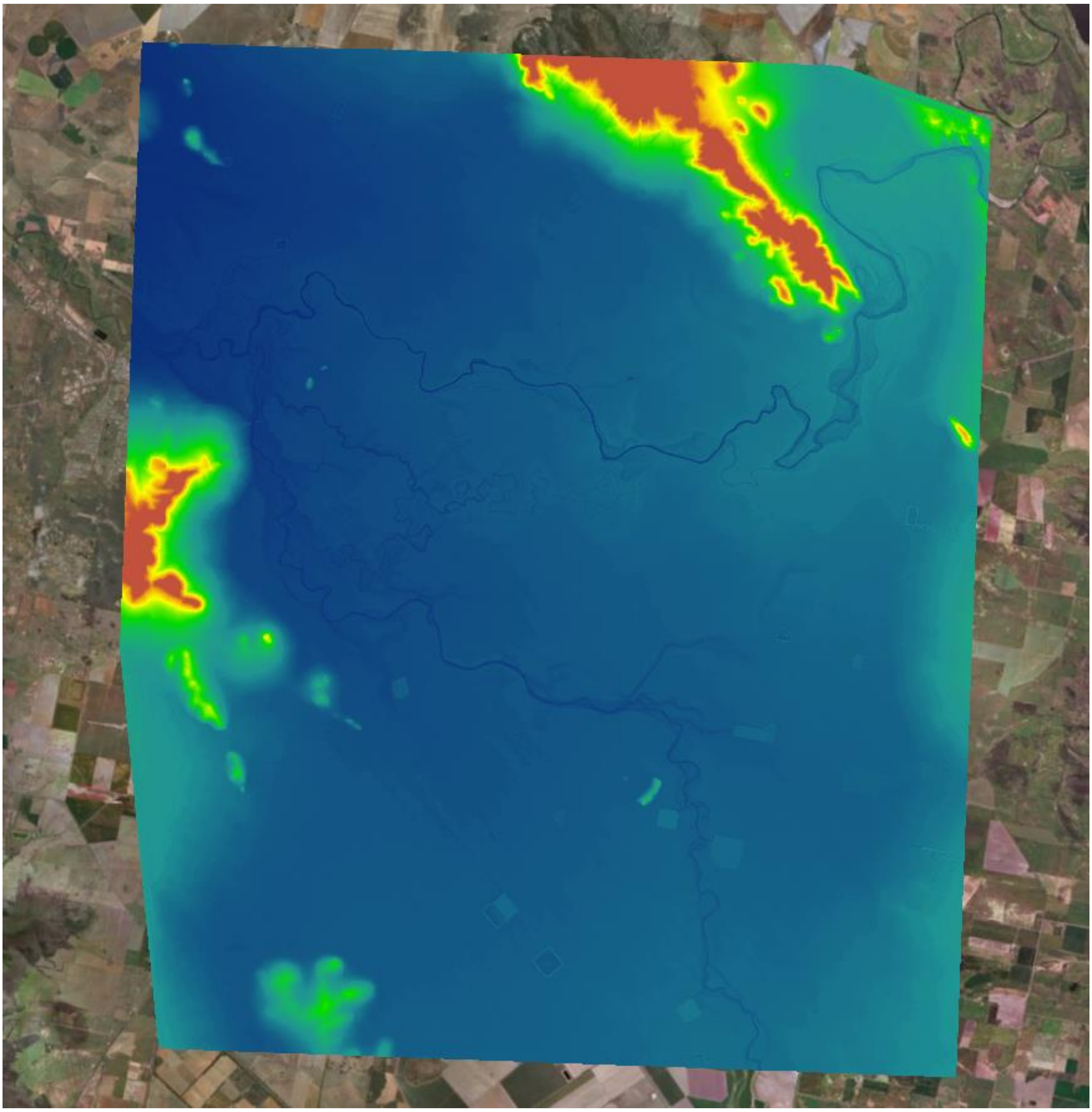


Figure 2: Aerial laser survey carried out in 2000 for the Carroll to Boggabri Flood Study (SMEC, 2003)

Figure 3: LiDAR survey carried out in 2017 for Photon Energy

Figure 4 illustrates the comparison between the 2000 Lidar (Blue) and the 2017 drone survey over the site (Red) using a east-west cross section positioned centrally on the property. There are some differences between the levels, but there is a good overall match between the two sets of data.

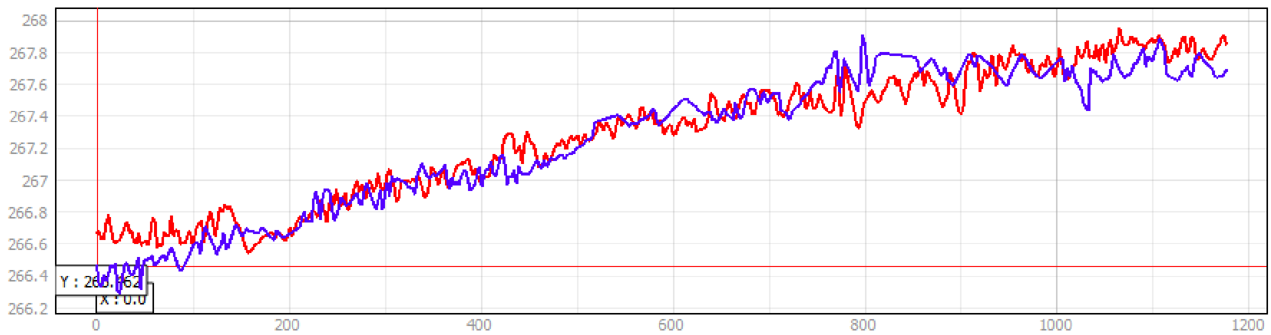


Figure 4: Comparison of Lidar data, (2000 Lidar – Blue and 2017 drone lidar – Red)

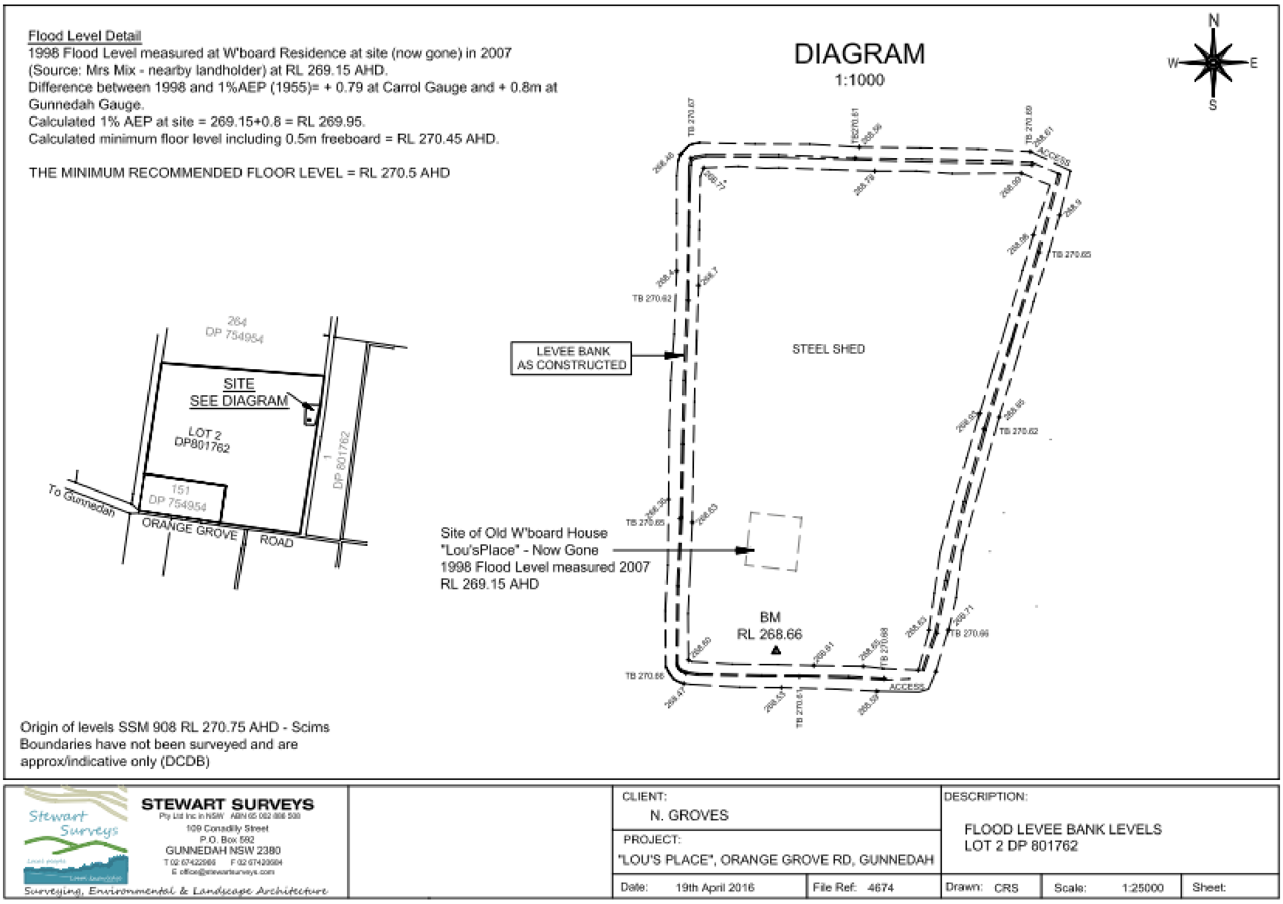


Figure 5: Construction details for ring levee at 765 Orange Grove Road (Myalla, or "Lou's Place")

5.3 Previous assessments, studies and sources of flood information

Previous assessments of flood levels around the site include the following:

- Stewart Surveys, which estimated a 1% AEP flood level at RL 269.95 at 765 Orange Grove Road (Myalla, or "Lou's Place", Lot 2 DP 801762)
- NSW SES FloodSafe brochure, which refers to estimated flood levels at the Gunnedah Gauge (Cohen's Bridge) for the 1998, 1955 and the 1% AEP flood level (available on-line)
- Gunnedah and Carroll Floodplain Management Plan 1999, SMEC Study, updated 2014, which approximates the 1955 flood to the 1% AEP flood event. (available on-line)
- Carroll to Boggabri Flood Study and Compendium of Data 2003, SMEC Study, which discusses the flood history and flood data and provides a Flood Frequency Analysis for the gauges.
- Carroll to Boggabri Floodplain Management Plan 2006, Webb McKeown & Associates on behalf of Department of Natural Resources (available on-line), which relies on earlier modelling by SMEC and infers conclusions for the purposes of planning.
- Preliminary flood impact assessment described in *Gunnedah Solar Farm – Flood Impact Assessment, SY17199B005 REP 31P Rev02*, **pitt&sherry**, 22 March 2018.

5.4 Hydrology

5.4.1 Gauges

The nearest River Gauges to the site are as follows:

- Gauge 419001 – Catchment area = 17100 km², Namoi River at Gunnedah located about 10 km downstream of the proposed solar farm site

- Gauge 419006 – Catchment area = 4670 km², Peel River at Carroll Gap, located about 25 km upstream of the proposed solar farm site
- Gauge 419007 – Catchment area = 5700 km², Namoi River, Downstream Keepit Dam located about 28 km upstream of the proposed solar farm site.

The gauge catchment areas and flow records were obtained from the NSW Department of Primary Industries Office of Water Real Time Data – Rivers and Streams data portal, http://realtimedata.water.nsw.gov.au/water.stm. Flood frequency analyses were carried out on the flow records at Gauges 419001, 419006 and 419007, as described in Section 5.4.3.

No flood frequency analyses were done on the available gauges on the Mooki River, Gauge 419084 and Gauge 419027. The Mooki river banks are about 10 km to the South of the site. A scaling factor was applied, based on the design flows from the Namoi River.

The catchment of the Namoi River at the site is 9961km², which is about 58% of the total area of the catchment at Gauge 419001.

A summary of the river gauge data is provided in Table 3.

Table 3: Available river gauge information

	Gauge 419001	Gauge 419006	Gauge 419007
Site commence	27/11/1891	04/12/1923	14/01/1924
Available discharge rate	02/12/1968 to current	26/02/1973 to current	19/06/1973 to current
Available stream water level	02/12/1968 to current	26/02/1973 to current	19/06/1973 to current
Available discharge volume	01/12/1891 to 01/01/2017	01/12/1923 to 01/01/2017	01/12/1923 to 01/01/2017

5.4.2 Flood frequency analysis of gauge data

The flood frequency analysis of gauge data was analysed using the available discharge rate data as the discharge volume data contained missing data during some of the extreme flood events.

The annual maxima flood data were extracted from the NSW Department of Primary Industries Office of Water Real Time Data – Rivers and Streams data portal records for each gauge and each calendar year and subject to a Flood Frequency Analysis (FFA) using the program HEC-SSP and the Log Pearson III (LPIII) statistical distribution. The results are illustrated in Figure 6, Figure 7 and Figure 8, and Table 4, which show the computed flow distribution and the 95%ile and 5%ile confidence limits. Catchment yields (flow per km²) are summarised in Table 5.

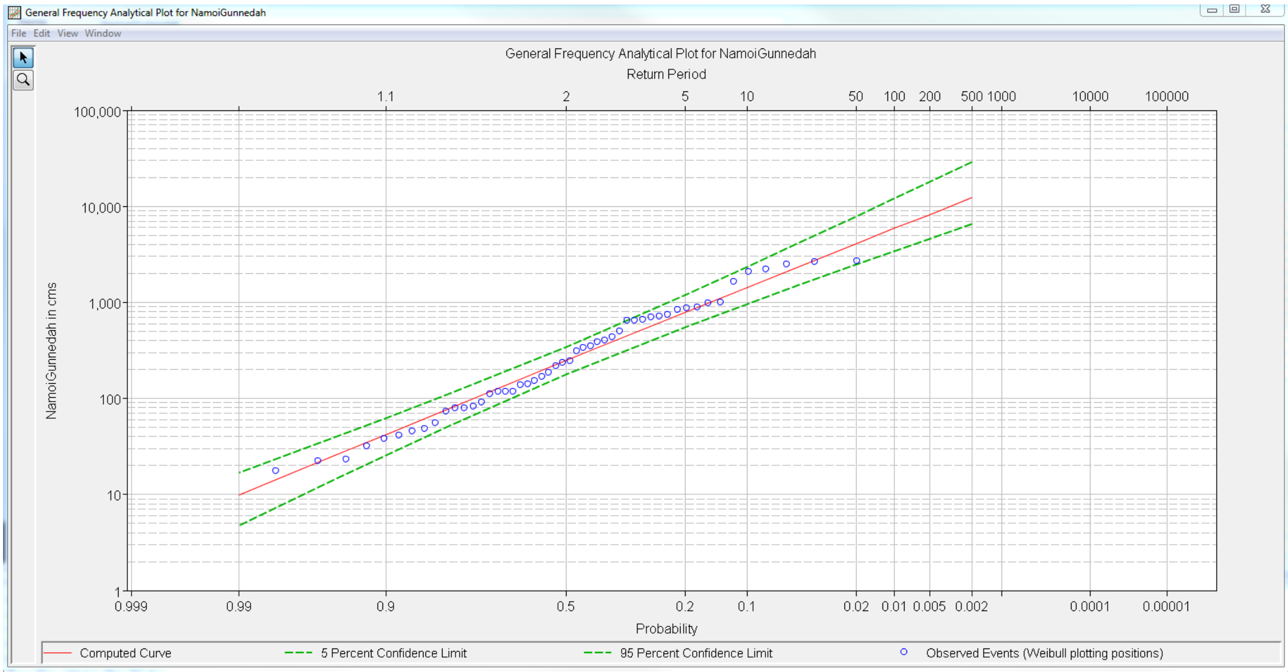


Figure 6: Results of LPIII flood frequency analysis of flow records from 1968 to 2017 at Gauge 419001 (units, cms = m³/s)

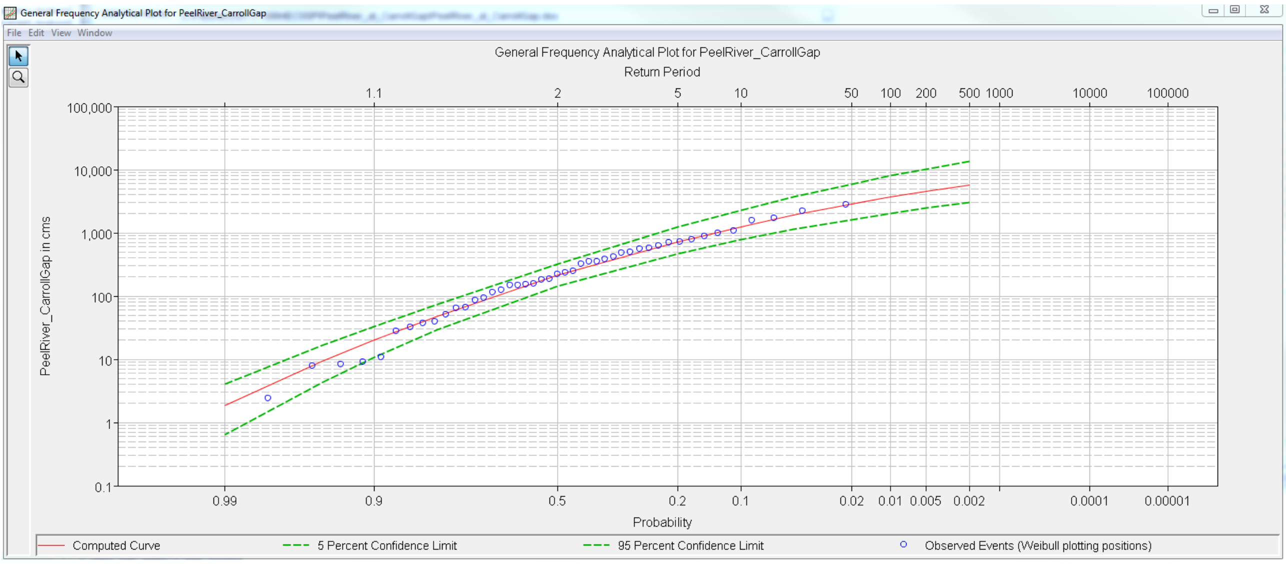


Figure 7: Results of LPIII flood frequency analysis of flow records from 1973 to 2017 at Gauge 419006 (units, cms = m³/s)

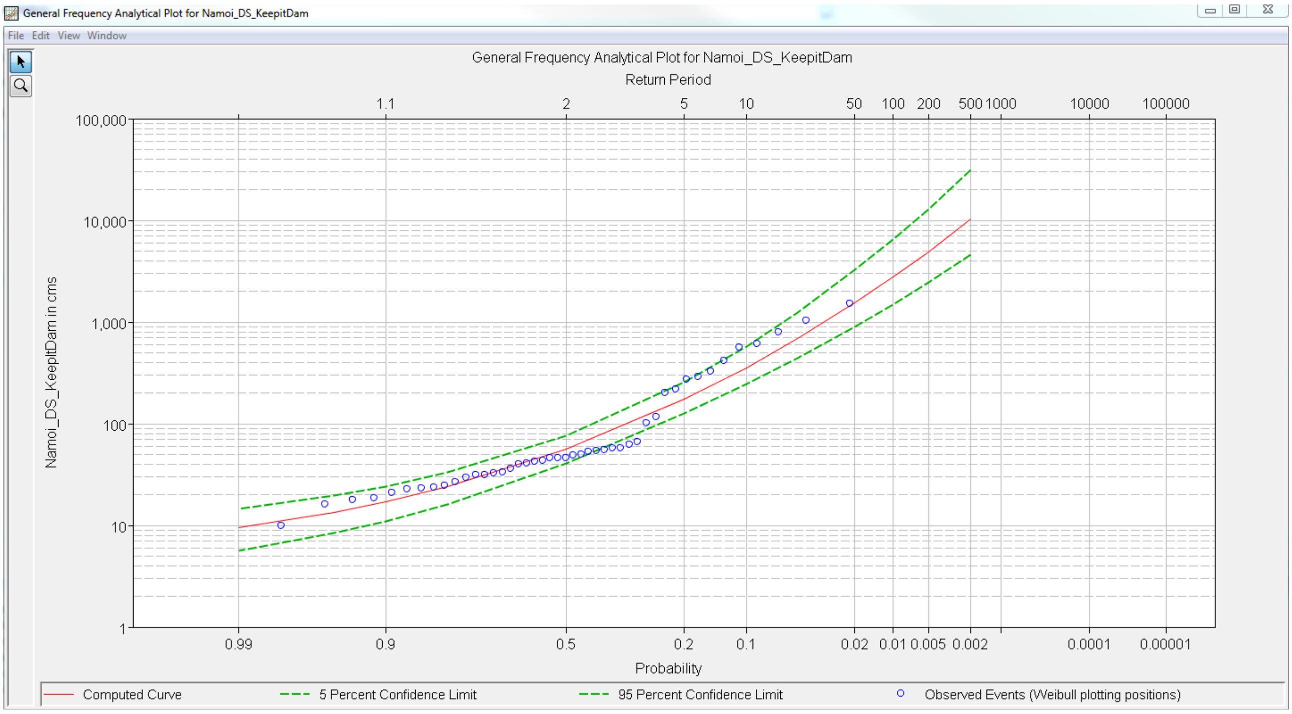


Figure 8: Results of LPIII flood frequency analysis of flow records from 1973 to 2017 at Gauge 419007 (units, cms = m³/s)

Table 4: Results of LPIII flood frequency analysis of flow record at river Gauges

AEP%	Gauge 419001 Namoi @ Gunnedah			Gauge 419006 Peel @ Carroll Gap			Gauge 419007 Namoi @ D/S Keepit Dam		
	95% (m³/s)	Computed (m³/s)	5% (m³/s)	95% (m³/s)	Computed (m³/s)	5% (m³/s)	95% (m³/s)	Computed (m³/s)	5% (m³/s)
0.2%	6,555	12,332	28,967	3,009	5,695	13,427	4,606	10,229	31,213
0.5%	4,596	8,223	17,955	2,450	4,511	10,195	2,450	4,916	12,939
1%	3,422	5,881	12,102	2,034	3,656	7,959	1,496	2,779	6,534
2%	2,473	4,074	7,868	1,631	2,851	5,943	897	1,544	3,238
5%	1,511	2,344	4,134	1,127	1,888	3,672	438	684	1,234
10%	967	1,432	2,343	779	1,255	2,291	243	354	572
20%	556	787	1,189	469	725	1,226	126	173	253
50%	180	248	344	142	212	321	41	56	76
80%	51	78	110	29	48	74	16	24	33
90%	26	42	62	11	20	33	11	17	24

Table 5: 1%AEP Catchment Yield

Gauge	1%AEP computed flow (m³/s)	Catchment (km²)	1%AEP Yield (m³/s per km²)
419001 Namoi @ Gunnedah	5,881	17,100	0.34
419006 Peel @ Carroll Gap	3,656	4,670	0.78
419007 Namoi @ D/S Keepit Dam	2,779	5,700	0.49

5.4.3 Flood frequency analysis at the site

The flood frequency analysis (FFA) at the site was estimated by combining the daily flows from the two river Gauges 419006 and 419007 with data obtained from the NSW Department of Primary Industries – Office of Water. No routing was applied at the upstream gauge locations because they were close to upstream boundary of the hydraulic model, and the hydraulic model routes the flood hydrograph to the site as part of its computations. The FFA was generated using HEC-SSP as per Section 5.4.2 and the results are shown in Table 6 and Figure 9.

