waihora ellesmere trust

Water balance model – Graeme H

Water balance model of Lake Ellesmere (Te Waihora)

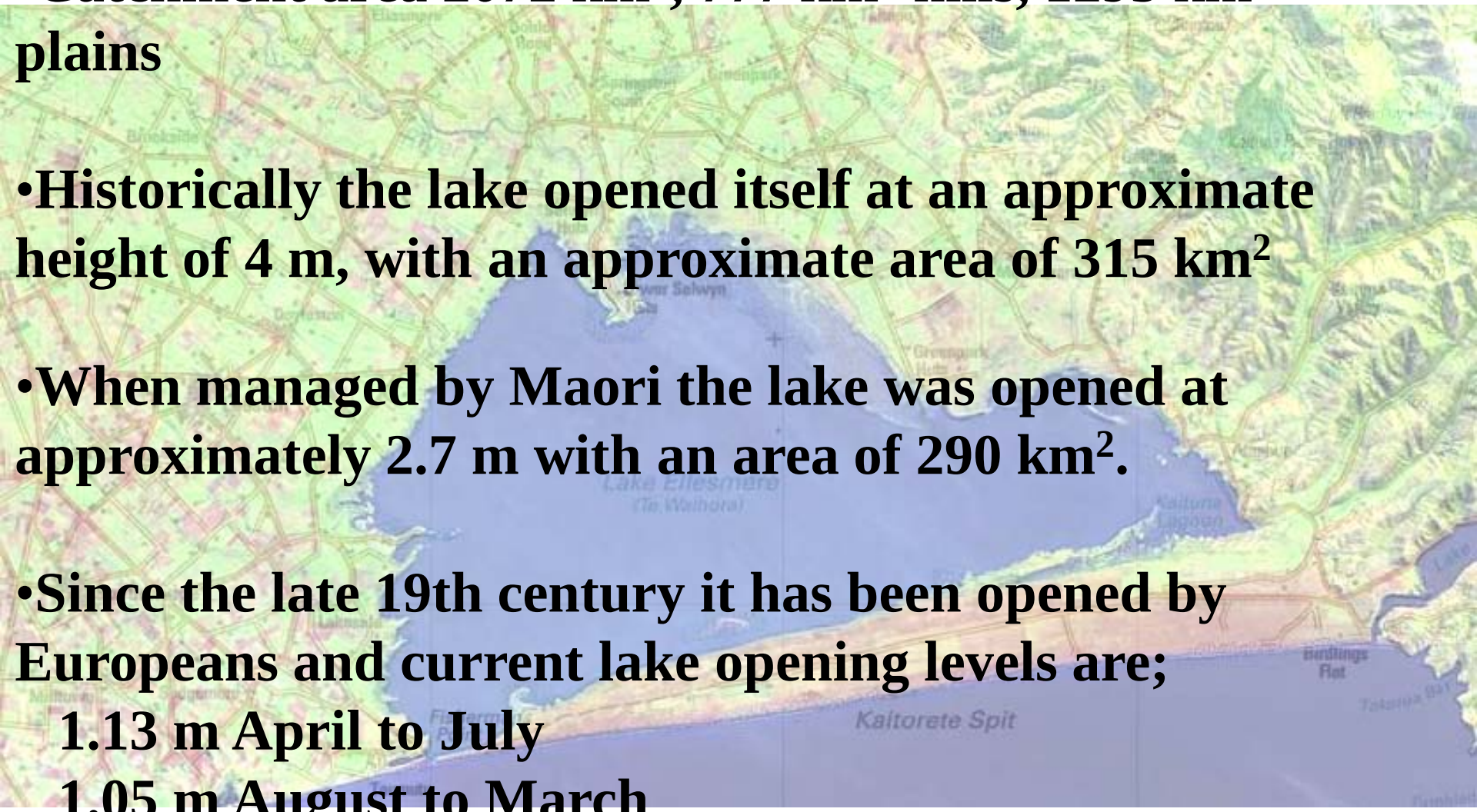
Graeme Horrell

- **Background**
- **Lake variables**
- **Water balance**
- **Model development**
- **Model output**

NIWA

Taihoro Nukurangi

Background



- Catchment area 2072 km^2, 777 km^2 hills, 1295 km^2 plains

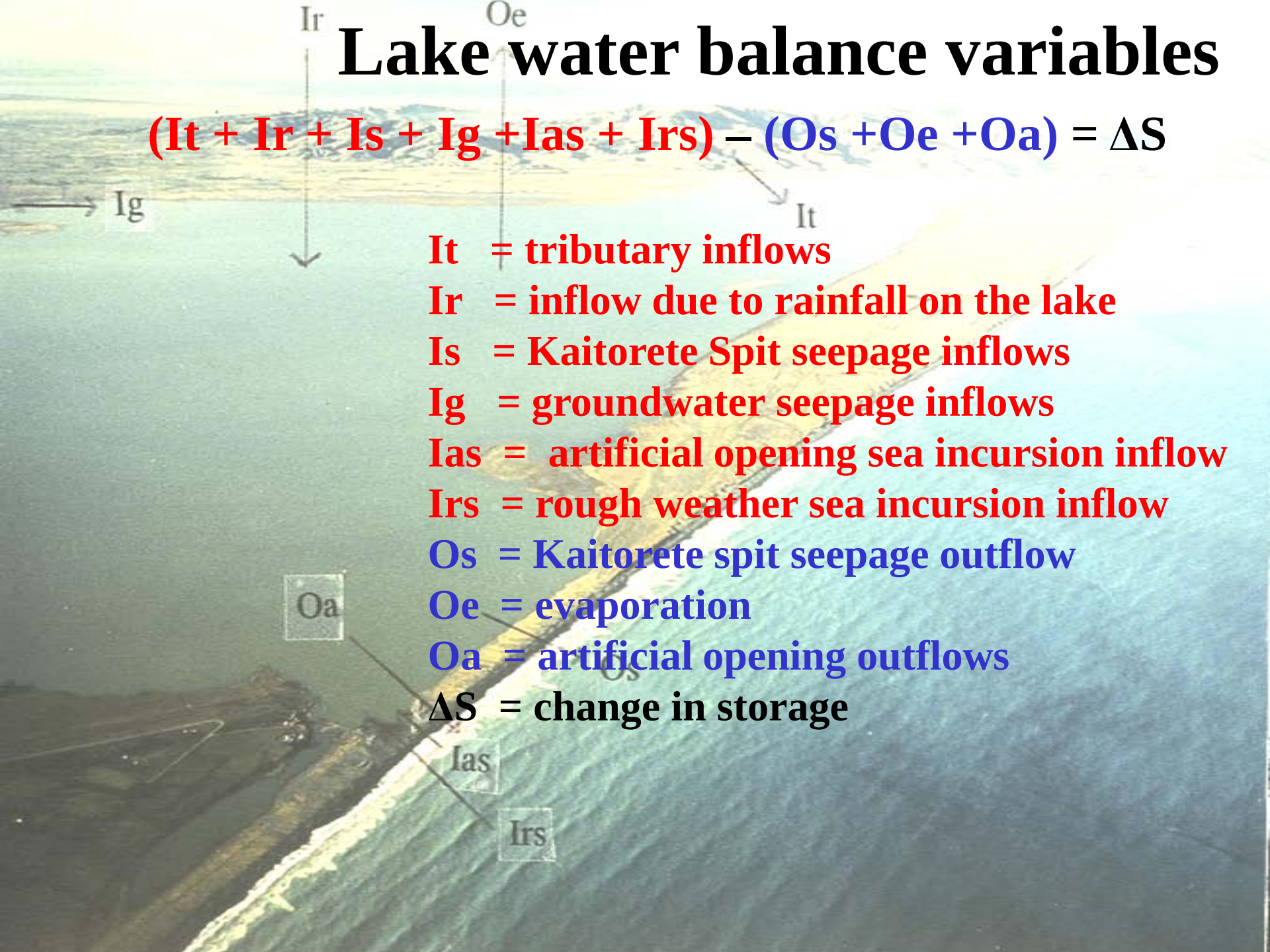
- Historically the lake opened itself at an approximate height of 4 m, with an approximate area of 315 km^2

- When managed by Maori the lake was opened at approximately 2.7 m with an area of 290 km^2.

