BAY OF PLENTY REGIONAL COUNCIL
TOI MOANA

Rotorua Lakes Design Levels Technical Report 2022

Bay of Plenty Regional Council
Operations Publication 2022/03
July 2022

Prepared by Ingrid Pak (Senior Environmental Engineer)

5 Quay Street
P O Box 364
Whakatāne
NEW ZEALAND

ISSN: 1176-5550 (Print)
ISSN: 1179-9587 (Online)

Document control

Document information

Document name:	Rotorua Lakes Design Levels Update
Contact person:	Ingrid Pak
Status:	Final

Document review

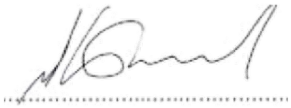
Review timeframe:	
Reviewers:	Peter Blackwood

Document history

Author	Description of change	Date	Version
Ingrid Pak	Draft report	June 2021	V1
Ingrid Pak	Final Report	July 2022	V2

Distribution control

Person	Role	Date of issue	Version
Mark Townsend	Engineering Manager	June 2022	V2

Authorised by: Mark Townsend  Date: 4 May 2022.....

Reviewed by: Peter Blackwood  Date: 6 April 2022.....

Acknowledgements

Peter Blackwood for guidance and review.

The EDS team for maintenance and supply of the data set.

Contents

Part 1: **Introduction**

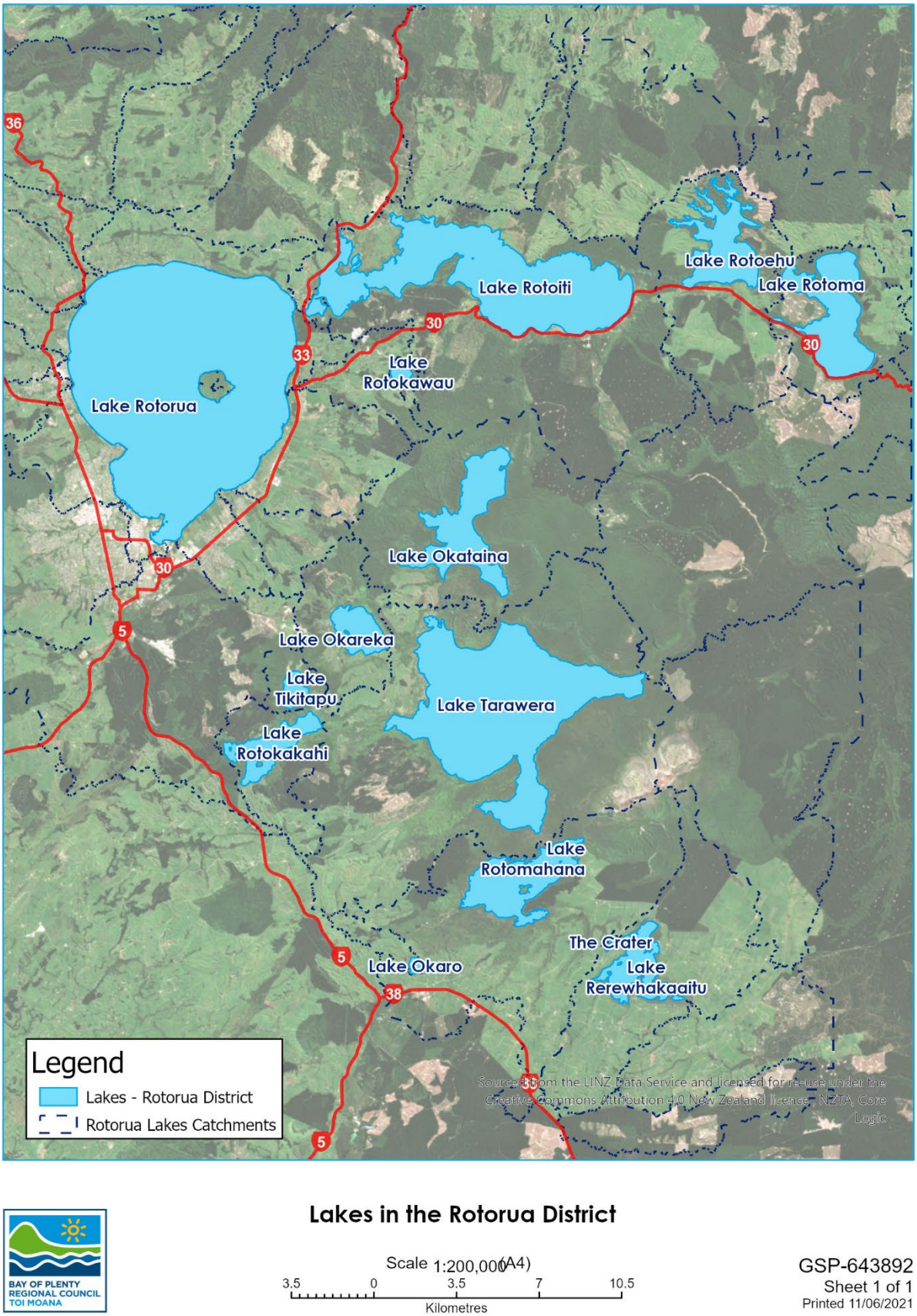
Design levels for the twelve Rotorua Lakes have originally been contained in the Regional Council's Environmental Data Summaries – Air Quality, Meteorology, Hydrology and Water Temperature, Environmental Report 2001/01. They were subsequently updated in Environmental Data Summaries – Air Quality, Meteorology, Hydrology and Water Temperature, Report to 31 December 2005 (published) and again in Environmental Data Summaries 2010 (audited but not published).

The most recent analysis using recorded data and standard frequency analysis up to 31 December 2020 is contained within this report. The derived design levels include a freeboard to account for estimate imprecision; local wind set up; wave run-up; seiche; construction tolerances; and the likely joint probability of the above factors. All recorded levels and design levels are to Moturiki Datum (1953).

Estimates for Climate Change impacts on design lake levels are being assessed and reported on separately to this report.

The twelve lakes analysed and reported on are:

- Part 3: Lake Rotorua
- Part 4: Lake Rotoiti
- Part 5: Lake Ōkāreka
- Part 6: Lake Tarawera
- Part 7: Lake Rerewhakaaitu
- Part 8: Lake Rotomā
- Part 9: Lake Rotoehu
- Part 10: Lake Ōkataina
- Part 11: Lake Rotokakahi (Green Lake)
- Part 12: Lake Tikitapu (Blue Lake)
- Part 13: Lake Rotomahana
- Part 14: Lake Ōkaro



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Lakes in the Rotorua District

Scale 1:200,000 (A4)

3.5 0 3.5 7 10.5

Kilometres

GSP-643892
Sheet 1 of 1
Printed 11/06/2021

Figure 1: Rotorua Lakes

Part 2: **Flood analysis methodology**

Lake level data is available for the twelve Rotorua Lakes (Figure 1). Records began as early as 1925. Some of the lakes have natural surface outlets, some have controlled surface outlets, and some have no surface outlets.

The data used in this analysis is the annual maximum level record for the period of time since the recorder was installed, or since outlet control was put in place. The annual maxima and frequency analyses are presented in Parts 3 to 14.

A number of analysis methods were used. At site flood frequency analyses were applied to:

- The continuous series of annual maxima for the period of record, or since lake level control was installed.

Analyses of statistical gauged data involved plotting calendar year annual maxima from the gauged level data. Event probability positions were plotted based on Gringoten formula as follows:

$$F(Qi) = (i - 0.44) / (n + 0.12)$$

Where i is the rank of each flood in the order of flow magnitude, and n is the total number of years in the record.

A range of methods were used to calculate the annual exceedance probability, these include the EV1, GEV, Log Pearson 3, Generalized Pareto and the Generalized Logistic. Probability distributions were then fitted to plotted points by the method of L-Moments (Hosking, 1990).

Exceedance probabilities for annual (AEP) probabilities were plotted using the Gumbel reduced variate, described by McKerchar and Pearson (1989) as follows:

$$\text{Annual Probability: } y(Qi) = -\ln[-\ln(1-1/T)]$$

Where T is the desired recurrence interval. The resulting Gumbel plots were assessed by means of visual comparison for best fit.

The best fitting distribution was selected based on visual inspection of the analysis plots. Where the analysis did not include the large flood events of the early 1960s (either because no recorder was in place at the time or outlet controls were installed later) an EV1 distribution was selected.

Part 3: **Lake Rotorua**

Lake Rotorua lake levels are controlled by stop logs at the outlet weir (Ōhau Channel weir). The natural lake outlet control was severely modified by enlargement of the Ōhau Channel in 1972-73 which resulted in a lake level drop of around 0.4 metres. Following that date, lake levels were controlled by gabions until a permanent structure was completed in September 1989. The weir is designed to keep the lake level high in times of low inflows (BOPRC, 2005).

The lake level frequency analysis was carried out for the period post installation of the outlet control, i.e. 1973 onwards. The data used in this analysis is the annual maximum level record as presented in Table 1 and Figure 2.

As the analysis was carried out for the post control period only and therefore the large flood events of the early 1960s are not included in the analysis, it is prudent to use the EV1 distribution to generate design levels. Table 2 shows a summary of the generated design levels and Figure 3 shows the various distributions graphically.

The minor increase in the 1% AEP levels is influenced by some large events since 2010.

Table 1: Lake Rotorua - Annual Maxima 1973-2020

FL150407 Lake Rotorua at Mission Bay							
YEAR	**Level (m)**	**YEAR**	**Level (m)**	**YEAR**	**Level (m)**	**YEAR**	**Level (m)**
1973	280.043	1985	280.042	1997	280.080	2009	280.086
1974	280.004	1986	280.231	1998	280.450	2010	280.215
1975	279.950	1987	279.952	1999	280.128	2011	280.405
1976	280.061	1988	280.071	2000	280.122	2012	280.328
1977	280.104	1989	280.200	2001	280.151	2013	280.071
1978	279.900	1990	280.238	2002	280.030	2014	280.097
1979	280.159	1991	280.057	2003	280.020	2015	280.017
1980	279.878	1992	280.089	2004	280.128	2016	280.052
1981	279.976	1993	280.054	2005	280.131	2017	280.462
1982	279.912	1994	280.228	2006	280.105	2018	280.177
1983	280.173	1995	280.228	2007	280.133	2019	280.044
1984	279.915	1996	280.153	2008	280.195	2020	280.002

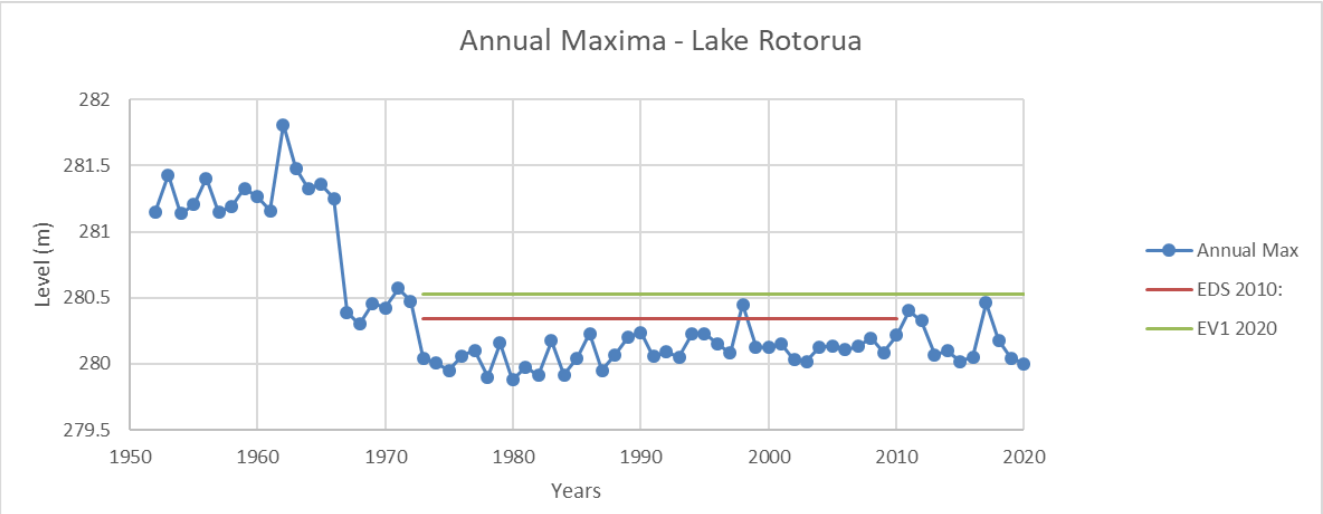

Figure 2: Lake Rotorua - Annual Maxima 1973-2020 and 1% AEP level

Table 2: Lake Rotorua – Frequency Analysis 1973-2020

Lake Rotorua at Mission Bay

Return Period		EV1	GEV	LogPearson3	
T	**Y_T**	**Q_{T1}**	**Q_{T2}**	**K**	**Q_{T3}**
1.01	-1.5293	**279.892**	279.874	-1.748	279.882
1.111	-0.8344	**279.963**	279.958	-1.169	279.957
1.5	-0.0940	**280.040**	280.043	-	-
1.667	0.0877	**280.059**	280.063	-0.366	280.062
2	0.3665	**280.088**	280.093	-0.129	280.093
2.33	0.5786	**280.109**	280.116	0.047	280.115
5	1.4999	**280.205**	280.210	0.782	280.211
10	2.2504	**280.282**	280.282	1.335	280.283
20	2.9702	**280.357**	280.347	1.835	280.348
25	3.1985	**280.380**	280.367	1.988	280.368
50	3.9019	**280.453**	280.426	2.444	280.427
100	4.6001	**280.525**	280.481	2.878	280.484
200	5.2958	**280.597**	280.534	3.294	280.538
500	6.2136	**280.692**	280.599	3.826	280.607

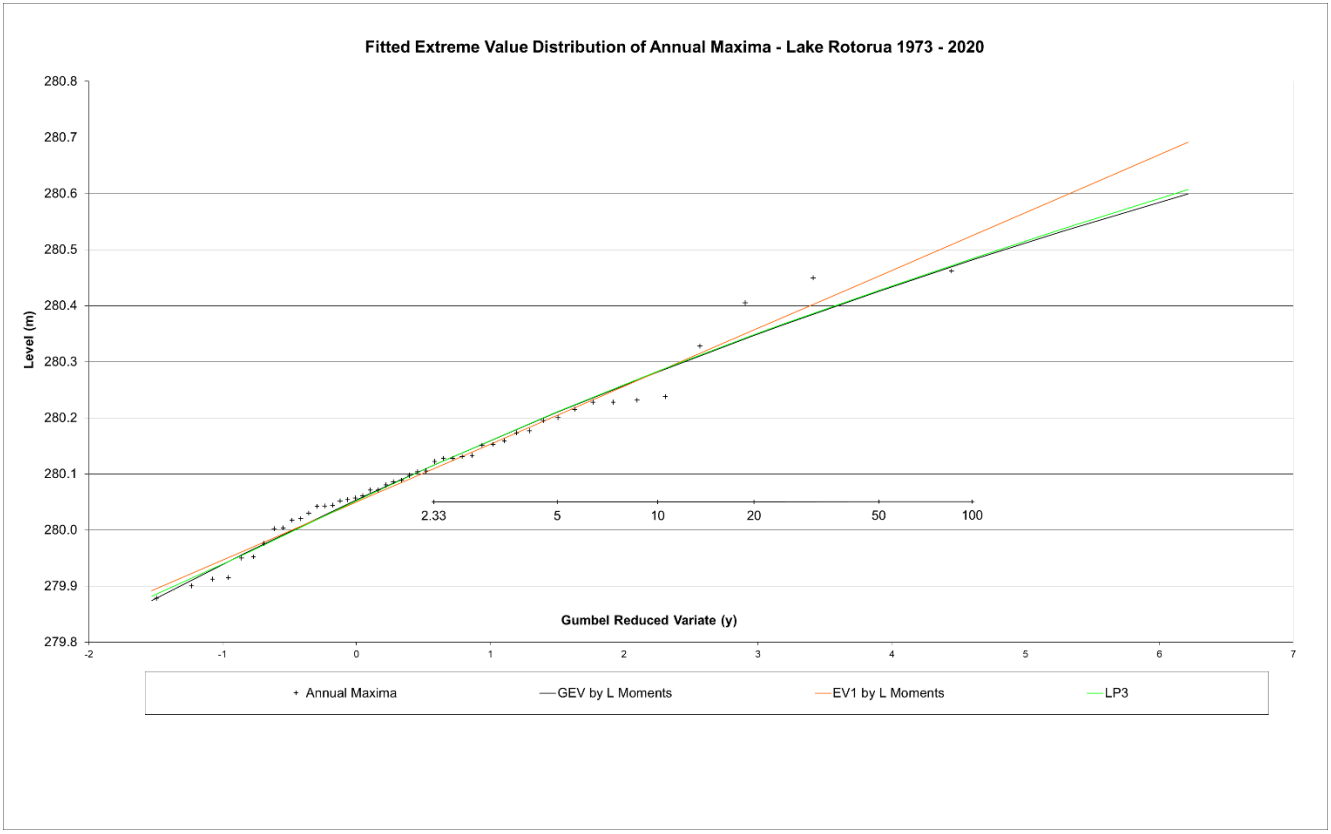

Figure 3: Lake Rotorua – Fitted Extreme Value Distribution 1973-2020

Part 4: **Lake Rotoiti**

Lake Rotoiti discharges into the Kaituna River via the Okere Gates control structure commissioned in 1982 (BOPRC, 2005). The lake level frequency analysis was carried out for the period post installation of the outlet control, i.e. 1983 onwards. The data used in this analysis is the annual maximum level record as presented in Table 3 and Figure 4.