Table 6: Results of LPIII flood frequency analysis of flow record at site

AEP%	Flow: 5% Confidence Limit (m^3/s)	Flow: Computed (m^3/s)	Flow: 95% Confidence Limit (m^3/s)
0.2%	6,810	13,400	34,300
0.5%	4,630	8,620	20,200
1%	3,370	5,990	13,100
2%	2,380	4,030	8,190
5%	1,420	2,250	4,110
10%	893	1,340	2,260
20%	506	725	1,120
50%	163	228	320
80%	47.9	73.8	106
90%	24.8	41.4	62.1
95%	14.3	25.9	40.6
99%	5.1	10.8	18.8

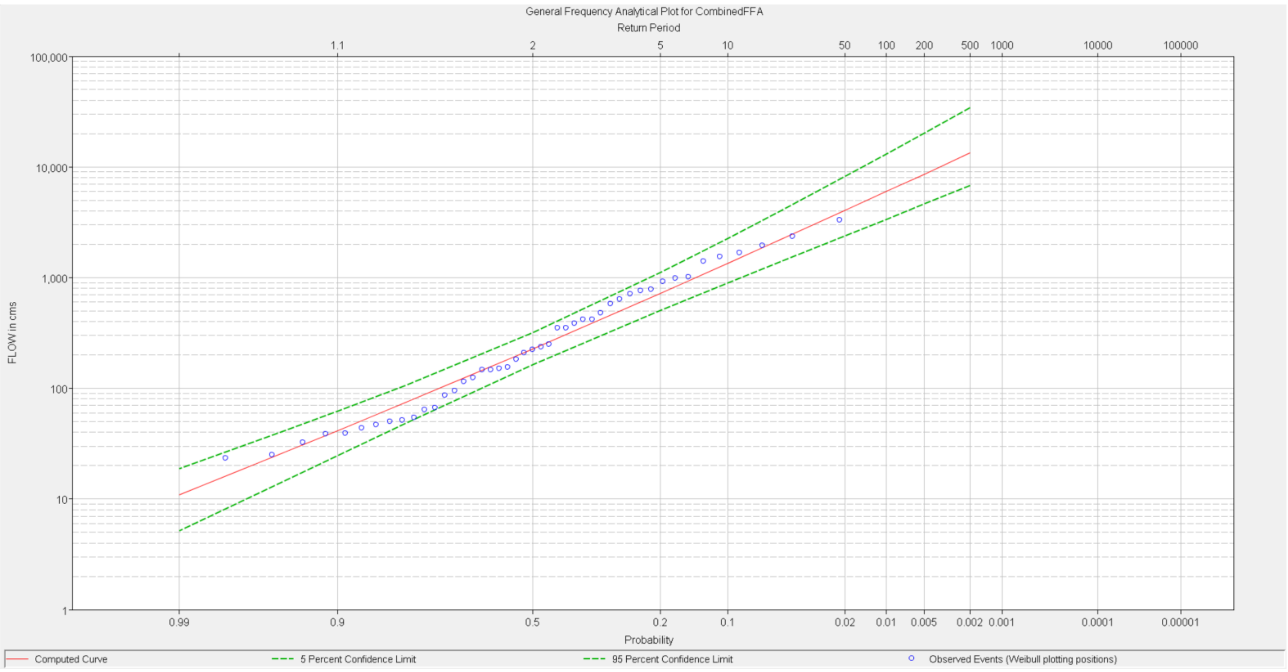


Figure 9: Results of LPIII flood frequency analysis of flow record from 1973 to 2017 at site (units, cms = m^3/s)

The computed flow of 5,990m^3/s for the Namoi River at the proposed Solar Farm site represents a yield of 0.60m^3/s per square kilometre for the 1% AEP flood event, which agrees fairly with the observed yields at the nearby gauges as summarised in Table 5.

5.4.4 Hydrological verification

Testing for changes to Keepit Dam releases and catchment

A double mass curve was created that compares the cumulative flows from river Gauge 419007 with cumulative flows from river Gauges 419001 and 419006 for the period 1973 to 2017, as shown in Figure 10. The double mass curve illustrates the consistency of flows in these gauges, and changes in the slope of the curve indicate a change in the flow releases from Keepit Dam, or a change to the catchment characteristics.

Gauge 419007, downstream of Keepit Dam, was installed after construction of the dam. The Gauge records therefore include the effects of the dam on flows.

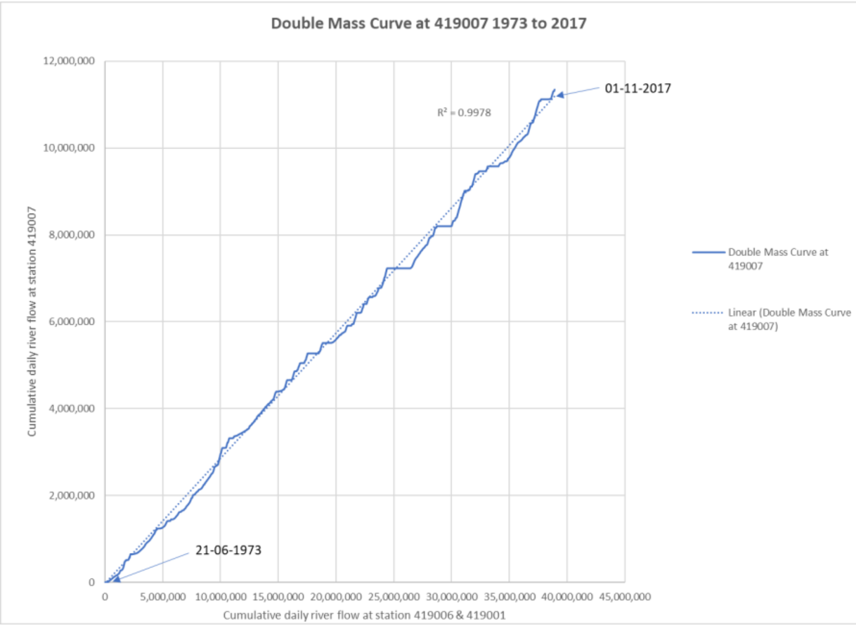


Figure 10: Double Mass Curve that compares cumulative flow at Gauge 419007 with cumulative flow from Gauges 419006 and 419001 for the period between 1973 and 2017

The construction of the Keepit Dam in 1960 has changed flows downstream, as indicated in the changes to the slope of the double mass curve in Figure 10. These changes have reduced the 1%AEP flows in the Namoi River, and may account for the differences between flows and flood levels for the 1955 flood and 1%AEP flood, as discussed elsewhere in this assessment (e.g. Figure 14).

Previous assessments – NSW SES

NSW SES has estimated flood levels at the Gunnedah Gauge (Cohen's Bridge) for the 1998, 1955 and the 1% AEP flood level, as shown in Figure 11. It is unknown how the 1% AEP flood level was derived.

The Table in Figure 11 suggests that the 1%AEP is equivalent to the 1955 flood water level plus 0.13m, and that the 1955 flood was of a lesser magnitude than the 1%AEP flood.

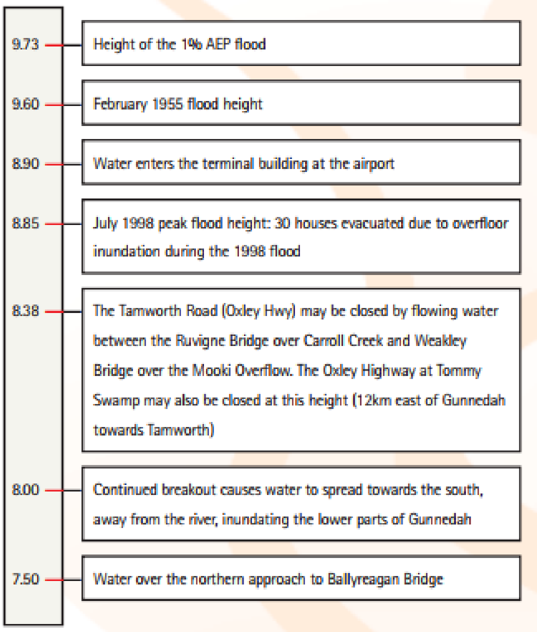


Figure 11: Key heights in metres at Gunnedah (Cohen's Bridge) Gauge. Source SES NSW FloodSafe brochure

Previous assessments – NSW DPI Gauge Rating

The NSW Department of Primary Industries current rating curve for Gauge 419001 Namoi @ Gunnedah is shown in Figure 12, and it is based on the cross section shown in Figure 13.

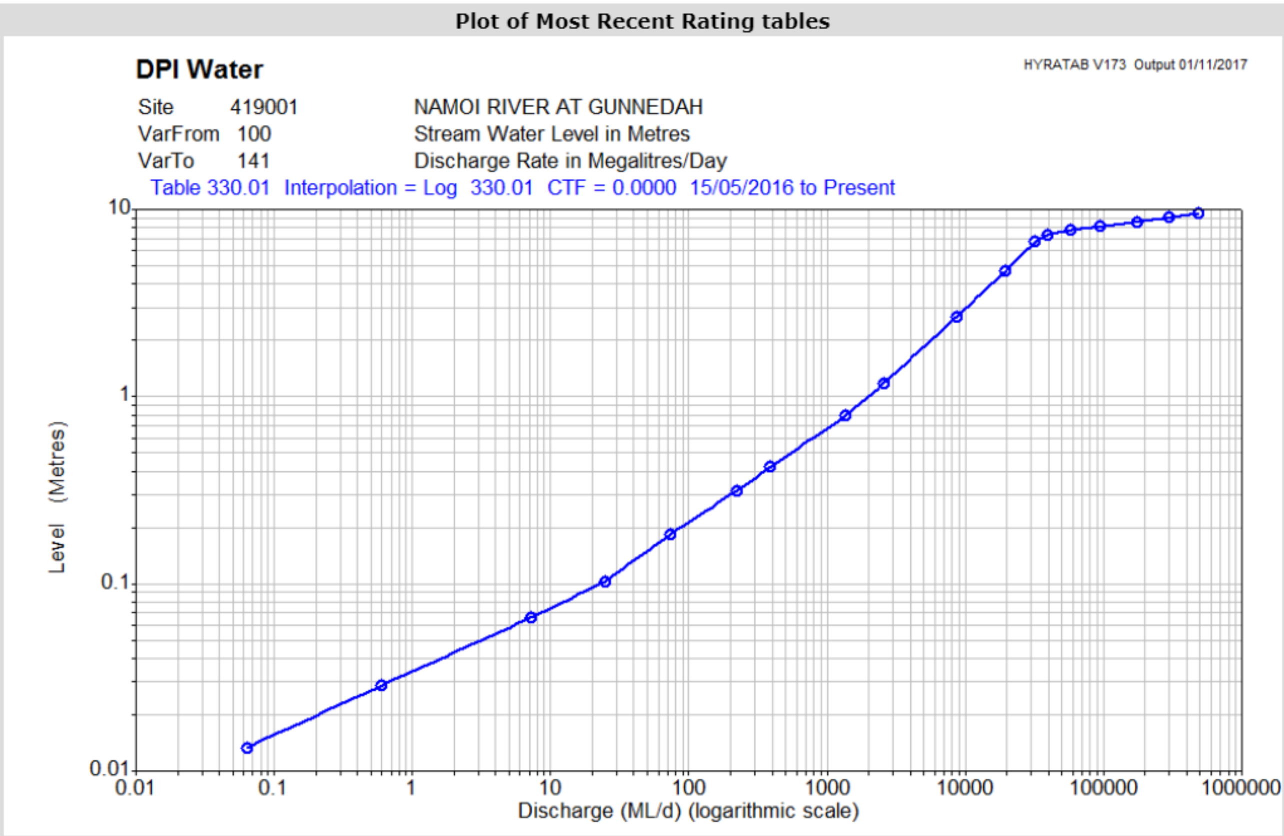


Figure 12: Rating Table of Gauge 419001, obtained from NSW Department of Primary Industries

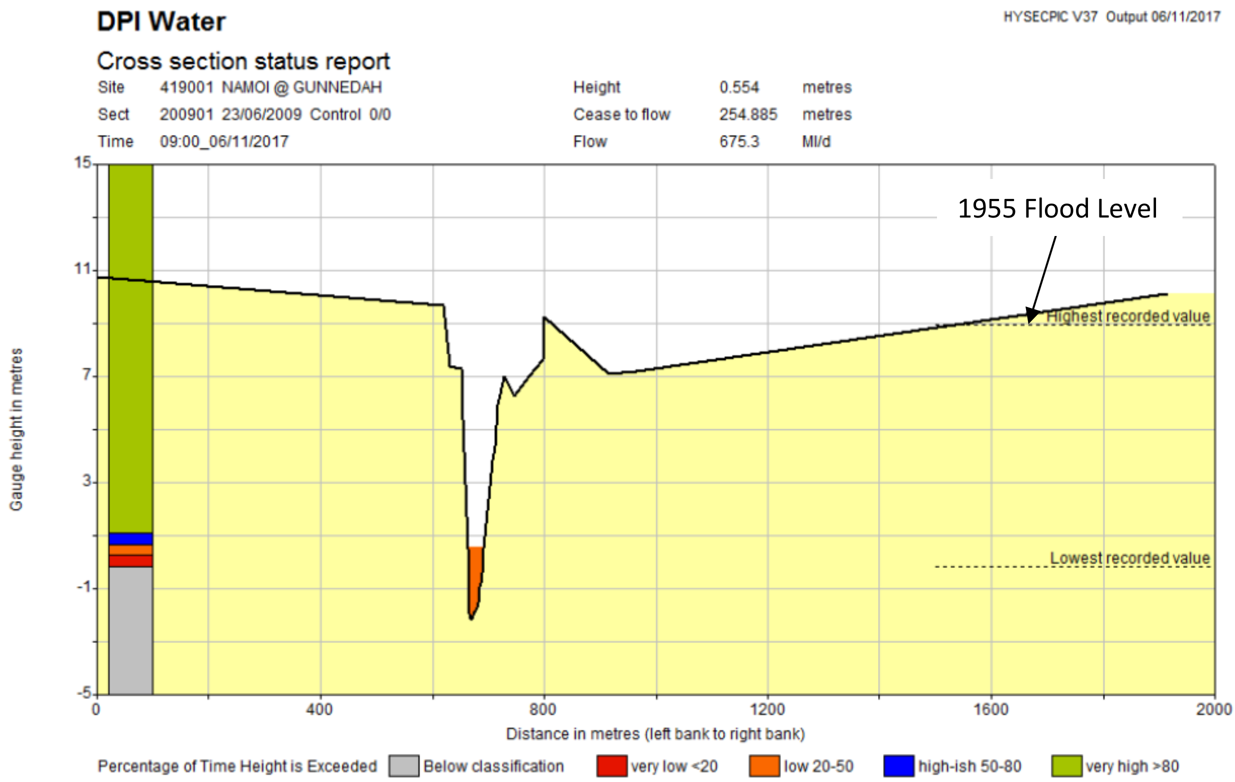


Figure 13: Cross Section at Gauge 419001, obtained from NSW Department of Primary Industries, dated 06-11-2017

Regional Flood Frequency Estimation (RFFE)

The website rffe.arr-software.org includes a function for Regional Flood Frequency Estimation (RFFE), which is commonly used to estimate flood flows under the following conditions and limitations:

- Catchments should be less than 1,000km²
- Catchments should not contain dams or weirs that could significantly affect the rainfall-runoff behaviour.

As the catchment for the site greatly exceeds 1,000km², and it contains the Keepit Dam, the RFFE was not used to verify or estimate flood flows at the site.

Previous flood studies – Carroll to Boggabri Flood Study and Compendium of Data (SMEC, 2003)

The Carroll to Boggabri Flood Study and Compendium of Data was reviewed for this study. Relevant findings are reproduced in Table 7 and Table 8.

Table 7: SMEC Study Peak Discharges and Volumes, Gunnedah (419001) (Source SMEC, 2003)

Event	Peak Flow (ML/d)
February 1955	800,030
January 1962	134,365
January 1964	281,356
February 1971	401,585
January 1974	237,354
January 1976	313,031
January 1984	341,951
July 1998	227,504
November 2000	234,051

Table 8: SMEC Study Flood Frequency Analysis Results

Gauge 419001 Namoi @ Gunnedah	
Year	**AEP (%)**
February 1955	1.0
November 2000	5.4
July 1998	7.3
Jan – Feb 1984	7.3

Comparison of SMEC FFA

The 2003 SMEC study estimated the 1% AEP discharge at Gauge 419001 to be about 9,160m³/s (February 1955 event), but this study estimates it to be 5,881m³/s (see Table 4), based on the available gauge data online (1973 to present).

The SMEC FFA includes the 1955 flood event which was one of the largest recorded flood events, however this event was prior to the construction of Keepit Dam in 1960. The purpose of Keepit Dam is for flood mitigation among other uses (Water NSW, 2018). The FFA estimated during this study uses gauge data post Keepit Dam and therefore excludes the 1955 event and results in lower design event flow estimates.

It appears that the construction of the Keepit Dam has reduced flows as illustrated in Figure 14.

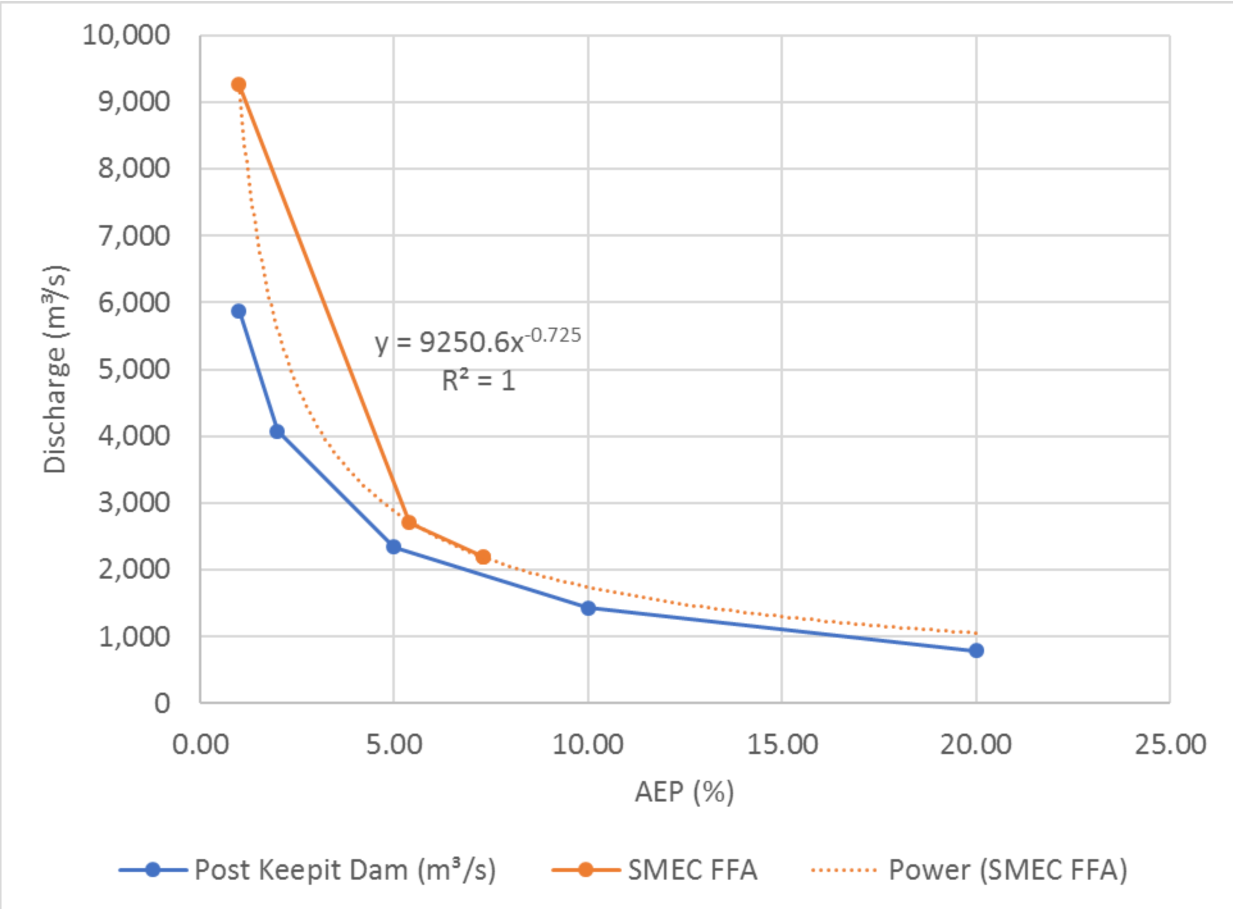


Figure 14: Comparison of SMEC FFA for gauge 419001

5.5 Hydraulics

5.5.1 Software

The hydraulic modelling software used for the peak flood level estimation was HEC-RAS Version 5.0.4 in 2D mode. 2D mode was preferred as water is allowed to flow naturally whereas in 1D mode the modeller makes decisions on flow paths. 2D mode also provides a better representation of the floodplain storage.

5.5.2 Input data

Terrain Data

The sources of the revised terrain data are described in Section 5.2. The data were processed using the HEC-RAS program to yield a grid with a grid size of up to 30m for the floodplain. The grid size and cell orientation was varied to provide finer detail at hydraulic features such as rivers, tributaries, table drains, irrigation drains and levees to represent channel invert levels and levee crest levels, as illustrated in Figure 15.

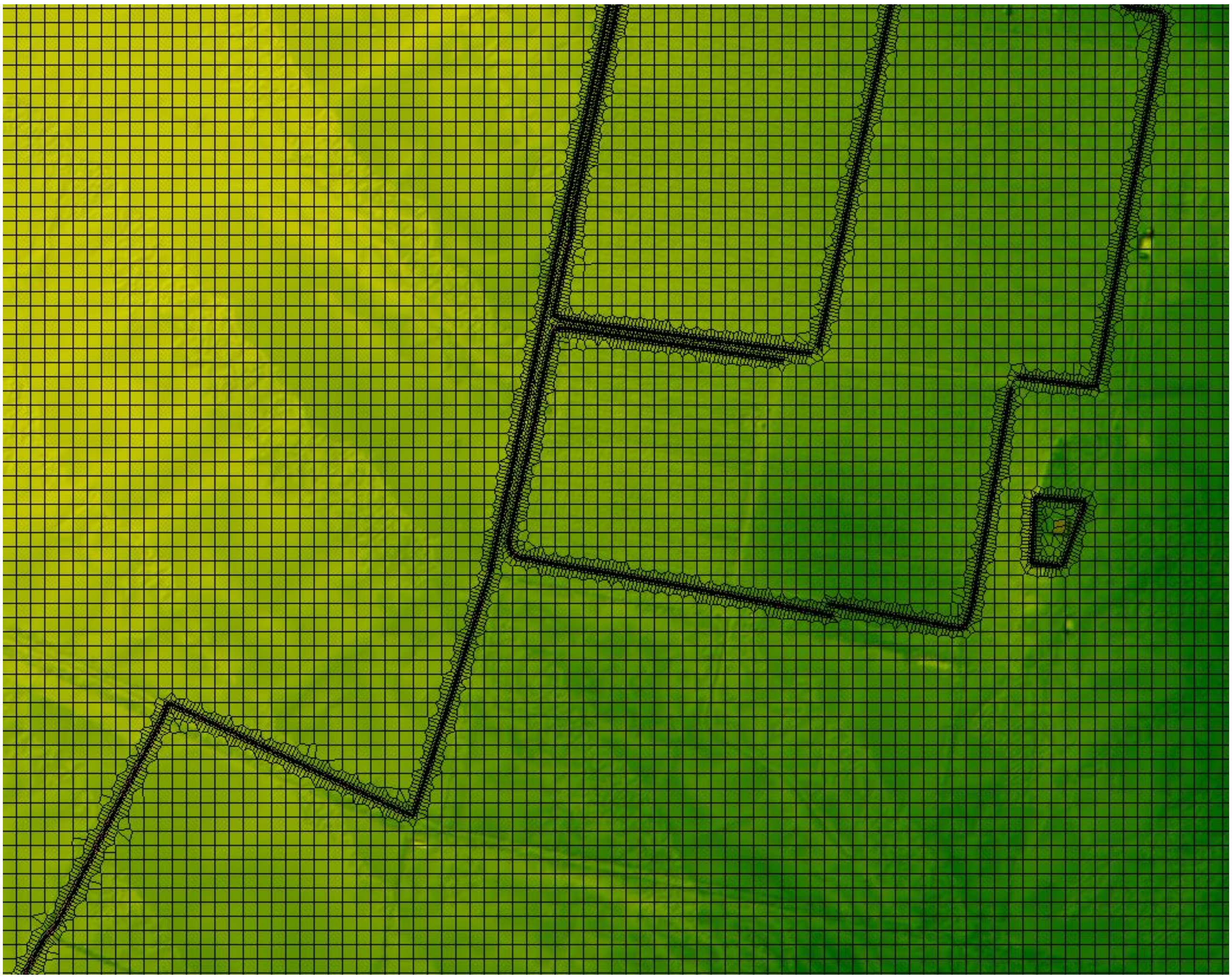


Figure 15: Example of grid cell adjustments at levees and channels around the solar farm site

The roughness of the floodplain was described as a single roughness value that covers the state of crops, vegetation and general farm fences. A low estimate of the roughness was used because it conservatively over-estimates impacts. The fences around the Solar Farm were described as discrete features that included representations of the nature and degree of blockage that would occur from flood debris.

Flows

An assessment of the gauge records is described in Section 5.4. Four design events were modelled

- 10%AEP, scaled from 1984 event
- 5% AEP, scaled from 1984 event
- 1955 event, which approximates 1%AEP
- PMF scaled from 1984 event

Design events based on 1984 event

The major flood event of January 1984 was used to generate a hydrograph shape for the 10%, 5% and PMF design events. The 1984 event is the largest on record for Gauge 419006, and it falls between the 5% AEP and 2% AEP probabilities.

The 10%, 5% and PMF design flow hydrographs in the Namoi River were scaled from the 1984 event hydrographs, as illustrated in Figure 16.

The 10%, 5% and PMF design flow hydrographs in the Mooki River were similarly based on the 1984 event hydrographs, scaled from the ratio of flows between the Namoi and Mooki Rivers, as illustrated in Figure 17.

