THE UNIVERSITY OF
NEW SOUTH WALES

Water Research
Laboratory

School of Civil and
Environmental Engineering

6th July 2010

Our Ref: WRL 10075.01 GPS L100706

Infigen Pty Ltd
Level 22, 56 Pitt Street
Sydney NSW 2000

Attention: Chris McGrath

Dear Sir,

RE: LAKE GEORGE FLOOD MAPPING

Infigen Pty Ltd (Infigen) commissioned the University of New South Wales (UNSW) Water Research Laboratory (WRL) to map Lake George water surface levels. Lake water surface contours were required for the 1:10, 1:20, 1:50 and 1:100 exceedance probability levels. This letter provides a description of the data, methodology and outcomes of our analysis.

1.0 DATA

The data as listed were available to WRL for the analysis:

- Topographical land surface contours to Australian Height Datum (AHD) registered in Map Grid of Australia (MGA) coordinates in 0.5m intervals. These contours were provided to WRL via email by Monteath & Powys Pty Ltd on 17 June 2010. The contours were delivered in three AutoCAD DWG files covering three land parcels "CWF II - Contours Northern Section.dwg", "CWF II - Contours Middle Section.dwg" and "CWF II - Contours Southern Section.dwg";
- Lake George depth time series. A composite depth time series for Lake George covering the period from 1817 to 2009 has previously been compiled by UNSW as part of an undergraduate thesis (Bowd, 2009). This time series relies on information as described in Russell (1887), Jacobsen and Schuett (1979) and more recent information provided by Geoscience Australia. The composite time series is illustrated in Figure 1; and

- Lake George gauge datum. The Lake George depth time series was converted to a water surface level time series by applying a datum adjustment of 672.879 m AHD provided by Geoscience Australia (pers comms Tim Ransley, Geoscience Australia, 29 June 2010)

2.0 METHODOLOGY

The following tasks were undertaken to develop water surface level contours at the required probability levels:

1. Conversion of the lake depth time series to a water surface time series by applying a datum adjustment of 672.879 m AHD;
2. Statistical analysis of the water surface time series to determine the relevant exceedance probability levels;
3. Mapping of the exceedance probability levels as contours for the three provided land parcels using automated GIS techniques; and
4. Manual review of the automatically generated contours.

2.1 Statistical Analysis

A frequency analysis was performed on the available time series of water level in Lake George as presented in Figure 3. The frequency analysis included:

- Finding the maximum recorded water level for each year resulting in an annual series of water levels as presented in Figure 2;
- Ranking the annual series of water levels;
- Developing the plotting position of each of the water levels in the annual series using the following formula (Cunnane, 1978), where *i* is the rank of the water level, *n* is the total length of the record, and *P(i)* is the plotting position:

$$P(i) = \frac{i - 0.4}{N + 0.2}$$

- Plotting each water level against its plotting position on a probability plot.

The plot resulting from the frequency analysis is presented in Figure 3, with the results summarised in Table 1.

A review of Figure 2 shows that in numerous instances the annual water level shows a strong correlation to the previous and subsequent years i.e. the historical records show that once the lake level is elevated, it typically remains elevated through several

calendar years. While the elevated water level periods are most likely the result of several rainfall runoff events to the lake, these shorter temporal scale level fluctuations are not recorded in the available time series. Note that the effects of the annual water levels being correlated to one another was not considered in this analysis, and hence the inverse of the probabilities presented may not coincide with the annual recurrence interval. In strict terms, the statistical analysis used here assumes that the annual time series is uncorrelated.

Note also that we have not attempted to fit a statistical distribution to the data. Our experience has shown that it is difficult to fit one of the standard distributions typically recommended in hydrological manuals to water level records. These standard statistical distributions are typically applied to flow time series, which usually do not exhibit a strong upper bound with decreasing probability of exceedance. Water level series such as the subject series for Lake George, however, do have a tendency to trend towards an upper bound due to the incrementally smaller increases in water level with increasing inflow volume. This being the case we have estimated the required exceedance probability levels from the plotting position analysis presented in Figure 3.

Table 1
Summary of Lake George Water Levels Exceedance Probability

Exceedance Probability	Water Level (m AHD)
1:100	680.3
1:50	680.2
1:20	679.8
1:10	678.2

Note also, that the time series indicates that the 19th century levels were generally higher than those recorded in the 20th and early 21st centuries. The CSIRO analysis of likely climate change for the region (CSIRO 2006) also predicts that the general climate trend for the region is for less rainfall and higher evaporation on average for the period to 2070. On this basis, inclusion of the full time series from 1817 to 2009 in the statistical analysis can be considered conservative.