- Since the late 19th century it has been opened by Europeans and current lake opening levels are;
  - 1.13 m April to July
  - 1.05 m August to March
- Current area of 189 km^2, mean depth 1.4m

Lake water balance variables

(It + Ir + Is + Ig +Ias + Irs) – (Os +Oe +Oa) = ΔS



It = tributary inflows
Ir = inflow due to rainfall on the lake
Is = Kaitorete Spit seepage inflows
Ig = groundwater seepage inflows
Ias = artificial opening sea incursion inflow
Irs = rough weather sea incursion inflow
Os = Kaitorete spit seepage outflow
Oe = evaporation
Oa = artificial opening outflows
ΔS = change in storage

Tributary inflows

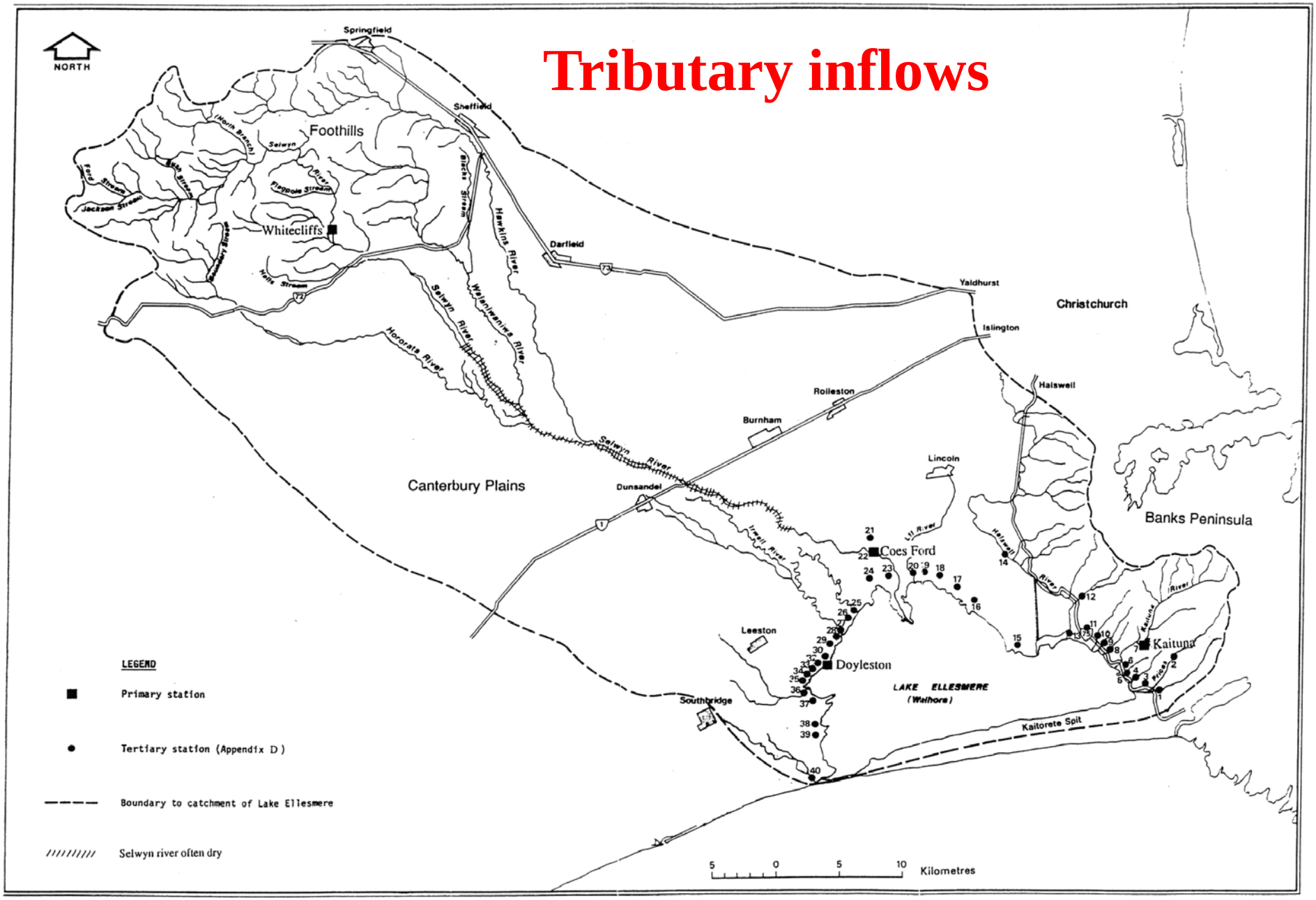
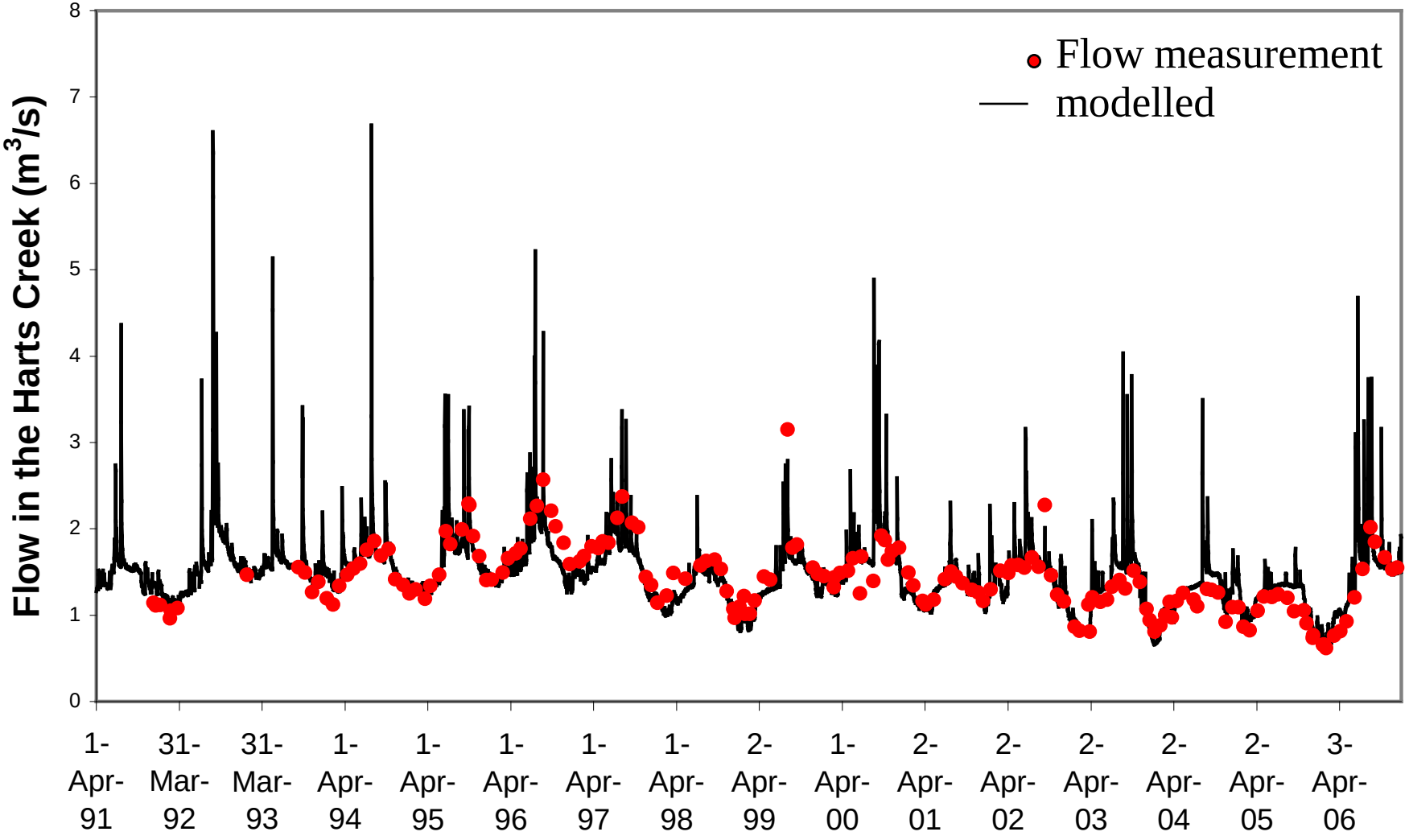


