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WATTLE RANGE COUNCIL

Appendix 1 - Lake George

Lake George Tidal Inlet analysis

301015-03541 – 002

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**WATTLE RANGE COUNCIL
APPENDIX 1 - LAKE GEORGE
LAKE GEORGE TIDAL INLET ANALYSIS**

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PROJECT 301015-03541 - APPENDIX 1 - LAKE GEORGE

REV	DESCRIPTION	ORIG	REVIEW	WORLEY- PARSONS APPROVAL	DATE	CLIENT APPROVAL	DATE
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B	Draft	C Adamantidis	A Nielsen	A Nielsen	26-Sep-14		
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1 ESCOFFIER ANALYSIS OF LAKE GEORGE OUTLET

The cross-sectional stability of a tidal inlet has been first analysed by Escoffier in 1940. Escoffier's theory analysed the permanency of the stability of the entrance depending on its size and the maximum current speed at the entrance. The relationship between cross-sectional area and maximum velocity is illustrated in Figure 1. When the maximum velocity is equal to the equilibrium velocity, the cross-sectional flow area is in equilibrium and the entrance is stable. When the maximum velocity is lower than the equilibrium velocity, the current is not strong enough to move the sediments carried into the inlet by littoral drift and the sediments will be deposited into the entrance reducing the cross-sectional area. When the maximum velocity is higher than the equilibrium velocity, the sediment transport capacity of the inlet currents will be larger than the volume of sediment carried into the inlet entrance by littoral drift and the entrance will therefore erode and the cross-sectional area will increase. From this and Figure 1, it can be observed that:

- if the cross-sectional area A is lower than A_1 ($A < A_1$), the sediments will deposit into the entrance and the entrance will tend to close over time;
- if $A > A_e$, the sediments will be deposited into the inlet entrance and the entrance cross-sectional area will reduce until $A = A_e$;
- if $A = A_1$, the equilibrium is unstable. If there is any storm depositing or removing some sediment from the entrance, the entrance would either close or widen to reach the equilibrium area A_e ; and
- if $A = A_e$, the equilibrium is stable. If a storm deposits or removes some sediments from the entrance it will recover to reach $A = A_e$.

If the cross sectional area is higher than the value which yields the maximum velocity in Figure 1, the entrance cross sectional area will increase and the entrance will erode until $A = A_e$.



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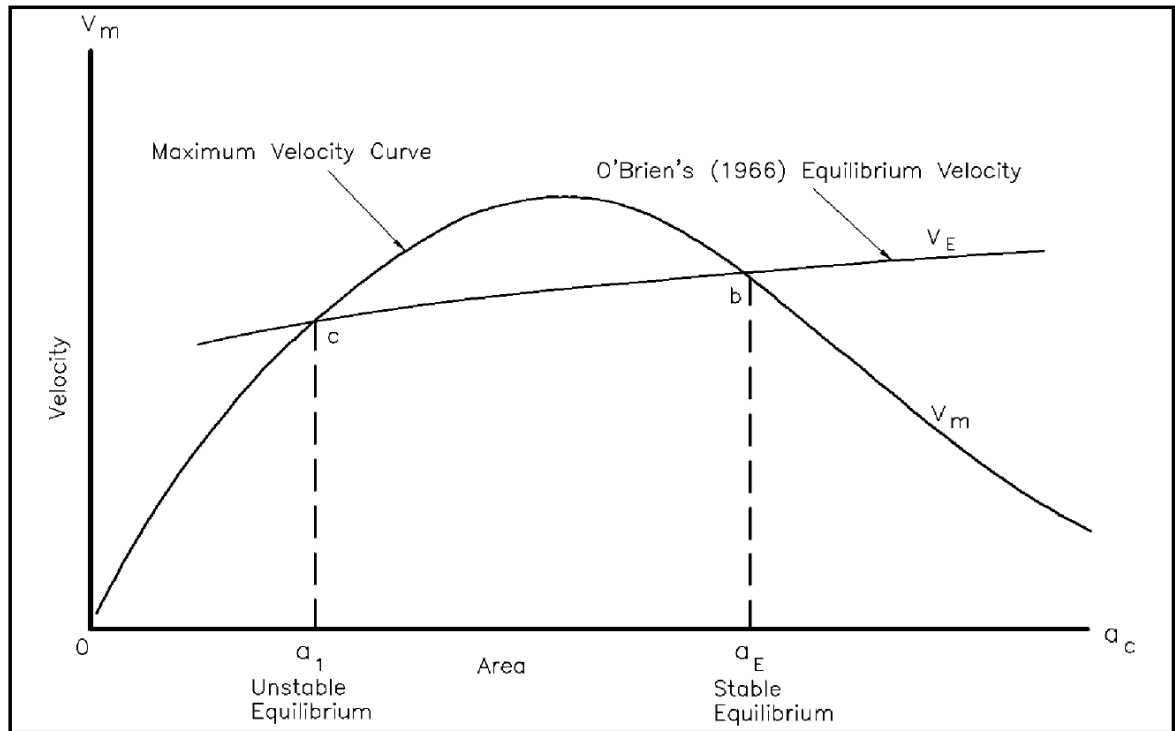