2.2 Mapping

The required exceedance probability levels were mapped against the provided topographical data sets using ARCMAP v9.3 GIS software (ESRI, 2008). The process for mapping the water levels was as follows:

- The 0.5m contours for each of the north, middle and south land parcels were imported into ARCMAP;
- The 0.5m contours were converted into a Triangulated Irregular Network (TIN) representation of the surface using standard features in the ARCMAP 3D Analyst software. An example of the TIN for the north land parcel is presented in Figure 4;
- The 3D Analyst toolbox routine "TIN Contour" was then used to interpolate land surface contours at the levels specified in Table 1.
- The automatically generated contours were visually inspected and manually adjusted where there were obvious conflicts with the original contour data.

3.0 RESULTS

Lands surface contours at the specified levels are provided in ERSI shape file format. Separate files are provided containing the exceedance level contours for each land parcel as summarised in Table 2 below.

Table 2
Summary of Result files

Land Parcel	Contour File Name
North	Contour_north_r1.shp
Middle	Contour_middle_1.shp
South	Contour_south_r3.shp

4.0 QUALIFICATIONS

1. Statistical analysis of Lake George levels is based on the lake water level time series developed as described in Section 1.0 above and presented in Figures 1 and 2 attached to this report. While WRL understands that this time series is the best available record of Lake George levels, WRL are unable to independently verify the accuracy of these recorded levels. In lieu of independent checking we recommend a nominal level accuracy +/- 0.1m be applied;
2. Contour mapping of the nominated lake exceedance levels has been developed using the GIS interpretation techniques as described in Section 2.2. The

mapping is based on 0.5m land surface contours as provided by Monteath & Powys Pty Ltd. As such, the spatial location of the contours as provided by WRL should be considered indicative only. WRL recommends that a qualified surveyor locate the contours using appropriate surveying techniques should accurate spatial location of the exceedance level contours be required.

5.0 REFERENCES

Bowd, M (2009), Study of Lake George, New South Wales. *Undergraduate Thesis submitted for the Degree of Bachelor of Engineering (Honours), School of Civil and Environmental Engineering, The University of New South Wales.*

CSIRO (2006), Climate Change in the Murrumbidgee Catchment. *Report prepared by the CSIRO for the New South Wales Government.*

Cunnane, C (1978), Unbiased Plotting Positions – A Review, *Journal of Hydrology*, **37**:205-222.

Jacobsen, G and Schuett, A W (1979), Water Levels, Balance and Chemistry of Lake George, New South Wales, *BMR Journal of Australian Geology and Geophysics* **4**(1): 25 – 32.

Russell, H C, A., B. and S., F. R. (1887). Notes Upon Floods in Lake George. *Journal and Proceedings of the Royal Society of New South Wales* **20**: 241 – 260.

Please contact Mr Grantley Smith on 02 8071 9800 should you wish to discuss this investigation further.

Yours faithfully,

(for)

B M Miller
Manager.