As the analysis was carried out for the post control period only and therefore the large flood events of the early 1960s are not included in the analysis it is prudent to use the EV1 distribution to generate design levels. Table 4 shows a summary of the generated design levels and Figure 5 shows the various distributions graphically.

Table 3: Lake Rotoiti - Annual Maxima 1983-2020

FL289316 Lake Rotoiti at Okawa Bay							
YEAR	Level (m)	YEAR	Level (m)	YEAR	Level (m)	YEAR	Level (m)
1983	279.59	1993	279.34	2003	279.209	2013	279.267
1984	279.32	1994	279.37	2004	279.265	2014	279.254
1985	279.41	1995	279.46	2005	279.232	2015	279.245
1986	279.42	1996	279.3	2006	279.289	2016	279.208
1987	279.34	1997	279.27	2007	279.216	2017	279.433
1988	279.4	1998	279.35	2008	279.285	2018	279.368
1989	279.42	1999	279.37	2009	279.23	2019	279.239
1990	279.38	2000	279.28	2010	279.245	2020	279.226
1991	279.23	2001	279.202	2011	279.385		
1992	279.29	2002	279.285	2012	279.383		

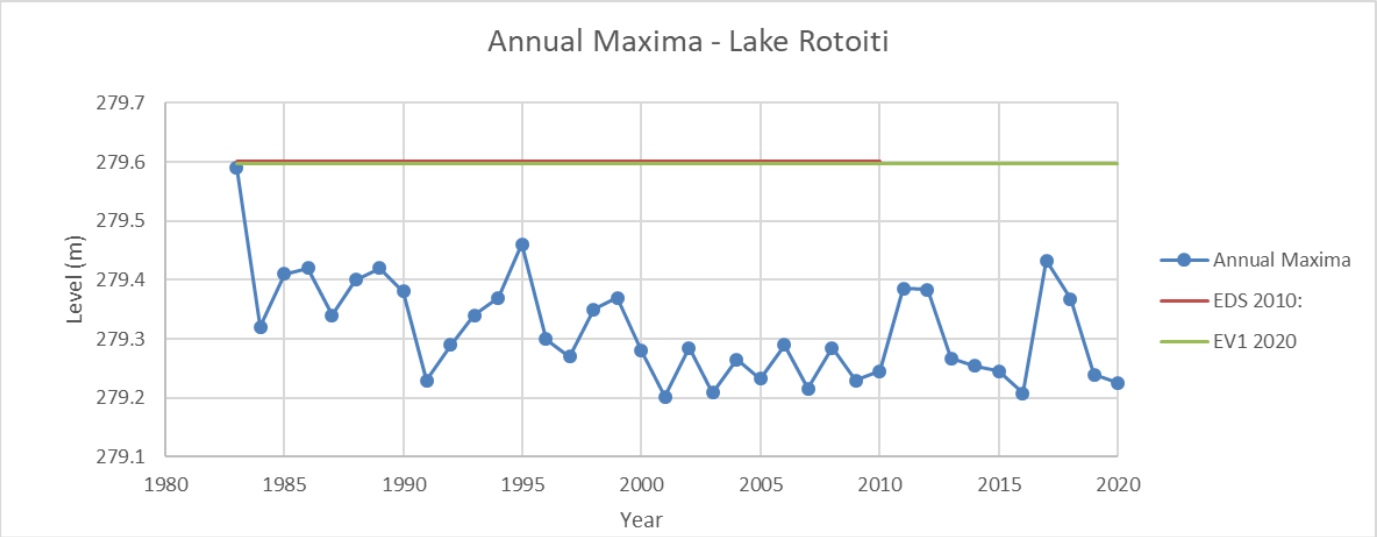

Figure 4: Lake Rotoiti - Annual Maxima 1983-2020 and 1% AEP level

Table 4: Lake Rotoiti – Frequency Analysis 1983-2020

Lake Rotoiti at Okawa Bay

Return Period		EV1	GEV	LogPearson3		GPA	GLO
T	**Y_T**	**Q_{T1}**	**Q_{T2}**	**K**	**Q_{T3}**	**Q_{T4}**	**Q_{T5}**
1.01	-1.5293	**279.169**	279.167	-1.656	279.172		279.240
1.111	-0.8344	**279.217**	279.217	-1.146	279.216		279.267
1.5	-0.0940	**279.269**	279.269	-	-	279.182	279.299
1.667	0.0877	**279.282**	279.282	-0.383	279.283	279.213	279.307
2	0.3665	**279.301**	279.302	-0.149	279.303	279.255	279.321
2.33	0.5786	**279.316**	279.317	0.026	279.318	279.285	279.331
5	1.4999	**279.380**	279.381	0.768	279.383	279.385	279.382
10	2.2504	**279.433**	279.433	1.339	279.432	279.441	279.429
20	2.9702	**279.483**	279.482	1.860	279.477	279.480	279.480
25	3.1985	**279.499**	279.498	2.019	279.491	279.490	279.498
50	3.9019	**279.548**	279.546	2.500	279.533	279.516	279.556
100	4.6001	**279.597**	279.593	2.961	279.573	279.534	279.621
200	5.2958	**279.646**	279.640	3.406	279.612	279.548	279.694
500	6.2136	**279.710**	279.702	3.976	279.661	279.561	279.803

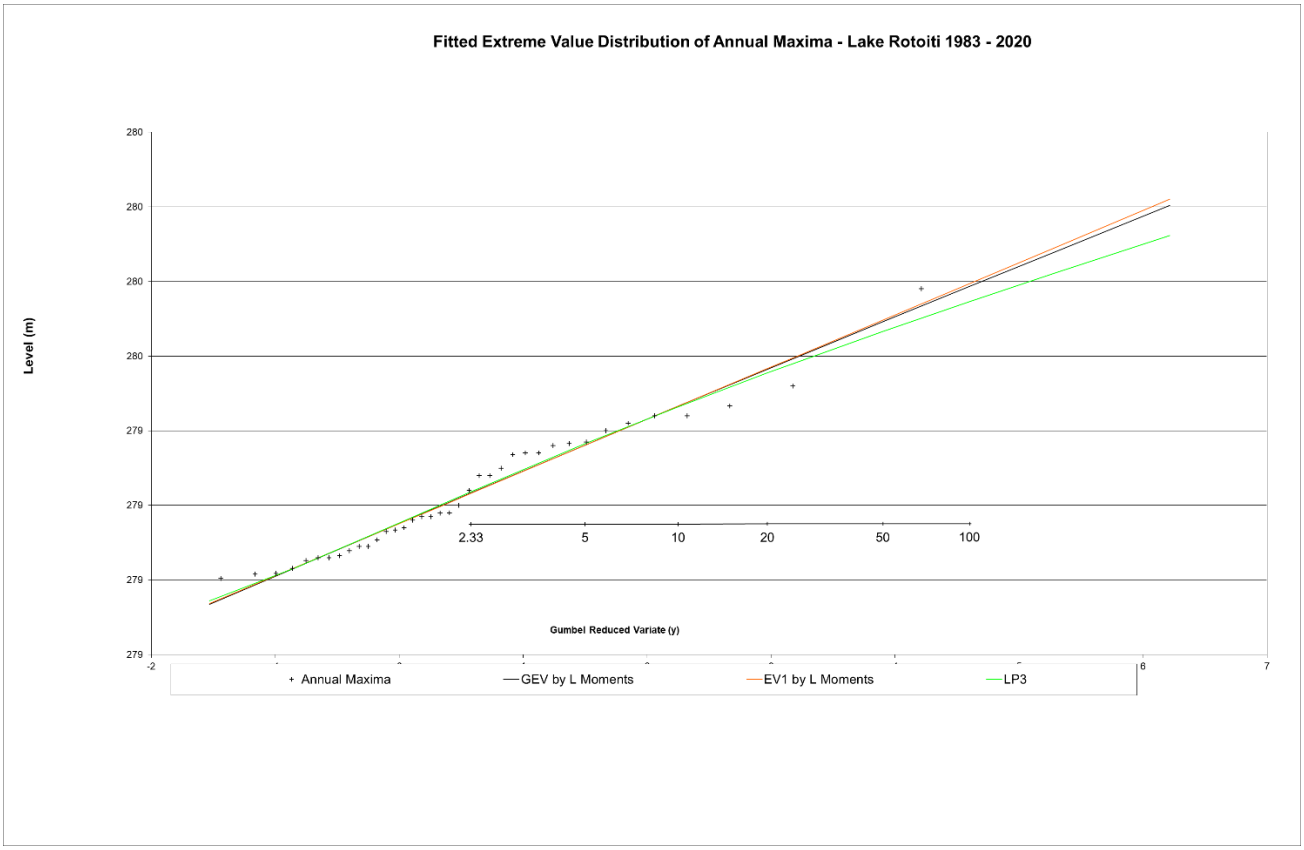

Figure 5: Lake Rotoiti – Fitted Extreme Value Distribution 1983-2020

Part 5: **Lake Ōkāreka**

A control structure on the southern side of the lake was installed in the late 1960s and is operated as a high level overflow pipeline to Lake Tarawera to maintain lake levels within a controlled range. This has resulted in the peak levels being significantly reduced (BOPRC, 2005). The lake level frequency analysis was carried out for the period post installation of the outlet control, i.e. 1971 onwards. The data used in this analysis is the annual maximum level record as presented in Table 5 and Figure 6.

As the analysis was carried out for the post control period only and therefore the large flood events of the early 1960s are not included in the analysis it is prudent to use the EV1 distribution to generate design levels. Table 6 shows a summary of the generated design levels and Figure 7 shows the various distributions graphically.

The minor increase in the 1% AEP levels is influenced by the large 2017 event.

Table 5: Lake Ōkāreka - Annual Maxima 1971-2020

FJ330944 Lake Ōkāreka at Acacia Bay							
YEAR	**Level (m)**	**YEAR**	**Level (m)**	**YEAR**	**Level (m)**	**YEAR**	**Level (m)**
1971	354.101	1984	353.649	1997	353.955	2010	354.117
1972	353.964	1985	353.797	1998	354.294	2011	354.197
1973	353.522	1986	353.879	1999	353.943	2012	354.126
1974	353.454	1987	353.533	2000	353.993	2013	353.865
1975	353.714	1988	353.849	2001	353.998	2014	353.834
1976	353.666	1989	354.108	2002	353.95	2015	353.889
1977	353.604	1990	354.089	2003	353.905	2016	353.878
1978	353.589	1991	353.865	2004	354.203	2017	354.567
1979	354.039	1992	353.879	2005	354.053	2018	354.171
1980	353.834	1993	353.760	2006	354.082	2019	354.078
1981	353.779	1994	353.900	2007	353.981	2020	353.848
1982	353.760	1995	354.095	2008	354.249		
1983	353.826	1996	354.039	2009	354.004		

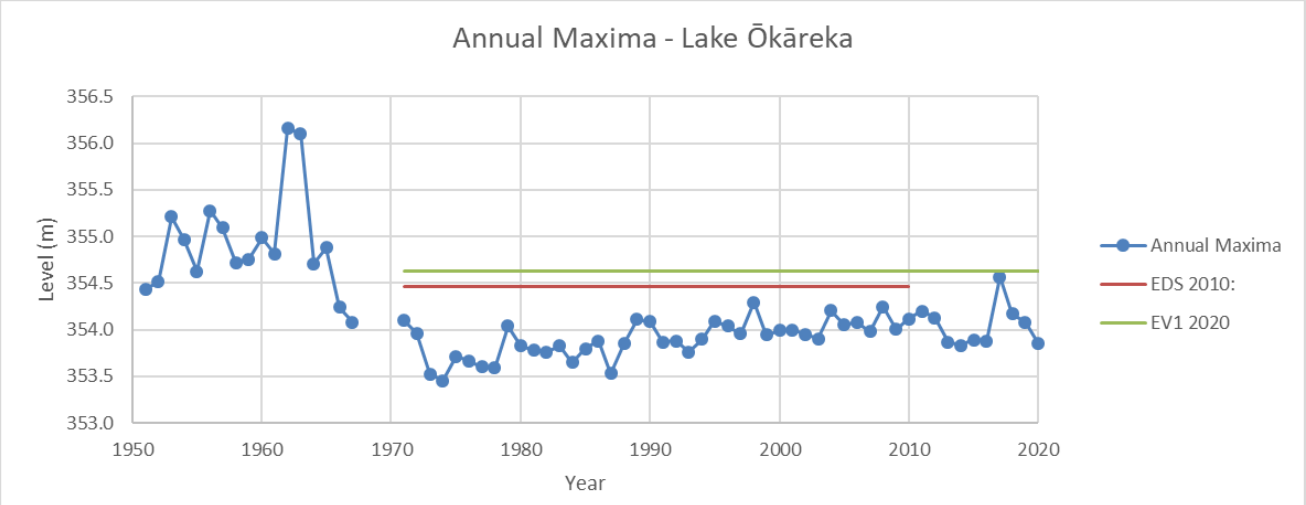

Figure 6: Lake Ōkāreka - Annual Maxima 1971-2020 and 1% AEP level

Table 6: Lake Ōkāreka – Frequency Analysis 1971-2020

Lake Ōkāreka at Acacia Bay

Return Period		EV1	GEV	LogPearson3		GPA	GLO
T	**Y_T**	**Q_{T1}**	**Q_{T2}**	**K**	**Q_{T3}**	**Q_{T4}**	**Q_{T5}**
1.01	-1.5293	**353.564**	353.436	-2.236	353.449		353.746
1.111	-0.8344	**353.684**	353.652	-1.268	353.657		353.831
1.5	-0.0940	**353.813**	353.837	-	-	353.487	353.921
1.667	0.0877	**353.844**	353.876	-0.272	353.871	353.625	353.943
2	0.3665	**353.893**	353.932	-0.020	353.925	353.791	353.976
2.33	0.5786	**353.930**	353.971	0.158	353.963	353.889	354.002
5	1.4999	**354.090**	354.116	0.835	354.109	354.131	354.111
10	2.2504	**354.220**	354.206	1.294	354.208	354.211	354.199
20	2.9702	**354.345**	354.275	1.679	354.290	354.247	354.282
25	3.1985	**354.385**	354.294	1.792	354.315	354.253	354.309
50	3.9019	**354.507**	354.345	2.118	354.385	354.266	354.389
100	4.6001	**354.628**	354.385	2.415	354.449	354.272	354.468
200	5.2958	**354.749**	354.418	2.690	354.508	354.275	354.547
500	6.2136	**354.908**	354.451	3.026	354.580	354.277	354.649