Figure 2.8 Lake Ellesmere Tributaries

Kaituna River recorder on Banks Peninsula

Doyleston Drain at Lake Road

Tributaries contribute 62 % of inflows - 12.5 $m^3 s^{-1}$



Rainfall contributes 16% of inflows - 3.3 $m^3 s^{-1}$

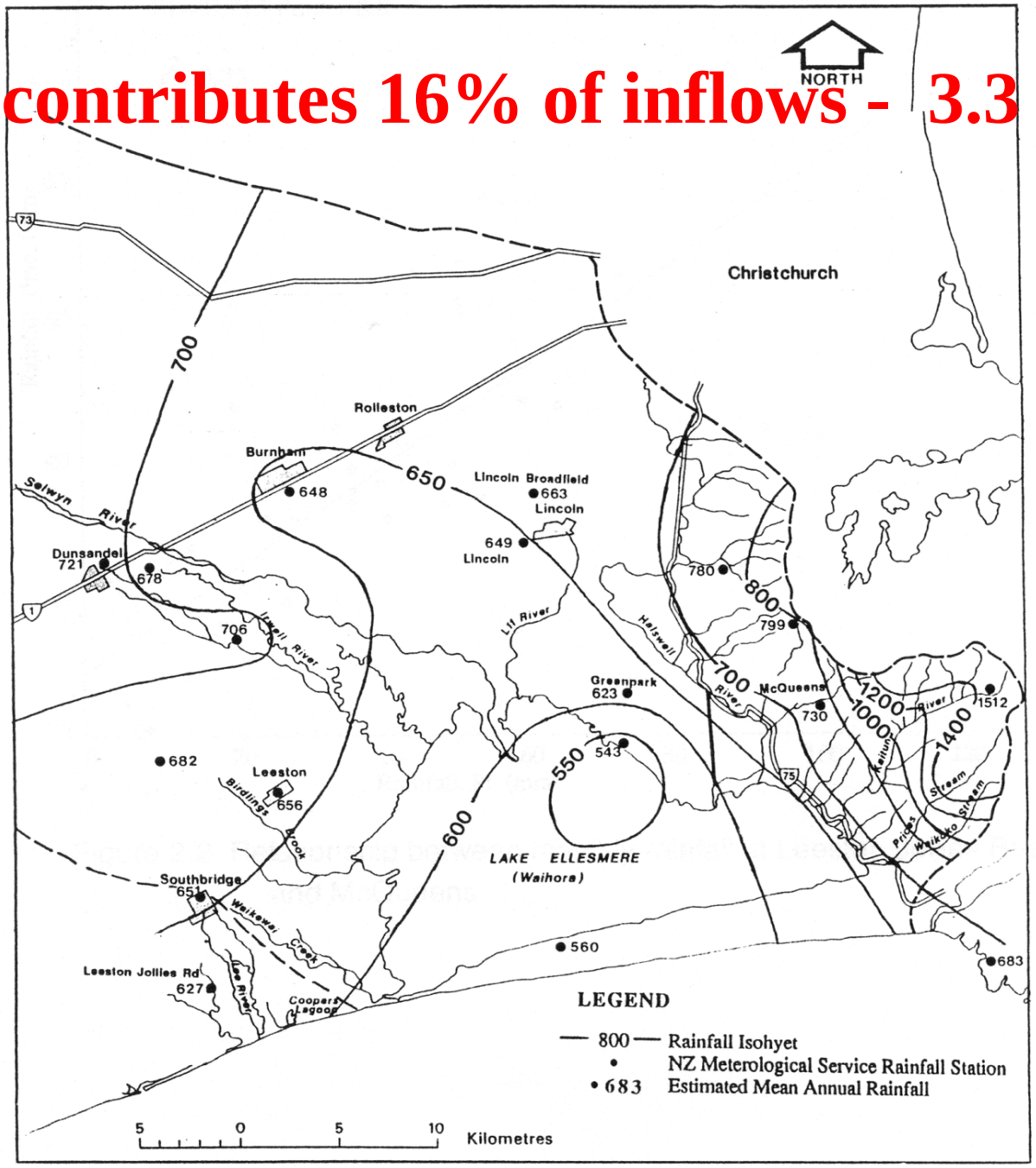


Figure 2.1 - Mean Annual Rainfall ($mm.a^{-1}$) (1961-1990)

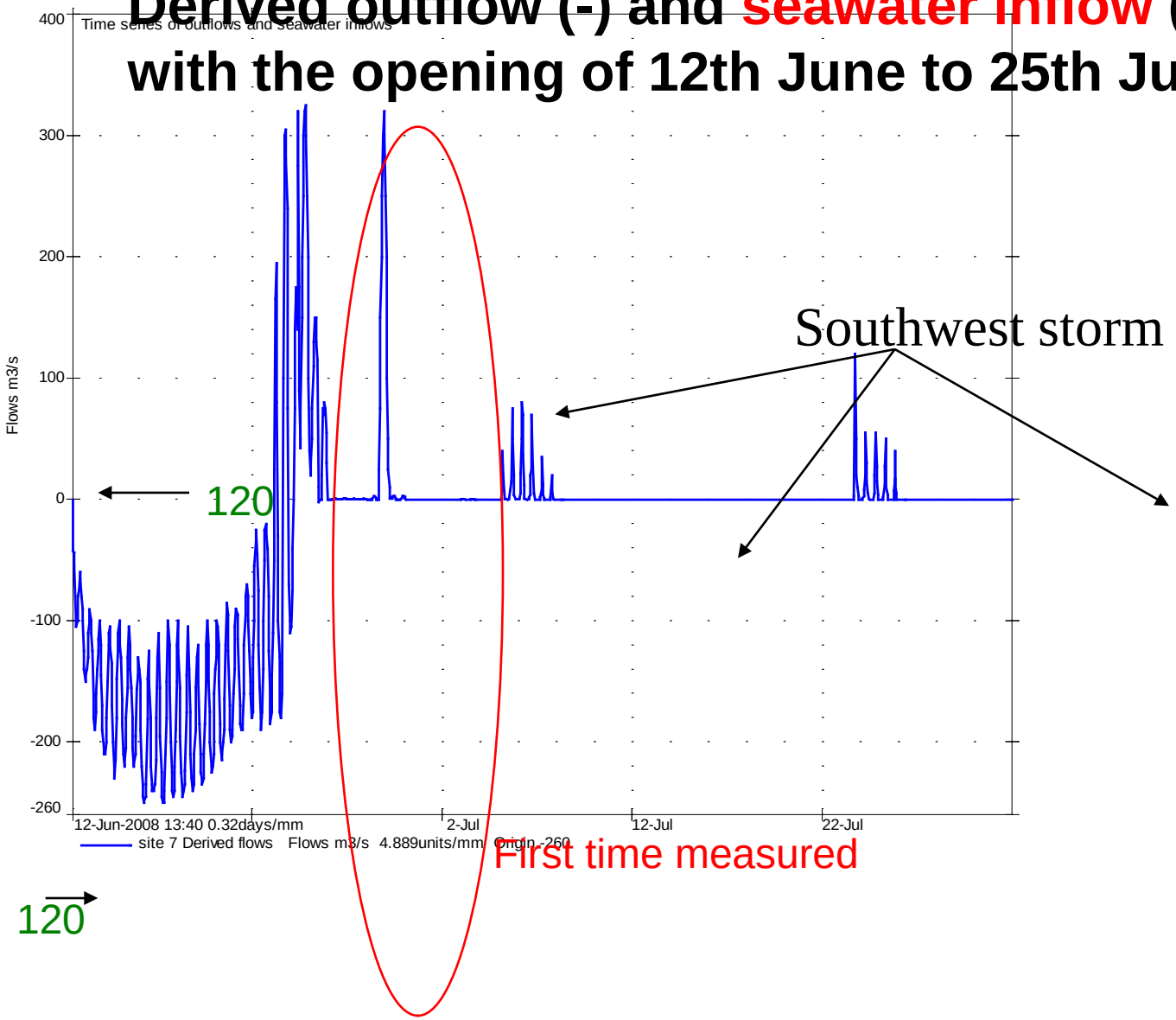
Groundwater seepage represents 2% of inflows

$0.4\ m^3\ s^{-1}$

Artificial opening sea incursions

23rd June 2008 outflows are approximately 160 $m^3 s^{-1}$,
2 hours later seawater inflows exceeded 250 $m^3 s^{-1}$

Derived outflow (-) and seawater inflow (+) associated with the opening of 12th June to 25th June 2008.