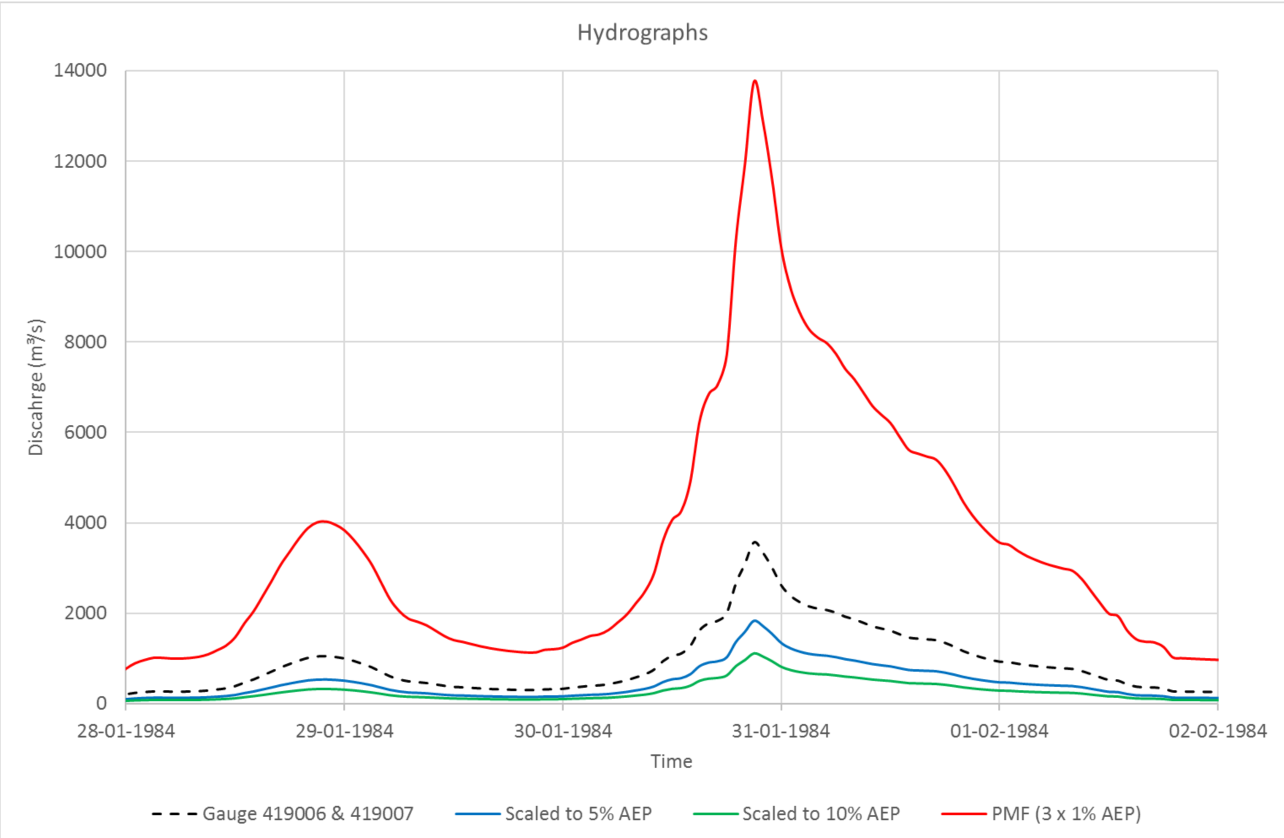


Figure 16: Flood Hydrographs for 10%, 5% and PMF events for the Namoi River based on 1984 event

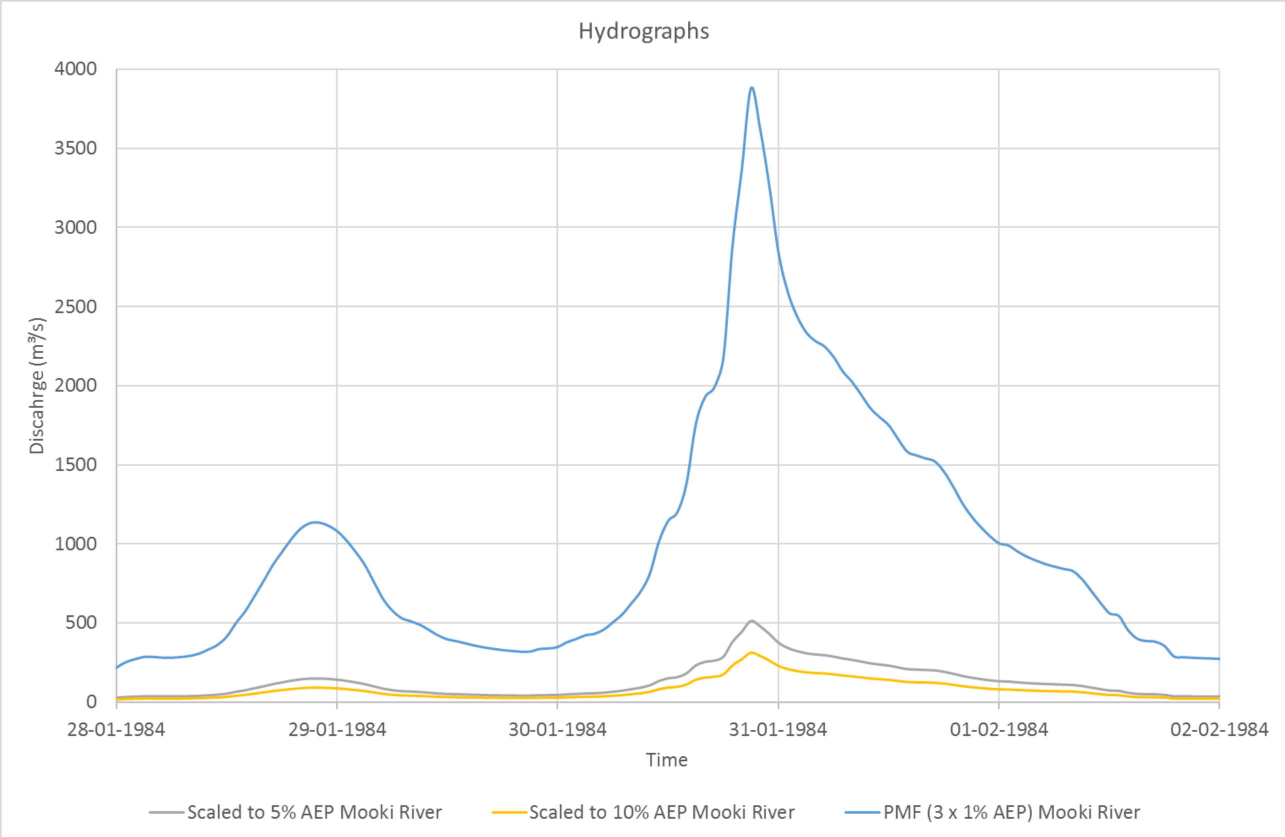


Figure 17: Flood Hydrographs for 10%, 5% and PMF events for the Mooki River based on 1984 event, using scaling factor from 1955 event

1955 event

The 1955 flood event was used as a scenario and calibration event. The recorded gauge discharge for the Namoi River at Peel River and the Mooki River at Breeza were acquired from the SMEC 2003 study and used as inflow into the hydraulic model as illustrated in Figure 18. Two flood levels within the model boundary were available for calibration, these were also acquired from the SMEC 2003 study. The recorded levels were at Gauge 419001 and a post found behind Battery Hill house.

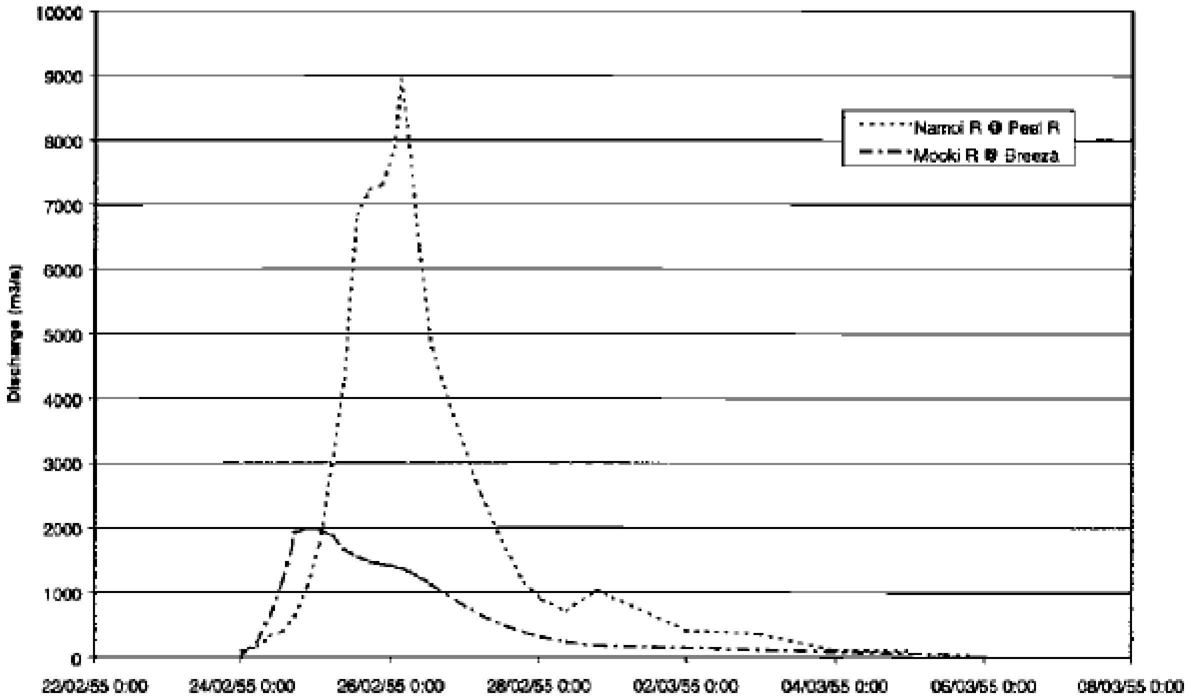


Figure 18: 1955 Gauged discharge hydrographs for the 1955 event for the Namoi River and Mooki River (SMEC, 2003)

Boundaries

Three boundary conditions were applied:

- The tail water condition at the downstream boundary, which was set to a normal depth with a hydraulic gradient of 0.00075 (m/m)
- Inflows at the upstream boundaries for the Namoi River and Mooki River were applied as hydrographs

The upstream and downstream boundaries were set at about 15km and 21km upstream and 9km downstream of the site respectively, as illustrated in Figure 19. The distances between the boundaries and the site are sufficient to ensure that hydraulic conditions at the site are not significantly affected by assumptions of conditions at the boundaries.

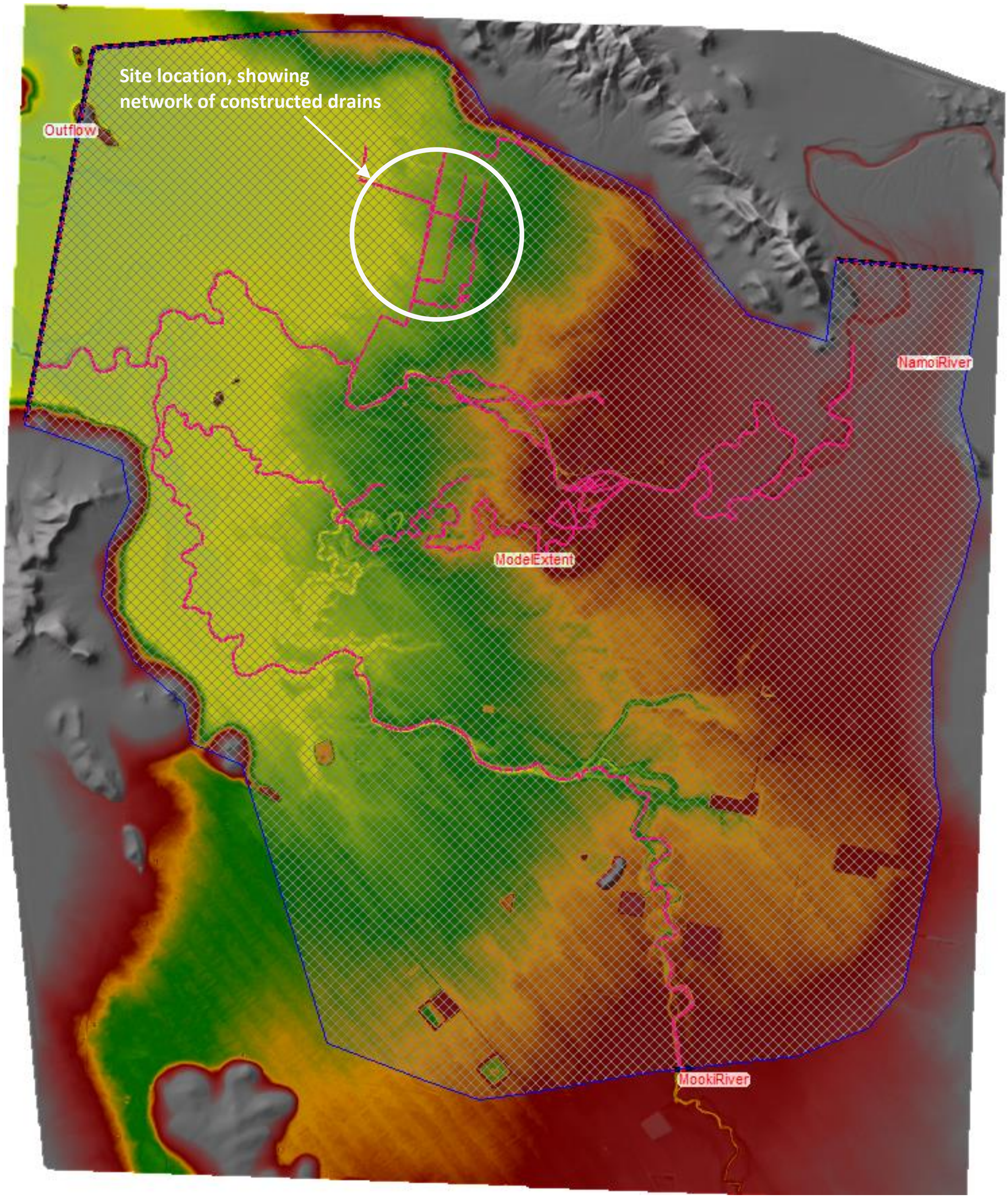


Figure 19: Model domain and boundaries

Fences and floodplain roughness

A uniform Manning's roughness coefficient was applied to the 2D model domain. A variety of Manning's values were tested during the 1955 calibration event, a Manning's roughness value of 0.045 achieved a good match with the recorded gauge and historical flood mark. This roughness value was used for the design event modelling and the fence configuration modelling.

General farm fences and stock fences are not represented in the model as individual fence lines but are included in the floodplain roughness. The resistance to flow by the stock fences is difficult to predict because it depends on the degree of blockage by flood debris. There are further uncertainties related to whether gates are open or closed, or whether fences are pushed over by flood water, or where fences have been added or removed. The approach taken is considered appropriate for the purposes of this study.

Security fences for the Solar Farm are represented in the model as lateral structures with vertical barriers and slots to represent the blocked and open sections of the fence, and open gates. Several fence configurations were tested, which included different fence plans, degrees of blockage, and numbers of open gates which was discussed in the previous report (SY17199B005 REP 31P Rev02).

Individual solar panels were not represented as discrete structures or as changes in the floodplain roughness value for the following reasons

- The solar panels stand on posts above the ground, and the ground will be grassed. The effects on flooding would not be pronounced, because floodwaters would generally pass below the panels and around posts, and the combined cross-sectional area of these posts is negligible in the context of the floodplain.
- The solar panels are corralled behind the security fences such that they would only influence flow within the area enclosed by the fences
- The final arrangement of solar panels within the security fences has not been determined accurately, and it is unlikely that the modelling will reflect the final arrangements of the panels in plan.

Bridges and structures

The Chandos Street bridge (Figure 20) is located at the downstream boundary of the model and does not significantly affect flooding at the subject site. The difference between invert levels along the Namoi River at the Chandos Street bridge and the site is about 9m. The bridge is located about 16km downstream and any head losses caused by the bridge are unlikely to extend this far upstream.

Culverts at farm drains were not modelled as culverts, but the drainage channels were extended to provide hydraulic continuity along the drainage channels.

5.5.3 River behaviour

On-line imagery of the site shows a varying width, low flow channel about 20 to 25m wide, as shown in Figure 20. Figure 20 shows the view upstream from the Chandos Street crossing over the Namoi River, which is located at the downstream boundary of the model. There is an extensive floodplain that extends beyond the river that is inundated in flood events.

Figure 20: Google street view of Chandos Street crossing over Namoi River at Gunnedah

6. Flood model results

6.1 Existing situation

The 1955 flood event was simulated to provide confidence that the model can simulate large historical flood events. The historical flows were applied to the upstream boundary conditions. Several scenarios were run for the 1955 flood event with varying roughness and a downstream boundary gradient.

The recorded peak water level at Gauge 419001 for the 1955 flood event was 264.46 m AHD at 11:00 am on the 26th of February.

A list of recorded flood levels was included in the 2003 SMEC report. A 1955 flood level mark within the model boundary was available as verification on model performance. The flood level is located on a post found behind Battery Hill house, which was 272.61 m RL. The location of the Gauge and the historical flood mark in relation to the site and hydraulic model domain is illustrated in Figure 21.

Figure 21: Location of Gauge and flood mark (red boundary is the property boundary)

The scenario which achieved best fit against historical flood data is shown in Table 9. The model achieves a reasonable fit between the available flood levels for the 1955 event.

Table 9: 1955 model result

Manning's Roughness	Downstream Gradient (m/m)	Model minus Gauge 419001 level (m)	Model minus 1955 flood mark (m)
0.045	0.00075	-0.01	0.05

The design events included in the modelling are the 10% AEP, 5% AEP, 1955, and PMF. The design events use the same Manning's roughness and downstream boundary gradient as the 1955 flood event.

The model results for flood levels in the existing (base line) situation, are shown in the flood maps in Appendix A.

6.2 Fence Configuration 4 – drop down fences

The original flood report (SY17199B005 REP 31P Rev02) discussed a number of potential fence configurations which are modelled to assess flood behaviour and impact of the solar farm. Fence Configuration 3 was developed and modelled and included measures to reduce flood impact (ie laneways) while also acknowledging potential blockage of the chain wire fence. In terms of blockages pattern it assumed:

- Fence 100% blocked up to 0.5m above ground
- Fence 50% blocked above 0.5m above ground

A number of alternate fence configurations have been considered culminating in a new configuration, Fence Configuration 4. Fence Configuration 4 involves a combination of conventional security fencing and drop-down fencing designed to allow flood water into and through the development site during significant flood events to minimise potential redirection of flood flows due to fence blockage.

It comprises the following:

- A single perimeter fence around the solar farm footprint; and
- Drop-down fences in certain locations (modelled as fencing being removed from locations of early flooding and key high velocity areas)
- No laneways

Figure 22 details the location of drop down fencing for Configuration 4. This layout was selected based on the flood model results with drop-down fencing applied in areas of greatest flood flows and generally where fences are aligned perpendicular to the flood flows. The layout was optimised through various iterations using the flood model. The precise location and details of the drop-down fence would be finalised as part of detailed design. Note that in relation to blockage the modelling assumes:

- In areas of drop-down fence the blockage is nil, presenting no barrier to flood flow
- In the areas of conventional security fence, 100% blocked to 0.5m; 50% blocked above.

Configuration 4 represents one possible layout for the drop-down fencing and is modelled within this updated flood assessment to assess its effectiveness as a mitigation option. Should it be considered necessary, further flood modelling can be undertaken once the fence layout is finalised at detailed design stage, post approval.

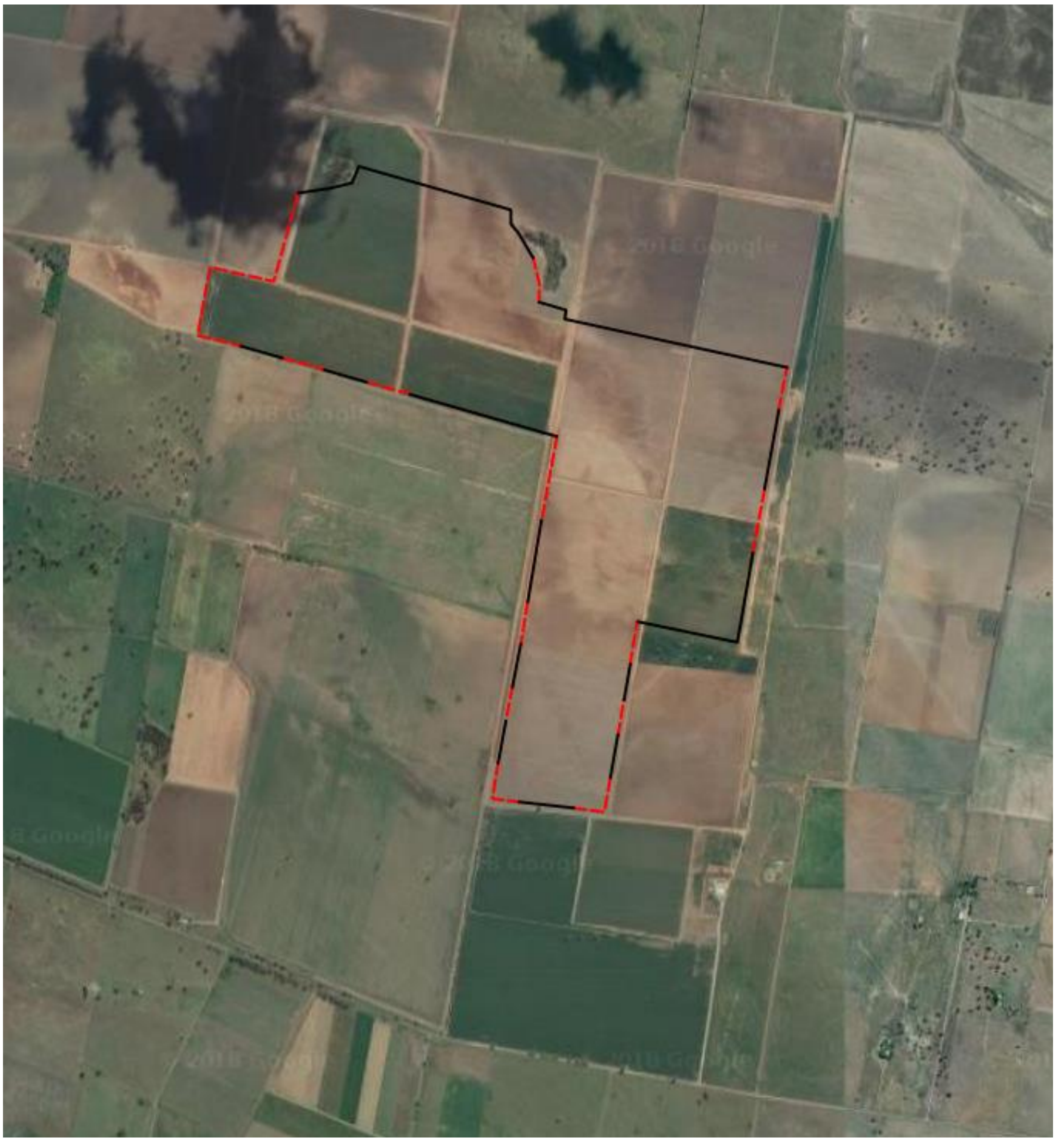


Figure 22: Fence Configuration 4 layout (red lines are the drop down fences modelled as fence openings)

The model results for flood levels in Configuration 4 are shown in the flood maps in Appendix A and in the tables of flood levels at the sensitive receivers in Table 11, Table 12, Table 13 and Table 14.

The model results indicate that Configuration 4 produces a maximum change in the 1955 flood level of up to about 0.063 m (63mm) directly adjacent to the eastern boundary, about 0.027 m (27 mm) at the north-west property boundary and up to about 0.002m (2mm) at the most affected sensitive receiver. Compared to the baseline, flood levels are reduced to the north and west of the fence and increase to the east, southeast and southwest.

The model results indicate that Configuration 4 produces the following:

- In the 10% AEP event, the fences increase water levels by about 0.004 m (4mm) for about 300 m from the eastern fence boundary in the southern-most part of the site. There is no increase in water level at the property boundary on the east. Water levels are reduced on the western side of the boundary on average by about 0.002 m (2 mm).
- In the 5% AEP event, the fences increase water levels by about 0.016 m (16 mm) for about 300 m from the eastern fence boundary in the southern-most part of the site. The typical increase in water level along the property boundary on the east is about 0.001 m (1 mm). Water levels are reduced on the western side of the boundary by about 0.005 m (5 mm).

- the 1955 event, the fences increase water levels by about 0.02 m (20 mm) for about 300 m from the fence boundary to the North-West and East. The typical increase in water level along the property boundary on the East is about 0.02 m (20 mm); about 0.018 m (18 mm) in the North and about 0.04 m (40 mm) in the North-West. Water levels are reduced on the western side of the boundary by about 0.007m (7 mm).
- In the PMF event, the fences increase water levels by about 0.02 m (20 mm) for about 300 m from the fence boundary to the North-West and East. The typical increase in water level along the property boundary on the East is about 0.04 m (40 mm); about 0.014 m (14 mm) in the North and about 0.01 m (10 mm) in the North-West. Water levels are reduced on the western side of the boundary by about 0.007m (7 mm).

The model clearly indicates the benefits of the drop-down fence. Any changes to flood conditions (afflux and velocity) are virtually negated under Fence Configuration 4 with the drop-down fences.