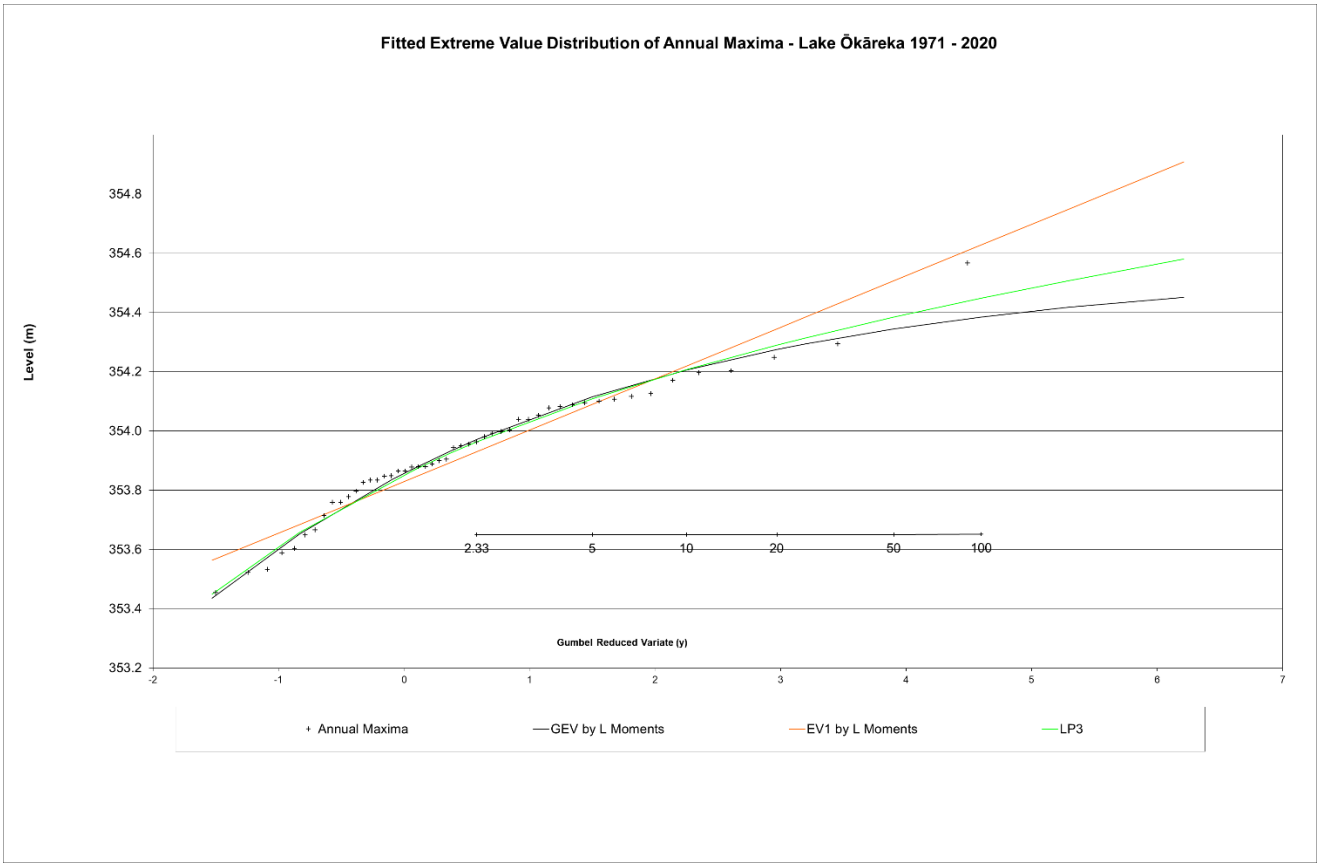

Figure 7: Lake Ōkāreka – Fitted Extreme Value Distribution 1971-2020

Part 6: **Lake Tarawera**

Lake Tarawera has a natural outflow into the Tarawera River. The lake level frequency analysis was carried out for the period of record, i.e. 1925 onwards. The data used in this analysis is the annual maximum level record as presented in Table 7 and Figure 8.

A Log Pearson 3 distribution gives the best fit for the data analysed and has been used to generate design levels. Table 8 shows a summary of the generated design levels and Figure 9 shows the various distributions graphically.

There is no obvious explanation for the trend of dropping lake levels over time (almost 0.5 m on 50 year moving average since 1925). Perhaps the outlet control at the head of the Tarawera River is gradually eroding and dropping.

Table 7: Lake Tarawera - Annual Maxima 1925-2020

FJ567596 Lake Tarawera at Te Wairoa							
YEAR	**Level (m)**	**YEAR**	**Level (m)**	**YEAR**	**Level (m)**	**YEAR**	**Level (m)**
1925	298.448	1951	298.247	1975	298.096	1999	298.117
1926	298.422	1952	298.247	1976	298.095	2000	298.000
1927	298.499	1953	298.277	1977	298.078	2001	298.031
1928	298.549	1954	298.247	1978	298.021	2002	297.990
1929	298.503	1955	298.125	1979	298.120	2003	297.974
1930	298.295	1956	298.216	1980	297.995	2004	298.043
1931	298.270	1957	298.171	1981	298.052	2005	298.015
1932	298.321	1958	298.186	1982	298.003	2006	298.106
1933	298.333	1959	298.155	1983	298.059	2007	297.993
1934	298.409	1960	298.125	1984	297.999	2008	298.048
1935	298.422	1961	298.094	1985	297.969	2009	297.950
1936	298.549	1962	298.407	1986	298.138	2010	298.027
1937	298.473	1963	298.285	1987	297.951	2011	298.134
1938	298.473	1964	298.179	1988	298.015	2012	298.127
1939	298.333	1965	298.291	1989	298.108	2013	298.027
1940	298.397	1966	298.258	1990	298.087	2014	297.933
1941	298.321	1967	298.310	1991	298.022	2015	297.925
1942	298.351	1968	298.171	1992	298.038	2016	297.930
1943	298.257	1969	298.293	1993	297.962	2017	298.179
1944	298.269	1970	298.202	1994	298.001	2018	298.108
1947	298.070	1971	298.324	1995	298.043	2019	298.018
1948	298.186	1972	298.257	1996	298.033	2020	297.940
1949	298.155	1973	298.093	1997	298.052		
1950	298.155	1974	298.081	1998	298.167		

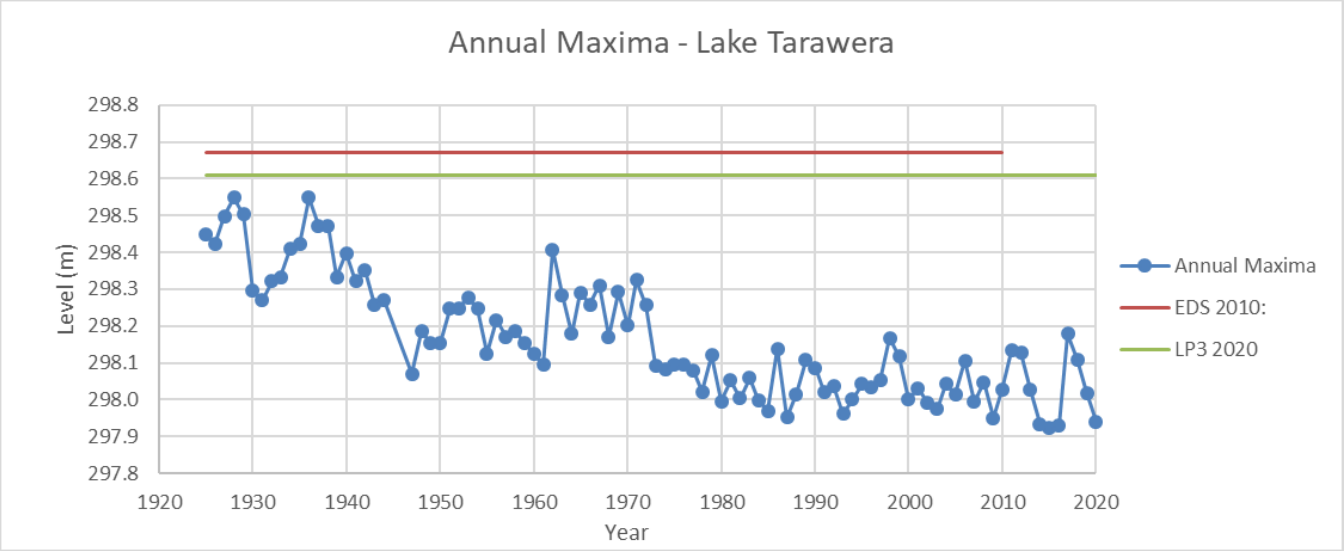

Figure 8: Lake Tarawera - Annual Maxima 1925-2020 and 1% AEP level

Table 8: Lake Tarawera – Frequency Analysis 1925-2020

Lake Tarawera at Te Wairoa

Return Period		EV1	GEV	LogPearson3	
T	**Y_T**	**Q_{T1}**	**Q_{T2}**	**K**	**Q_{T3}**
1.01	-1.5293	297.888	297.880	-1.873	**297.863**
1.111	-0.8344	297.979	297.977	-1.199	**297.972**
1.5	-0.0940	298.076	298.077	-	**-**
1.667	0.0877	298.100	298.102	-0.343	**298.109**
2	0.3665	298.136	298.139	-0.101	**298.148**
2.33	0.5786	298.164	298.167	0.076	**298.176**
5	1.4999	298.285	298.288	0.799	**298.292**
10	2.2504	298.384	298.384	1.328	**298.377**
20	2.9702	298.478	298.474	1.799	**298.453**
25	3.1985	298.508	298.502	1.942	**298.476**
50	3.9019	298.600	298.588	2.363	**298.544**
100	4.6001	298.692	298.672	2.761	**298.608**
200	5.2958	298.783	298.754	3.140	**298.669**
500	6.2136	298.904	298.860	3.620	**298.746**

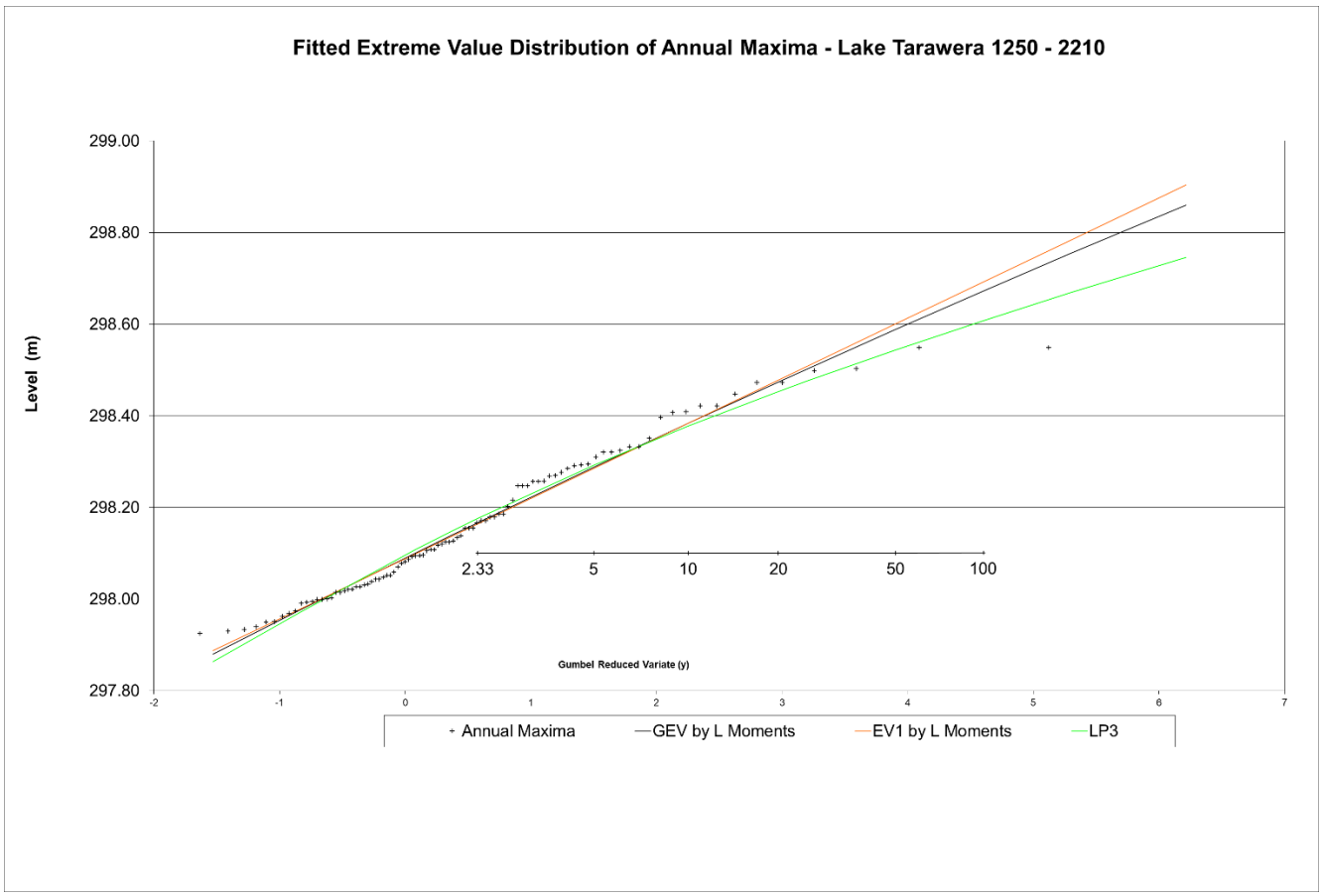

Figure 9: Lake Tarawera – Fitted Extreme Value Distribution 1925-2020

Part 7: **Lake Rerewhakaaitu**

A control structure on the eastern side of the lake is operated during periods of high water levels to divert water from Rerewhakaaitu into the Mangaharakeke Stream (Rangitāiki catchment) (BOPRC, 2005).

The lake level frequency analysis was carried out for the period post installation of the outlet control, i.e. 1983 onwards. The data used in this analysis is the annual maximum level record as presented in Table 9 and Figure 10.

As the analysis was carried out for the post control period only and therefore the large flood events of the early 1960s are not included in the analysis, it is prudent to use the EV1 distribution to generate design levels. Table 10 shows a summary of the generated design levels and Figure 11 shows the various distributions graphically.

The significant increase in the 1% AEP level is due to several large rainfall events since 2010.