Figure 1 - Escoffier (1940) curve, maximum and equilibrium velocities versus inlet cross-sectional area (C.E.M., Chap. II-6)

However, the equilibrium cross-sectional area may be subject to long term changes. O'Brien (1969) determined a relationship between cross-sectional area and tidal prism. Assuming a maximum velocity $u_i = \hat{u}_i \sin(\omega t)$ with ω the angular frequency of the tide and t the time, it follows:

$$\Omega_i = \frac{A_i \hat{u}_i T}{\pi} \quad (1)$$

with Ω_i = Tidal Prism of the estuary

A_i = Cross-sectional area of the inlet entrance

T = Tidal period

This formula is usually presented as:

$$A = C\Omega^n \quad (2)$$



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with C and n free parameters. These parameters can be obtained by analysing the correlation between the tidal prism and the cross-sectional area of several estuaries located within the same region.

O'Brien (1969)'s empirical relationship used $C = 4.69 \times 10^{-4}$ and $n = 0.85$, in imperial units, for the values of the exponents C and n in Equation 2 above. In the absence of site-specific data, this cross-sectional area-tidal prism relationship has been used for the Lake George inlet.

The stability of the Lake George outlet was analysed using the Channel Equilibrium Area model created by the Coastal Inlets Research Program (CIRP) from the US Army Corps of Engineers. This model allows the determination of the Escoffier curve and therefore the estimation of the channel equilibrium area based on the channel and outlet characteristics, the tidal prism and the tidal parameters. The parameters used in the calculation are as follows:

- Fundamental Ocean Tide Amplitude – this value is one half of the tidal range and the spring tide is typically used (around 0.45 m for Lake George);
- Ocean Overtide Amplitude – M4 tidal constituent amplitude (0.001 for Beachport);
- Tidal Period (24.84 hrs for diurnal tides);
- Tidal Mean Basin Surface Area – Surface area of the lake and estuary (estimated to be around 60,000,000 m²);
- Hydraulic Radius – average depth of the channel (estimated to be around 2 m after the channel has been dredged);
- Channel width – width of the minimum cross sectional area (estimated from aerial photography to be around 25 m)
- Channel length – estimated to be around 1250 m from aerial photography;
- Channel area – estimated to be around 50 m²
- Entrance loss coefficient K_{en} – value from 0.05 for a relatively streamlined inlet, to 0.25 for an inlet with dual jetties (i.e. 0.25 used here);
- Exit loss coefficient K_{ex} – a value of 1.0 for the exit loss coefficient describes a relatively deep bay and complete loss of kinetic head – smaller values can be tried during calibration); and
- Manning's Coefficient (n value) – this bed resistance parameter may have typical values between 0.025 and 0.05 for inlets (a value of 0.025 was used in the calculation).

The results of the analysis are provided in Figure 2. These results were compared with five-minute water level data within the middle basin of Lake George provided by the South Eastern Water Conservation and Drainage Board for September 2007, when it was known from weir management history provided by the South Eastern Water Conservation and Drainage Board that the weir was open, and a tidal signal was clearly discernible in the water level data. It was found that the CEA model correctly predicted the amplitude of the tidal signal within the Lake based on the channel



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properties provided. It should be noted that the model is only able to predict the tidal amplitude within the Lake, but does not take into account factors such as freshwater inputs to the lake, barometric setup and tidal setup due to friction through the entrance channel which would influence the mean level within the lake.

The Escoffier curve resulting from the model is illustrated in Figure 3. From this figure, it is observed that the existing channel is unstable, with a cross-sectional area too low to maintain an open channel with the channel tending to close over time. Given the very low tidal range within the lake and therefore the low tidal prism, as well as the various dimensions of the channel entrance, the current velocities will be low and this would result in sand deposition within the entrance over time. Therefore the lake entrance tends to reduce and would eventually close if dredging is stopped. Flood events may increase the flow at the entrance and generate erosion that would deepen the entrance temporarily.