6.3 Electrical substation

An electrical substation is proposed at the south-west corner of the site and would be constructed on a new fill platform above the flood levels, as illustrated in Figure 23. The effect of the electrical substation was modelled by raising the land at the approximate substation location so that it would not become inundated during the model scenarios. Table 10 summarises the flood levels from Configuration 4 and adds a freeboard of 0.5m to recommend a height of the fill platform, depending on the degree of flood immunity desired.

Table 10: Flood depths at electrical substation – Configuration 4

AEP	Flood level (mAHD)	Recommended height of fill platform above ground (mAHD)
10%	268.16	268.66
5%	268.32	268.82
1955 flood event	268.78	269.28
PMF	269.04	269.54

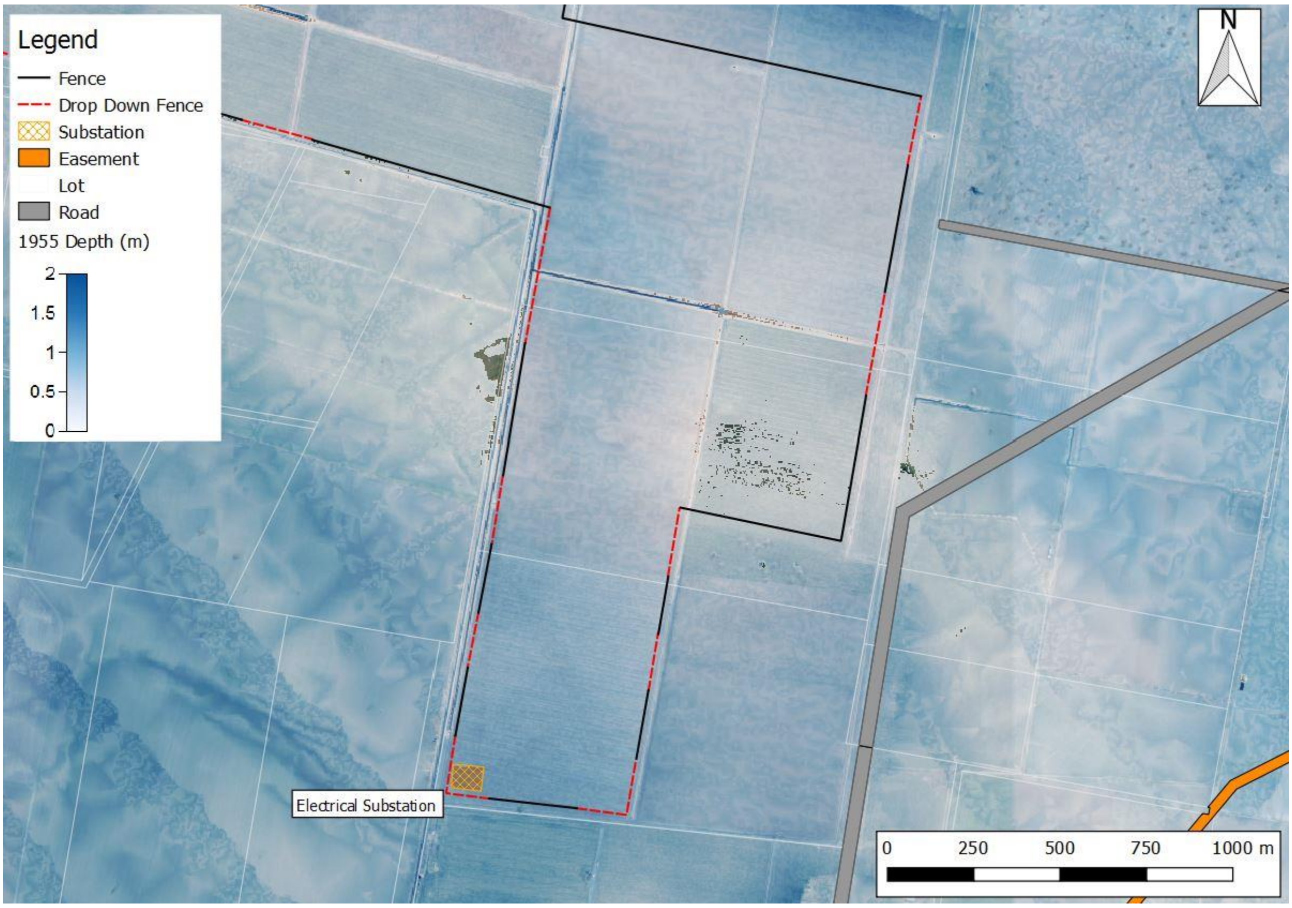


Figure 23: Location of electrical substation and flood depths for 1955 flood event Configuration 4

6.4 Flow distribution

The *Draft Floodplain Management Plan for the Upper Namoi Valley Floodplain 2016* (Government of NSW, 2016) includes the following assessment criteria for the distribution of flows (Section 45.5a)

> *A flood approval must not be granted … if … the flood work is likely to … redistribute peak flood flow by more than 5% on adjacent landholdings …*

As illustrated in the figures of flow depths and velocities for both fence configurations in Appendix A, and the impacts tabulated in Table 11, Table 12, Table 13 and Table 14, the modelling indicates that the criteria that limit changes to flow distribution will be met.

6.5 Flood levels

The *Draft Floodplain Management Plan for the Upper Namoi Valley Floodplain 2016* (Government of NSW, 2016) includes the following assessment criteria for flood levels (Section 45.5b)

> *A flood approval must not be granted … if … the flood work is likely to … increase flood levels by more than 20cm on adjacent landholdings …*

As described below, illustrated in the Figures in Appendix A and according to the impacts tabulated in Table 11, Table 12, Table 13 and Table 14, the modelling indicates that the criteria that limit changes to flood levels will be met.

6.6 Velocities

The modelling provides indications of the velocities in the existing scenario and for the proposed development and adopted fence configuration.

The *Draft Floodplain Management Plan for the Upper Namoi Valley Floodplain 2016* (Government of NSW, 2016) includes the following assessment criteria for velocities (Section 45.5c)

> *A flood approval must not be granted … if … the flood work is likely to … increase flow velocity by more than 50% … for a range of flood scenarios including at a minimum the relevant large design flood, unless Increases by more than 50% are in isolated areas … , and flow velocity is not increased by more than 50% at the boundary …*

As described below, the modelling indicates that the criteria that limit changes to velocities will be met.

Velocity maps for 1955 flood event and PMF flows for the existing situation are shown in Appendix A, Figure SY17199-F006 and SY17199-F008 respectively. These show that the maximum velocities in the floodplain are about 0.6 m/s for the 1955 flood event and about 0.8 m/s for the PMF.

The Carroll-Boggabri Floodplain Management Plan (FMP) September 2006 includes maximum permissible velocities for different ground conditions for crop, bare soil and native grass (FMP Table 4). These recommended maximum permissible velocities are 0.6, 0.4 and 0.8 m/s respectively. The FMP also notes, however, that "… in the majority of the floodplain, the velocity of flood flow is already greater than that which will cause significant erosion" (FMP Section 8.4.4).

Velocity maps for 1955 flood event and PMF flows for Fence Configuration 4 are shown in Appendix A, Figure SY17199-F406 and SY17199-F408 respectively. These show that the maximum velocities in the floodplain are about 0.6 m/s for the 1955 flood event and about 0.8 m/s for the PMF, and that they occur in the same location as the existing case. Localised higher velocities are shown where floodwaters flow through the drop-down fence and over the gaps in the partially blocked fence.

The following are inferred from these results:

- When the water depth exceeds 0.5m, water begins to flow through the partially blocked section of the fence above 0.5m. The velocity pattern follows the idealised representation of the partial blockage in the model, but it illustrates how the model works, and is a credible indication of how flow might pass through a fence that is partially blocked by debris. Importantly, the pattern is less visible in areas where there are maximum depths and velocities, and this is because the 0.5m blockage has proportionally less effect in these areas than in areas where the depth is closer to 0.5m
- Maximum velocities around the fences occur where flood water passes through drop-down sections or over or through gaps in the debris at the fences
- The maximum velocities at the boundaries of the site will correspond to drop-down sections and the gaps in the debris blockage at the fences, which is a comparable situation to the blockage of ordinary stock fences in neighbouring paddocks

6.7 Impacts at sensitive receivers

Flood behaviour was considered at the sensitive receivers surrounding the Solar Farm by comparing predicted flood levels under the baseline (existing) situation with flood levels under Fence Configuration 4.

The locations of sensitive receivers are indicated in the flood maps in Appendix A. Further details of the sensitive receivers, such as the names and addresses of individual landowners, are withheld from this flood study for reasons of privacy.

Flood levels and changes to flood levels at sensitive receivers are tabulated in Table 11, Table 12, Table 13 and Table 14.

Flow depths are categorised as follows

- Shallow flow depths: depths less than 0.1m (100mm), which is typically less than the depth of flow needed to rise above the floor levels of slab-on-ground houses and sheds
- Moderate flow depths; depths between 0.1m (100mm) and 0.45m (450mm), which is typically up to knee-deep
- Deep flow depths; depths above 0.45m. Water this deep is difficult to keep out of houses by sand-bagging.

Results shown as '-', indicate that the sensitive receiver is not affected by flooding under the nominated event.

Table 11: Flood model results at sensitive receivers - 10%AEP event

Receiver	Peak flood level (m AHD)		Change Conf. 4 (m)	Comments
	Existing	Conf. 4		
01.	-	-	-	
02.	0.033	0.033	0.000	No change
03.	-	-	-	
04.	-	-	-	
05.	0.019	0.019	0.000	No change
06.	-	-	-	
07.	-	-	-	
08.	-	-	-	
09.	-	-	-	
10.	-	-	-	
13.	-	-	-	
14.	-	-	-	
16.	-	-	-	
17.	-	-	-	
18.	-	-	-	
19.	-	-	-	
21.	-	-	-	
22.	-	-	-	
23.	-	-	-	
24.	-	-	-	
26.	-	-	-	
27.	-	-	-	
28.	-	-	-	
29.	-	-	-	
30.	-	-	-	
31.	0.193	0.193	0.000	No change

Table 12: Flood model results at sensitive receivers - 5%AEP event

Receiver	Peak flood level (m AHD)		Change Conf. 4 (m)	Comments
	Existing	Conf. 4		
01.	0.092	0.092	0.000	No change
02.	0.092	0.092	0.000	No change
03.	-	-	-	
04.	-	-	-	
05.	0.067	0.067	0.000	No change
06.	-	-	-	
07.	-	-	-	
08.	-	-	-	
09.	-	-	-	
10.	0.119	0.119	0.000	No change
13.	-	-	-	
14.	0.103	0.102	-0.001	Small decrease to moderate flood depths
16.	-	-	-	
17.	-	-	-	
18.	-	-	-	
19.	-	-	-	
21.	-	-	-	
22.	-	-	-	
23.	-	-	-	
24.	-	-	-	
26.	-	-	-	
27.	-	-	-	
28.	-	-	-	
29.	0.025	0.025	0.000	No change
30.	-	-	-	
31.	0.206	0.206	0.000	No change

Table 13: Flood model results at sensitive receivers – 1955 flood event

Receiver	Peak flood level (m AHD)		Change Conf. 4 (m)	Comments
	Existing	Conf. 4		
01.	0.613	0.615	0.002	Small increase to deep flood depths
02.	0.172	0.172	0.000	No change
03.	-	-	-	
04.	-	-	-	
05.	0.126	0.126	0.000	No change
06.	-	-	-	
07.	0.070	0.070	0.000	No change
08.	-	-	-	
09.	-	-	-	
10.	0.441	0.441	0.000	No change
13.	-	-	-	
14.	0.758	0.760	0.002	Small increase to deep flood depths
16.	-	-	-	
17.	-	-	-	
18.	-	-	-	
19.	0.407	0.407	0.000	No change
21.	-	-	-	
22.	-	-	-	
23.	-	-	-	
24.	0.153	0.153	0.000	No change
26.	-	-	-	
27.	0.010	0.010	0.000	No change
28.	-	-	-	
29.	1.028	1.027	0.000	No change
30.	0.861	0.861	0.000	No change
31.	0.926	0.927	0.000	No change

Table 14: Flood model results at sensitive receivers PMF event

Receiver	Peak flood level (m AHD)		Change Conf. 4 (m)	Comments
	Existing	Conf. 4		
01.	0.905	0.909	0.004	Small increase to deep flood depths
02.	0.244	0.244	0.000	No change
03.	-	-	-	-
04.	-	-	-	-
05.	0.167	0.167	0.000	No change
06.	0.144	0.144	0.000	No change
07.	0.232	0.232	0.000	No change
08.	-	-	-	-
09.	-	-	-	-
10.	0.626	0.626	0.000	No change
13.	-	-	-	-
14.	1.042	1.043	0.001	Small increase to deep flood depths
16.	-	-	-	-
17.	-	-	-	-
18.	-	-	-	-
19.	0.682	0.682	0.000	No change
21.	-	-	-	-
22.	-	-	-	-
23.	-	-	-	-
24.	0.478	0.478	0.000	No change
26.	0.226	0.224	-0.002	Small decrease to moderate flood depths
27.	0.241	0.241	0.000	No change
28.	-	-	-	-
29.	1.414	1.414	0.000	No change
30.	1.255	1.255	0.000	No change
31.	1.379	1.379	0.000	No change

7. Effects of Solar Farm on flood behaviour

The construction of security fences of any configuration will affect flood levels in the floodplain assuming that flood debris mats could accumulate on the security fences and partially obstruct or hinder flows. The blockages will cause flows to back up on the upstream sides of the fences and to drop on the downstream sides of the fences. The degree of flood debris blockage is difficult to predict and is likely to be uneven in the horizontal and vertical dimensions. The range of impacts is indicated by the impacts for the different Fence Configurations that have been reviewed.

The distribution of areas of increased flood levels and decreased flood levels changes with the direction of flow across the floodplain, which changes according to the AEP of the event, and the timing within the event. For instance, in the 10% AEP event, flow breaks out of the Namoi River, approaches the site from the south and is hindered from escaping to low ground to the north by the fence, thus creating an area of increased flood levels to the south and west of the site. Fence Configuration 4 was developed with this flood in mind and includes drop down fencing in the southern part of the site to reduce impedance to floodwaters. Likewise, in the 1955 flood event, flow approaches from the south and east at different times in the flood event, and it is the hindrance to the eastern flows that causes an increase to flood levels to the east of the site.

Fence Configuration 4 was developed and modelled to estimate the additional mitigating benefit of drop-down fencing option designed to minimise blockage and redirection of floodwater. The model shows that drop-down fencing produces an entirely acceptable outcome whereby the proposed development would have negligible flood impacts on surrounding properties. Modelling of Fence Configuration 4 indicates that the fences and their debris blockages could increase the 1955 flood event upstream flood levels by about 0.063m (63mm) directly adjacent to the eastern boundary, about 0.027 (27mm) at the northern property boundary and up to about 0.002m (2mm) at the most affected sensitive receiver. Some areas could experience reduced flood levels, particularly to the north and west of the Solar Farm. These impacts are within the limits recommended in the Carroll-Boggabri Flood Management Plan and are considered minor.

The model indicates that the development:

- would not adversely affect beneficial inundation; the modelling predicts no appreciable change to inundation area
- would not cause changes to erosion, siltation and riparian vegetation; as the site is not located close to the Namoi River, it is considered that the proposed development will not appreciably change erosion, siltation, riparian vegetation or the stability of river banks
- would not affect existing flood Emergency Management and access procedures in place for the region
- would not increase the risk to life from flood
- would not have appreciable adverse social or economic costs to the community.

With respect to this last point, the economic costs relate to the changes to flooding, which are mapped in Appendix A. There are many social and economic benefits associated with the construction and operation of the proposed Solar Farm, however a more comprehensive economic assessment in the context of flooding is beyond the scope of the current study.

The proposed development is compatible with the hydraulic function of flood storage. Though the proposed security fences create a hindrance to flow as it is distributed through the site, there is no appreciable reduction in flood storage as there would be with, for instance, the placement of a significant volume of fill in the area. It is expected that floodwaters will continue to seep or flow through the fences to occupy the same volume of flood storage as is currently available.

The *Draft Floodplain Management Plan for the Upper Namoi Valley Floodplain 2016* (Government of NSW, 2016) includes assessment criteria for compliant development relating to flow distribution (less than 5%

change), flood levels (less than 20cm increase) and flow velocity (less than 50% increase). The proposed development meets these criteria based on Fence Configuration 4.

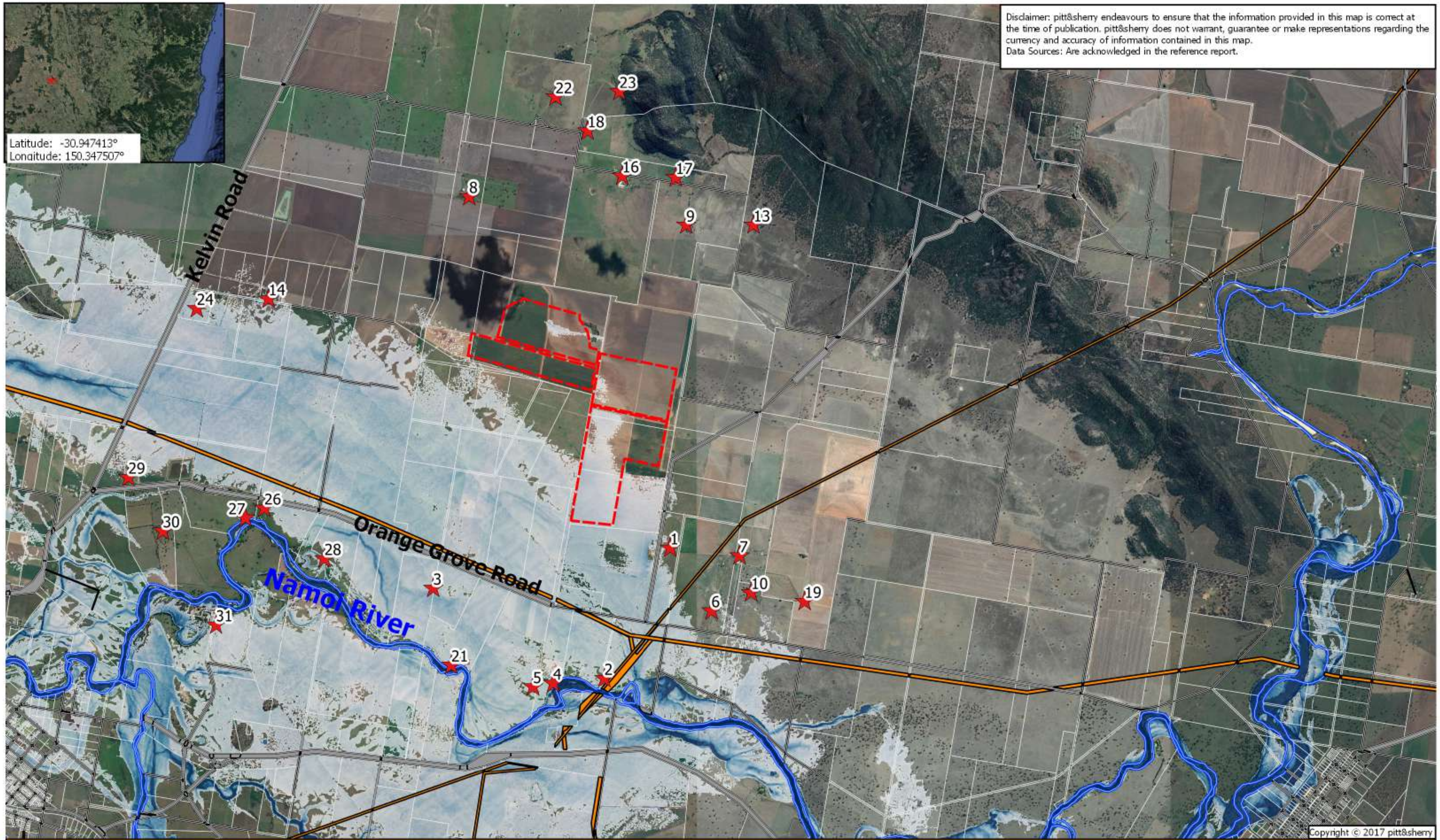
8. Refences

- Government of NSW, *Draft Floodplain Management Plan for the Upper Namoi Valley Floodplain 2016*, viewed on-line 07 June 2018 (https://www.water.nsw.gov.au/__data/assets/pdf_file/0017/672011/Draft-Floodplain-Management-Plan-for-the-Upper-Namoi-Valley-Floodplain-2016.pdf)
- SMEC 2013, *CARROLL to BOGGABRI Flood Study and Compendium of Data*, SMEC Australia Pty Ltd, viewed 23 January 2018.
- Water NSW 2018, Keepit Dam, Water NSW, https://www.waternsw.com.au/supply/visit/keepit-dam, viewed 24 January 2018.

Appendix A

Model results

List of Figures



Data sources:
Base image from Google Earth
Reference Report:
SY17199B005 REP 31P REV05

N

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 55
1:80,922 When printed at A4

Legend

- Solar Farm
- Easement
- Cadastre
- Road
- Water Corridor
- SensitiveRecievers

10% AEP Existing Scenario (m)

2
1.5
1
0.5
0

pitt&sherry

Project Number	SY17199
Figure Number	SY17199-F001
Revision	3
Author	mdugan
Reviewer	mjacobs
Date	28-06-2018

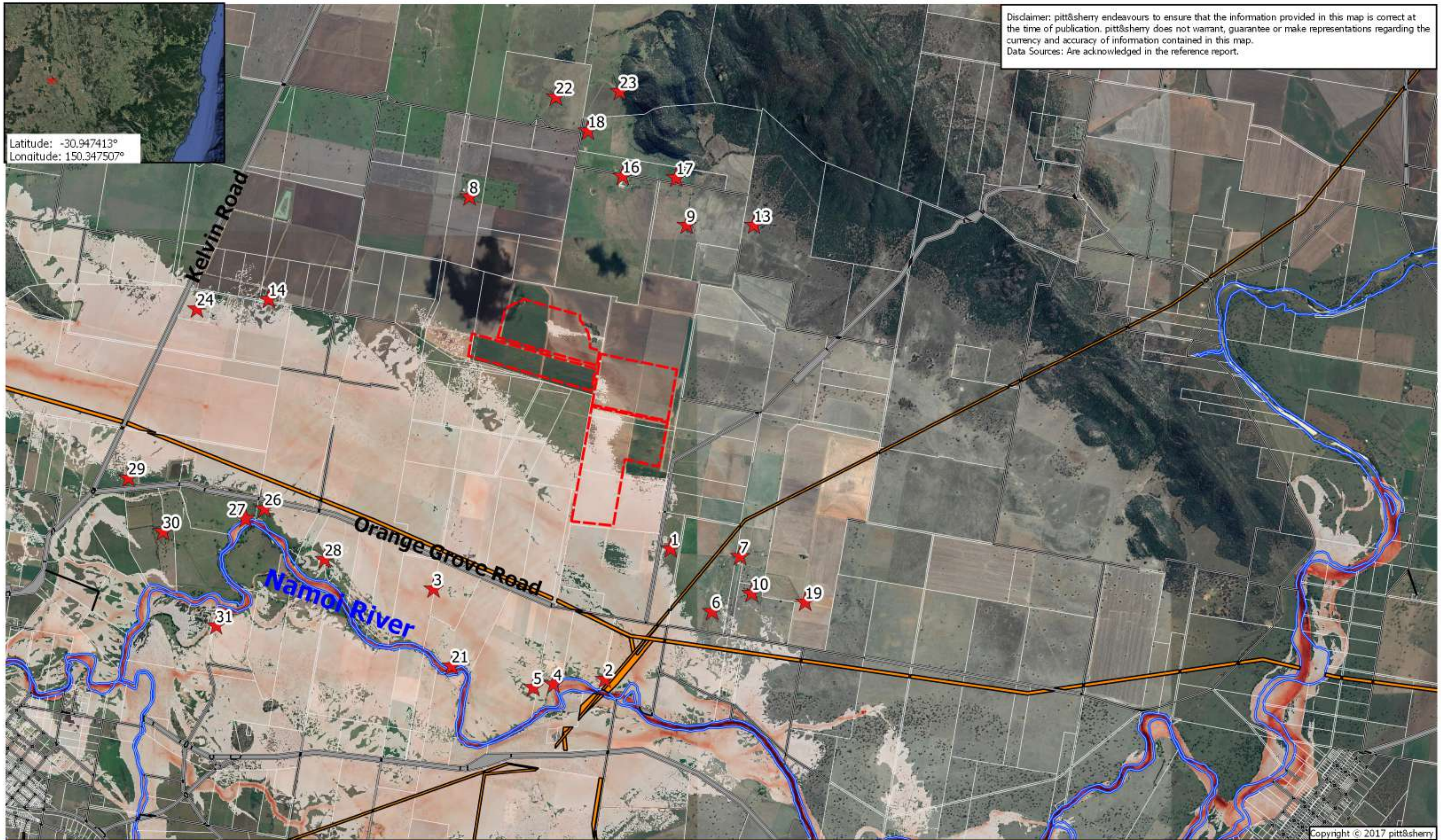
Photon Energy Engineering Australia Pty Ltd

PHOTON ENERGY

Orange Grove Road, Gunnedah

10% AEP Flood Depth
Existing Scenario

File: C:/dms/1/SY17199 - Gunnedah Solar Farm_3/GIS/SY17199-F001.qgsSY17199-F001.qgs