Artificial opening sea incursions
represent 13% of inflows - 2.6 m3 s-1

Rough weather sea incursions

Rough weather sea incursions contribute to 7% of inflows – 1.5 m^3 s^{-1}

Rough weather sea incursions – approximately 80 m^3 s^{-1} 24th July 2008

Seepage out flows through Kaitorete spit

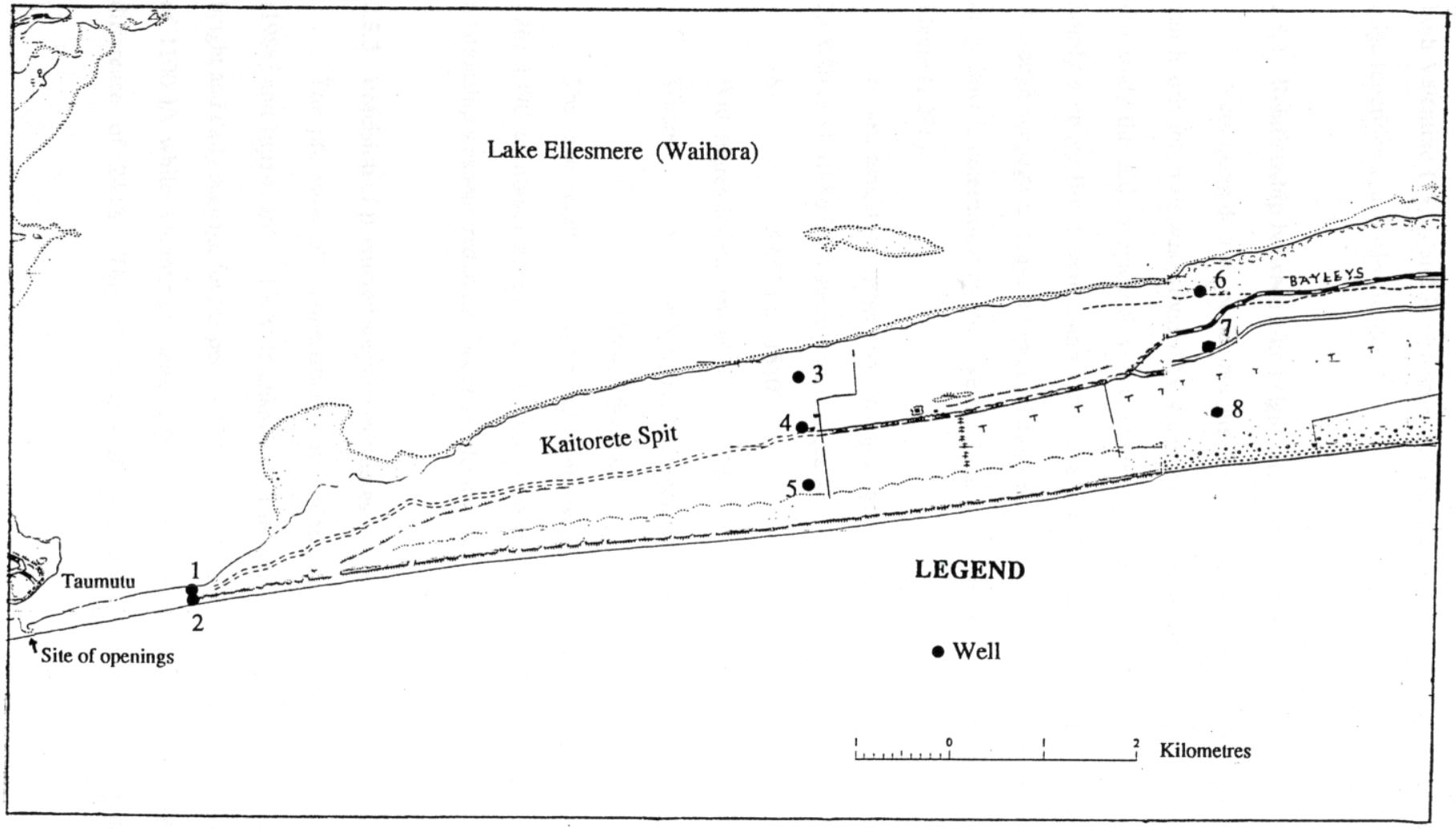


Figure 2.19 Well locations

Represents 6% of outflows – 1.2 $m^3 s^{-1}$

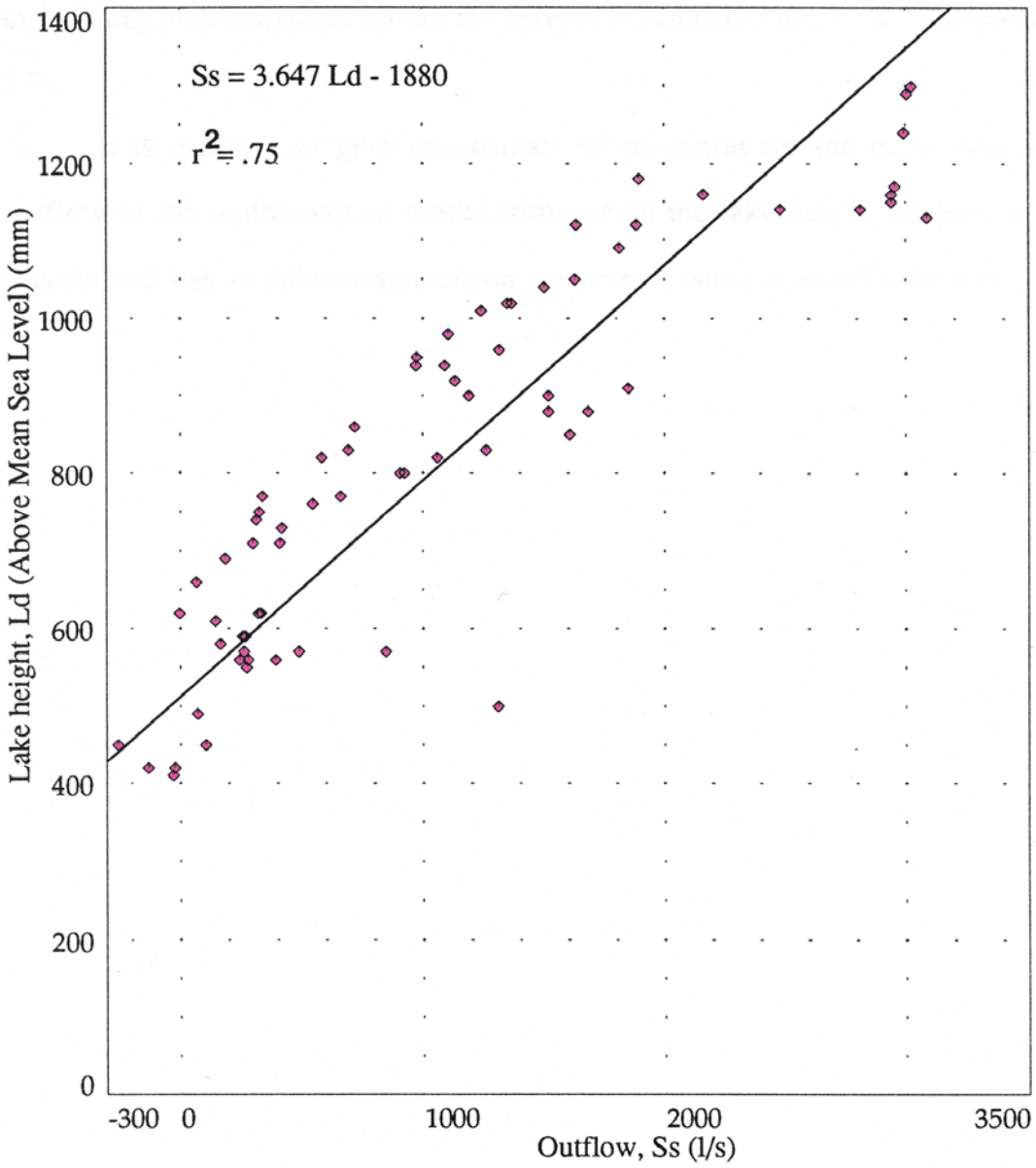
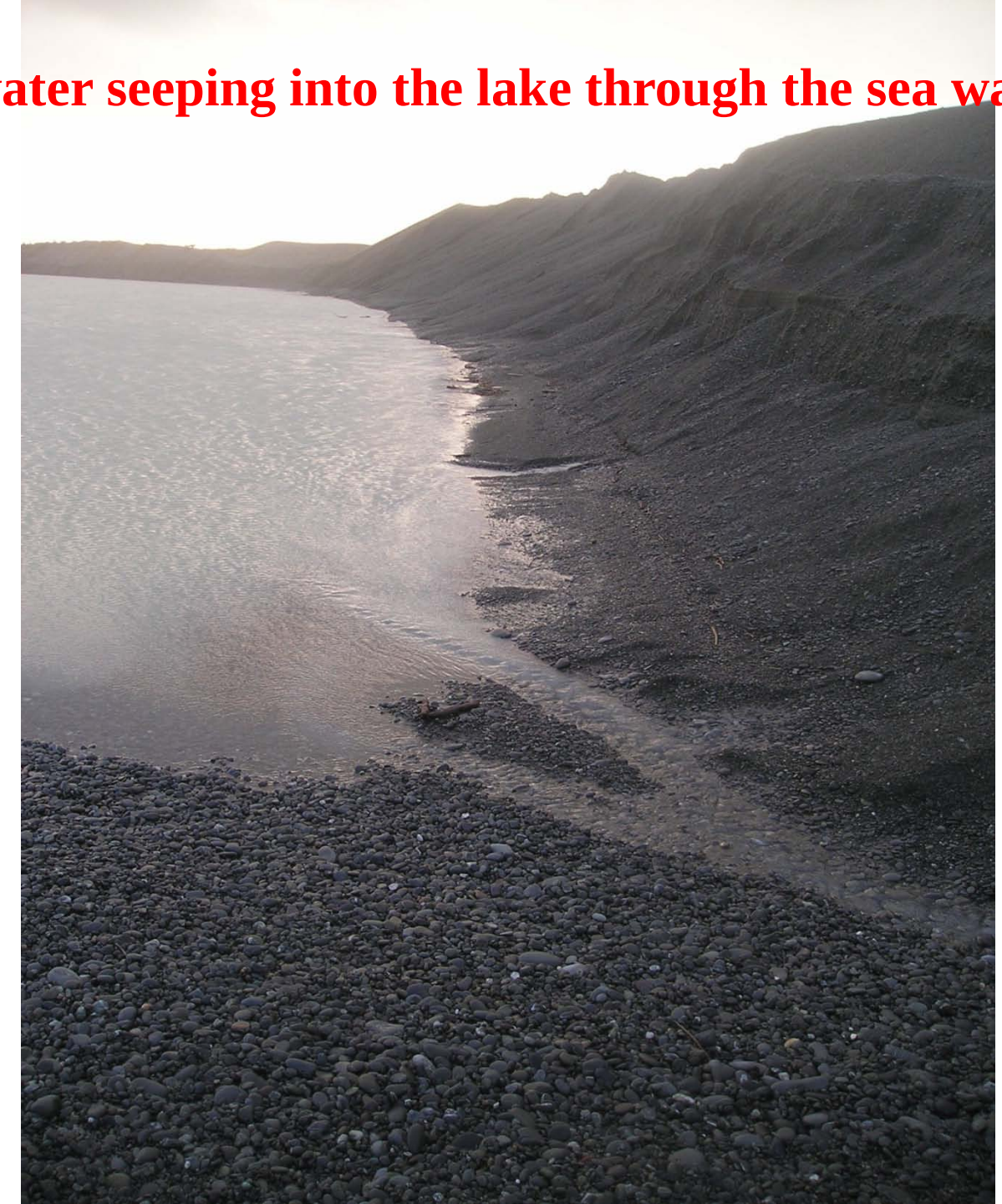


Figure 2.21 Relationship between daily seepage outflow and lake height: Kaitorete Spit