Table 9: Lake Rerewhakaaitu - Annual Maxima 1983-2020

GI442508 Lake Rerewhakaaitu at Homestead Arm							
YEAR	**Level (m)**	**YEAR**	**Level (m)**	**YEAR**	**Level (m)**	**YEAR**	**Level (m)**
1983	435.275	1993	435.279	2003	435.185	2013	436.483
1984	435.128	1994	434.468	2004	435.400	2014	436.020
1985	435.277	1995	435.047	2005	435.700	2015	435.602
1986	435.598	1996	435.700	2006	436.480	2016	435.174
1987	435.282	1997	435.761	2007	436.258	2017	436.850
1988	434.559	1998	435.780	2008	436.115	2018	437.023
1989	435.358	1999	435.621	2009	435.892	2019	436.637
1990	435.414	2000	435.631	2010	436.070	2020	436.145
1991	435.217	2001	435.620	2011	436.867		
1992	435.317	2002	435.586	2012	436.871		

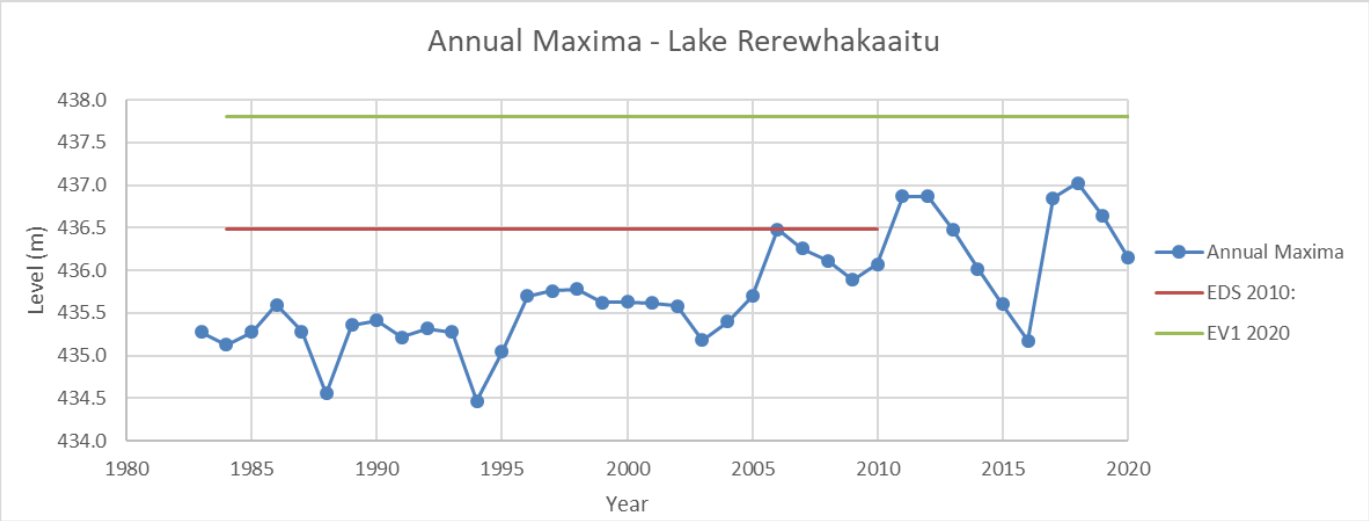

Figure 10: Lake Rerewhakaaitu - Annual Maxima 1983-2020 and 1% AEP level

Table 10: Lake Rerewhakaaitu – Frequency Analysis 1983-2020

Lake Rerewhakaaitu at Homestead Arm

Return Period		EV1	GEV	LogPearson3	
T	**Y_T**	**Q_{T1}**	**Q_{T2}**	**K**	**Q_{T3}**
1.01	-1.5293	**434.662**	434.552	-2.073	434.442
1.111	-0.8344	**435.018**	434.986	-1.239	434.964
1.5	-0.0940	**435.397**	435.417	-	-
1.667	0.0877	**435.490**	435.518	-0.305	435.549
2	0.3665	**435.633**	435.669	-0.057	435.705
2.33	0.5786	**435.742**	435.782	0.121	435.817
5	1.4999	**436.213**	436.245	0.821	436.256
10	2.2504	**436.598**	436.593	1.312	436.565
20	2.9702	**436.966**	436.903	1.736	436.831
25	3.1985	**437.083**	436.997	1.862	436.910
50	3.9019	**437.443**	437.274	2.231	437.143
100	4.6001	**437.801**	437.531	2.573	437.358
200	5.2958	**438.157**	437.769	2.894	437.560
500	6.2136	**438.627**	438.061	3.294	437.812

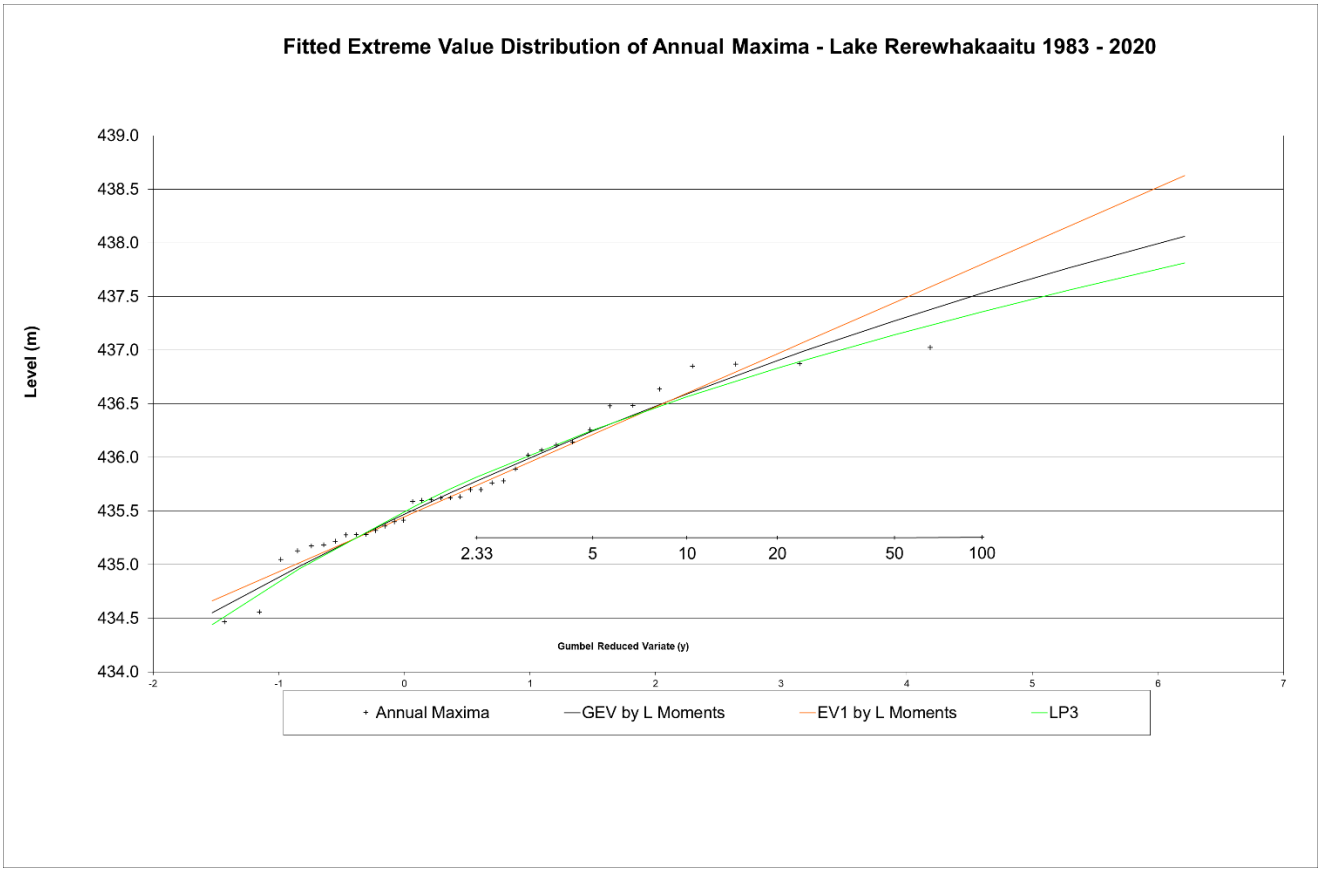

Figure 11: Lake Rerewhakaaitu – Fitted Extreme Value Distribution 1983-2020

Part 8: **Lake Rotomā**

Lake Rotomā has no natural surface outflow. A piped outflow towards Lake Rotoehu has been installed for extreme high lake levels.

The lake level frequency analysis was carried out for the period of record, i.e. 1953 onwards. The data used in this analysis is the annual maximum level record as presented in Table 11 and Figure 12.

A Log Pearson 3 distribution gives the best fit for the data analysed and has been used to generate design levels. Table 12 shows a summary of the generated design levels and Figure 13 shows the various distributions graphically.

Table 11: Lake Rotomā - Annual Maxima 1953-2020

HL373185 Lake Rotomā at Otangiwai Point							
YEAR	**Level (m)**	**YEAR**	**Level (m)**	**YEAR**	**Level (m)**	**YEAR**	**Level (m)**
1953	315.901	1970	317.390	1987	315.379	2004	314.586
1954	315.864	1971	317.734	1988	314.150	2005	314.595
1955	315.558	1972	317.722	1989	315.437	2006	315.267
1956	316.901	1973	316.561	1990	315.719	2007	314.948
1957	316.775	1974	315.598	1991	315.490	2008	314.574
1958	315.697	1975	315.637	1992	314.779	2009	314.390
1959	315.727	1976	315.765	1993	314.190	2010	314.313
1960	315.605	1977	315.657	1994	312.953	2011	315.914
1961	315.483	1978	315.249	1995	313.649	2012	316.345
1962	317.525	1979	315.729	1996	314.267	2013	315.986
1963	317.495	1980	315.620	1997	314.188	2014	315.280
1964	316.646	1981	315.310	1998	314.519	2015	314.674
1965	316.321	1982	315.274	1999	314.932	2016	314.294
1966	316.521	1983	314.889	2000	314.871	2017	315.648
1967	316.802	1984	315.001	2001	314.871	2018	316.002
1968	316.618	1985	315.742	2002	314.857	2019	315.967
1969	316.326	1986	315.864	2003	314.217	2020	315.239

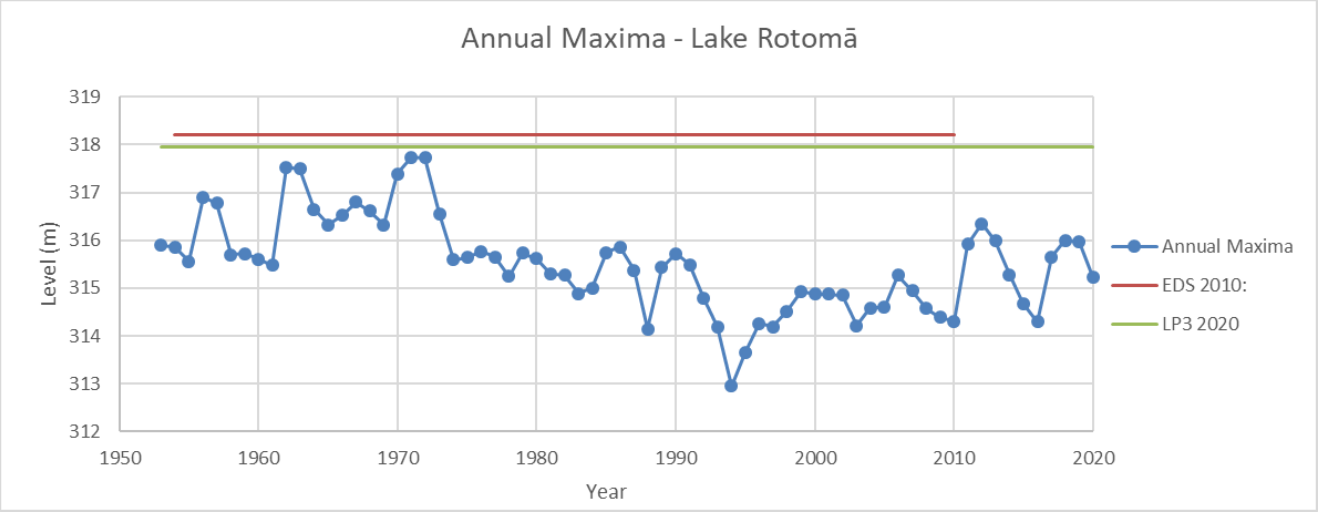

Figure 12: Lake Rotomā - Annual Maxima 1953-2020 and 1% AEP level

Table 12: Lake Rotomā – Frequency Analysis 1953-2020

Lake Rotomā at Otangiwai Point

Return Period		EV1	GEV	LogPearson3	
T	**Y_T**	**Q_{T1}**	**Q_{T2}**	**K**	**Q_{T3}**
1.01	-1.5293	313.826	313.455	-2.185	**313.364**
1.111	-0.8344	314.383	314.282	-1.259	**314.273**
1.5	-0.0940	314.977	315.044	-	**-**
1.667	0.0877	315.122	315.215	-0.283	**315.234**
2	0.3665	315.346	315.464	-0.031	**315.482**
2.33	0.5786	315.516	315.644	0.146	**315.658**
5	1.4999	316.254	316.344	0.831	**316.334**
10	2.2504	316.856	316.826	1.300	**316.799**
20	2.9702	317.433	317.223	1.697	**317.192**
25	3.1985	317.616	317.338	1.815	**317.309**
50	3.9019	318.180	317.659	2.154	**317.646**
100	4.6001	318.739	317.936	2.465	**317.955**
200	5.2958	319.297	318.175	2.754	**318.242**
500	6.2136	320.033	318.444	3.110	**318.597**

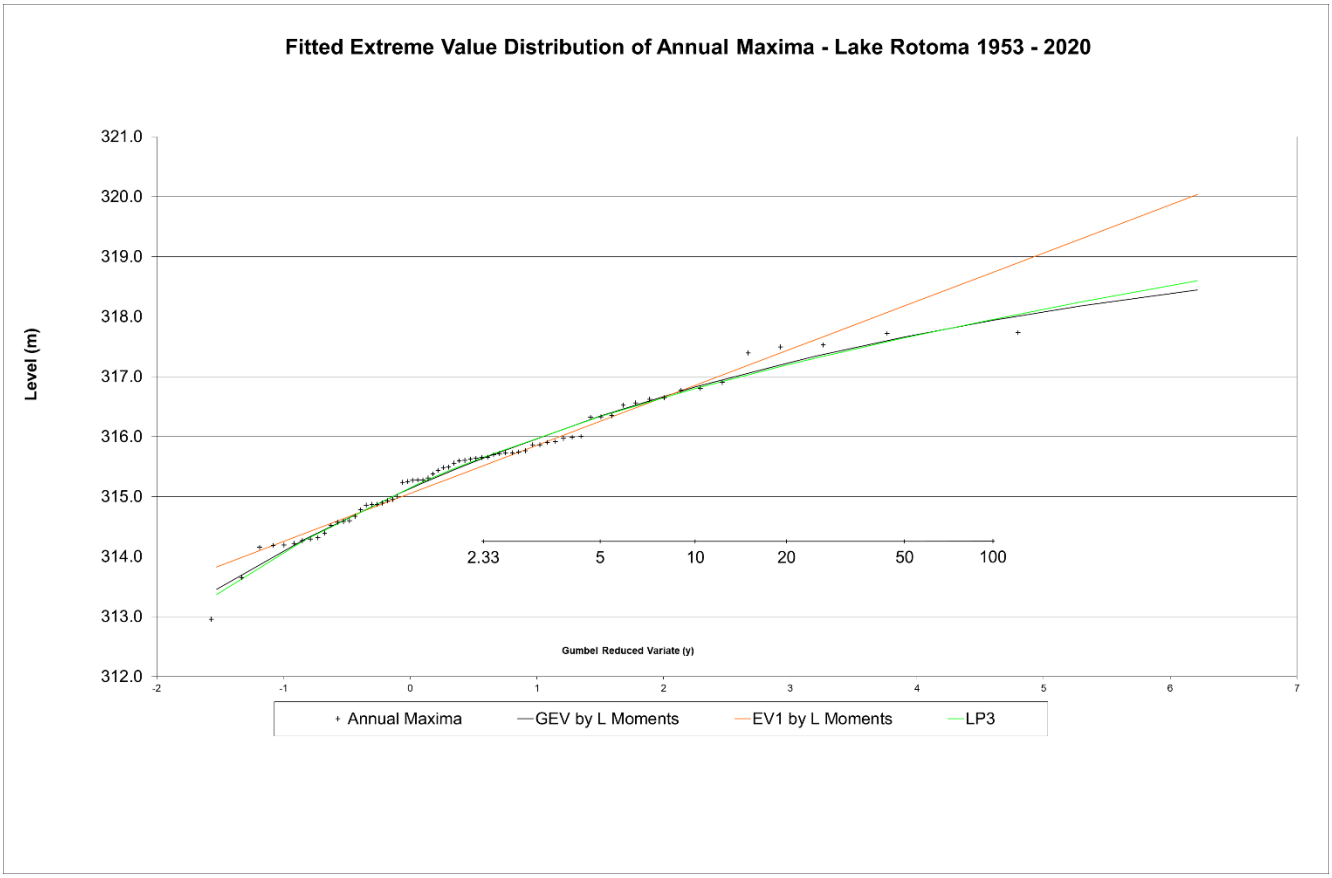

Figure 13: Lake Rotomā – Fitted Extreme Value Distribution 1953-2020

Part 9: **Lake Rotoehu**

Lake Rotoehu has no natural surface outflow.