Data sources:
Base image from Google Earth
Reference Report:
SY17199B005 REP 31P REV05

N

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 55
1:80,922 When printed at A4

Legend

- Solar Farm
- Easement
- Cadastre
- Road
- Water Corridor
- SensitiveRecievers

10% AEP Existing Scenario (m/s)

2.2
1.6
1
0.4
0

pitt&sherry

Project Number	SY17199
Figure Number	SY17199-F002
Revision	3
Author	mdugan
Reviewer	mjacobs
Date	28-06-2018

Photon Energy Engineering Australia Pty Ltd

PHOTON ENERGY

Orange Grove Road, Gunnedah

10% AEP Flood Velocity Existing Scenario

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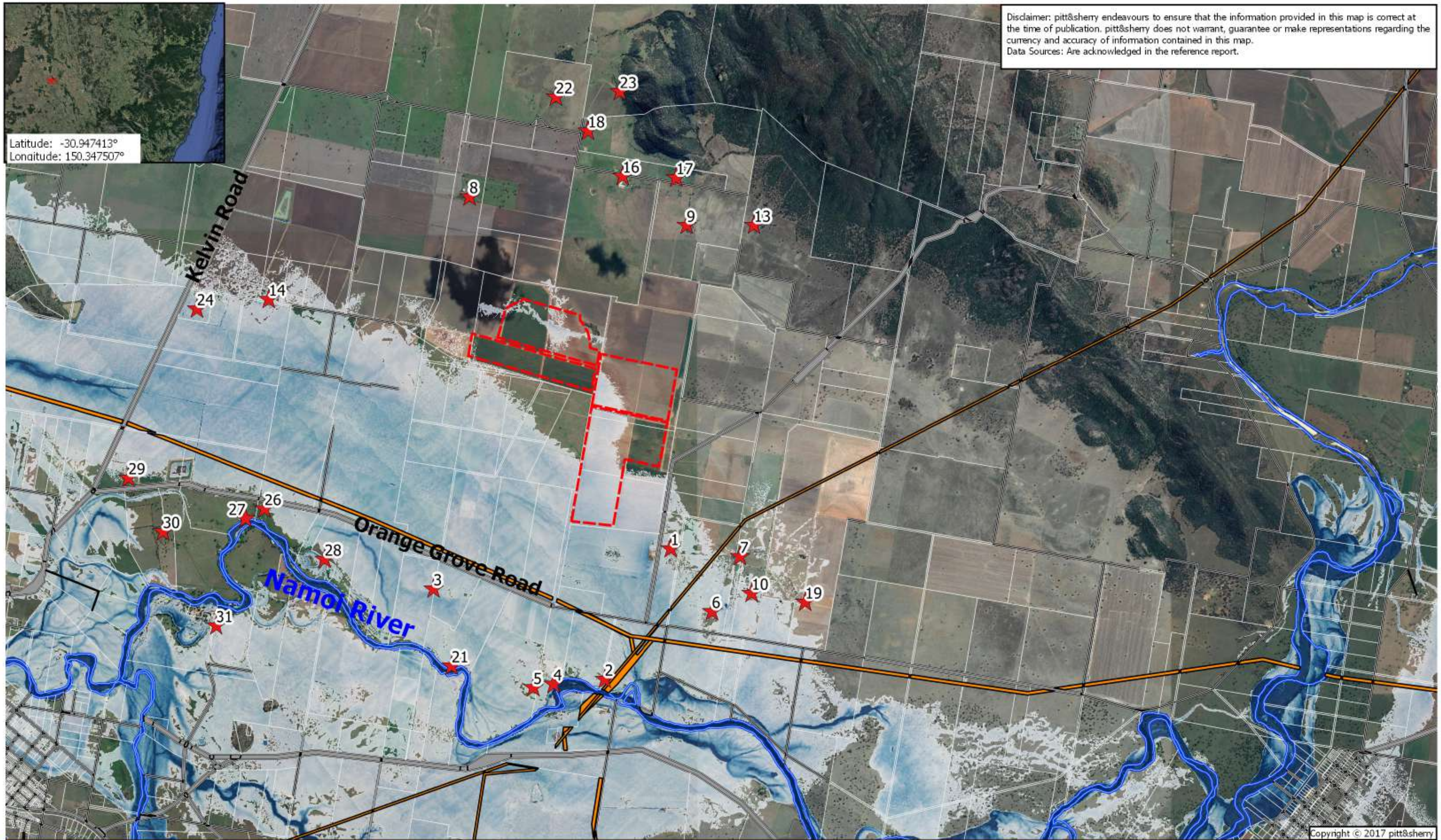


Data sources:
Base image from Google Earth
Reference Report:
SY17199B005 REP 31P REV05

N

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 55
1:80,922 When printed at A4

Legend

Solar Farm
Easement
Cadastre
Road
Water Corridor
SensitiveRecievers

5% AEP Existing Scenario (m)

2
1.5
1
0.5
0

pitt&sherry

Project Number	SY17199
Figure Number	SY17199-F003
Revision	3
Author	mdugan
Reviewer	mjacobs
Date	28-06-2018

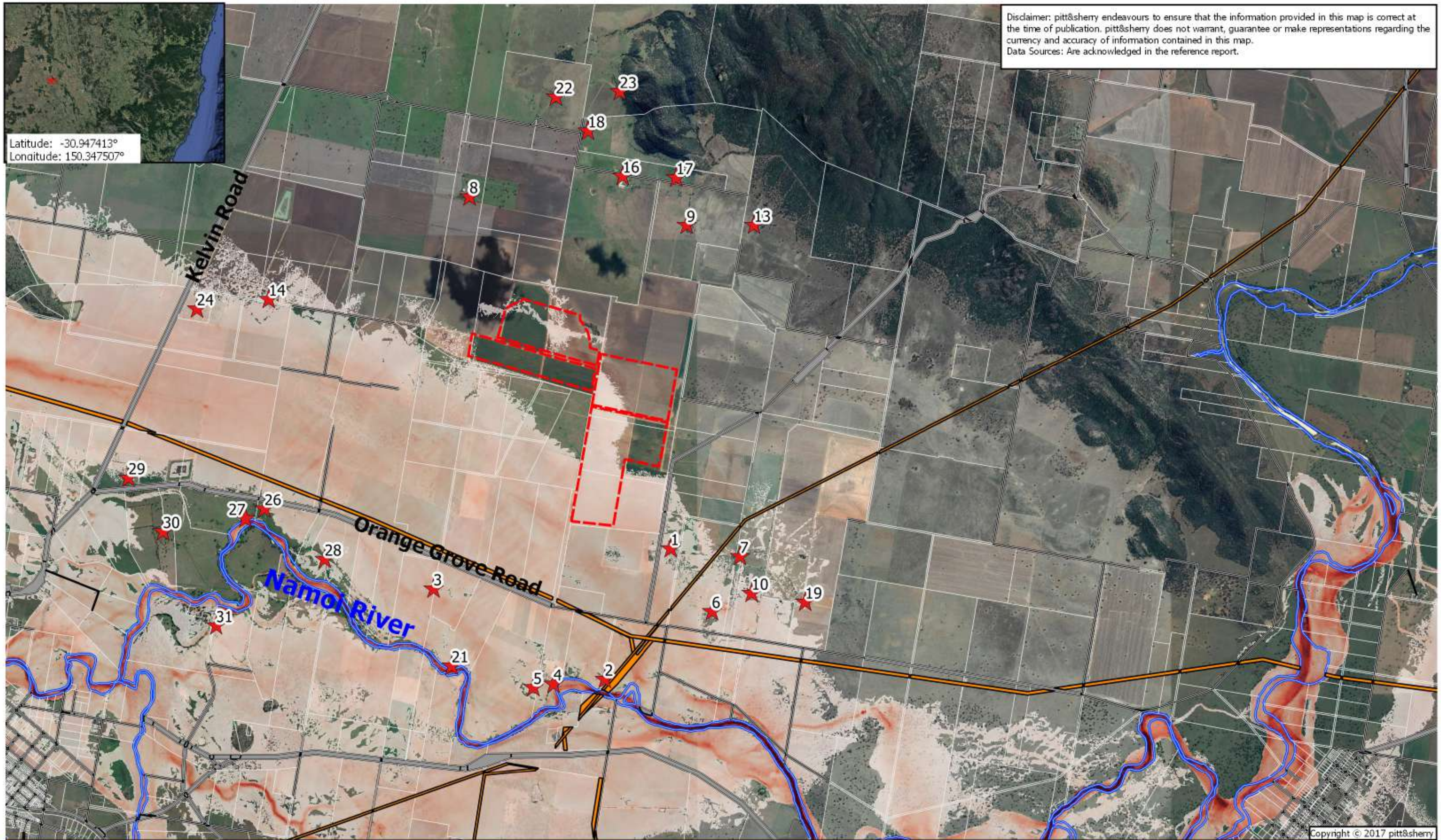
Photon Energy Engineering Australia Pty Ltd

PHOTON ENERGY

Orange Grove Road, Gunnedah

5% AEP Flood Depth
Existing Scenario

File: C:/dms/1/SY17199 - Gunnedah Solar Farm_3/GIS/SY17199-F003.qgsSY17199-F003.qgs



Data sources:
Base image from Google Earth
Reference Report:
SY17199B005 REP 31P REV05

N

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 55
1:80,922 When printed at A4

Legend

- Solar Farm
- Easement
- Cadastre
- Road
- Water Corridor
- SensitiveRecievers

5% AEP Existing Scenario (m/s)

2.2
1.6
1
0.4
0

pitt&sherry

Project Number	SY17199
Figure Number	SY17199-F004
Revision	3
Author	mdugan
Reviewer	mjacobs
Date	28-06-2018

Photon Energy Engineering Australia Pty Ltd

PHOTON ENERGY

Orange Grove Road, Gunnedah

5% AEP Flood Velocity
Existing Scenario

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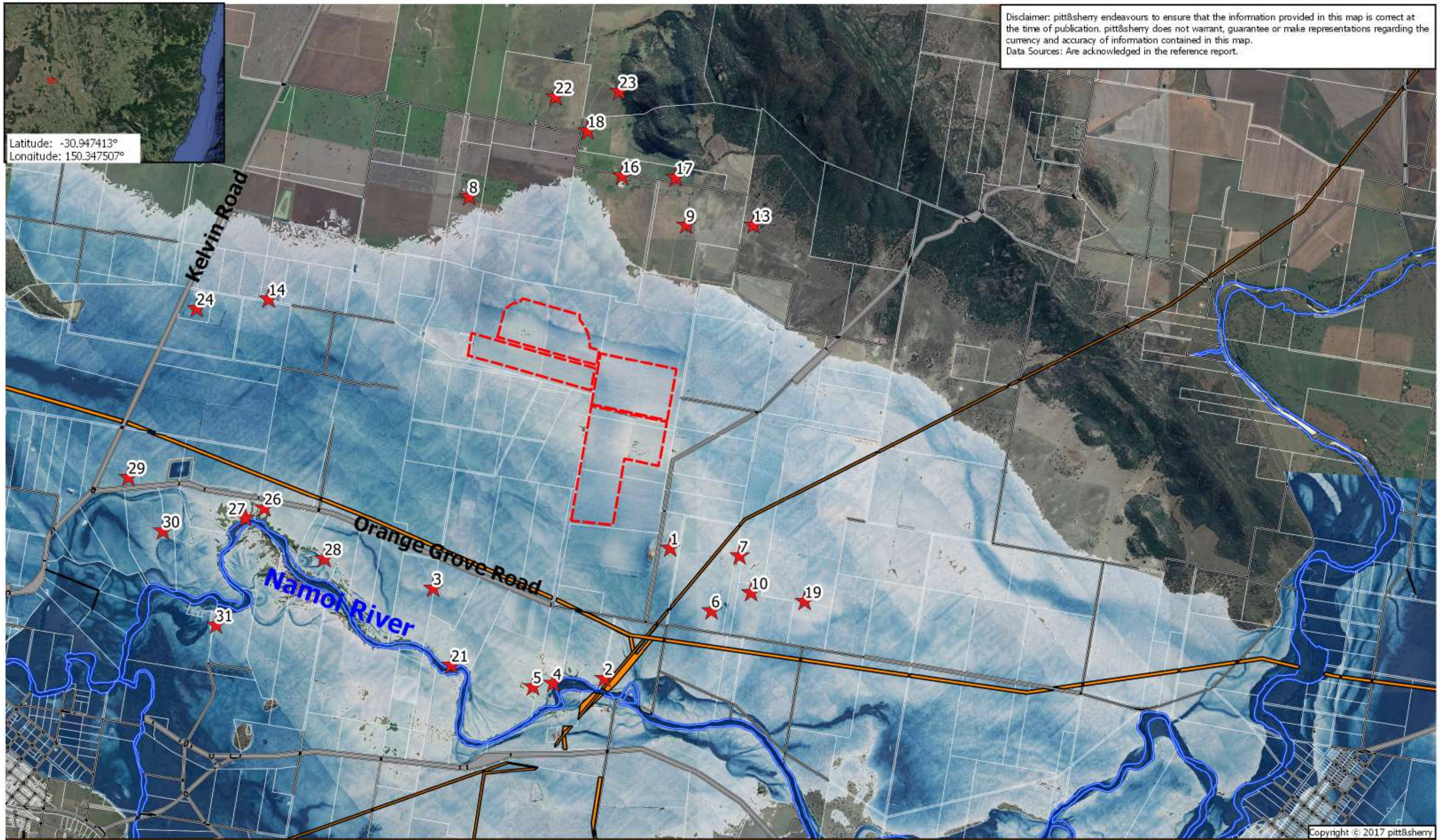

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Base image from Google Earth
Reference Report:
SY17199B005 REP 31P REV05

N

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 55
1:80,922 When printed at A4

Legend

- Solar Farm
- Easement
- Cadastre
- Road
- Water Corridor
- SensitiveRecievers

1955 Existing Scenario (m)

2
1.5
1
0.5
0

pitt&sherry

Project Number	SY17199
Figure Number	SY17199-F005
Revision	3
Author	mdugan
Reviewer	mjacobs
Date	28-06-2018

Photon Energy Engineering Australia Pty Ltd

PHOTON ENERGY

Orange Grove Road, Gunnedah

1955 Flood Depth Existing Scenario

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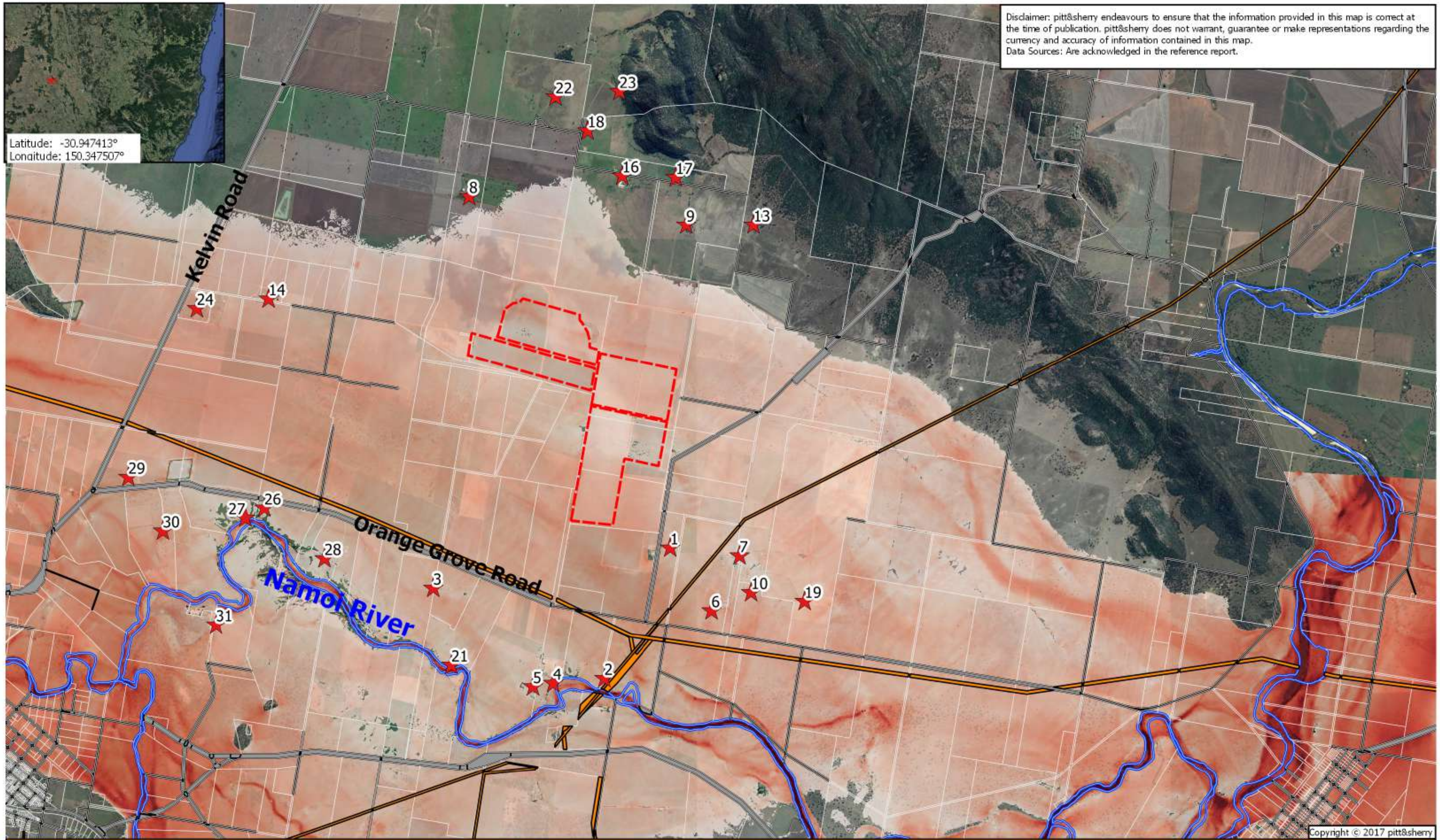

Data sources:
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Reference Report:
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N
0 1 2 km

Coordinate System: GDA 1994 MGA Zone 55
1:80,922 When printed at A4

Legend
- Solar Farm
- Easement
- Cadastre
- Road
- Water Corridor
- SensitiveRecievers

1955 Existing Scenario (m/s)
2.2
1.6
1
0.4
0

pitt&sherry

Project Number	SY17199
Figure Number	SY17199-F006
Revision	3
Author	mdugan
Reviewer	mjacobs
Date	28-06-2018

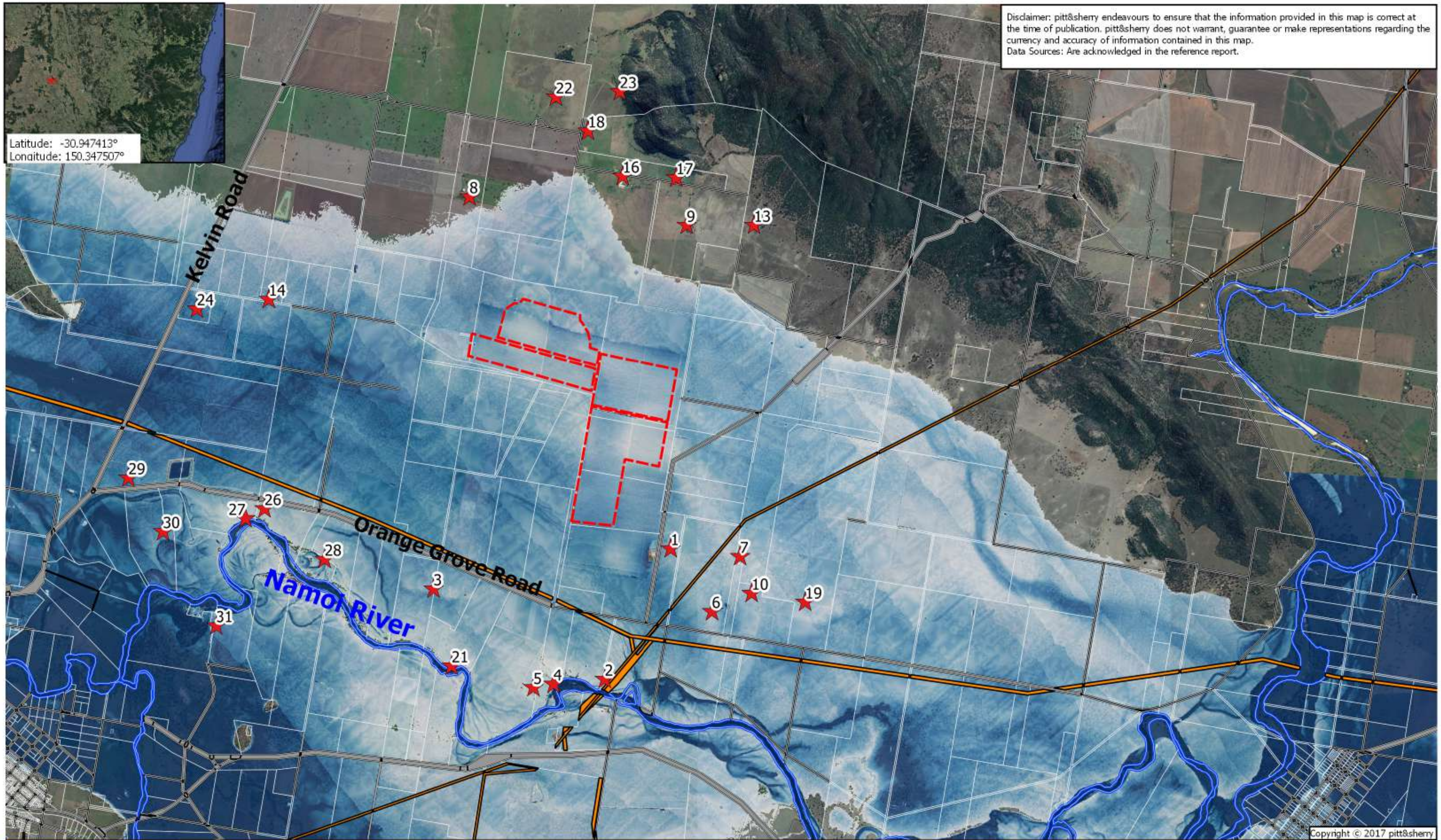
Photon Energy Engineering Australia Pty Ltd

PHOTON ENERGY

Orange Grove Road, Gunnedah

1955 Flood Velocity Existing Scenario

File: C:/dms/1/SY17199 - Gunnedah Solar Farm_3/GIS/SY17199-F006.qgsSY17199-F006.qgs



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Base image from Google Earth
Reference Report:
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N

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 55
1:80,922 When printed at A4

Legend

- Solar Farm
- Road
- Easement
- Water Corridor
- Cadastre
- SensitiveRecievers

PMF Existing Scenario (m)

2
1.5
1
0.5
0

pitt&sherry

Project Number	SY17199
Figure Number	SY17199-F007
Revision	3
Author	mdugan
Reviewer	mjacobs
Date	28-06-2018

Photon Energy Engineering Australia Pty Ltd

PHOTON ENERGY

Orange Grove Road, Gunnedah

Probable Maximum Flood Depth Existing Scenario

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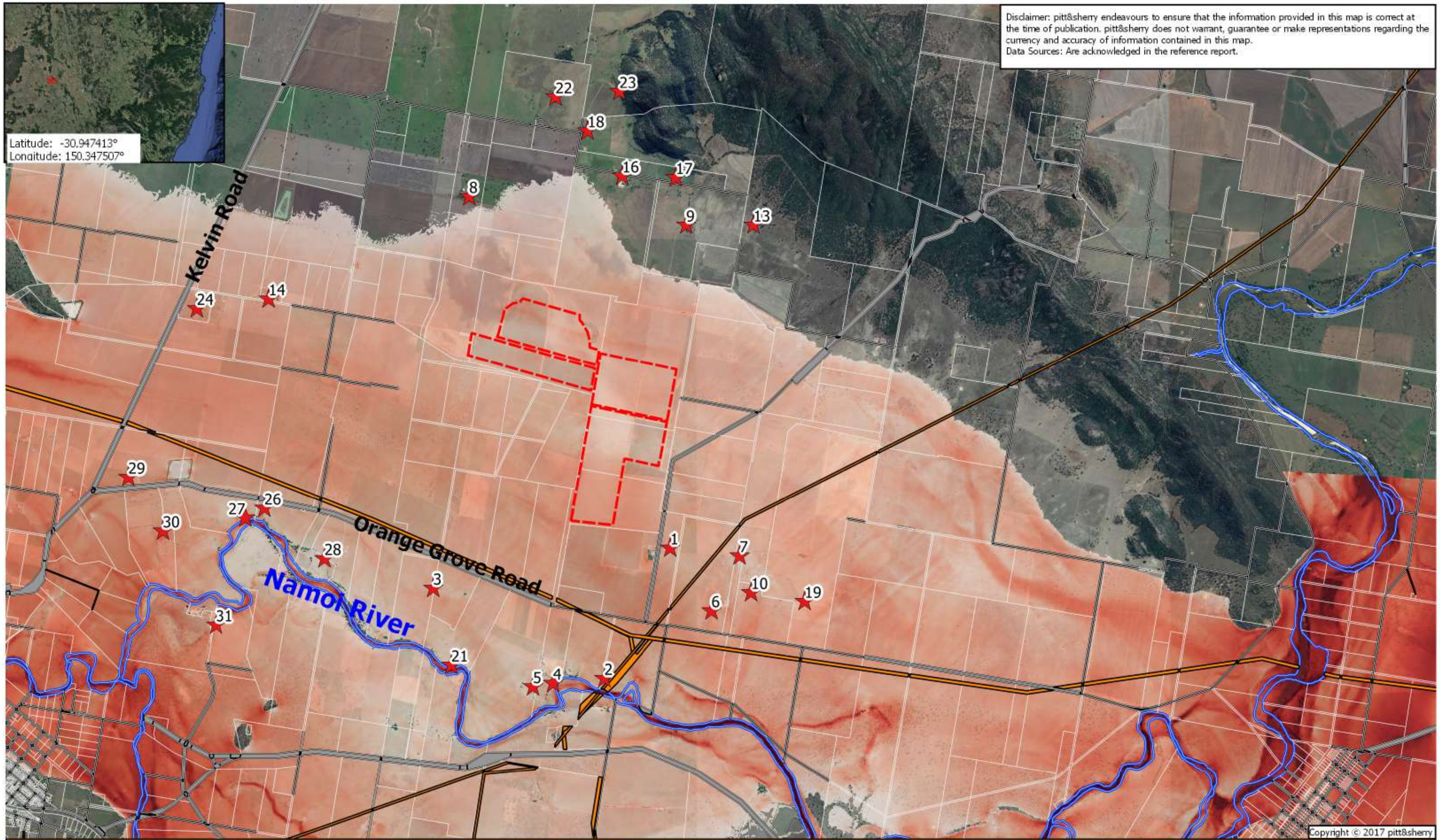