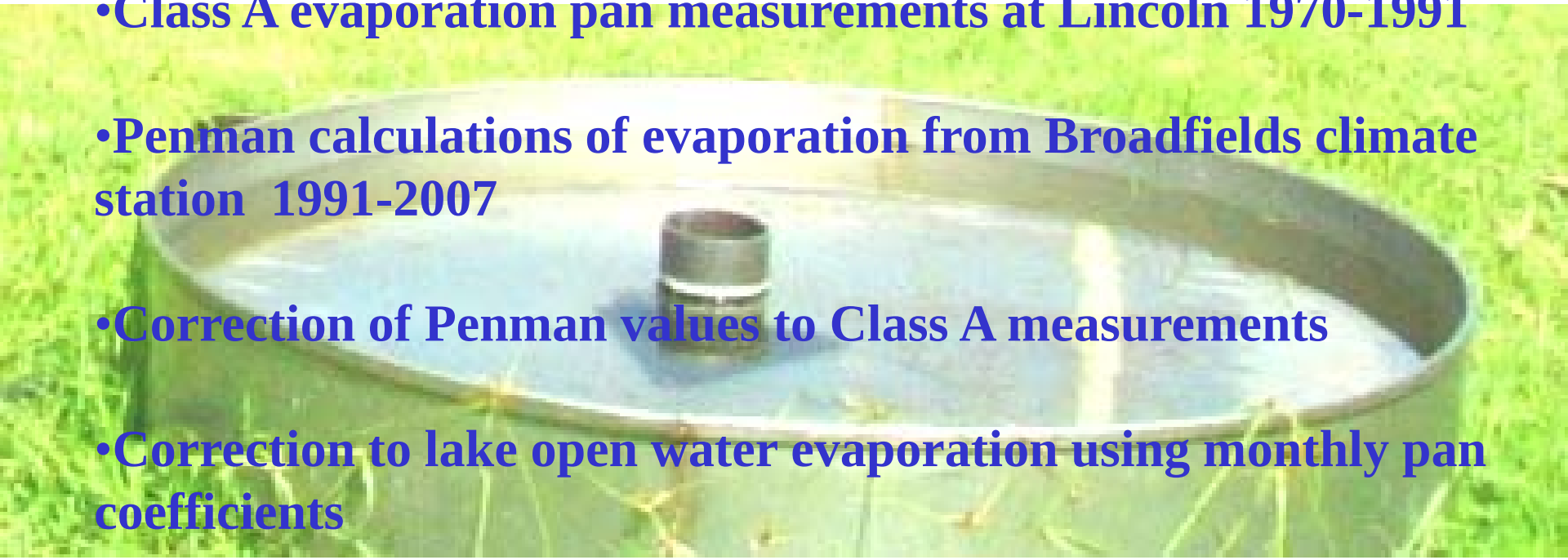
Sea water seeping into the lake through the sea wall



Evaporation

Lake evaporation was derived from:

- Class A evaporation pan measurements at Lincoln 1970-1991
- Penman calculations of evaporation from Broadfields climate station 1991-2007
- Correction of Penman values to Class A measurements
- Correction to lake open water evaporation using monthly pan coefficients



- Average annual lake evaporation is 1075 mm

Lake evaporation represents 34% of outflows – 6.6 $m^3 s^{-1}$

Artificial opening outflows

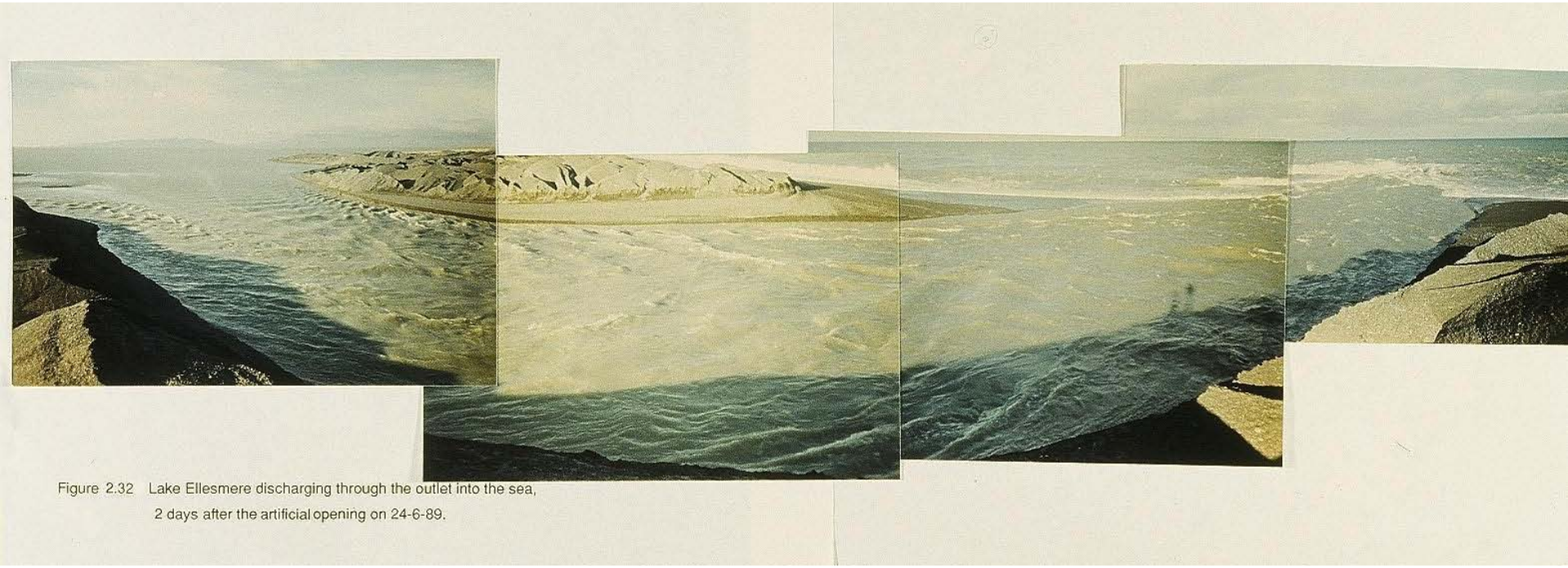


Figure 2.32 Lake Ellesmere discharging through the outlet into the sea, 2 days after the artificial opening on 24-6-89.

Artificial opening outflows represent 60% of outflows – 11.5 m^3 s^{-1}

Lake Ellesmere (Te Waihora) water balance

(It + Ir + Ig + Ias + Irs) - (Os + Oe + Oa) = Δs	Flow	%	Precision of variables
where: period : June 1986 - 2007	($m^3 s^{-1}$)		($m^3 s^{-1}$)
It = tributary inflows	12.5	62	1.2
Ir = rainfall inflows	3.3	16	0.3
Ig = groundwater	0.4	2	+ 0.4 or - 0.2
Ias = artificial opening sea incursion inflows	2.6	13	0.9
Irs = rough weather sea incursion inflows	1.5	7	+ 1.5 or - 0.7
Os = Kaitorete spit seepage outflows	1.2	6	0.3
Oe = evaporation outflows	6.6	34	1.1
Oa = artificial opening outflows	11.5	60	1.3
Δs = change in storage 9-6-1986 to 31-12-2007	0.1		

Total inflows (20.3 $m^3 s^{-1}$) are greater than the total outflows (19.4 $m^3 s^{-1}$) by 0.9 $m^3 s^{-1}$