WRL
Letter No. 10075

LAKE GEORGE RECORDED DEPTHS

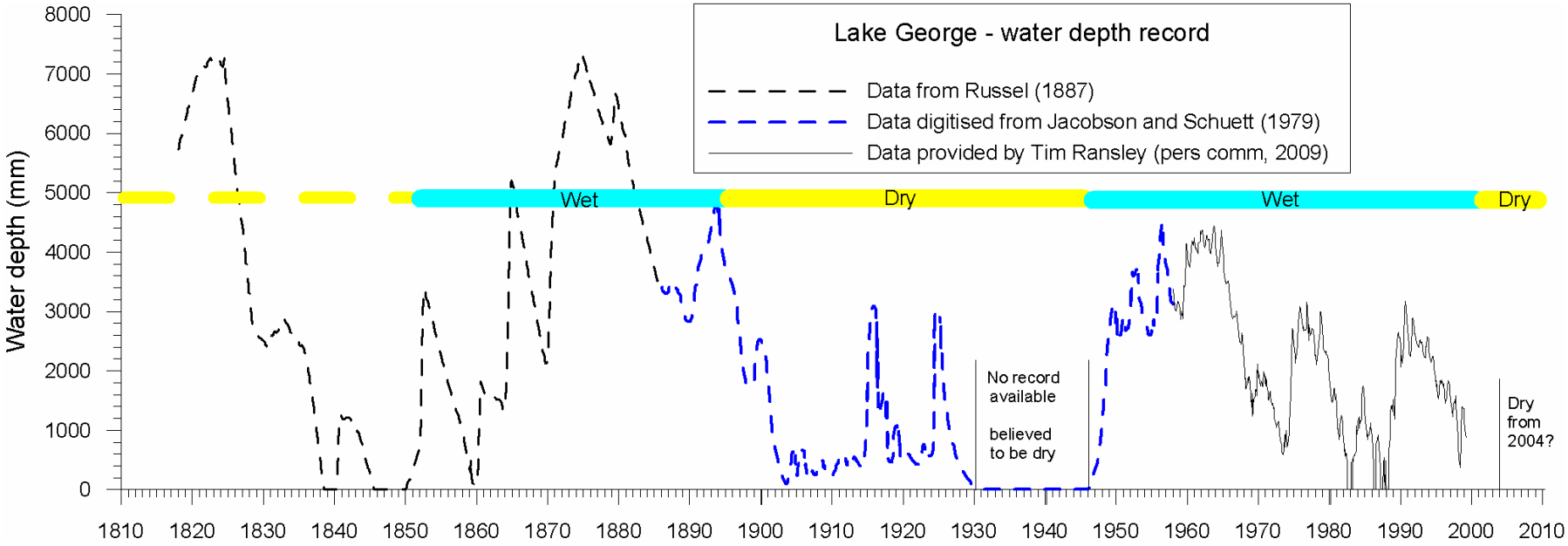

Figure
1

WRL

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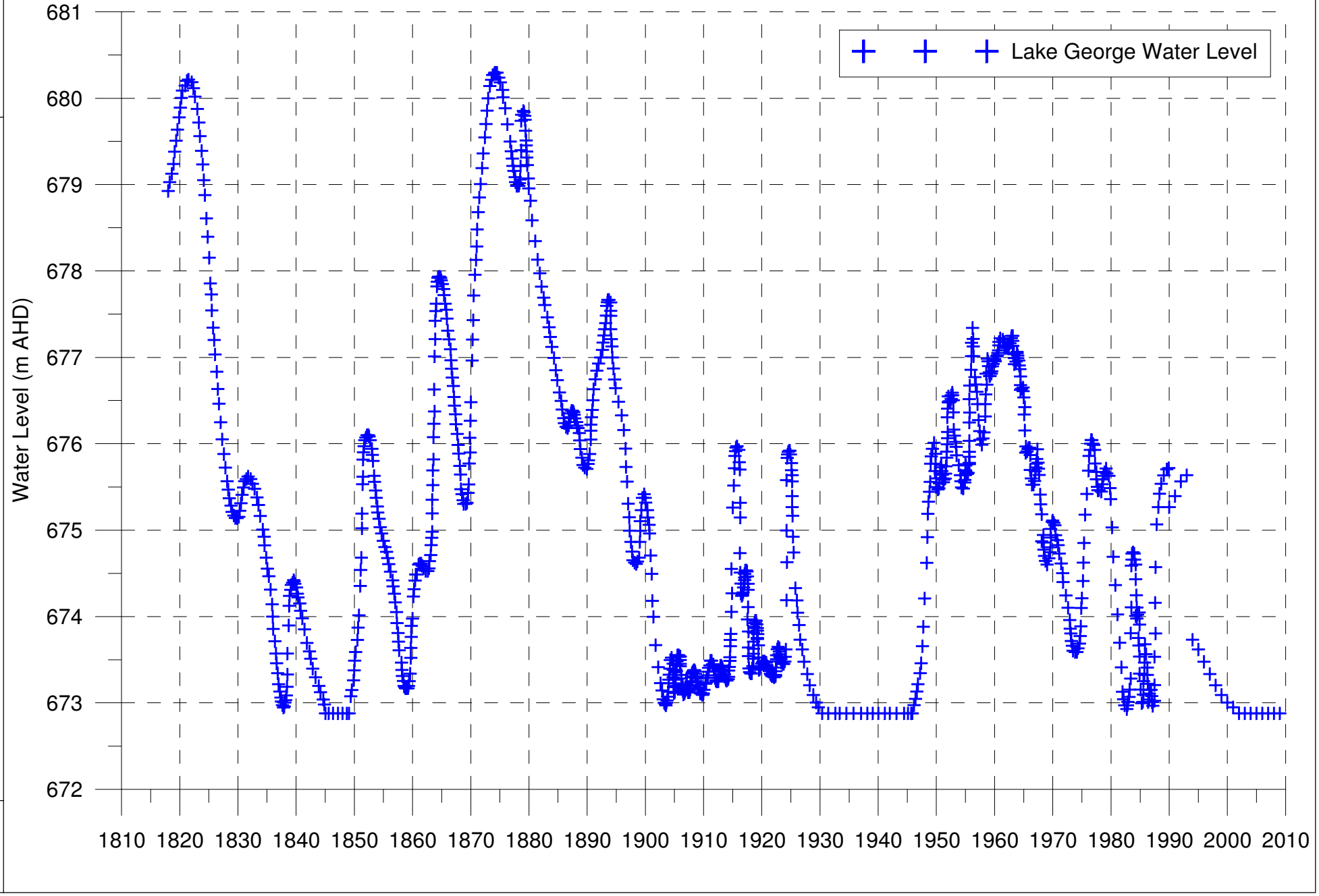
TIME SERIES OF WATER LEVEL IN LAKE GEORGE