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Base image from Google Earth
Reference Report:
SY17199B005 REP 31P REV05

N
0 1 2 km

Coordinate System: GDA 1994 MGA Zone 55
1:80,922 When printed at A4

Legend

- Solar Farm
- Easement
- Cadastre
- Road
- Water Corridor
- SensitiveRecievers

PMF Existing Scenario (m/s)

2.2
1.6
1
0.4
0

pitt&sherry

Project Number	SY17199
Figure Number	SY17199-F008
Revision	3
Author	mdugan
Reviewer	mjacobs
Date	28-06-2018

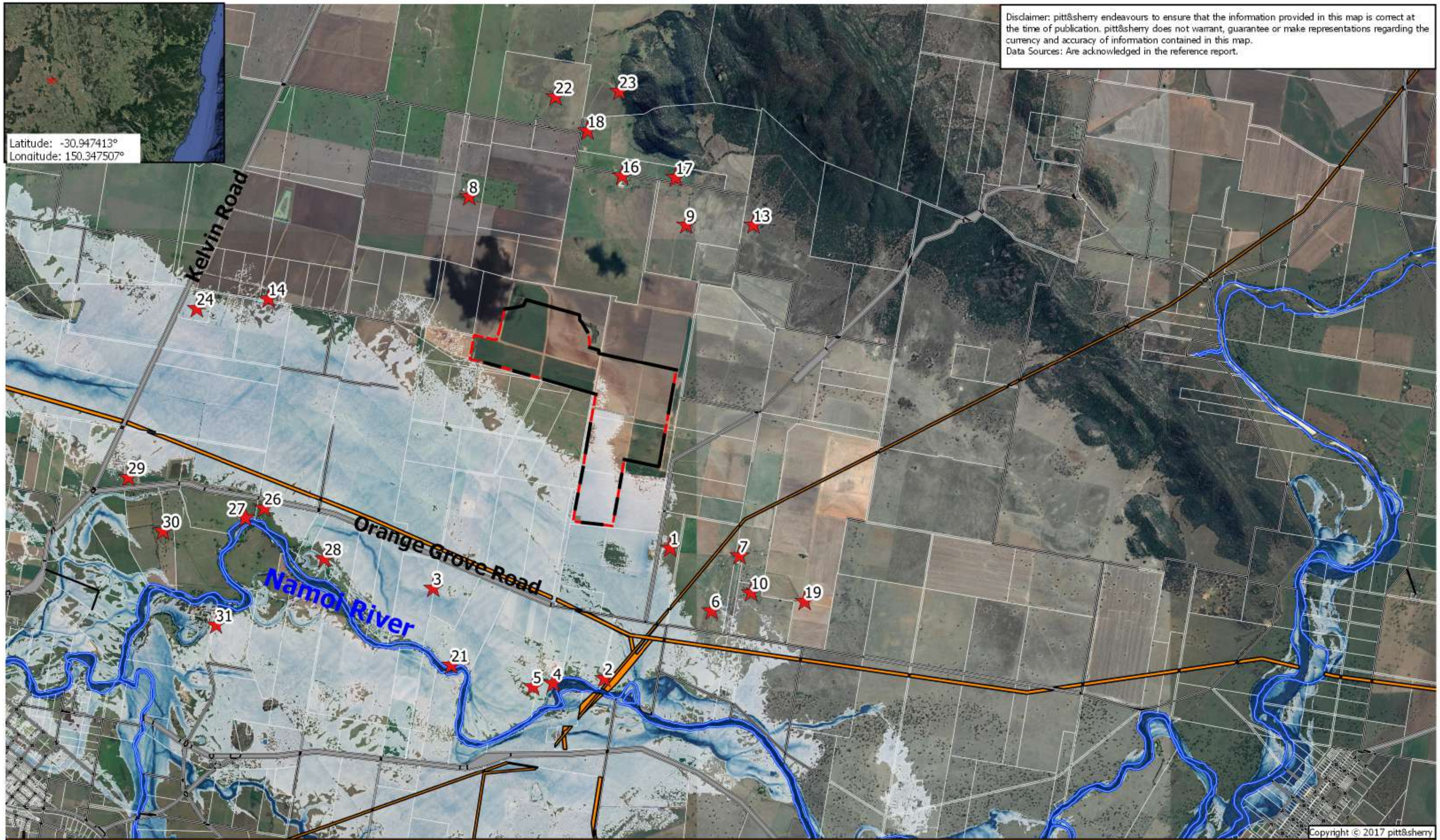
Photon Energy Engineering Australia Pty Ltd

PHOTON ENERGY

Orange Grove Road, Gunnedah

Probable Maximum Flood Velocity Existing Scenario

File: C:/dms/1/SY17199 - Gunnedah Solar Farm_3/GIS/SY17199-F008.qgsSY17199-F008.qgs



Data sources:
Base image from Google Earth
Reference Report:
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N

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 55
1:80,922 When printed at A4

Legend
- Fence
- Drop Down Fence
- Easement
- Cadastre
- Road
- Water Corridor
- SensitiveRecievers

10% AEP Configuration 4 Scenario (m)
2
1.5
1
0.5
0

pitt&sherry

Project Number	SY17199
Figure Number	SY17199-F401
Revision	3
Author	mdugan
Reviewer	mjacobs
Date	28-06-2018

Photon Energy Engineering Australia Pty Ltd

PHOTON ENERGY

Orange Grove Road, Gunnedah

10% AEP Flood Depth Configuration 4 Scenario

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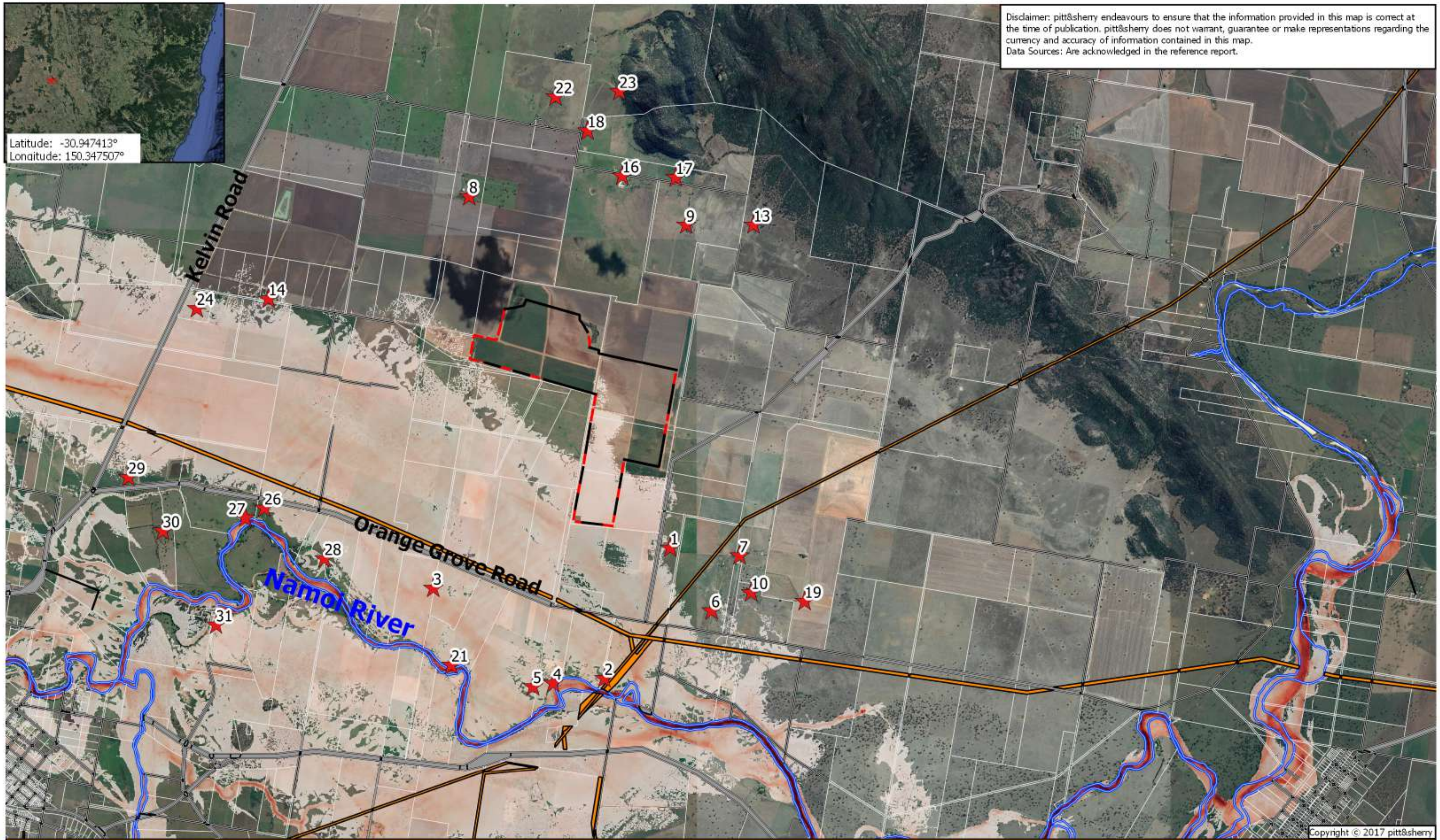

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N
0 1 2 km
Coordinate System: GDA 1994 MGA Zone 55
1:80,922 When printed at A4

Legend

- Fence
- Drop Down Fence
- Easement
- Cadastre
- Road
- Water Corridor
- SensitiveRecievers

10% AEP Configuration 4 Scenario (m/s)

2.2
1.6
1
0.4
0

pitt&sherry

Project Number	SY17199
Figure Number	SY17199-F402
Revision	3
Author	mdugan
Reviewer	mjacobs
Date	28-06-2018

Photon Energy Engineering Australia Pty Ltd

PHOTON ENERGY

Orange Grove Road, Gunnedah

10% AEP Flood Velocity Configuration 4 Scenario

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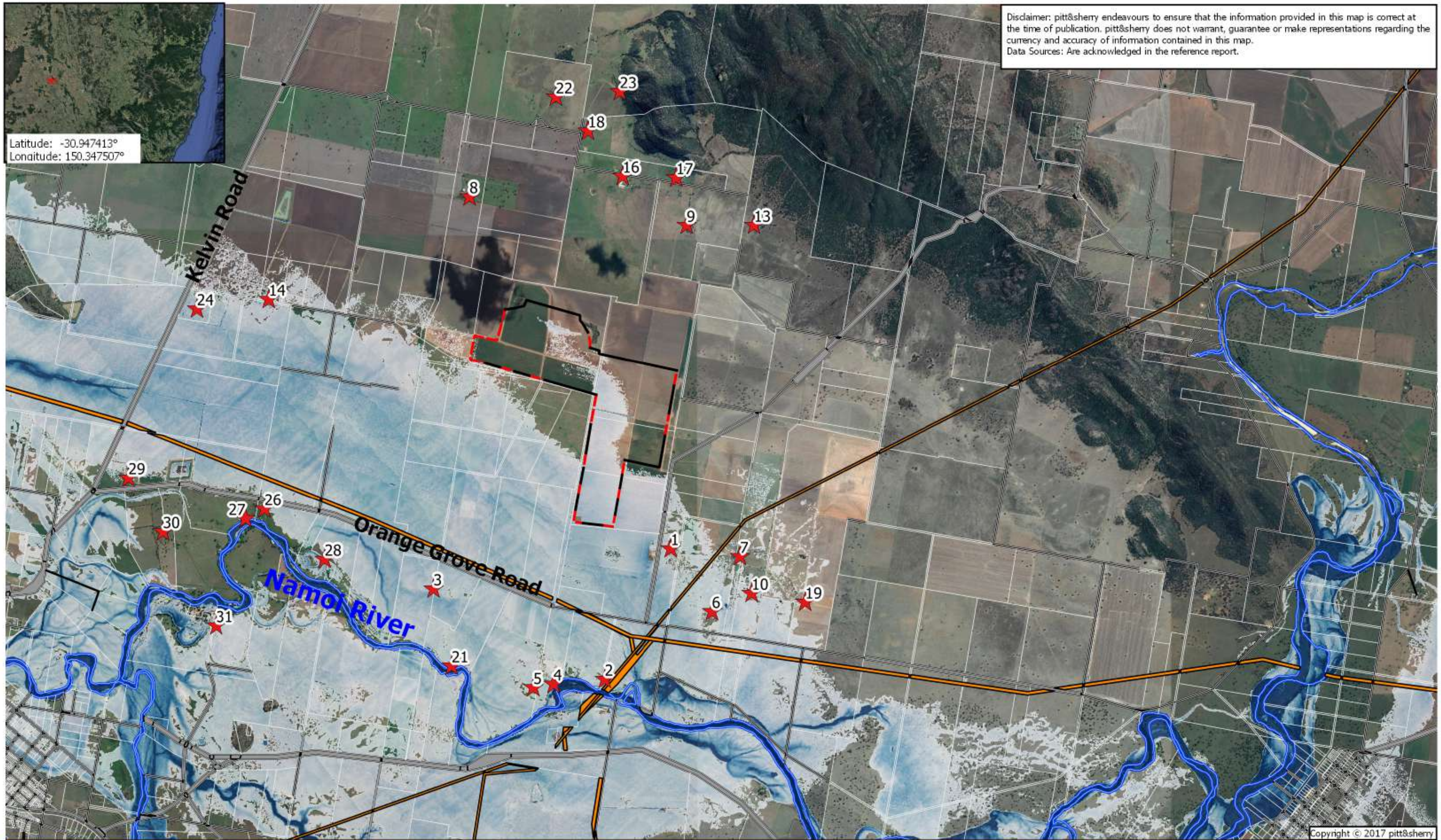

Data sources:
Base image from Google Earth
Reference Report:
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N

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 55
1:80,922 When printed at A4

Legend

- Fence
- Drop Down Fence
- Easement
- Cadastre
- Road
- Water Corridor
- SensitiveRecievers

5% AEP Configuration 4 Scenario (m)

2, 1.5, 1, 0.5, 0

pitt&sherry

Project Number	SY17199
Figure Number	SY17199-F403
Revision	3
Author	mdugan
Reviewer	mjacobs
Date	28-06-2018

Photon Energy Engineering Australia Pty Ltd

PHOTON ENERGY

Orange Grove Road, Gunnedah

5% AEP Flood Depth Configuration 4 Scenario

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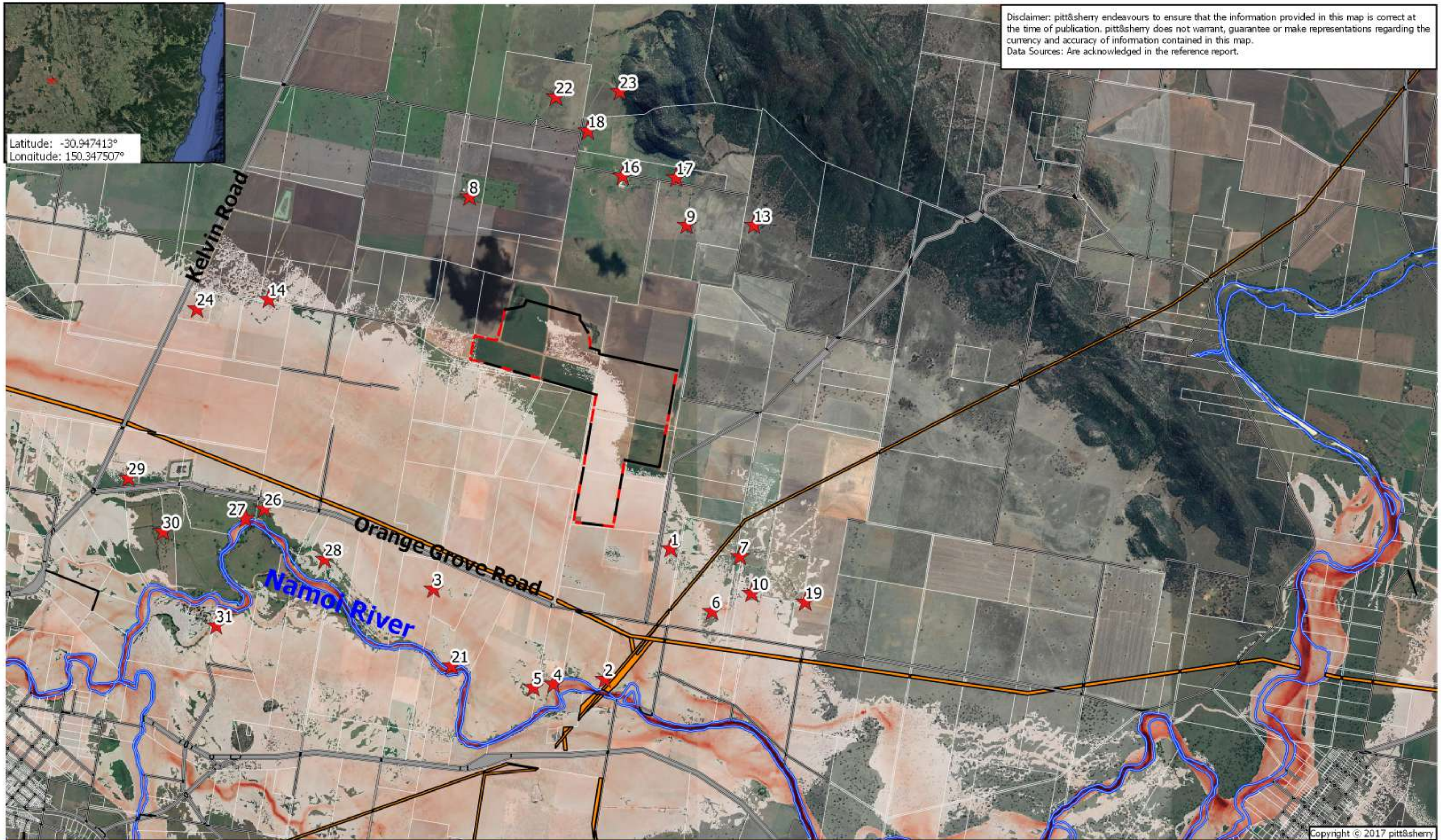

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Data Sources: Are acknowledged in the reference report.

Data sources:
Base image from Google Earth
Reference Report:
SY17199B005 REP 31P REV05

N

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 55
1:80,922 When printed at A4

Legend

- Fence
- Drop Down Fence
- Easement
- Cadastre
- Road
- Water Corridor
- SensitiveRecievers

5% AEP Configuration 4 Scenario (m/s)

2.2
1.6
1
0.4
0

pitt&sherry

Project Number	SY17199
Figure Number	SY17199-F404
Revision	3
Author	mdugan
Reviewer	mjacobs
Date	28-06-2018

Photon Energy Engineering Australia Pty Ltd

PHOTON ENERGY

Orange Grove Road, Gunnedah

5% AEP Flood Velocity Configuration 4 Scenario

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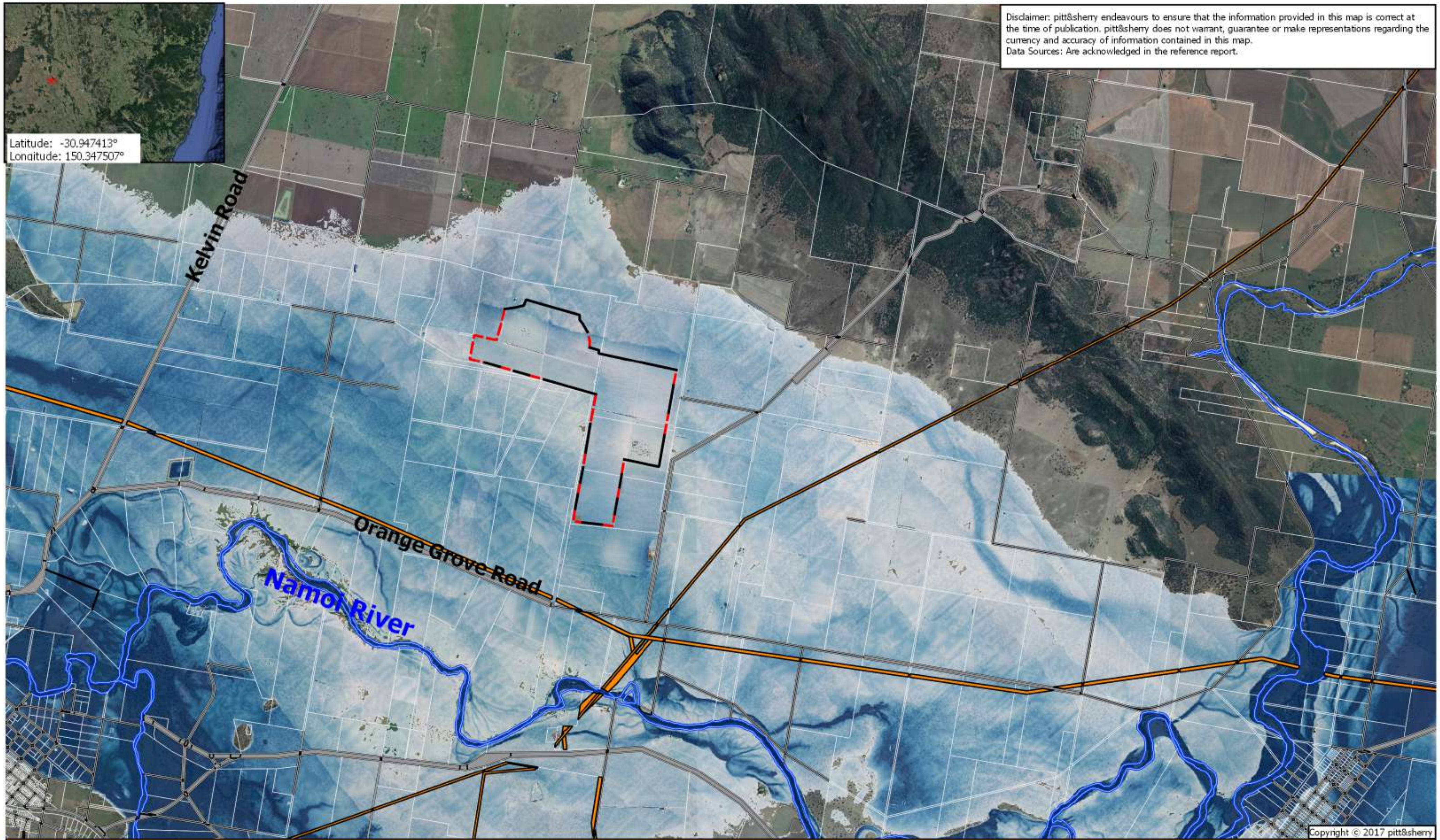


Data sources:
Base image from Google Earth
Reference Report:
SY17199B005 REP 31P REV05

N

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 55
1:80,922 When printed at A4

Legend

- Fence
- Drop Down Fence
- Easement
- Cadastre
- Road
- Water Corridor
- SensitiveRecievers

1955 Configuration 4 Scenario (m)

2
1.5
1
0.5
0

pitt&sherry

Project Number	SY17199
Figure Number	SY17199-F405
Revision	3
Author	mdugan
Reviewer	mjacobs
Date	28-06-2018