Tributary inflows

Groundwater inflows

Rough weather sea incursions

Evaporation

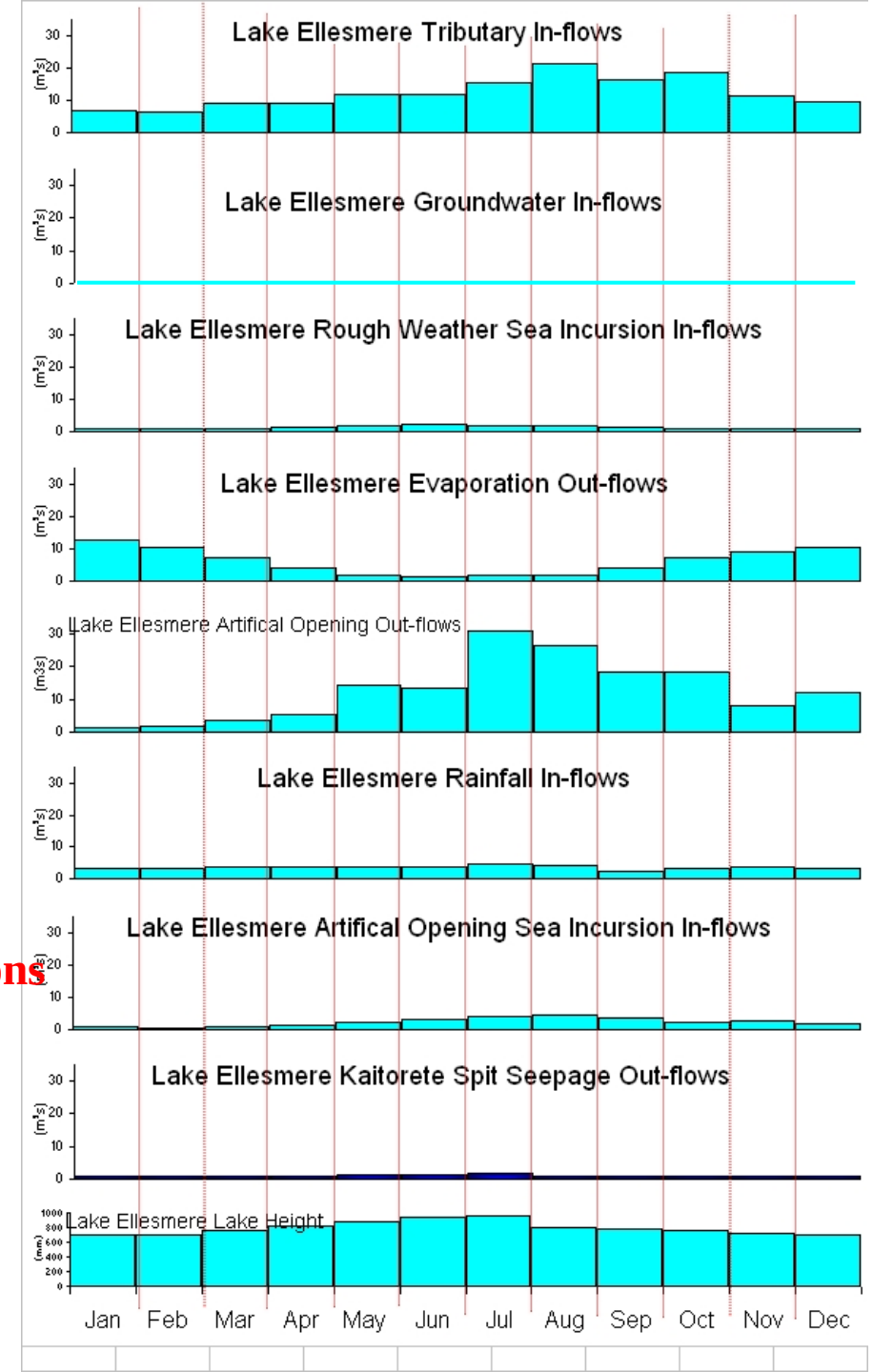
Outflows

Rainfall

Artificial opening sea incursions

Kaitorete Spit seepage

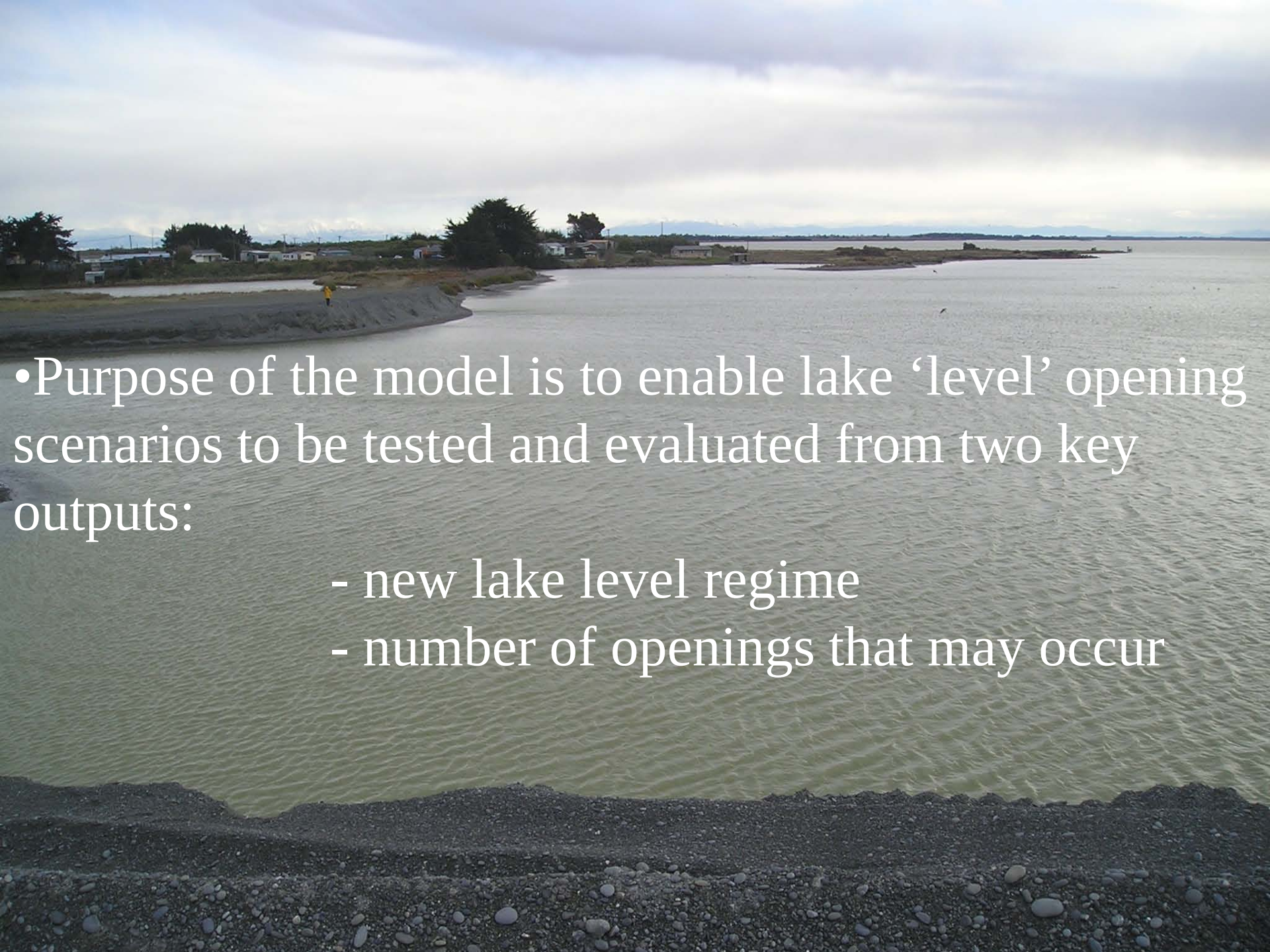
Lake level



Model development

Other necessary information

- Calm lake levels
- Lake area curve
- Wave conditions necessary for a successful opening, and the outlet closure
- Daily wave record



•Purpose of the model is to enable lake ‘level’ opening scenarios to be tested and evaluated from two key outputs:

- new lake level regime
- number of openings that may occur

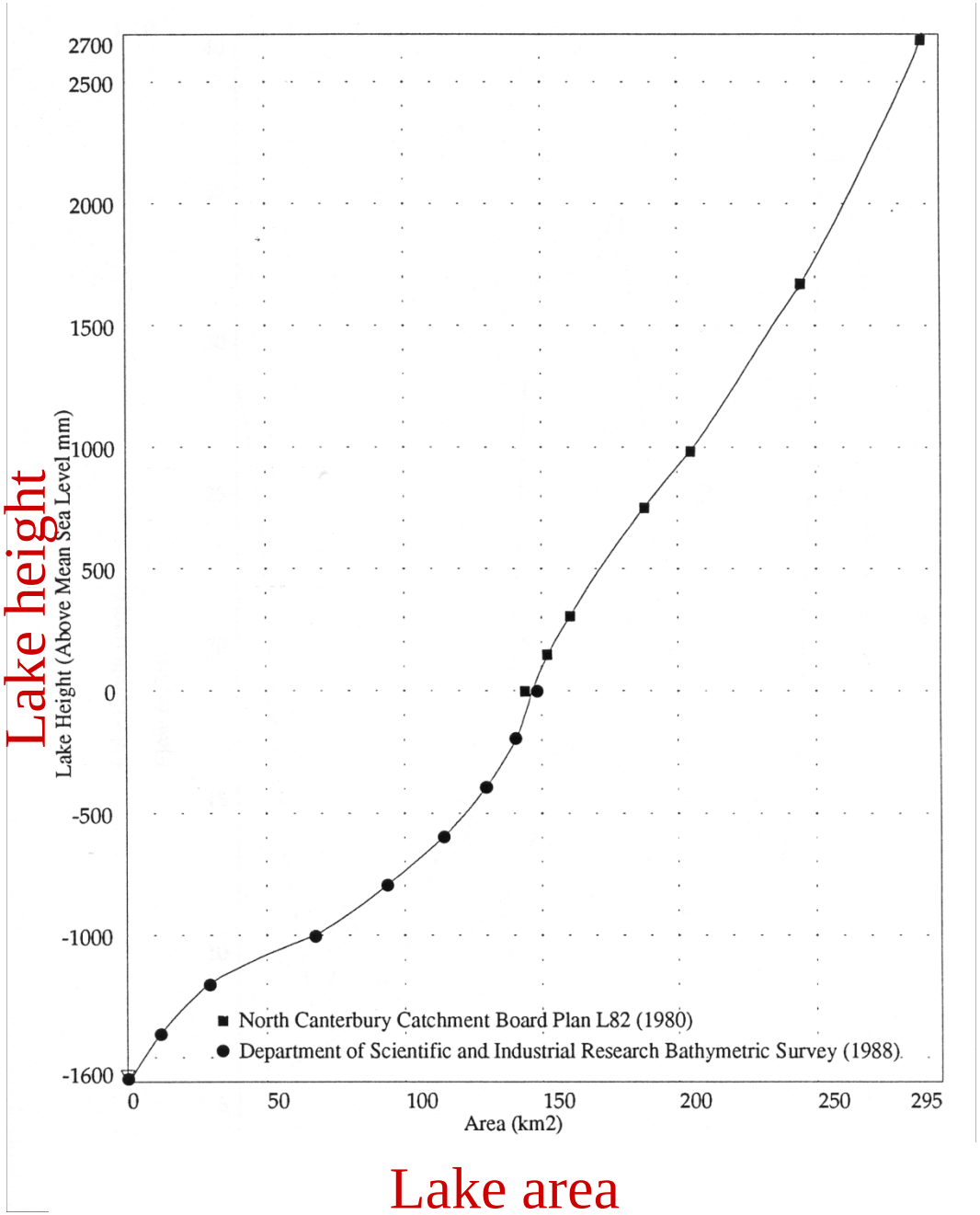
The Taumutu staff gauge – read daily form 1959 to 2005