The annual maxima lake level record shows abnormally low levels in 1988 and 1994. It was investigated if these may be erroneous recordings but it was found that surrounding lakes (Rotomā and Ōkataina) have similar negative spikes in their records, therefore these two maxima have been accepted as correct.

The lake level frequency analysis was carried out for the period of record, i.e. 1953 onwards (records missing for 1960 and 1961). The data used in this analysis is the annual maximum level record as presented in Table 13 and Figure 14.

An EV1 distribution gives the best fit for the data analysed and has been used to generate design levels. Table 14 shows a summary of the generated design levels and Figure 15 shows the various distributions graphically.

Table 13: Lake Rotoehu - Annual Maxima 1953-2020

GL838478 Lake Rotoehu at Te Pohue Bay							
YEAR	**Level (m)**	**YEAR**	**Level (m)**	**YEAR**	**Level (m)**	**YEAR**	**Level (m)**
1953	294.829	1970	296.927	1987	295.043	2004	295.155
1954	295.345	1971	296.967	1988	294.054	2005	295.028
1955	295.193	1972	296.848	1989	294.984	2006	295.389
1956	295.879	1973	296.053	1990	295.057	2007	295.069
1957	295.619	1974	295.430	1991	294.770	2008	295.076
1958	295.360	1975	295.511	1992	294.369	2009	294.831
1959	295.528	1976	295.538	1993	294.006	2010	295.004
1960		1977	295.400	1994	293.031	2011	295.565
1961		1978	295.066	1995	294.069	2012	295.853
1962	296.236	1979	295.316	1996	294.565	2013	295.399
1963	296.236	1980	295.165	1997	294.268	2014	295.014
1964	295.977	1981	295.060	1998	294.587	2015	294.715
1965	295.958	1982	294.966	1999	295.054	2016	294.888
1966	296.260	1983	294.877	2000	295.089	2017	295.532
1967	296.358	1984	294.883	2001	295.146	2018	295.956
1968	296.327	1985	295.297	2002	295.105	2019	295.980
1969	296.269	1986	295.428	2003	294.913	2020	295.827

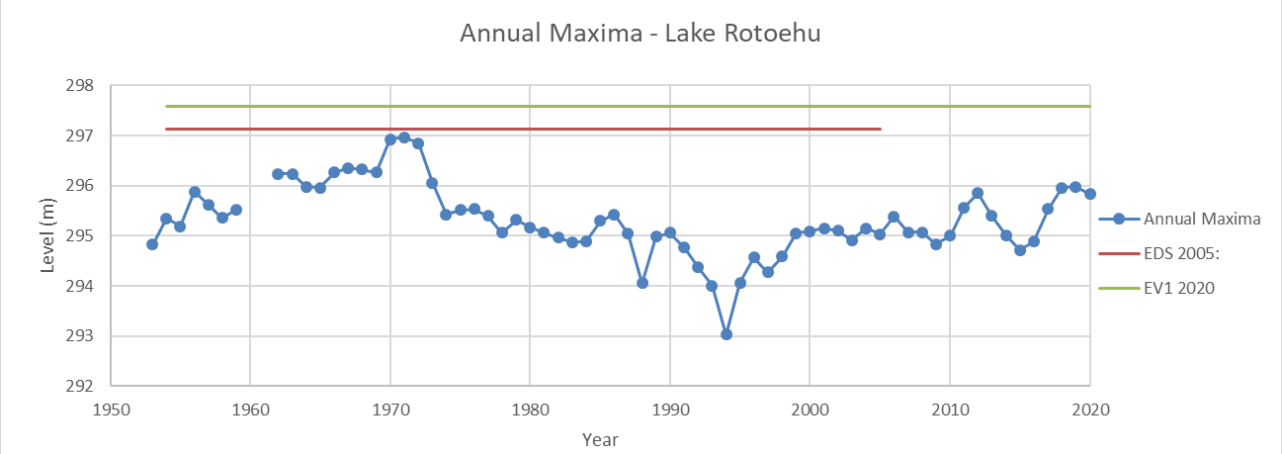

Figure 14: Lake Rotoehu - Annual Maxima 1953-2020 and 1% AEP level

Table 14: Lake Rotoehu – Frequency Analysis 1953-2020

Lake Rotoehu at Te Pohue Bay

Return Period		EV1	GEV	LogPearson3	
T	**Y_T**	**Q_{T1}**	**Q_{T2}**	**K**	**Q_{T3}**
1.01	-1.5293	**294.123**	293.846	-2.395	293.610
1.111	-0.8344	**294.515**	294.440	-1.291	294.392
1.5	-0.0940	**294.932**	294.983	-	-
1.667	0.0877	**295.035**	295.103	-0.239	295.140
2	0.3665	**295.192**	295.280	0.016	295.321
2.33	0.5786	**295.311**	295.407	0.192	295.447
5	1.4999	**295.831**	295.897	0.846	295.912
10	2.2504	**296.254**	296.230	1.271	296.216
20	2.9702	**296.659**	296.504	1.618	296.464
25	3.1985	**296.788**	296.582	1.719	296.536
50	3.9019	**297.185**	296.800	2.004	296.740
100	4.6001	**297.578**	296.987	2.257	296.921
200	5.2958	**297.970**	297.147	2.489	297.087
500	6.2136	**298.488**	297.325	2.766	297.285

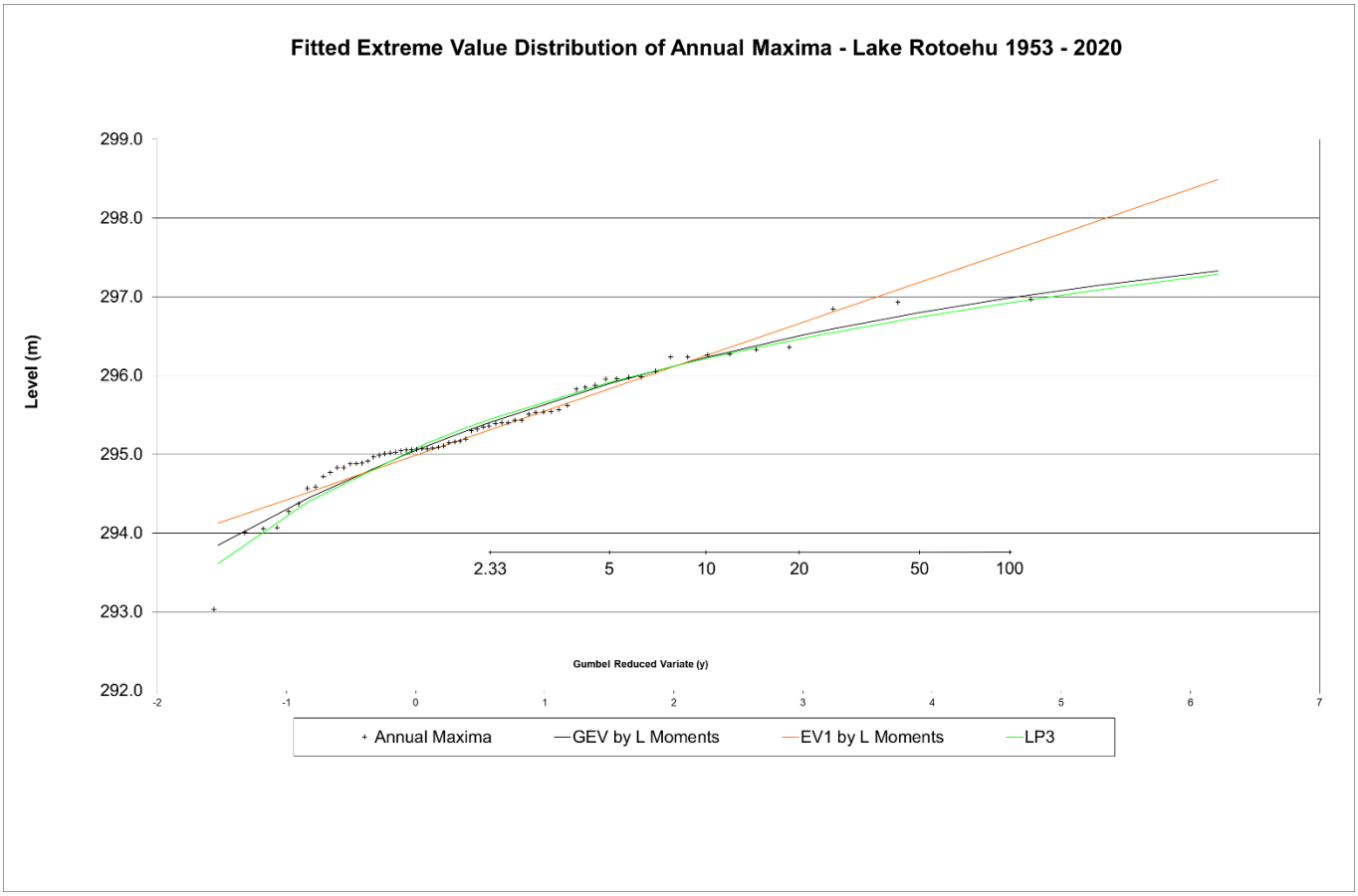

Figure 15: Lake Rotoehu – Fitted Extreme Value Distribution 1953-2020

Part 10: **Lake Ōkataina**

Lake Ōkataina has no natural surface outflow. (Possible groundwater flows towards Lake Tarawera have been identified.)

The lake level frequency analysis was carried out for the period of record, i.e. 1952 onwards. The data used in this analysis is the annual maximum level record as presented in Table 15 and Figure 16.

An EV1 distribution gives the best fit for the data analysed and has been used to generate design levels. Table 16 shows a summary of the generated design levels and Figure 17 shows the various distributions graphically.

Table 15: Lake Ōkataina - Annual Maxima 1952-2020

GK639728 Lake Ōkataina at Tauranganui Bay							
YEAR	**Level (m)**	**YEAR**	**Level (m)**	**YEAR**	**Level (m)**	**YEAR**	**Level (m)**
1952	307.802	1970	311.905	1988	307.419	2006	309.106
1953	308.686	1971	313.249	1989	308.167	2007	309.032
1954	309.098	1972	313.456	1990	308.694	2008	308.771
1955	309.006	1973	312.475	1991	308.569	2009	308.638
1956	310.165	1974	310.818	1992	308.340	2010	308.601
1957	310.165	1975	310.200	1993	307.672	2011	310.379
1958	309.585	1976	309.876	1994	306.956	2012	311.070
1959	309.433	1977	309.675	1995	307.901	2013	310.887
1960	309.159	1978	309.114	1996	308.690	2014	309.974
1961	309.067	1979	309.000	1997	308.740	2015	308.896
1962	311.765	1980	308.950	1998	309.020	2016	308.100
1963	312.185	1981	309.021	1999	309.502	2017	309.666
1964	311.897	1982	308.990	2000	309.573	2018	310.681
1965	311.353	1983	308.465	2001	309.399	2019	310.650
1966	311.268	1984	308.402	2002	309.373	2020	310.138
1967	311.923	1985	308.375	2003	308.707		
1968	311.969	1986	308.761	2004	308.417		
1969	311.847	1987	308.585	2005	308.507		

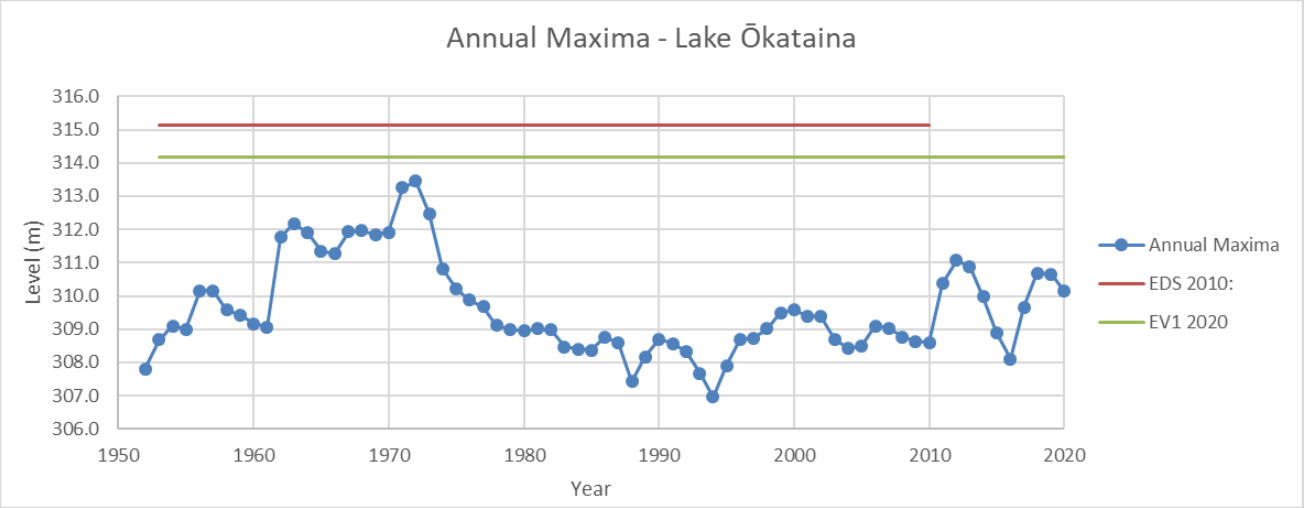

Figure 16: Lake Ōkataina - Annual Maxima 1952-2020 and 1% AEP level

Table 16: Lake Ōkataina – Frequency Analysis 1952-2020

Lake Ōkataina at Tauranganui Bay

Return Period		EV1	GEV	LogPearson3	
T	**Y_T**	**Q_{T1}**	**Q_{T2}**	**K**	**Q_{T3}**
1.01	-1.5293	**307.276**	307.421	-1.728	307.210
1.111	-0.8344	**308.059**	308.106	-1.165	308.002
1.5	-0.0940	**308.893**	308.869	-	-
1.667	0.0877	**309.098**	309.062	-0.370	309.123
2	0.3665	**309.412**	309.361	-0.133	309.457
2.33	0.5786	**309.650**	309.593	0.043	309.706
5	1.4999	**310.688**	310.635	0.779	310.750
10	2.2504	**311.533**	311.528	1.336	311.543
20	2.9702	**312.344**	312.424	1.840	312.261
25	3.1985	**312.601**	312.717	1.995	312.482
50	3.9019	**313.393**	313.646	2.456	313.141
100	4.6001	**314.179**	314.608	2.895	313.771
200	5.2958	**314.963**	315.608	3.318	314.377
500	6.2136	**315.997**	316.996	3.858	315.154

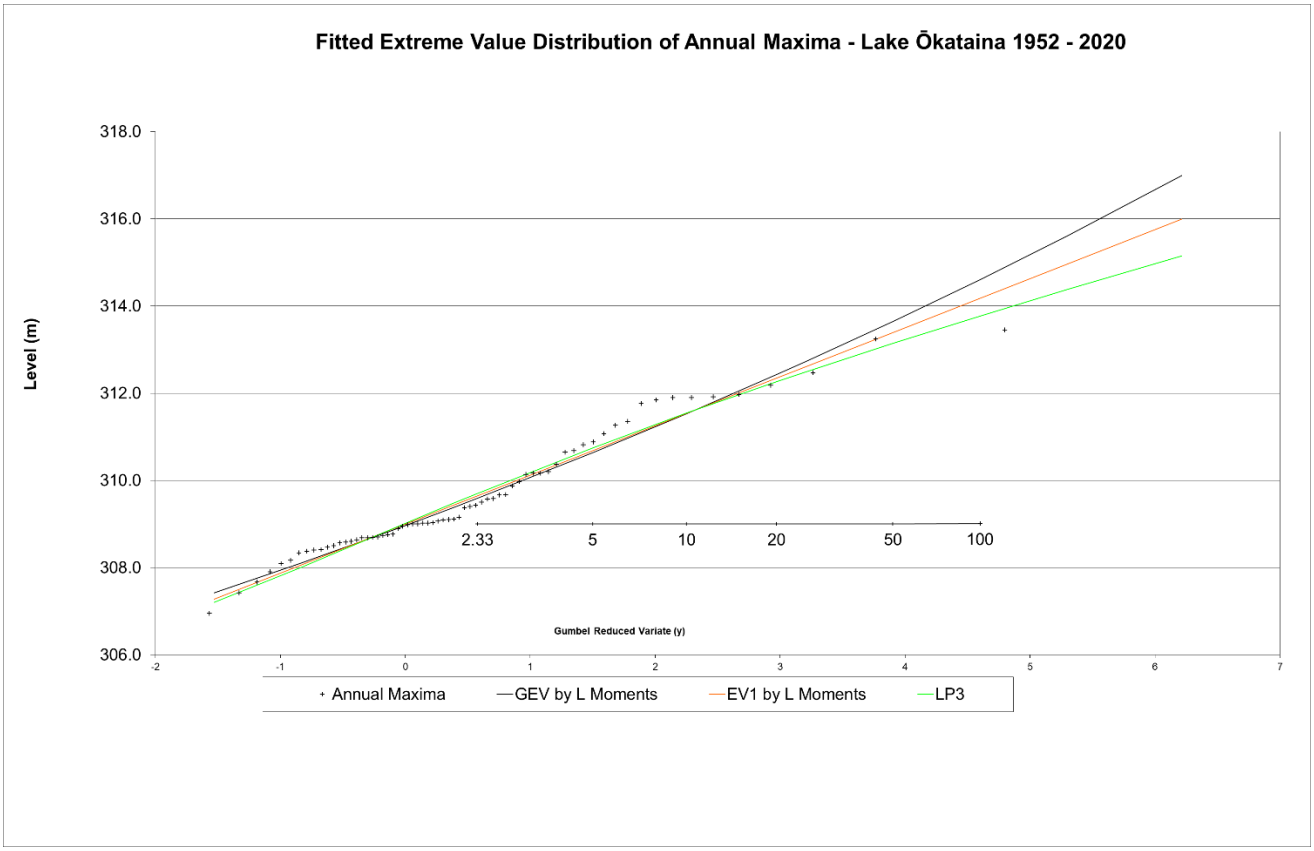

Figure 17: Lake Ōkataina – Fitted Extreme Value Distribution 1952-2020

Part 11: Lake Rotokakahi (Green Lake)

Lake Rotokakahi has a natural outflow to Lake Tarawera via the Wairoa Stream.