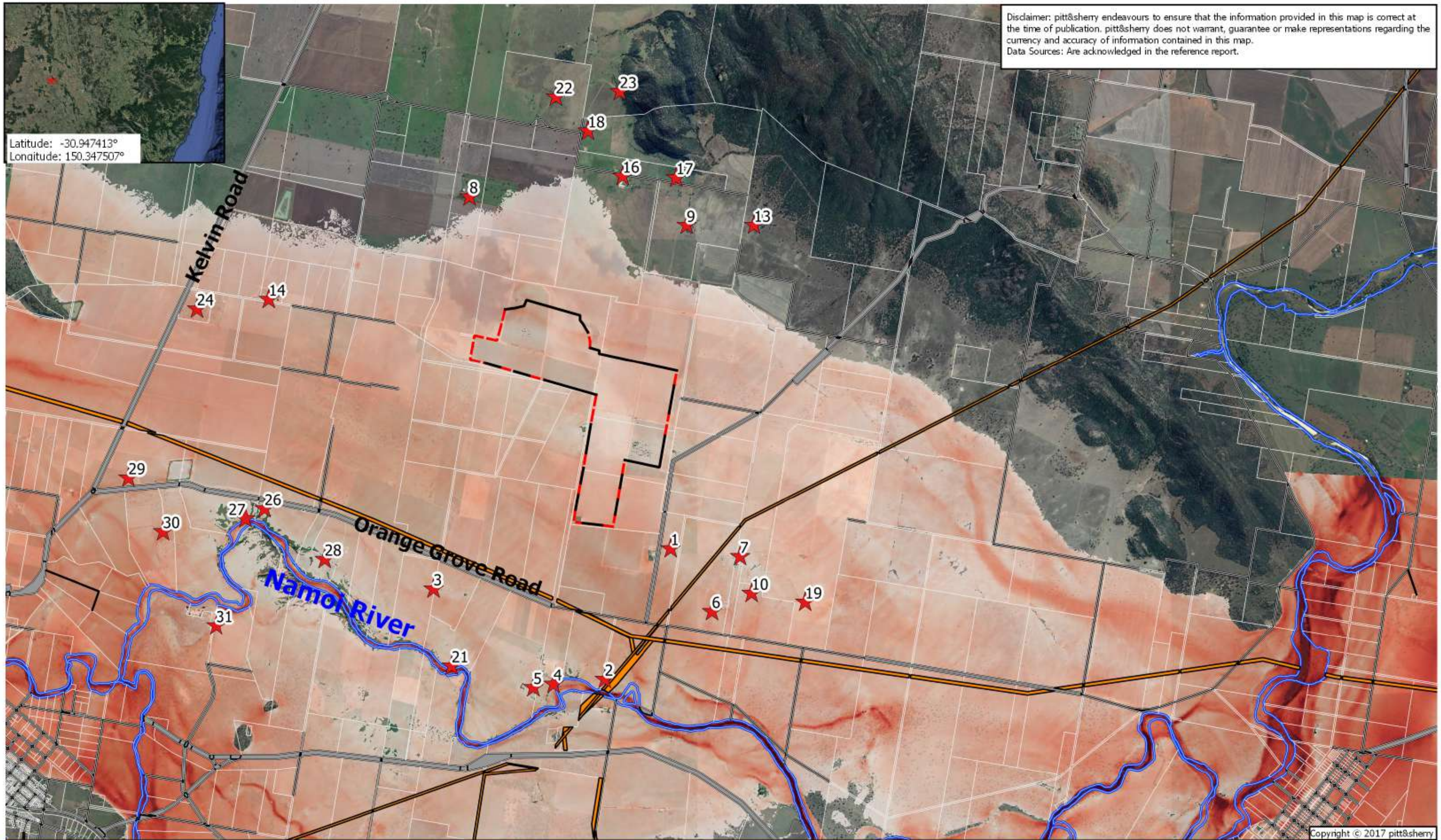
Photon Energy Engineering Australia Pty Ltd

PHOTON ENERGY

Orange Grove Road, Gunnedah

1955 Flood Depth
Configuration 4 Scenario

File: C:/dms/1/SY17199 - Gunnedah Solar Farm_3/GIS/SY17199-F405.qgsSY17199-F405.qgs



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Base image from Google Earth
Reference Report:
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N

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 55
1:80,922 When printed at A4

Legend
- Fence
- Drop Down Fence
- Easement
- Cadastre
- Road
- Water Corridor
- SensitiveRecievers

1955 Configuration 4 Scenario (m/s)
2.2
1.6
1
0.4
0

pitt&sherry

Project Number	SY17199
Figure Number	SY17199-F406
Revision	3
Author	mdugan
Reviewer	mjacobs
Date	28-06-2018

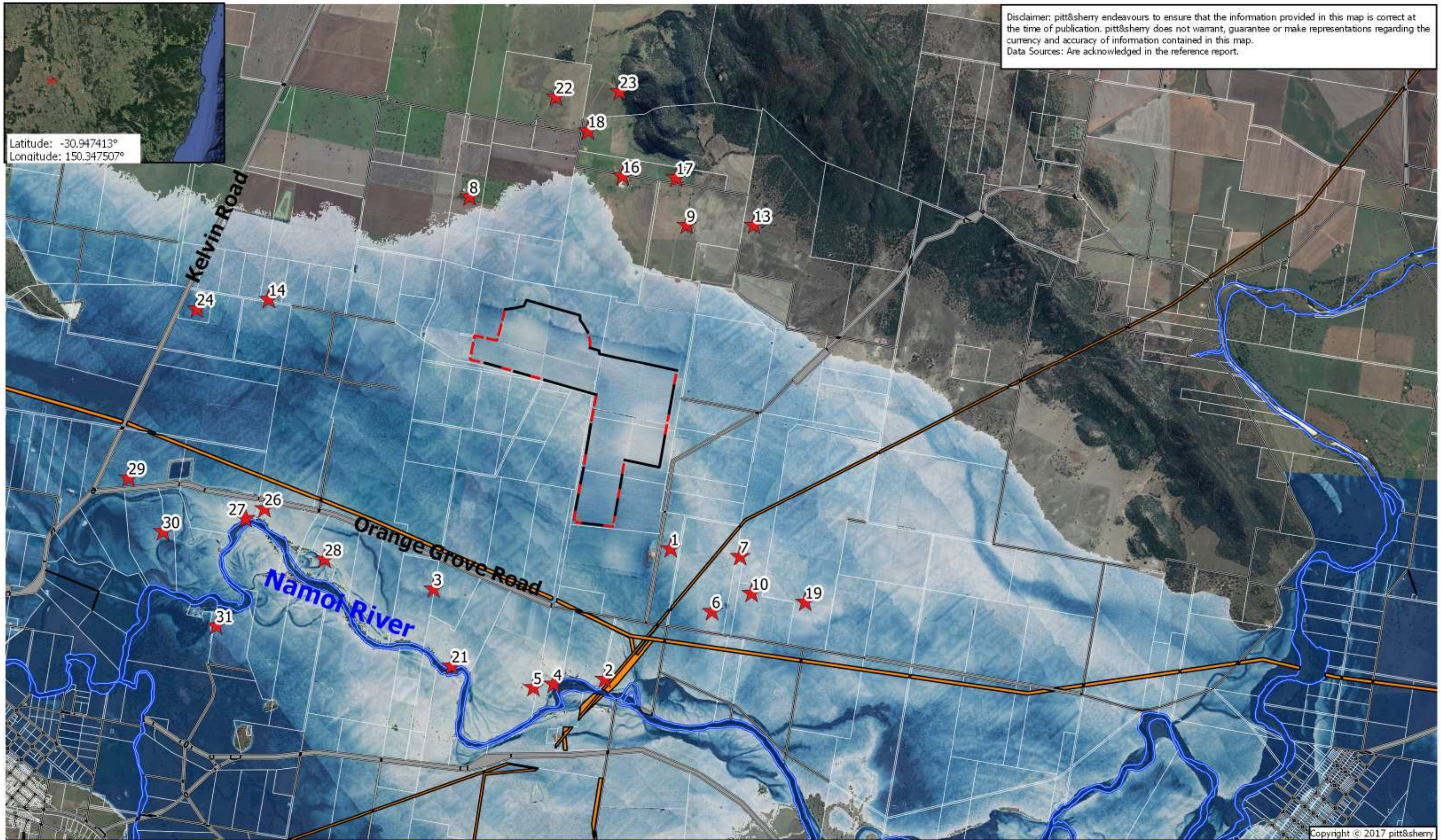
Photon Energy Engineering Australia Pty Ltd

PHOTON ENERGY

Orange Grove Road, Gunnedah

1955 Flood Velocity Configuration 4 Scenario

File: C:/dms/1/SY17199 - Gunnedah Solar Farm_3/GIS/SY17199-F406.qgsSY17199-F406.qgs



Data sources:
Base image from Google Earth
Reference Report:
SY17199B005 REP 31P REV05

N

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 55
1:80,922 When printed at A4

Legend

- Fence
- Drop Down Fence
- Easement
- Cadastre
- Road
- Water Corridor
- SensitiveRecievers

PMF Configuration 4 Scenario (m)

2, 1.5, 1, 0.5, 0

pitt&sherry

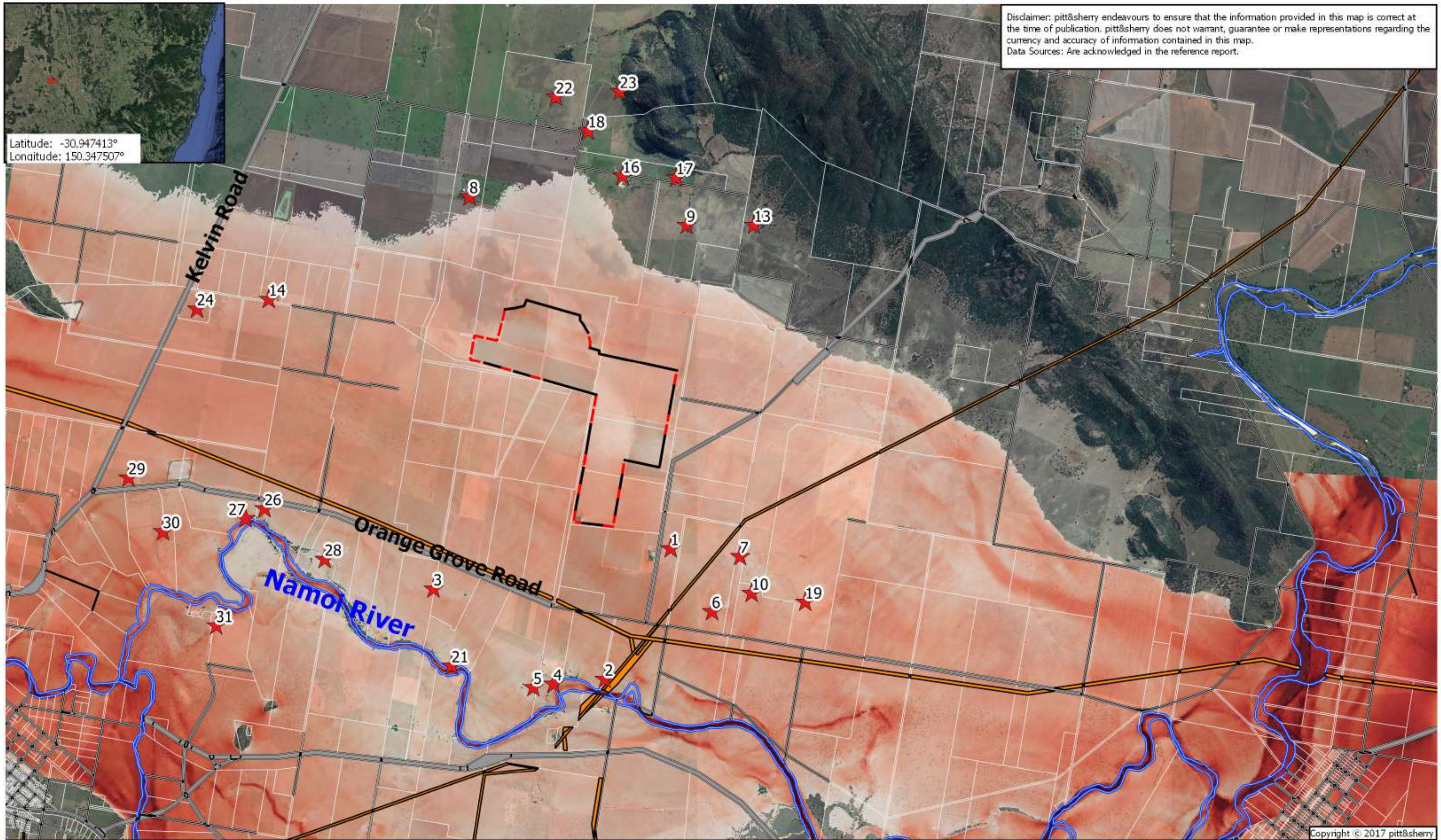
Project Number	SY17199
Figure Number	SY17199-F407
Revision	3
Author	mdugan
Reviewer	mjacobs
Date	28-06-2018

Photon Energy Engineering Australia Pty Ltd

PHOTON ENERGY

Orange Grove Road, Gunnedah

Probable Maximum Flood Depth Configuration 4 Scenario



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Data Sources: Are acknowledged in the reference report.

Data sources:
Base image from Google Earth
Reference Report:
SY17199B005 REP 31P REV05

N

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 55
1:80,922 When printed at A4

Legend

- Fence
- Drop Down Fence
- Easement
- Cadastre
- Road
- Water Corridor
- SensitiveRecievers

PMF Configuration 4 Scenario (m/s)

2.2
1.6
1
0.4
0

pitt&sherry

Project Number	SY17199
Figure Number	SY17199-F408
Revision	3
Author	mdugan
Reviewer	mjacobs
Date	28-06-2018

Photon Energy Engineering Australia Pty Ltd

PHOTON ENERGY

Orange Grove Road, Gunnedah

Probable Maximum Flood Velocity Configuration 4 Scenario

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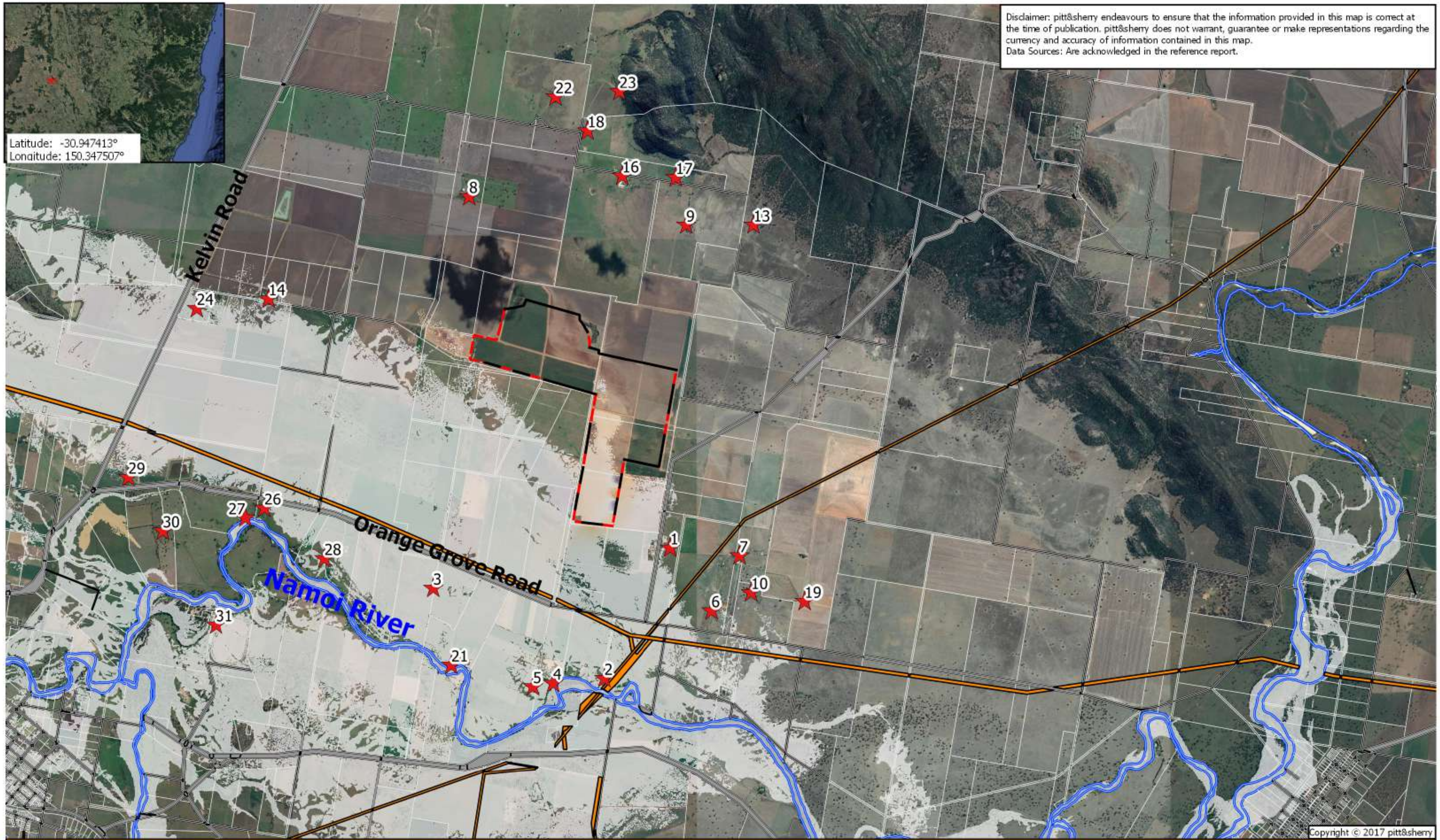


Data sources:
Base image from Google Earth
Reference Report:
SY17199B005 REP 31P REV05

N

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 55
1:80,922 When printed at A4

Legend

- Fence
- Drop Down Fence
- Easement
- Cadastre
- Road
- Water Corridor
- SensitiveRecievers

10% AEP Configuration 4 Difference (m)

0.1
0.05
0
-0.05
-0.1

pitt&sherry

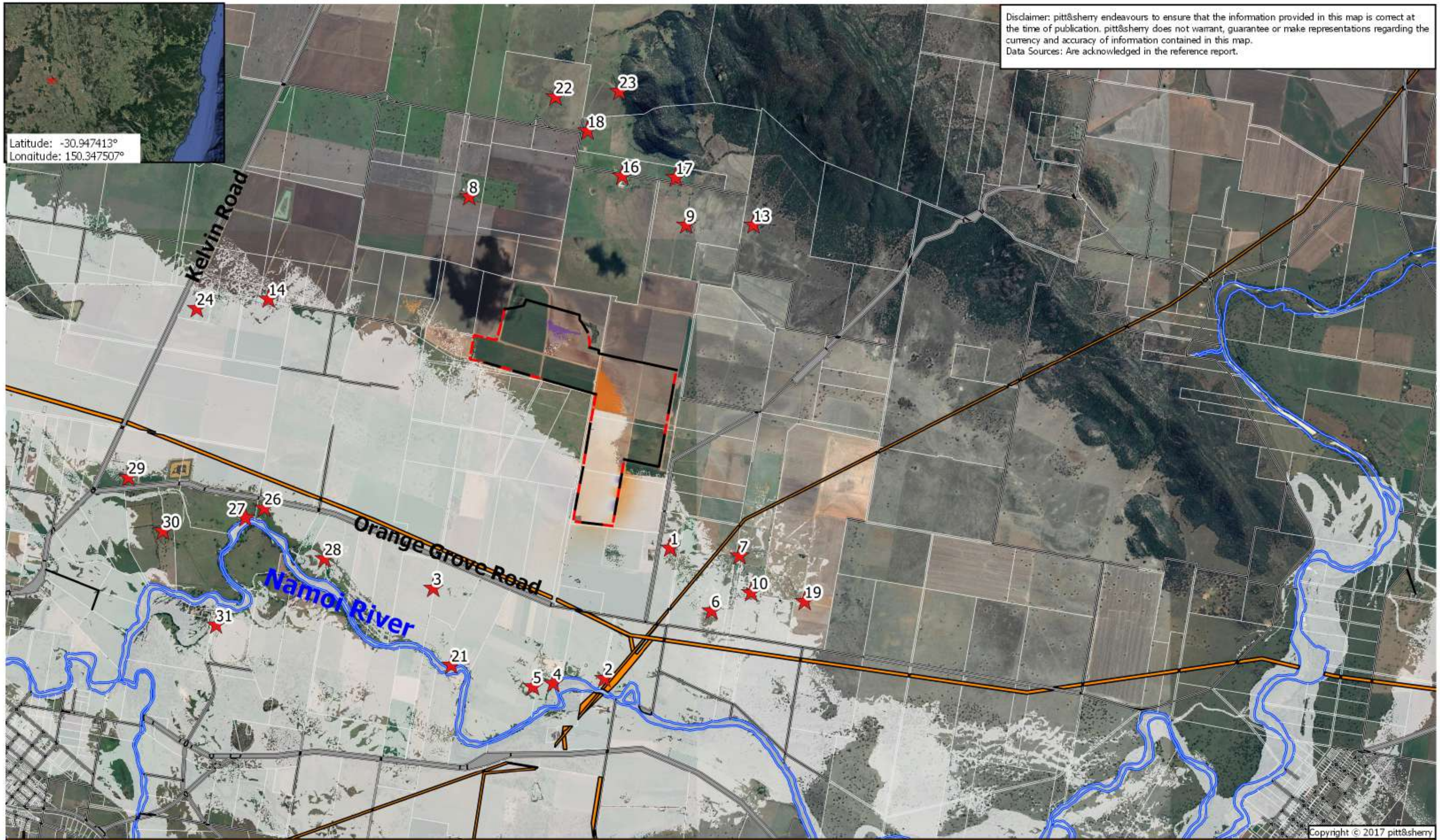
Project Number	SY17199
Figure Number	SY17199-F409
Revision	3
Author	mdugan
Reviewer	mjacobs
Date	28-06-2018

Photon Energy Engineering Australia Pty Ltd

PHOTON ENERGY

Orange Grove Road, Gunnedah

10% AEP Flood Depth change, Existing to Configuration 4



Data sources:
Base image from Google Earth
Reference Report:
SY17199B005 REP 31P REV05

N

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 55
1:80,922 When printed at A4

Legend

- Fence
- Drop Down Fence
- Easement
- Cadastre
- Road
- Water Corridor
- SensitiveRecievers

5% AEP Configuration 4 Difference (m)

0.1
0.05
0
-0.05
-0.1

pitt&sherry

Project Number	SY17199
Figure Number	SY17199-F410
Revision	3
Author	mdugan
Reviewer	mjacobs
Date	28-06-2018

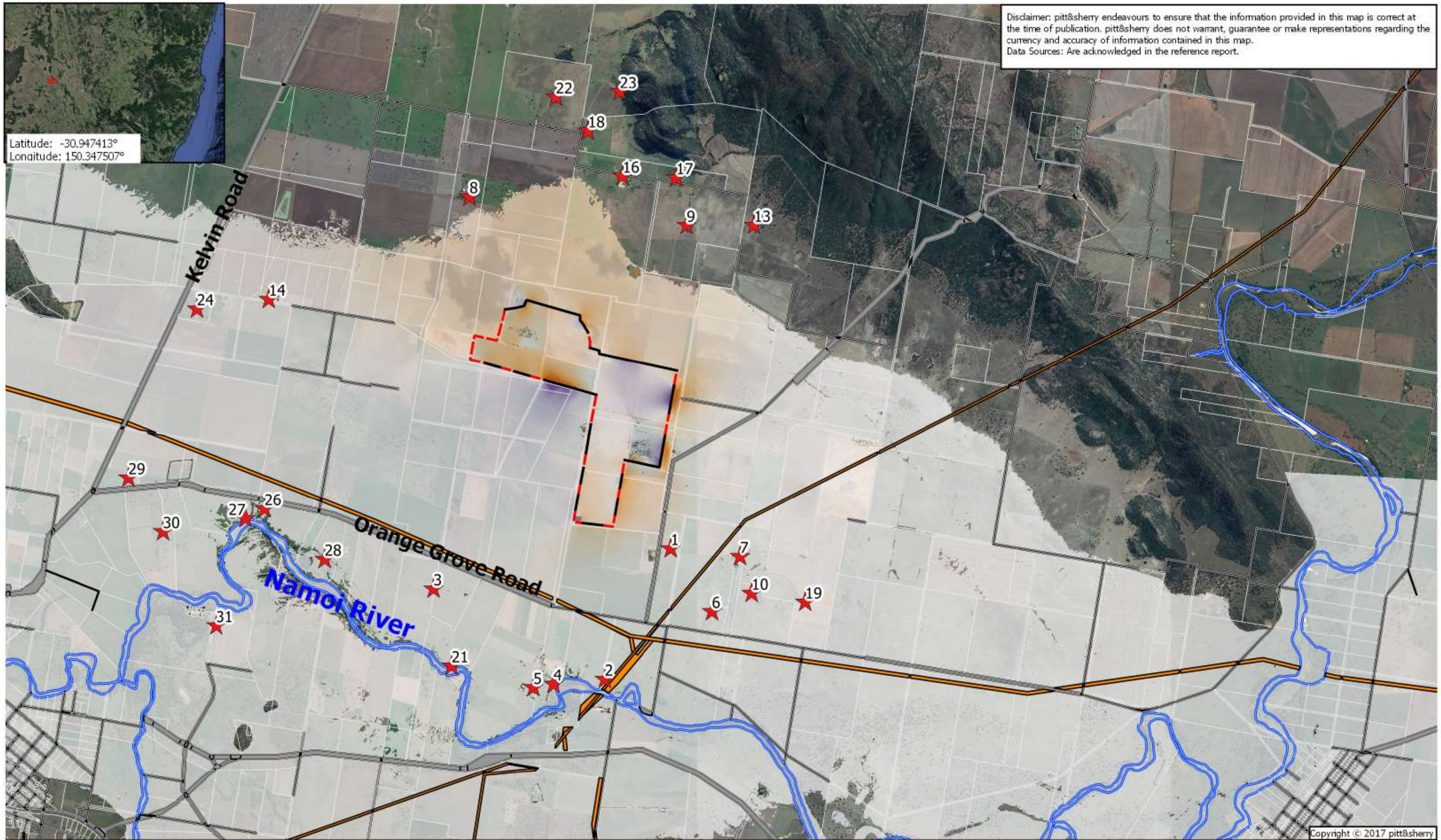
Photon Energy Engineering Australia Pty Ltd