Crucial to the model for – calm readings

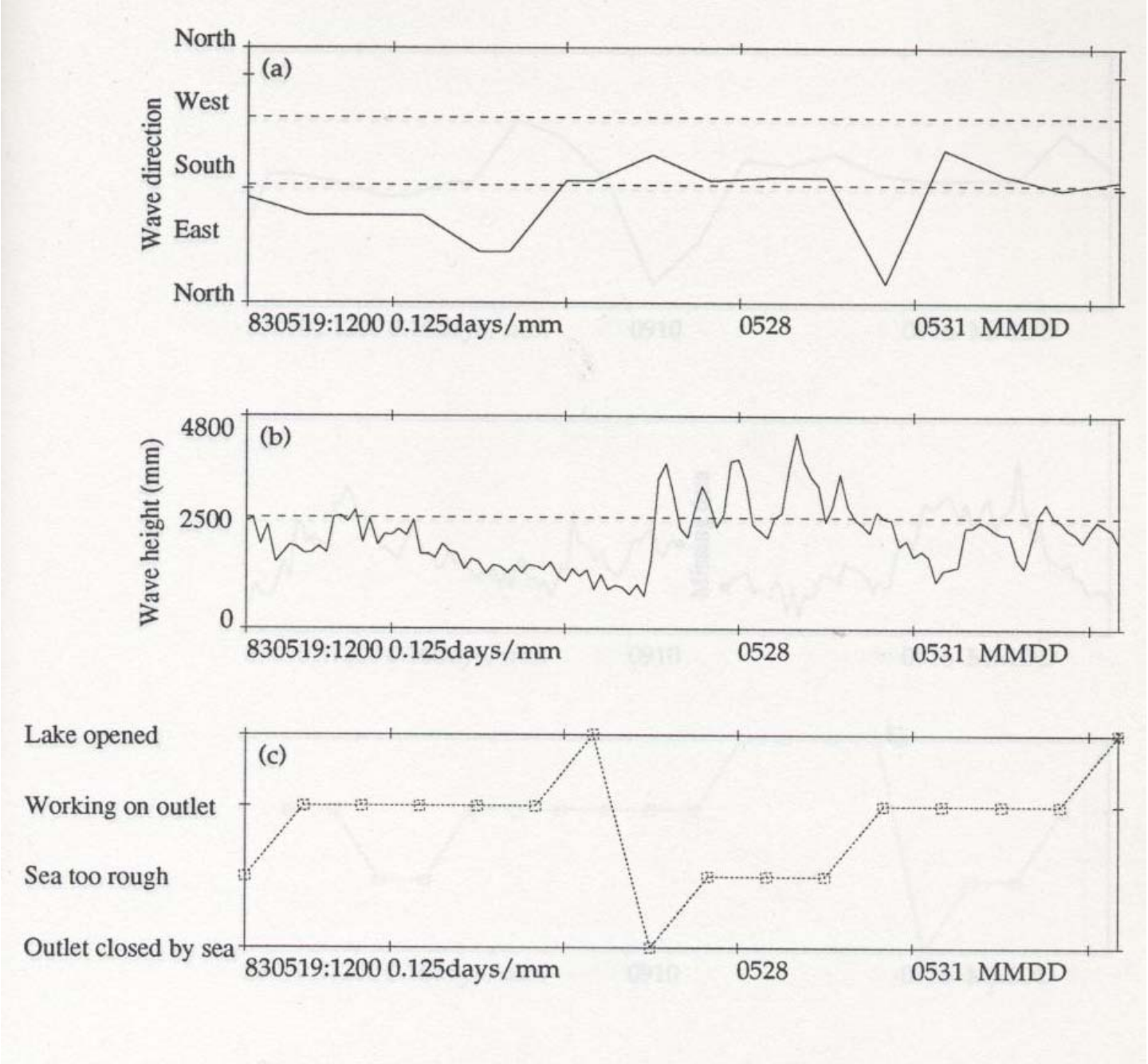
- wind and weather

- sea water overtopping barrier

Te Waihora area curve



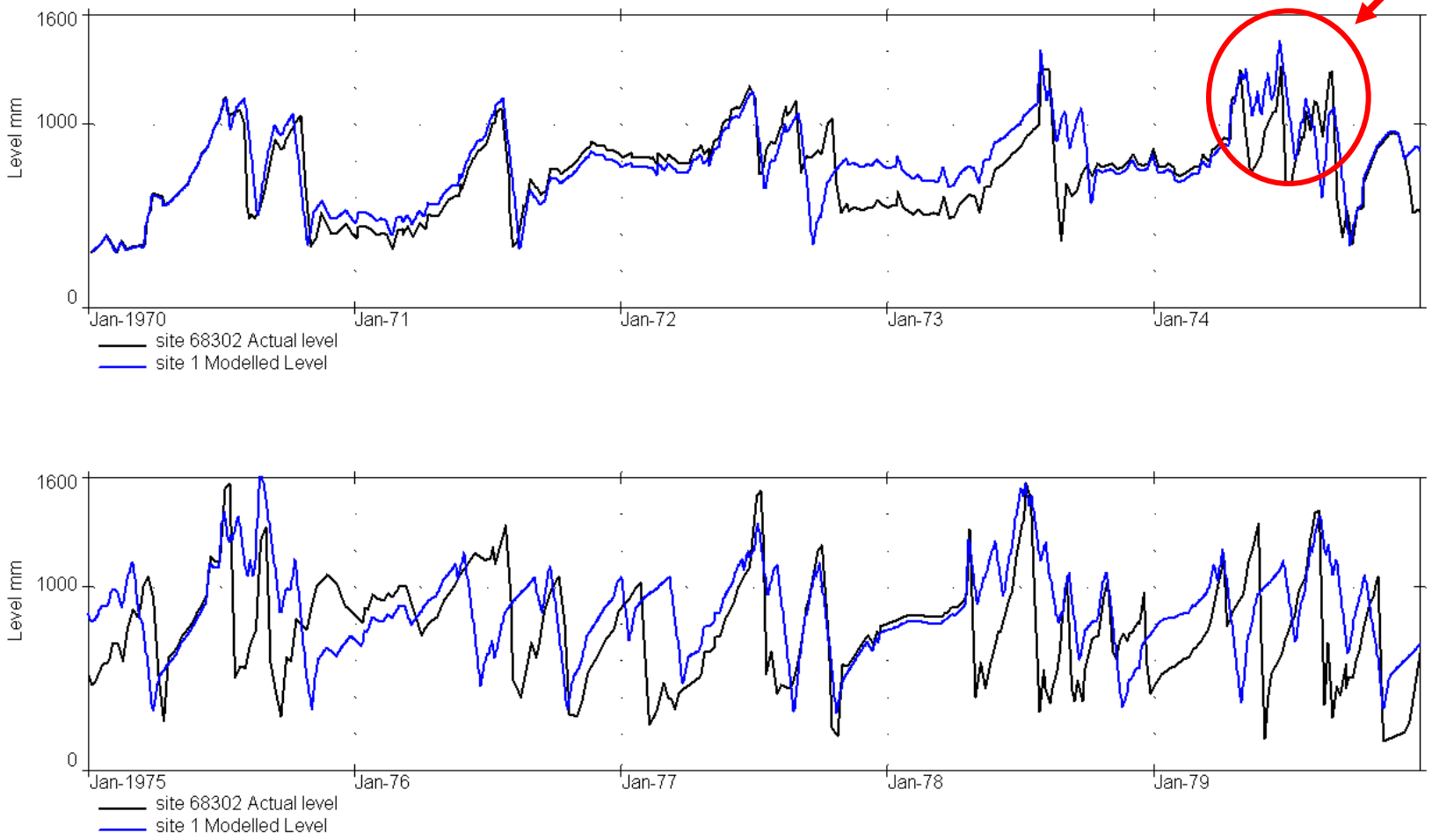
Deriving the relationship between sea conditions and the excavation of the opening



Model output

- 134 actual openings – model 137 (38 years)
- Modelling from 1st January each year – 133
- Comparison with Maori openings
- What did the natural lake levels look like ?