The lake level frequency analysis was carried out for the period of record, i.e. 1972 onwards. The data used in this analysis is the annual maximum level record as presented in Table 17 and Figure 18.

As the analysis was carried out on data records starting in 1972 and therefore the large flood events of the early 1960s are not included in the analysis, it is prudent to use the EV1 distribution to generate design levels. Table 18 shows a summary of the generated design levels and Figure 19 shows the various distributions graphically.

The small increase in the 1% AEP level is influenced by the large 2018 event.

Table 17: Lake Rotokakahi - Annual Maxima 1972-2020

FJ295574 Lake Rotokakahi at Te Wairoa Outlet							
YEAR	**Level (m)**	**YEAR**	**Level (m)**	**YEAR**	**Level (m)**	**YEAR**	**Level (m)**
1972	395.182	1985	394.978	1998	395.130	2011	395.075
1973	395.024	1986	395.072	1999	394.997	2012	395.049
1974	395.087	1987	394.897	2000	394.915	2013	394.967
1975	395.057	1988	395.002	2001	394.926	2014	394.955
1976	395.007	1989	395.087	2002	394.940	2015	395.009
1977	395.009	1990	395.049	2003	394.997	2016	394.983
1978	394.947	1991	394.988	2004	395.033	2017	395.151
1979	395.095	1992	395.061	2005	394.988	2018	395.359
1980	394.949	1993	395.062	2006	394.993	2019	395.007
1981	395.030	1994	395.041	2007	394.976	2020	394.863
1982	394.944	1995	395.100	2008	395.035		
1983	395.000	1996	395.099	2009	394.971		
1984	394.917	1997	395.023	2010	395.036		

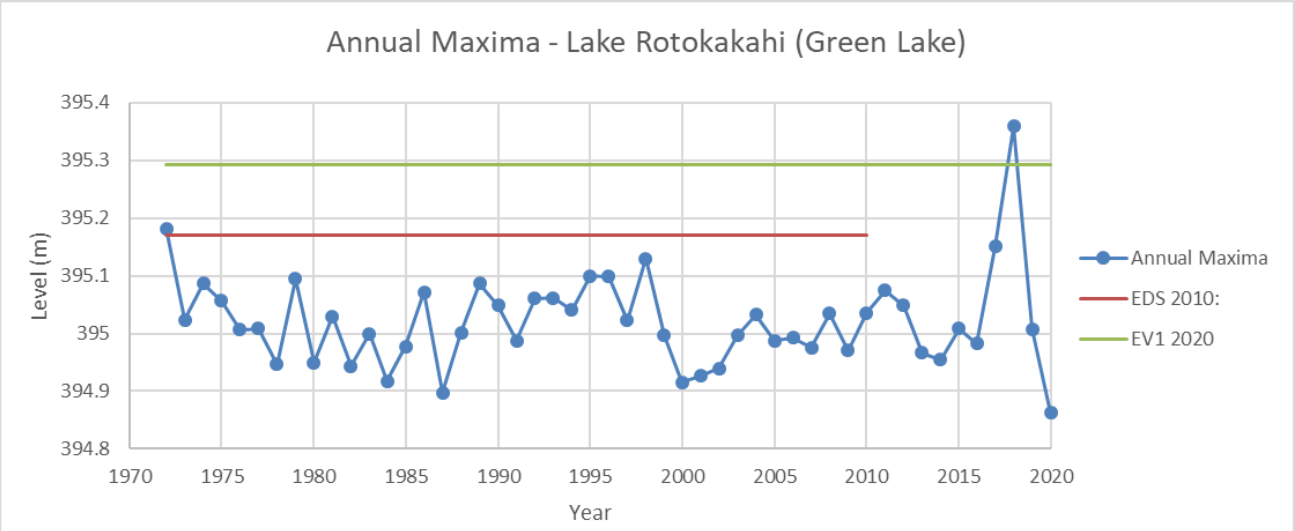

Figure 18: Lake Rotokakahi - Annual Maxima 1972-2020 and 1% AEP level

Table 18: Lake Rotokakahi – Frequency Analysis 1972-2020

Lake Rotokakahi at Te Wairoa Outlet

Return Period		EV1	GEV	LogPearson3	
T	**Y_T**	**Q_{T1}**	**Q_{T2}**	**K**	**Q_{T3}**
1.01	-1.5293	**394.890**	394.883	-1.302	394.915
1.111	-0.8344	**394.934**	394.931	-1.036	394.937
1.5	-0.0940	**394.980**	394.981	-	-
1.667	0.0877	**394.991**	394.993	-0.442	394.985
2	0.3665	**395.009**	395.011	-0.229	395.003
2.33	0.5786	**395.022**	395.025	-0.062	395.017
5	1.4999	**395.079**	395.082	0.701	395.079
10	2.2504	**395.126**	395.126	1.336	395.131
20	2.9702	**395.171**	395.167	1.941	395.181
25	3.1985	**395.185**	395.179	2.133	395.197
50	3.9019	**395.229**	395.217	2.715	395.245
100	4.6001	**395.273**	395.253	3.286	395.291
200	5.2958	**395.316**	395.288	3.849	395.338
500	6.2136	**395.373**	395.332	4.582	395.398

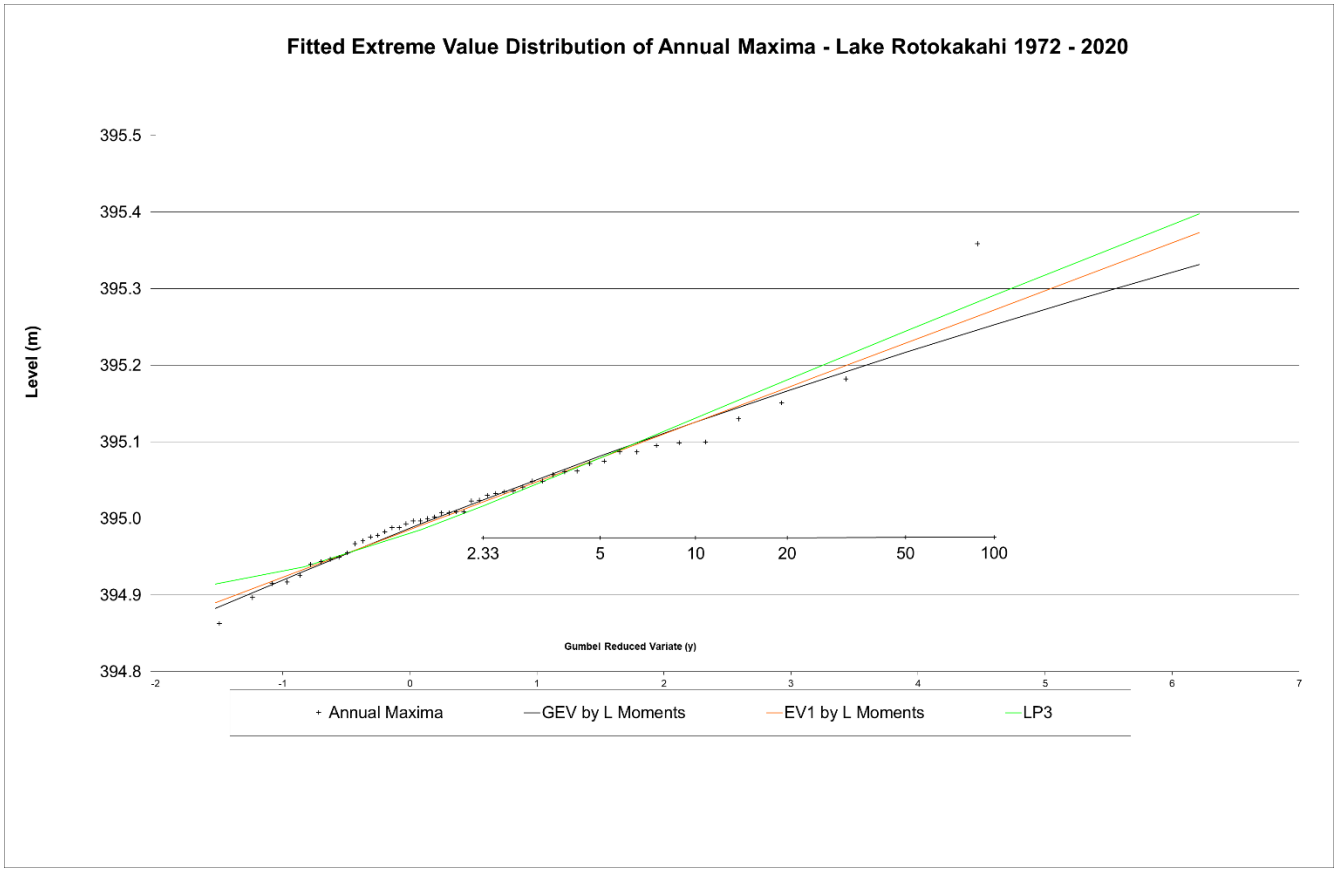

Figure 19: Lake Rotokakahi – Fitted Extreme Value Distribution 1972-2020

Part 12: **Lake Tikitapu (Blue Lake)**

Lake Tikitapu has no natural surface outflow. (Possible groundwater flows towards Lake Rotokakahi have been identified.)

The lake level frequency analysis was carried out for the period of record, i.e. 1972 onwards. The data used in this analysis is the annual maximum level record as presented in Table 19 and Figure 20.

As the analysis was carried out on data records starting in 1972 and therefore the large flood events of the early 1960s are not included in the analysis, it is prudent to use the EV1 distribution to generate design levels. Table 20 shows a summary of the generated design levels and Figure 21 shows the various distributions graphically.

The increase in the 1% AEP level is influenced by several large events since 2010.

Table 19: Lake Tikitapu - Annual Maxima 1972-2020

FJ211768 Lake Tikitapu At Tarawera Rd							
YEAR	**Level (m)**	**YEAR**	**Level (m)**	**YEAR**	**Level (m)**	**YEAR**	**Level (m)**
1972	418.675	1985	416.997	1998	418.152	2011	418.507
1973	418.077	1986	417.160	1999	418.051	2012	418.540
1974	418.035	1987	416.951	2000	417.893	2013	418.180
1975	418.143	1988	416.699	2001	417.715	2014	417.515
1976	418.045	1989	417.325	2002	417.731	2015	417.240
1977	417.944	1990	417.660	2003	417.408	2016	417.553
1978	417.693	1991	417.424	2004	417.942	2017	418.690
1979	417.839	1992	417.311	2005	417.945	2018	418.640
1980	417.816	1993	417.268	2006	418.133	2019	418.480
1981	417.651	1994	417.226	2007	417.926	2020	417.843
1982	417.627	1995	417.731	2008	417.840		
1983	417.075	1996	418.117	2009	417.667		
1984	417.000	1997	418.018	2010	417.888		

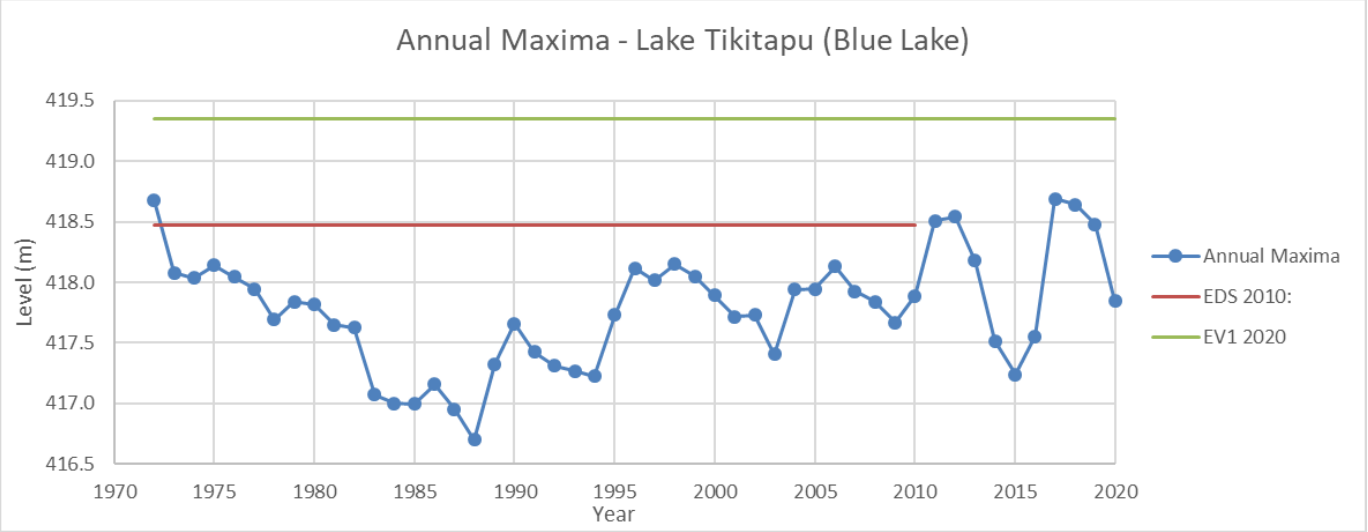

Figure 20: Lake Tikitapu - Annual Maxima 1972-2020 and 1% AEP level

Table 20: Lake Tikitapu – Frequency Analysis 1972-2020

Lake Tikitapu At Tarawera Rd

Return Period		EV1	GEV	LogPearson3	
T	**Y_T**	**Q_{T1}**	**Q_{T2}**	**K**	**Q_{T3}**
1.01	-1.5293	**416.951**	416.636	-2.386	416.642
1.111	-0.8344	**417.223**	417.145	-1.290	417.162
1.5	-0.0940	**417.513**	417.572	-	-
1.667	0.0877	**417.584**	417.661	-0.241	417.661
2	0.3665	**417.693**	417.788	0.014	417.781
2.33	0.5786	**417.776**	417.877	0.190	417.865
5	1.4999	**418.136**	418.197	0.845	418.177
10	2.2504	**418.429**	418.394	1.272	418.380
20	2.9702	**418.711**	418.541	1.621	418.546
25	3.1985	**418.800**	418.581	1.723	418.595
50	3.9019	**419.075**	418.685	2.010	418.732
100	4.6001	**419.348**	418.768	2.266	418.853
200	5.2958	**419.620**	418.832	2.500	418.965
500	6.2136	**419.979**	418.898	2.780	419.099