PHOTON ENERGY

Orange Grove Road, Gunnedah

5% AEP Flood Depth change, Existing to Configuration 4

File: C:/dms/1/SY17199 - Gunnedah Solar Farm_3/GIS/SY17199-F410.qgsSY17199-F410.qgs



Data sources:
Base image from Google Earth
Reference Report:
SY17199B005 REP 31P REV05

N

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 55
1:80,922 When printed at A4

Legend

- Fence
- Drop Down Fence
- Easement
- Cadastre
- Road
- Water Corridor
- SensitiveRecievers

1955 Configuration 4 Difference (m)

0.1
0.05
0
-0.05
-0.1

pitt&sherry

Project Number	SY17199
Figure Number	SY17199-F411
Revision	3
Author	mdugan
Reviewer	mjacobs
Date	28-06-2018

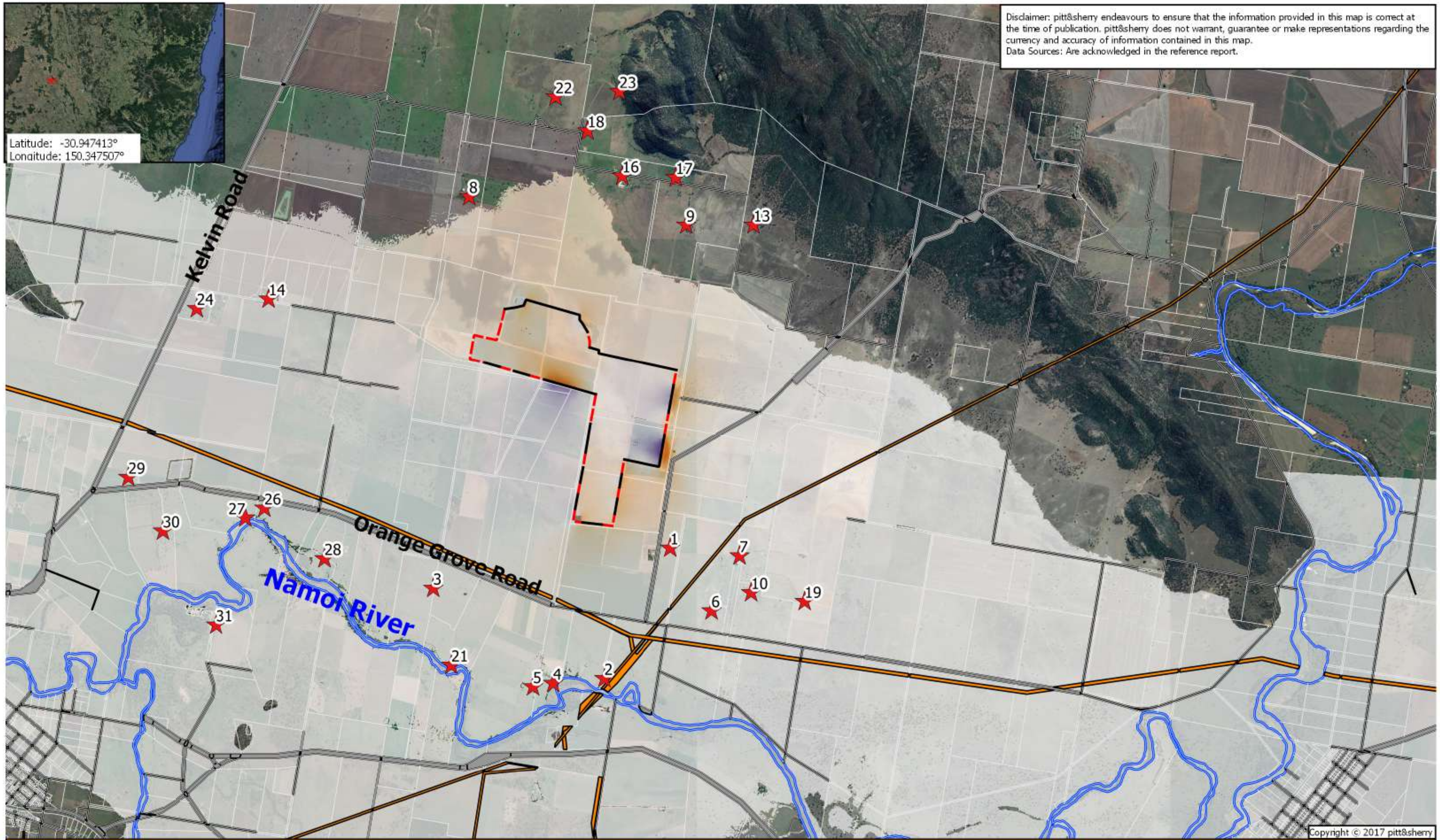
Photon Energy Engineering Australia Pty Ltd

PHOTON ENERGY

Orange Grove Road, Gunnedah

1955 Flood Depth change, Existing to Configuration 4

File: C:/dms/1/SY17199 - Gunnedah Solar Farm_3/GIS/SY17199-F411.qgsSY17199-F411.qgs



Data sources:
Base image from Google Earth
Reference Report:
SY17199B005 REP 31P REV05

N

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 55
1:80,922 When printed at A4

Legend

- Fence
- Drop Down Fence
- Easement
- Cadastre
- Road
- Water Corridor
- SensitiveRecievers

PMF Configuration 4 Difference (m)

0.1
0.05
0
-0.05
-0.1

pitt&sherry

Project Number	SY17199
Figure Number	SY17199-F412
Revision	3
Author	mdugan
Reviewer	mjacobs
Date	28-06-2018

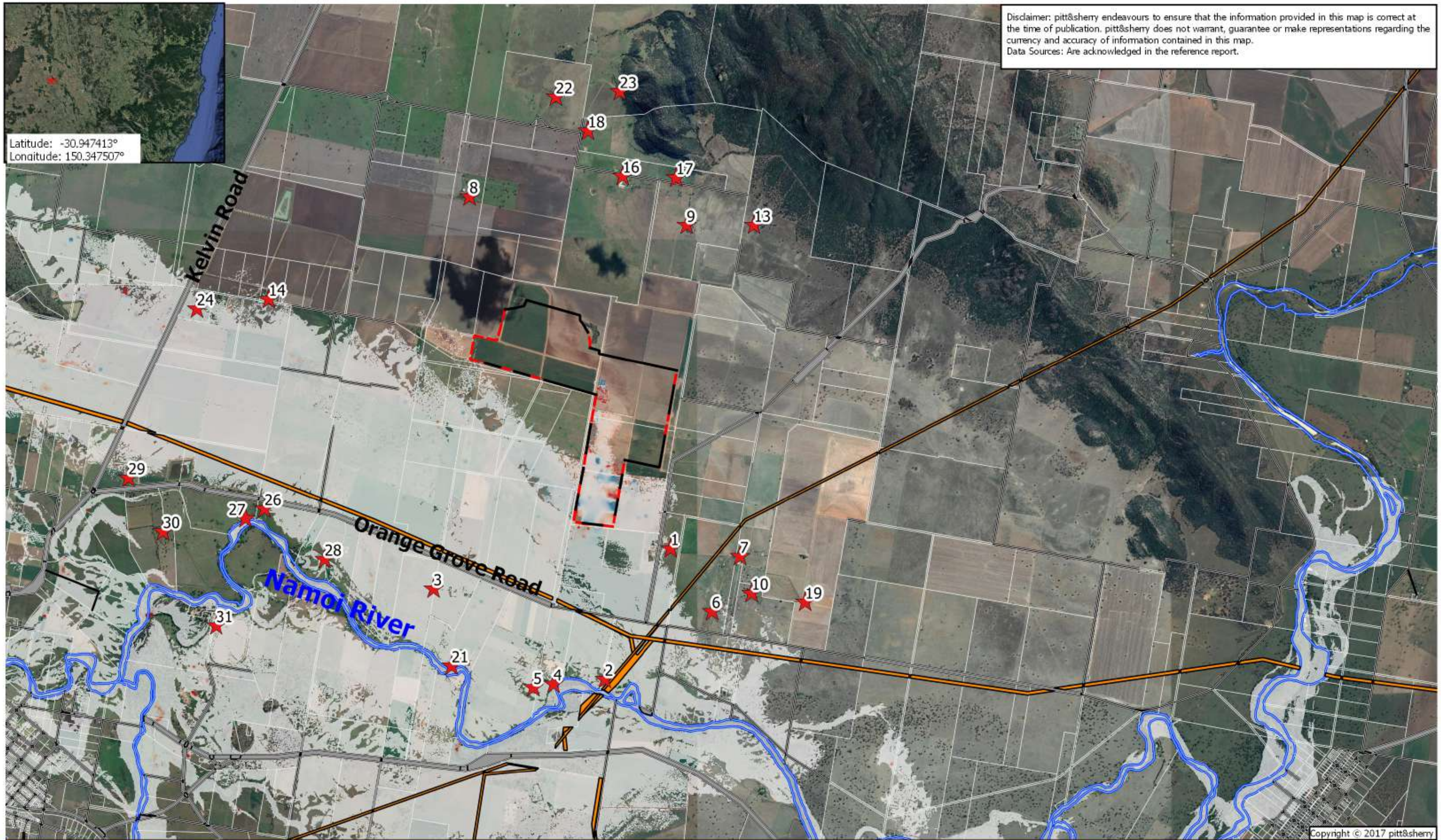
Photon Energy Engineering Australia Pty Ltd

PHOTON ENERGY

Orange Grove Road, Gunnedah

Probable Maximum Flood Depth change, Existing to Configuration 4

File: C:/dms/1/SY17199 - Gunnedah Solar Farm_3/GIS/SY17199-F412.qgsSY17199-F412.qgs



Disclaimer: pitt&sherry endeavours to ensure that the information provided in this map is correct at the time of publication. pitt&sherry does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.
Data Sources: Are acknowledged in the reference report.

Data sources:
Base image from Google Earth
Reference Report:
SY17199B005 REP 31P REV05

N

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 55
1:80,922 When printed at A4

Legend

- Fence
- Drop Down Fence
- Easement
- Cadastre
- Road
- Water Corridor
- SensitiveRecievers

10% AEP Configuration 4 Difference (%)

50
25
0
-25
-50

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Project Number	SY17199
Figure Number	SY17199-F421
Revision	3
Author	mdugan
Reviewer	mjacobs
Date	28-06-2018

Photon Energy Engineering Australia Pty Ltd

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Orange Grove Road, Gunnedah

10% AEP Flood Velocity change, Existing to Configuration 4

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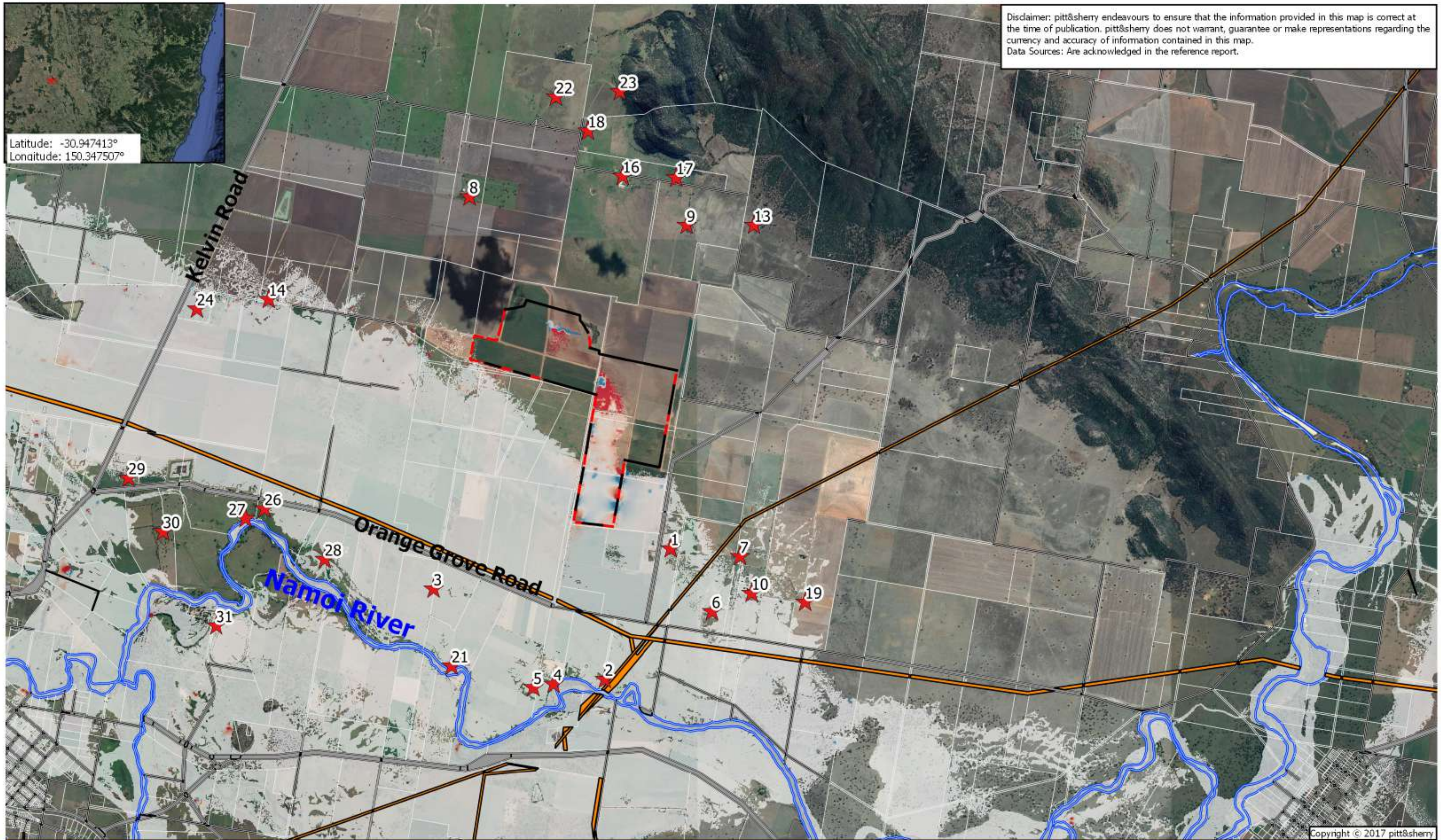
Data Sources: Are acknowledged in the reference report.



Data sources:
Base image from Google Earth
Reference Report:
SY17199B005 REP 31P REV05

N

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 55
1:80,922 When printed at A4

Legend

- Fence
- Drop Down Fence
- Easement
- Cadastre
- Road
- Water Corridor
- SensitiveRecievers

5% AEP Configuration 4 Difference (%)

50
25
0
-25
-50

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Project Number	SY17199
Figure Number	SY17199-F422
Revision	3
Author	mdugan
Reviewer	mjacobs
Date	28-06-2018

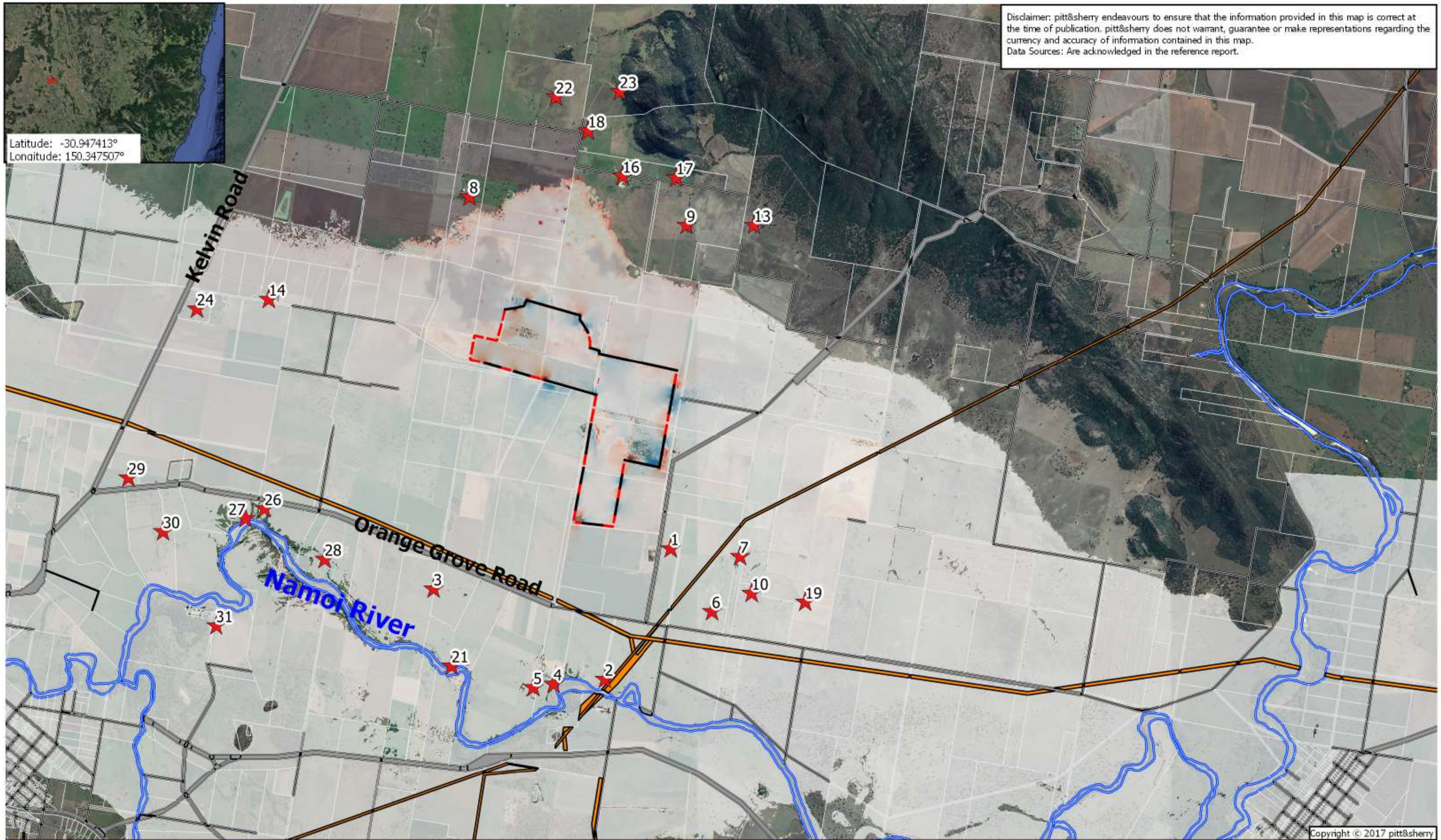
Photon Energy Engineering Australia Pty Ltd

PHOTON ENERGY

Orange Grove Road, Gunnedah

5% AEP Flood Velocity change, Existing to Configuration 4

File: C:/dms/1/SY17199 - Gunnedah Solar Farm_3/GIS/SY17199-F422.qgsSY17199-F422.qgs



Data sources:
Base image from Google Earth
Reference Report:
SY17199B005 REP 31P REV05

N

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 55
1:80,922 When printed at A4

Legend

- Fence
- Drop Down Fence
- Easement
- Cadastre
- Road
- Water Corridor
- SensitiveRecievers

1955 Configuration 4 Difference (%)

50
25
0
-25
-50

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Project Number	SY17199
Figure Number	SY17199-F423
Revision	3
Author	mdugan
Reviewer	mjacobs
Date	28-06-2018

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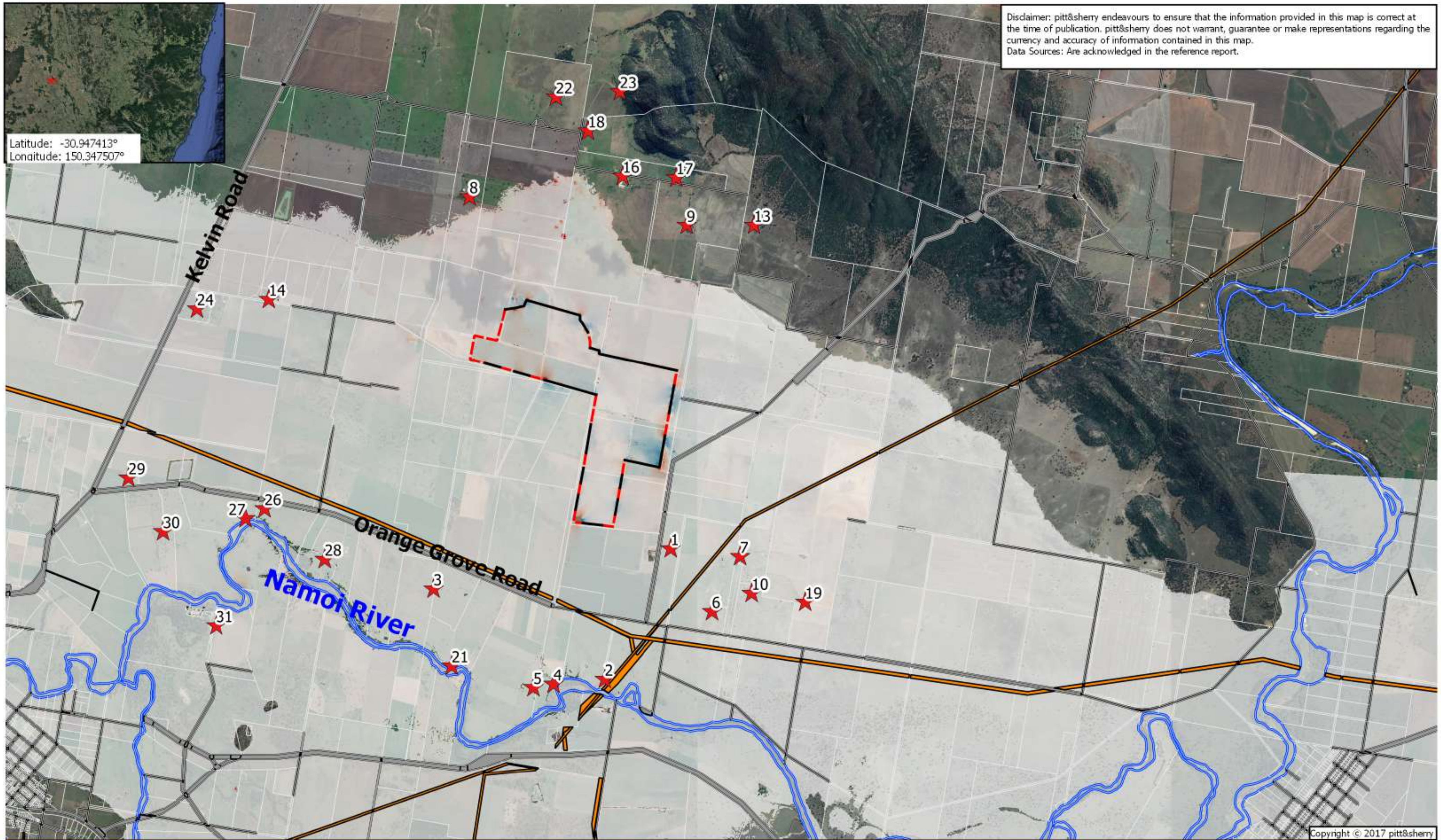
Orange Grove Road, Gunnedah

1955 Flood Velocity change, Existing to Configuration 4

File: C:/dms/1/SY17199 - Gunnedah Solar Farm_3/GIS/SY17199-F423.qgsSY17199-F423.qgs



Data sources:
Base image from Google Earth
Reference Report:
SY17199B005 REP 31P REV05

N

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 55
1:80,922 When printed at A4

Legend

- Fence
- Drop Down Fence
- Easement
- Cadastre
- Road
- Water Corridor
- SensitiveRecievers

PMF Configuration 4 Difference (%)

50
25
0
-25
-50

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Project Number	SY17199
Figure Number	SY17199-F424
Revision	3
Author	mdugan
Reviewer	mjacobs
Date	28-06-2018

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PHOTON ENERGY

Orange Grove Road, Gunnedah

Probable Maximum Flood Velocity change, Existing to Configuration 4

File: C:/dms/1/SY17199 - Gunnedah Solar Farm_3/GIS/SY17199-F424.qgsSY17199-F424.qgs

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Gunnedah Solar Farm – Updated Flood Impact Assessment

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