Number of openings dominated by the wave record



Comparison between actual and modelled lake level

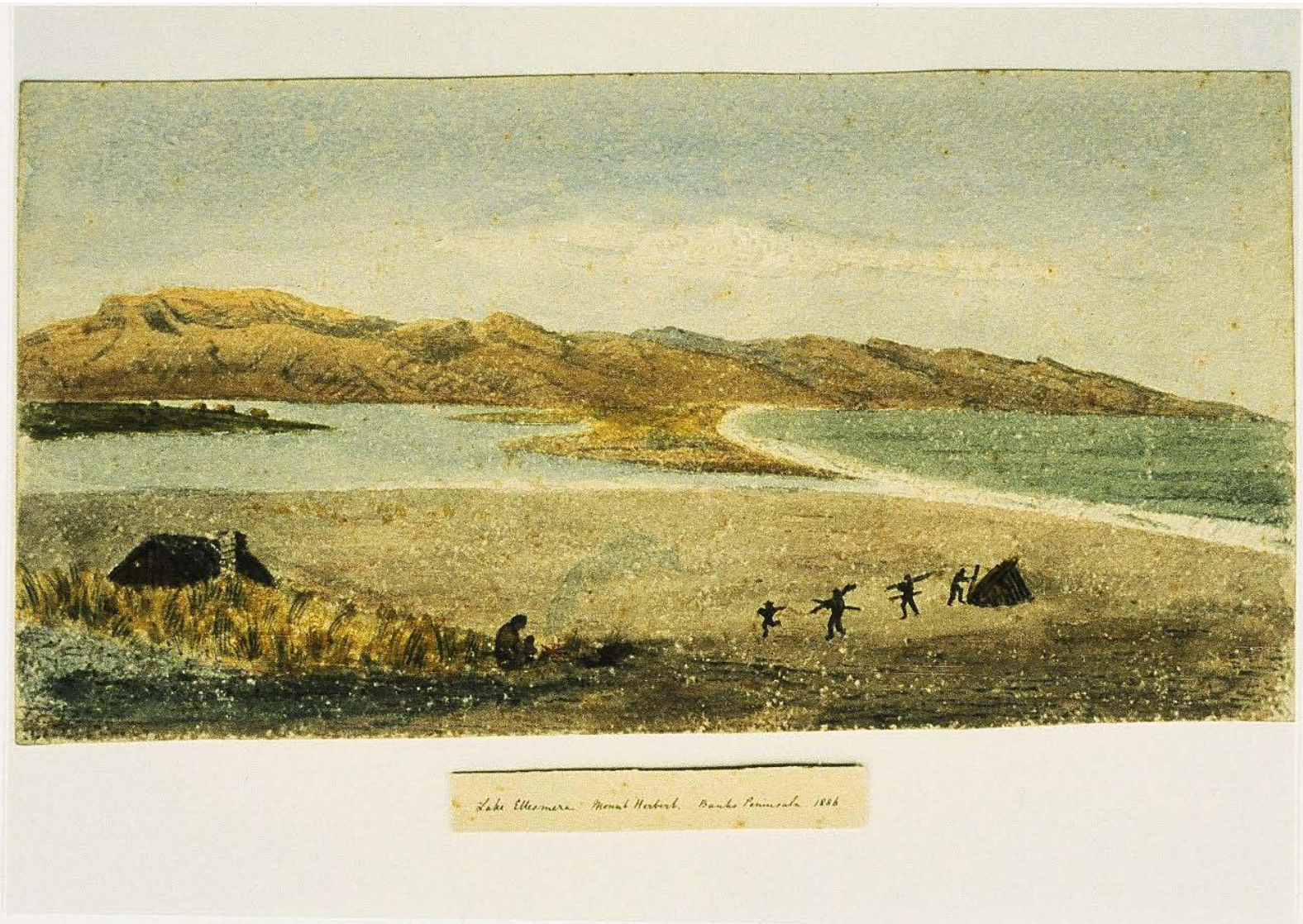


Figure 1.2 Historic opening 1886

(A.W. Hands, collection, Canterbury Museum)

Maori management

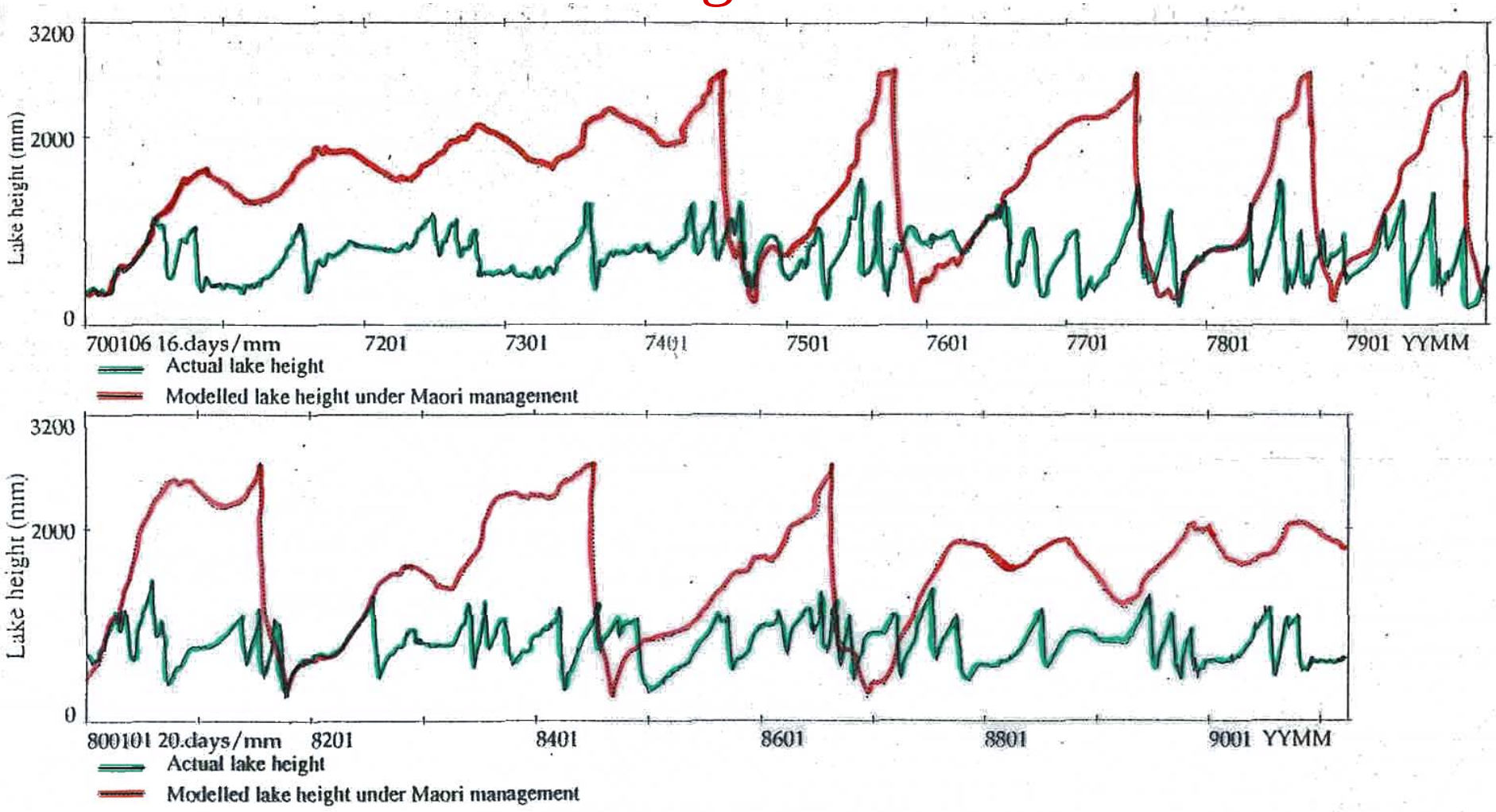


Figure 4.6 Comparison of lake heights under present management and Maori management: Lake Ellesmere

Natural conditions

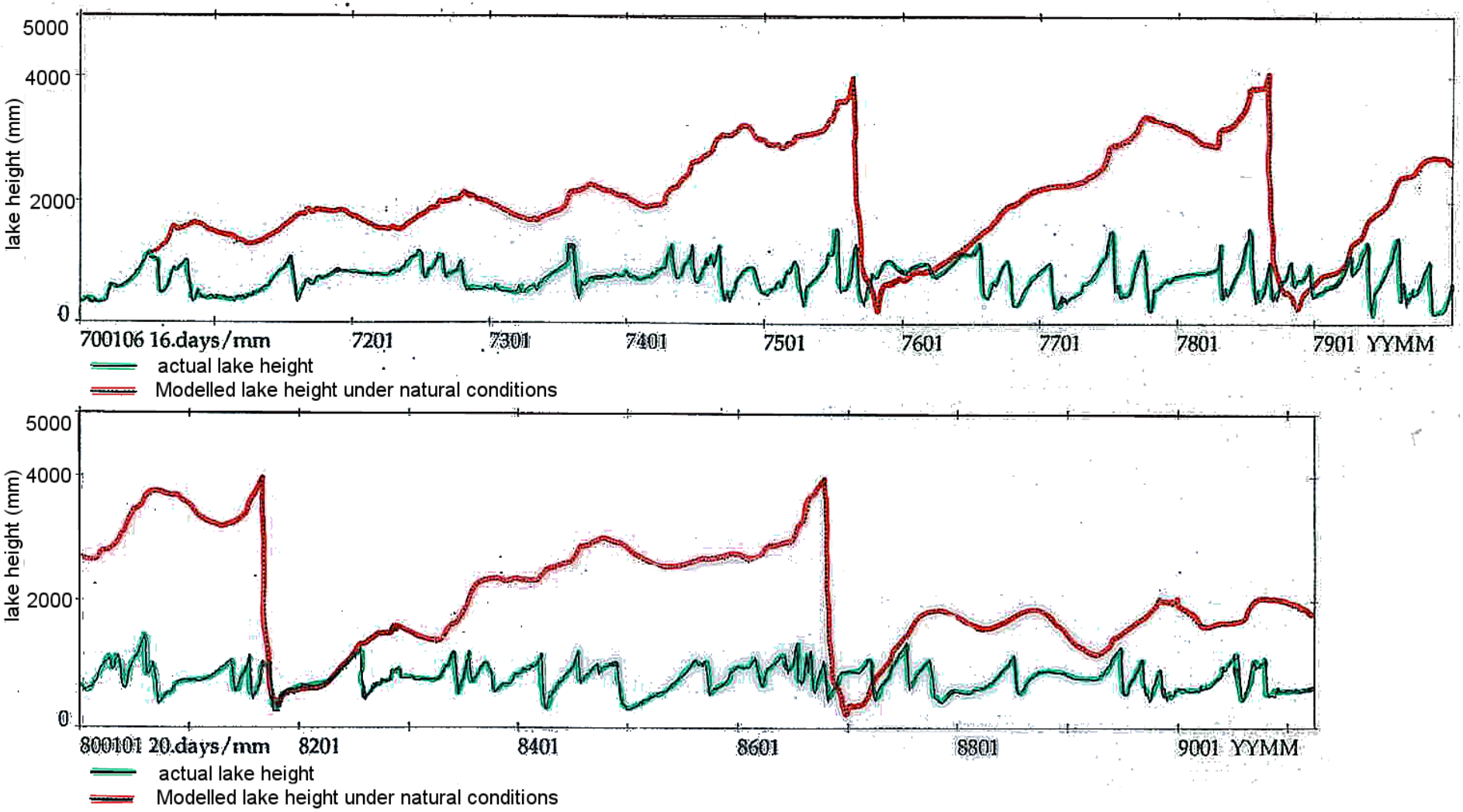


Figure 4.5 Comparison of lake heights under present management and natural conditions: Lake Ellesmere

Thank you