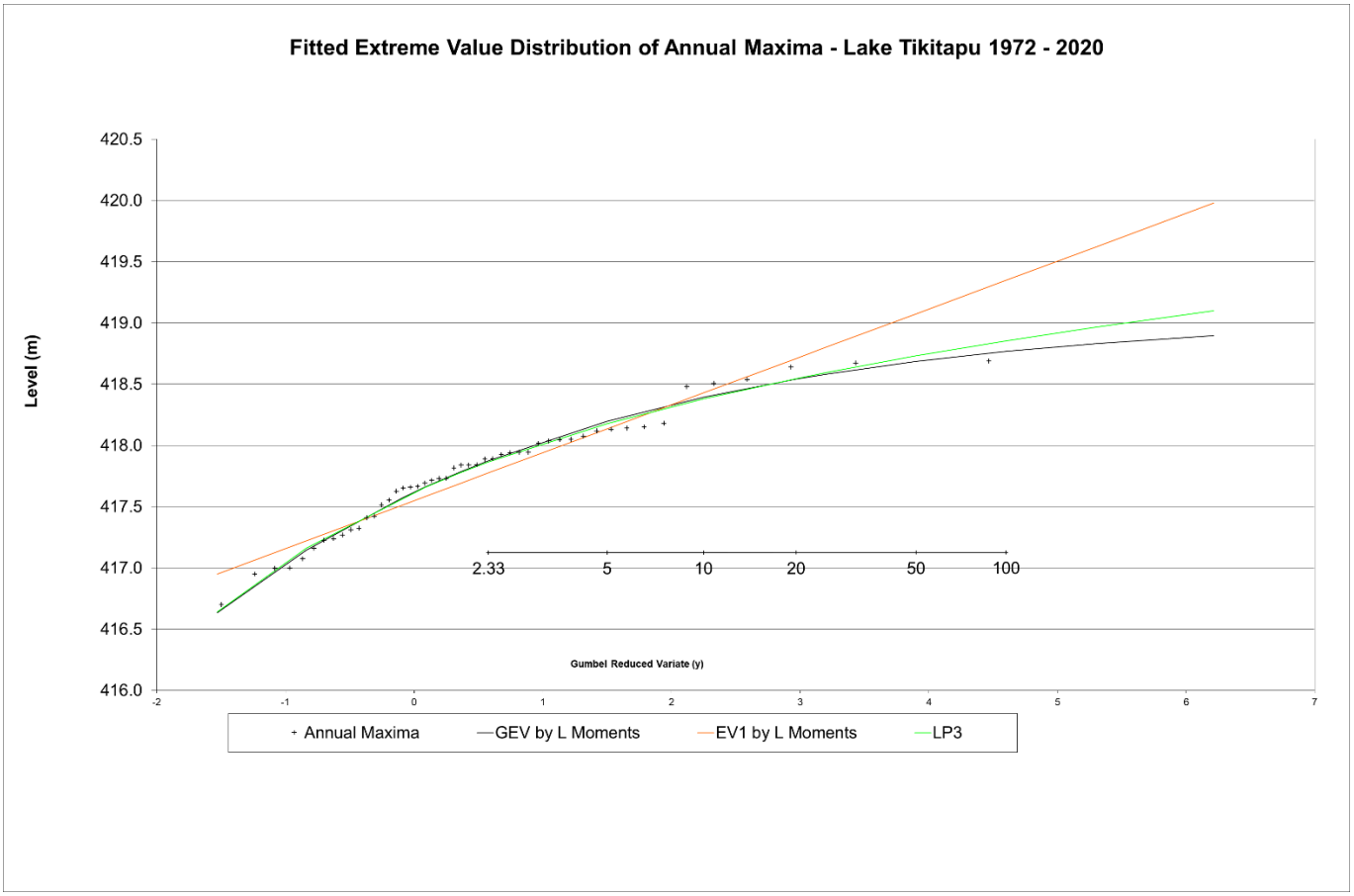

Figure 21: Lake Tikitapu – Fitted Extreme Value Distribution 1972-2020

Part 13: **Lake Rotomahana**

Lake Rotomahana has a high level overflow control via a culvert towards Lake Tarawera.

The lake level frequency analysis was carried out for the period of record, i.e. 1925 onwards. The data used in this analysis is the annual maximum level record as presented in Table 21 and Figure 22.

A Log Pearson 3 distribution gives the best fit for the data analysed and has been used to generate design levels. Table 22 shows a summary of the generated design levels and Figure 23 shows the various distributions graphically.

Table 21: Lake Rotomahana - Annual Maxima 1925-2020

GJ390082 Lake Rotomahana at Crater Bay							
YEAR	**Level (m)**	**YEAR**	**Level (m)**	**YEAR**	**Level (m)**	**YEAR**	**Level (m)**
1925	335.992	1951	338.385	1975	340.903	1999	338.686
1926	336.754	1952	338.690	1976	340.795	2000	338.505
1927	336.577	1953	339.421	1977	340.645	2001	338.128
1928	337.059	1954	339.604	1978	340.159	2002	338.029
1929	337.776	1955	339.238	1979	339.472	2003	337.558
1930	338.029	1956	340.183	1980	339.361	2004	337.770
1931	337.471	1957	340.153	1981	338.920	2005	338.029
1932	335.743	1958	339.696	1982	338.703	2006	338.731
1933	334.512	1959	339.482	1983	337.992	2007	338.691
1934	334.423	1960	339.366	1984	337.793	2008	338.800
1935	335.261	1961	339.208	1985	337.381	2009	338.623
1936	336.607	1962	340.762	1986	337.676	2010	338.890
1937	336.518	1963	340.946	1987	337.452	2011	339.855
1938	337.593	1964	340.702	1988	336.626	2012	340.378
1939	337.541	1965	340.550	1989	337.247	2013	340.039
1940	337.416	1966	340.878	1990	337.596	2014	339.574
1941	337.288	1967	341.155	1991	337.423	2015	338.920
1942	337.196	1968	341.137	1992	337.443	2016	337.992
1943		1969	340.952	1993	337.386	2017	339.394
1944		1970	340.545	1994	336.900	2018	340.271
1947	337.929	1971	342.035	1995	337.674	2019	340.237
1948	338.477	1972	342.108	1996	338.405	2020	339.776
1949	338.629	1973	341.651	1997	338.807		
1950	338.446	1974	340.621	1998	338.841		

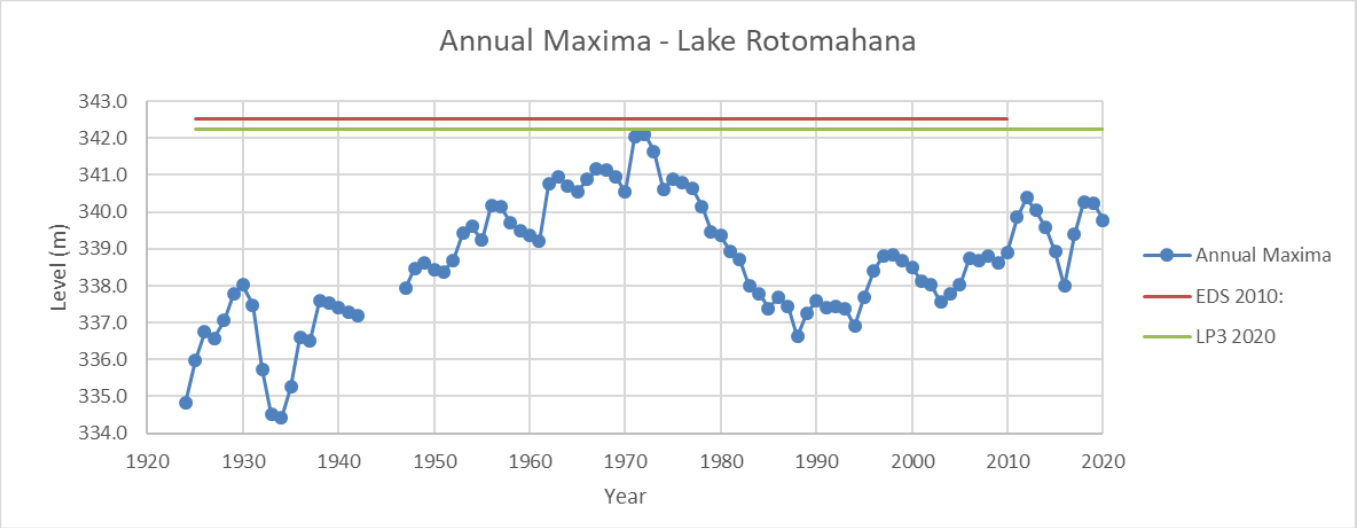

Figure 22: Lake Rotomahana - Annual Maxima 1925-2020 and 1% AEP level

Table 22: Lake Rotomahana – Frequency Analysis 1925-2020

Lake Rotomahana at Crater Bay

Return Period		EV1	GEV	LogPearson3	
T	**Y_T**	**Q_{T1}**	**Q_{T2}**	**K**	**Q_{T3}**
1.01	-1.5293	335.900	334.982	-2.453	**334.742**
1.111	-0.8344	336.820	336.585	-1.299	**336.591**
1.5	-0.0940	337.799	337.969	-	**-**
1.667	0.0877	338.039	338.265	-0.226	**338.318**
2	0.3665	338.408	338.690	0.029	**338.730**
2.33	0.5786	338.689	338.990	0.205	**339.015**
5	1.4999	339.907	340.098	0.849	**340.057**
10	2.2504	340.900	340.803	1.261	**340.726**
20	2.9702	341.852	341.348	1.594	**341.268**
25	3.1985	342.154	341.498	1.689	**341.423**
50	3.9019	343.084	341.902	1.959	**341.863**
100	4.6001	344.008	342.228	2.197	**342.251**
200	5.2958	344.928	342.493	2.412	**342.603**
500	6.2136	346.142	342.769	2.668	**343.020**

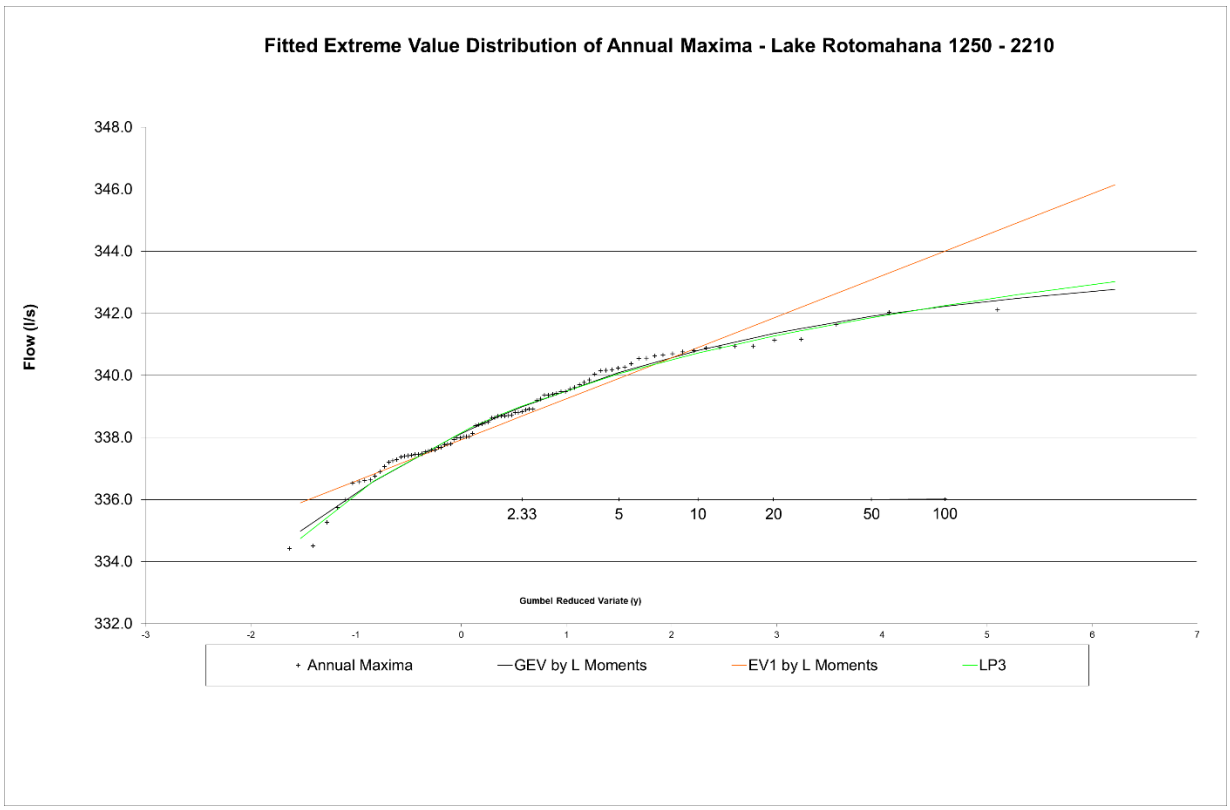

Figure 23: Lake Rotomahana – Fitted Extreme Value Distribution 1925-2020

Part 14: **Lake Ōkaro**

Lake Ōkaro has a natural outflow into Lake Rotomahana via the Haumi Stream.

The lake level frequency analysis was carried out for the period of record, i.e. 1990 onwards (sporadic readings between 1980 and 1989 have been excluded from analysis). The data used in this analysis is the annual maximum level record as presented in Table 23 and Figure 24.

As the analysis was carried out on data records starting in 1990 and therefore the large flood events of the early 1960s are not included in the analysis, it is prudent to use the EV1 distribution to generate design levels. Table 24 shows a summary of the generated design levels and Figure 25 shows the various distributions graphically.