Figure 2

Figure_ts.grf



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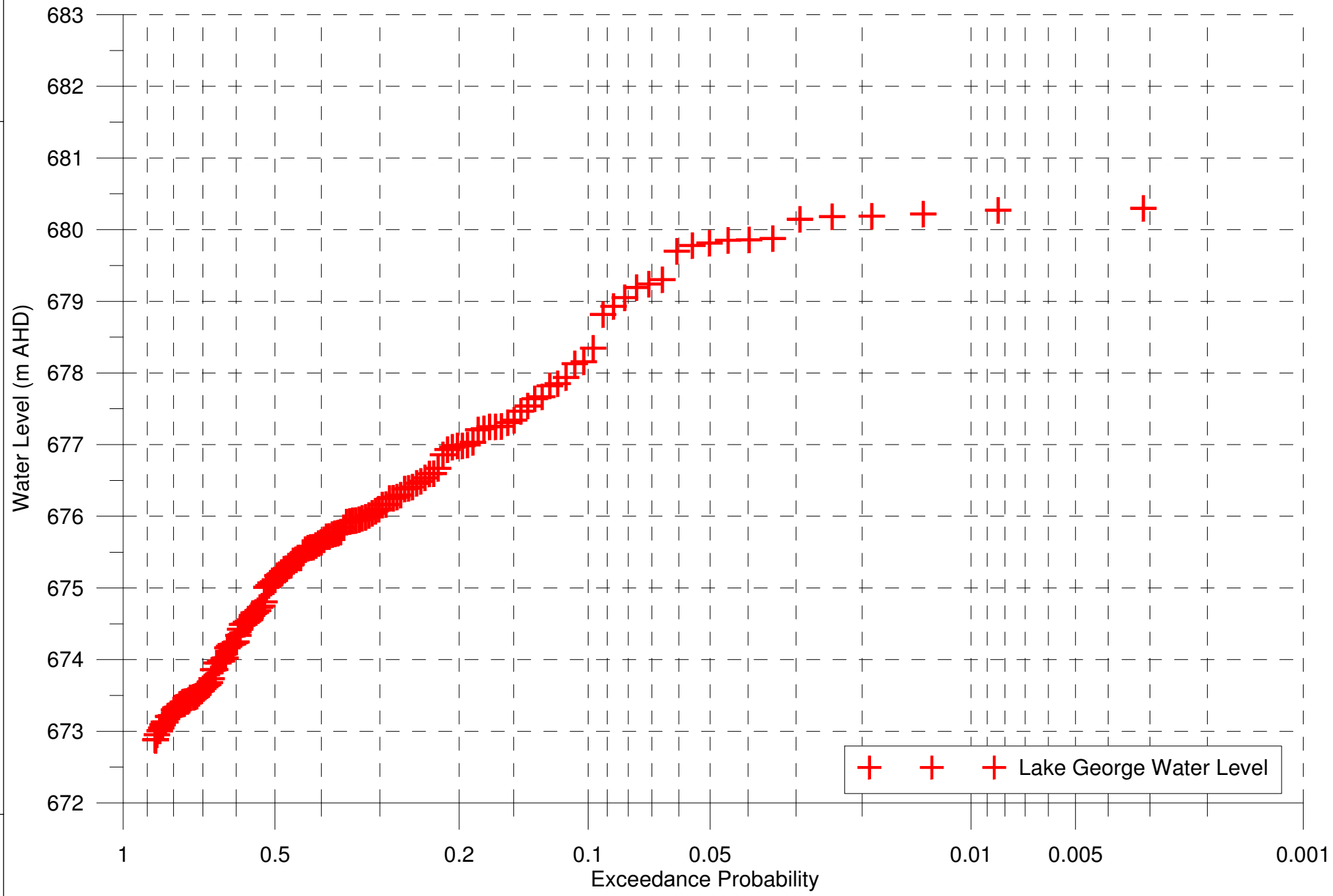
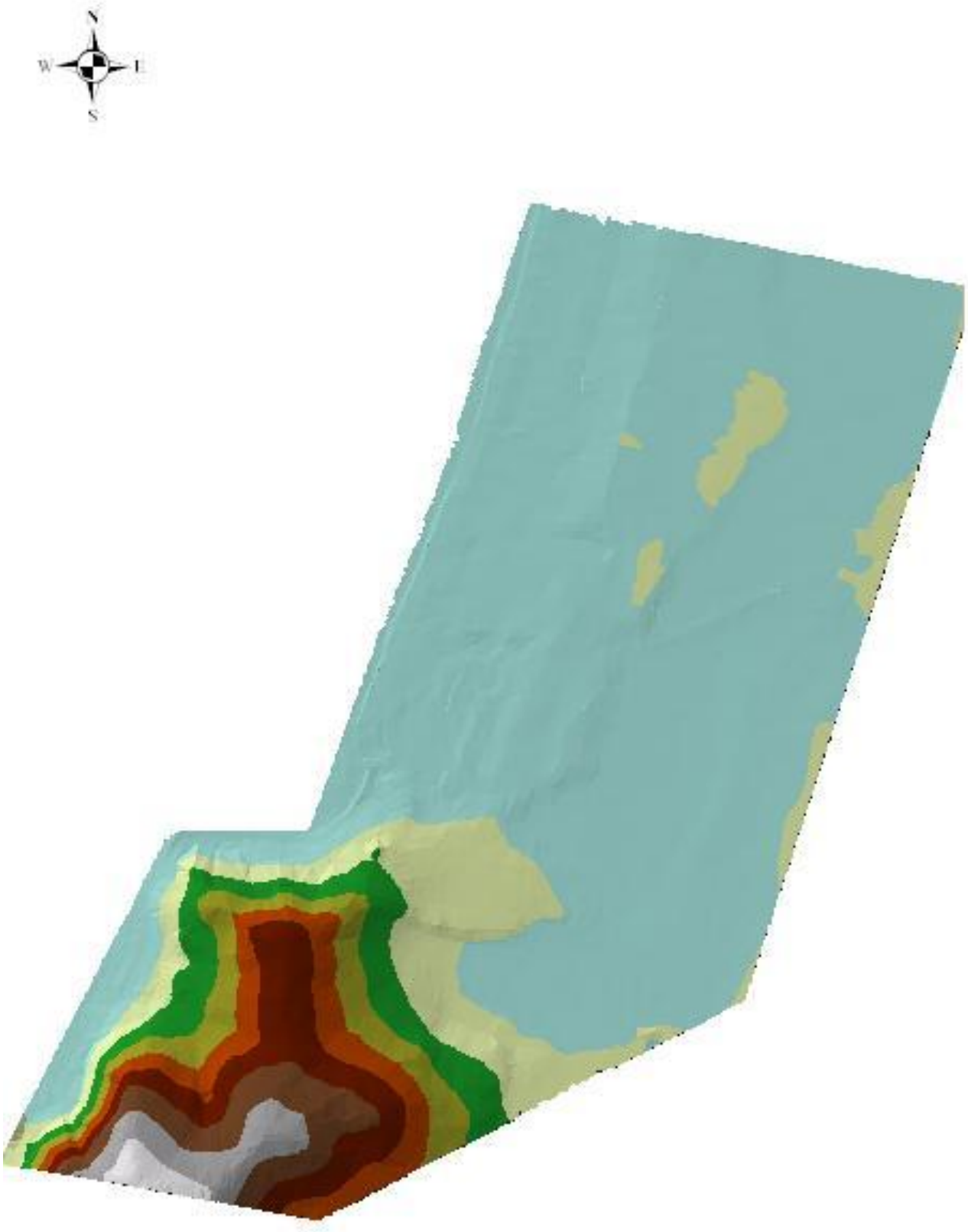
FREQUENCY ANALYSIS OF WATER LEVEL IN LAKE GEORGE

Figure 3

Figure_prob.grf





WRL Letter No. 10075	TRIANGULATED IRREGULAR NETWORK – NORTH AREA	Figure 4