Table 23: Lake Ōkaro - Annual Maxima 1990-2020

FI663578 Lake Ōkaro At Reserve							
YEAR	**Level (m)**	**YEAR**	**Level (m)**	**YEAR**	**Level (m)**	**YEAR**	**Level (m)**
1990	412.019	1998	411.775	2006	411.963	2014	411.804
1991	411.956	1999	411.731	2007	411.997	2015	411.748
1992	411.973	2000	411.696	2008	412.038	2016	411.936
1993	411.933	2001	411.881	2009	411.837	2017	411.861
1994	411.973	2002	411.829	2010	412.067	2018	411.646
1995	411.907	2003	411.971	2011	411.870	2019	411.798
1996	411.922	2004	412.106	2012	411.889	2020	411.646
1997	411.757	2005	411.960	2013	411.625		

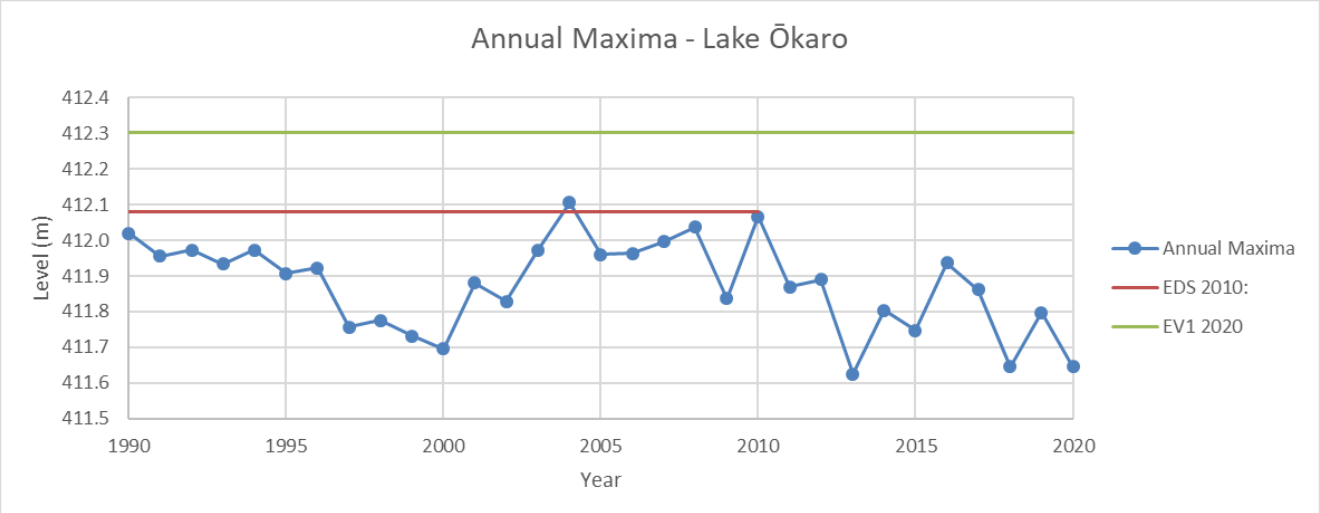

Figure 24: Lake Ōkaro - Annual Maxima 1990-2020 and 1% AEP level

Table 24: Lake Ōkaro – Frequency Analysis 1990-2020

Lake Ōkaro At Reserve

Return Period		EV1	GEV	LogPearson3	
T	**Y_T**	**Q_{T1}**	**Q_{T2}**	**K**	**Q_{T3}**
1.01	-1.5293	**411.651**	411.529	-2.573	411.547
1.111	-0.8344	**411.725**	411.697	-1.312	411.707
1.5	-0.0940	**411.803**	411.826	-	-
1.667	0.0877	**411.823**	411.852	-0.199	411.849
2	0.3665	**411.852**	411.887	0.057	411.882
2.33	0.5786	**411.875**	411.911	0.231	411.904
5	1.4999	**411.973**	411.992	0.854	411.983
10	2.2504	**412.052**	412.036	1.239	412.033
20	2.9702	**412.129**	412.066	1.542	412.071
25	3.1985	**412.153**	412.074	1.628	412.082
50	3.9019	**412.228**	412.093	1.867	412.113
100	4.6001	**412.302**	412.107	2.073	412.139
200	5.2958	**412.376**	412.117	2.256	412.162
500	6.2136	**412.473**	412.126	2.469	412.189

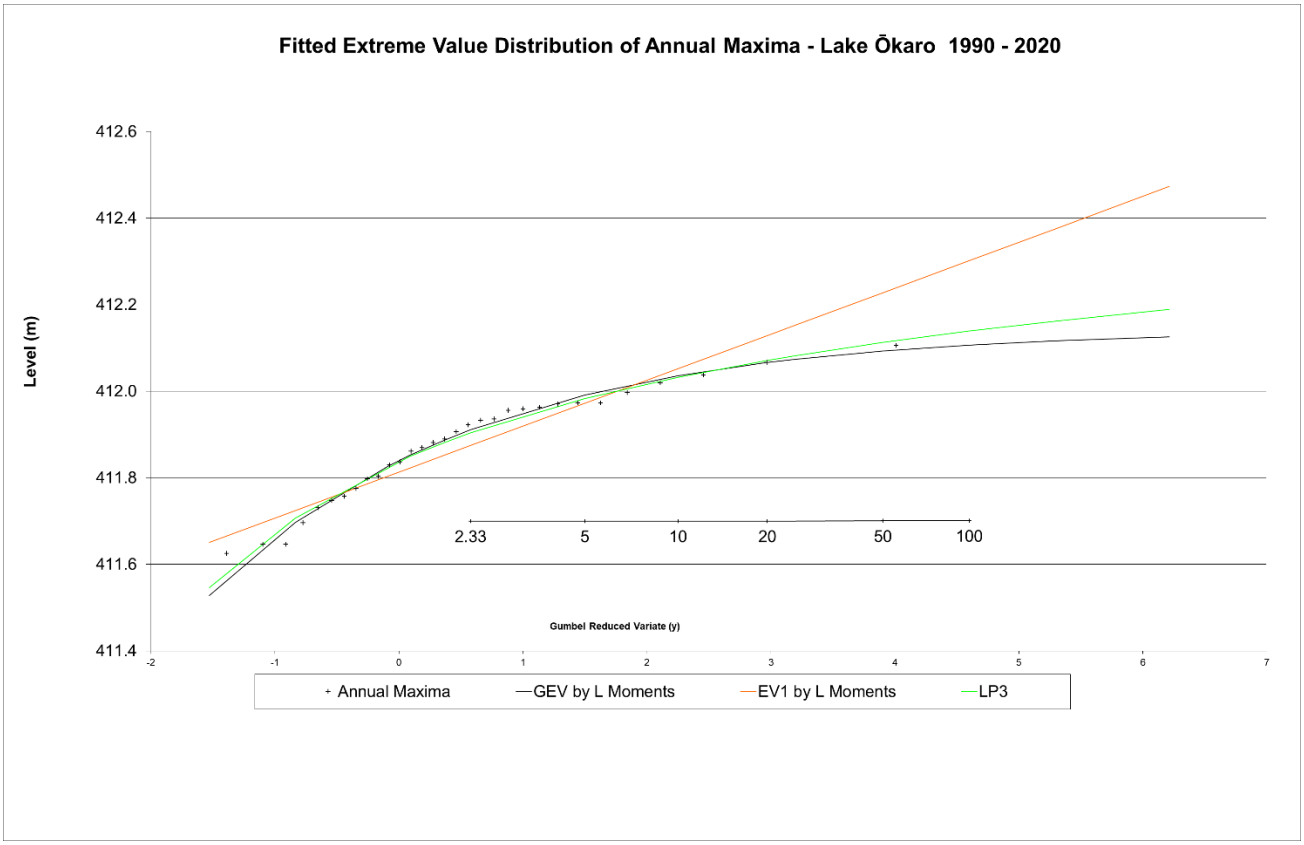

Figure 25: Lake Ōkaro – Fitted Extreme Value Distribution 1990-2020

Part 15: **Design levels**

Earlier estimates produced for the 50 year and 100 year return period (2% and 1% AEP) design levels for the Rotorua Lakes have been summarised in the Environmental Data Summaries 2005 (BOPRC, 2005) and Environmental Data Summaries 2010 (audited but not published). These are summarised in Table 25 below, together with the newly generated design levels using data up to 2020.

Table 25: Lake Levels Summary

			Site Details			1% level								
Lake	P Blackwood - 2% level letter 17/07/2002	Incl Freeboard	Site #	Site Name	Period of summary	2000 EDS	2000 EDS Plus FB	2005 EDS	2005 EDS Plus FB	2010 EDS	2010 EDS Plus FB	Period of summary	2020 Review	2020 Review Plus FB
Rotorua	281.18	0.8	14624	Mission Bay	1953									
		0.8	14615	Town Wharf	1953			280.787	281.587					
Pre control		0.8	14615	Town Wharf (1953 to Sept 72)	1953	280.45	281.25			280.80	281.60			
Post control		0.8	14615	Town Wharf	Sep-72					280.34	281.14	1973	280.525	281.325
Rotoiti	280.46	0.8	14601	Ōkere Falls	1906	279.73	280.53							
Pre control		0.8	1114675	Okawa Bay (1906 to 81)	1906			279.574	280.374	279.73	280.53			
Post control		0.8	1114675	Okawa Bay	1982			279.623	280.423	279.60	280.40	1983	279.597	280.397
Ōkāreka	355.2	0.7	15307	Acacia Bay	1952			354.5	355.2	354.46	355.16	1971	354.628	355.328
Tarawera	299.4	0.8	15301	Te Wairoa	1926			298.656	299.456	298.67	299.47	1925	298.608	299.408
Rerewhakaaitu	436.89	0.7	1015310	Homestead Arm	1984	436.37	437.07	435.814	436.514	436.49	437.19	1983	437.801	438.501
Rotomā	319.04	0.8	14717	Otangiwai Point	1954	318.72	319.52	318.137	318.937	318.21	319.01	1953	317.955	318.755
Rotoehu	298.16	0.7	14716	Te Pohue Bay	1954	297.89	298.59	297.119	297.819	~~295.31~~	~~296.01~~	1953	297.578	298.278
Ōkataina	314.9	0.8	15309	Tauranganui Bay	1953	315.00	315.80	315.118	315.918	315.13	315.93	1952	314.179	314.979
Rotokakahi	395.9	0.7	15344	Te Wairoa	1972	395.22	395.92	394.748	395.448	395.17	395.87	1972	395.273	395.973
Tikitapu	419.5	0.7	15347	Tarawera Road	1972	419.00	419.70	418.264	418.964	418.47	419.17	1972	419.348	420.048
Rotomahana		0.8	15338	Crater Bay	1925			342.715	343.515	342.53	343.33	1925	342.251	343.051
Ōkaro		0.7	1015325	Reserve	1990			412.127	412.827	412.08	412.78	1990	412.302	413.002

Part 16: **Freeboard**

This chapter is only slightly modified from Peter Blackwood's memo to Rotorua District Council – Design Flood Levels – Rotorua Lakes, 17 July 2002.

In determining design flood levels it is standard practice to add a freeboard allowance to levels that are calculated by computer models. The freeboard margin is not a safety margin. It is a provision for various factors as follows:

- Estimate imprecision.
- Local wind setup (generated by wind stress across the lake) and waves.
- Seiche.
- Tectonics
- Unlike most river floods, lake levels can remain high for several days (months). The adverse impact is probably worse under longer duration flooding (cf. Queenstown flooding from Lake Wakatipu) and therefore more freeboard is warranted.
- Construction tolerances.

The likely magnitude of the various components are:

Estimate imprecision 0.3 m: This is based on many years of experience in this field. It applies more particularly to river levels and experience after a detailed study on the Hutt River was that approximately 65% of pegged flood levels fell within +/- 0.22 m and 93% +/- 0.35 m. An alternative methodology is to apply standard errors – however, these are very large for the lakes. In the end some judgement has to be applied and it is unlikely that an engineer could conclude the accuracy of the flood levels is better than 0.3 m.

Local wind setup and waves (0.2 + 0.3 m): Local wind setup is likely to usually be in the order of 0.2 m, but this depends on bathymetry and fetch – in some locations this component would be greater, others less. To this should be added wave runup. This depends entirely on the slope of the beach (runup surface). However, a figure of 0.3 m is probably reasonable and compatible with observations.

Seiche 0.1 m: This depends on the particular location. Studies on Lake Rotoiti (ref. p.28 "Okere Radial Control Gates Lake Rotoiti to Kaituna River Operation Report", November 1998, M.R. Surman, Environment BOP Operations Report 98/14) show recorded seiche at Hinehopu to be low. However, at the Okere recorder seiche of up to 80 mm was recorded occasionally.

Tectonics 0.1 m: The Rotorua Lakes area is not a totally stable area, for example Lake Rotoiti is tilting downwards at Hinehopu (eastern shore).

In making recommendations on the appropriate freeboard the likely joint probability of the various factors is considered. That is the factors are not necessarily additive. At this stage it is recommended that the seiche component be discounted as it is unlikely to aggravate a reasonable concurrence of the above factors. Also, construction tolerances (minor levelling errors and ground settlement due to the weight of the building) have not been considered (but are a building code requirement).

The recommended freeboards are:

- 0.8 m for Lakes Rotorua, Rotoiti, Rotomā, Ōkataina, Tarawera and Rotomahana.
- 0.7 m for Lakes Ōkāreka, Rotoehu, Rerewhakaaitu, Rotokakahi, Tikitapu and Ōkaro.

Design levels, including freeboard, for a range of event sizes are summarised in Table 26.

Table 26: Design Lake levels for 50%, 20%, 10%, 5%, 2%, 1%, 0.5% and 0.2% AEP

2020 Design Level Summary		50%		20%		10%		5%		2%		1%		0.50%		0.20%	
	Freeboard	2yr	2yr + FB	5yr	5yr + FB	10yr	10yr + FB	20yr	20yr + FB	50yr	50yr + FB	100yr	100yr + FB	200yr	200yr + FB	500yr	500yr + FB
Lake Rotorua	0.8	280.09	280.89	280.20	281.00	280.28	281.08	280.36	281.16	280.45	281.25	280.52	281.32	280.60	281.40	280.69	281.49
Lake Rotoiti	0.8	279.30	280.10	279.38	280.18	279.43	280.23	279.48	280.28	279.55	280.35	279.60	280.40	279.65	280.45	279.71	280.51
Lake Ōkāreka	0.7	353.89	354.59	354.09	354.79	354.22	354.92	354.35	355.05	354.51	355.21	354.63	355.33	354.75	355.45	354.91	355.61
Lake Tarawera	0.8	298.15	298.95	298.29	299.09	298.38	299.18	298.45	299.25	298.54	299.34	298.61	299.41	298.67	299.47	298.75	299.55
Lake Rerewhakaait	0.7	435.63	436.33	436.21	436.91	436.60	437.30	436.97	437.67	437.44	438.14	437.80	438.50	438.16	438.86	438.63	439.33
Lake Rotomā	0.8	315.48	316.28	316.33	317.13	316.80	317.60	317.19	317.99	317.65	318.45	317.95	318.75	318.24	319.04	318.60	319.40
Lake Rotoehu	0.7	295.19	295.89	295.83	296.53	296.25	296.95	296.66	297.36	297.18	297.88	296.92	297.58	297.97	298.67	298.49	299.19
Lake Ōkataina	0.8	309.41	310.21	310.69	311.49	311.53	312.33	312.34	313.14	313.39	314.19	314.18	314.98	314.96	315.76	316.00	316.80
Lake Rotokakahi	0.7	395.01	395.71	395.08	395.78	395.13	395.83	395.17	395.87	395.23	395.93	395.27	395.97	395.32	396.02	395.37	396.07
Lake Tikitapu	0.7	417.69	418.39	418.14	418.84	418.43	419.13	418.71	419.41	419.08	419.78	419.35	420.05	419.62	420.32	419.98	420.68
Lake Rotomahana	0.8	338.73	339.53	340.06	340.86	340.73	341.53	341.27	342.07	341.86	342.66	342.25	343.05	342.60	343.40	343.02	343.82
Lake Ōkaro	0.7	411.85	412.55	411.97	412.67	412.05	412.75	412.13	412.83	412.23	412.93	412.30	413.00	412.38	413.08	412.47	413.17

Part 17: **Interdecadal Pacific Oscillation (IPO)**

Studies have shown that the IPO (Interdecadal Pacific Oscillation) phases influence the flood magnitude of some Bay of Plenty rivers (NIWA, 2014). For Bay of Plenty rivers, higher floods have tended to be clustered into periods from start of record to 1969; after 1997; and absent for the interval 1969-1997. For example, the Whakatane River had no floods greater than five year events in the period 1973 to 1997 (Blackwood, pers. commt.). These periods coincide with intervals when the IPO was in alternate phases. This suggests that the periods of record for the various Rotorua Lakes span across at least one “wet” phase and one “dry” phase.

Where the analysis of the period of record data spans more than two phases the analysis may result in higher or lower design levels than if it would span across evenly between wet and dry phases. Some datasets do not include the large rainstorms of the 1960s and early 1970s, in the active phase. Applying an EV1 distribution to these datasets is appropriate to mitigate this. The magnitude of flood peaks in the 2004 “Manawatu Floods” were far higher than expected due to erroneously adopting an EV3 distribution, even though there was around 50 years of data. NIWA confirmed that EV1 or even a slight EV2 was appropriate for these rivers (Peter Blackwood pers. commt.)

Part 18: **Climate Change**

Estimates for Climate Change impacts on design lake levels are being assessed and reported on separately to this report.

Peak levels in the larger Rotorua Lakes are not expected to increase much with Climate Change. This is because the lake levels are affected by long duration climatic periods, which are less impacted by Climate Change – as against stormwater and major rivers, where the impact is forecast to be very significant. Initial indications are that we would expect the increase in level to 2120 to be less than 0.5 m for the smaller lakes (Lake Rotoehu, Lake Rotomā, Lake Ōkataina, Lake Ōkāreka, Lake Rerewhakaaitu, Lake Tikitapu, Lake Rotokakahi, Lake Rotomahana, and Lake Okaro), and less than 0.1 m for the larger lakes (Lake Rotorua, Lake Rotoiti and Lake Tarawera).

Part 19: **References**

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