Should the channel geometry be changed such that the cross-sectional area be increased to a value greater than around 600 m² over its entire length (and the channel be allowed to modify its dimensions naturally – i.e. is not constrained by the training walls), the channel would be in an unstable equilibrium and would tend to increase its cross-sectional area until a stable equilibrium is reached (i.e. around 3000 m²). Under such conditions, the channel would be in an unstable scouring mode (i.e. it would continue to scour until the stable equilibrium is reached). It is not considered feasible to modify the channel such that the cross-sectional area is in a stable equilibrium, as the channel would need to be excavated to a much greater width and depth than exists at present and severe bank erosion could result. In addition, increasing the channel dimensions to a level required to achieve a stable equilibrium would lead to increasing tidal ranges within the lake and a change in the ecology of the lake due to the increased tidal range and modified salinities.



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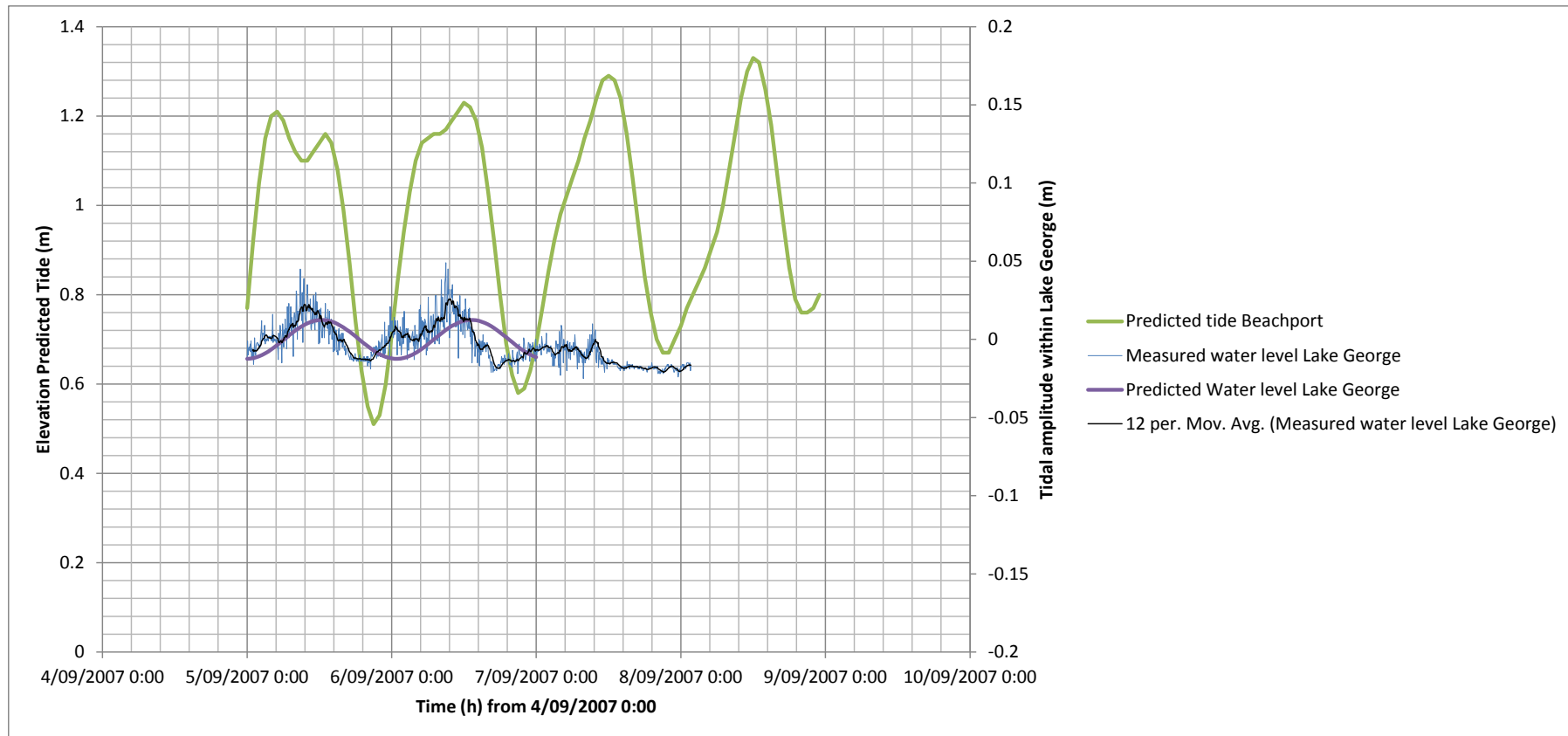


Figure 2 – Comparison of measured lake levels within the middle basin of Lake George with predicted ocean tide and predicted lake tidal signal from CEA model



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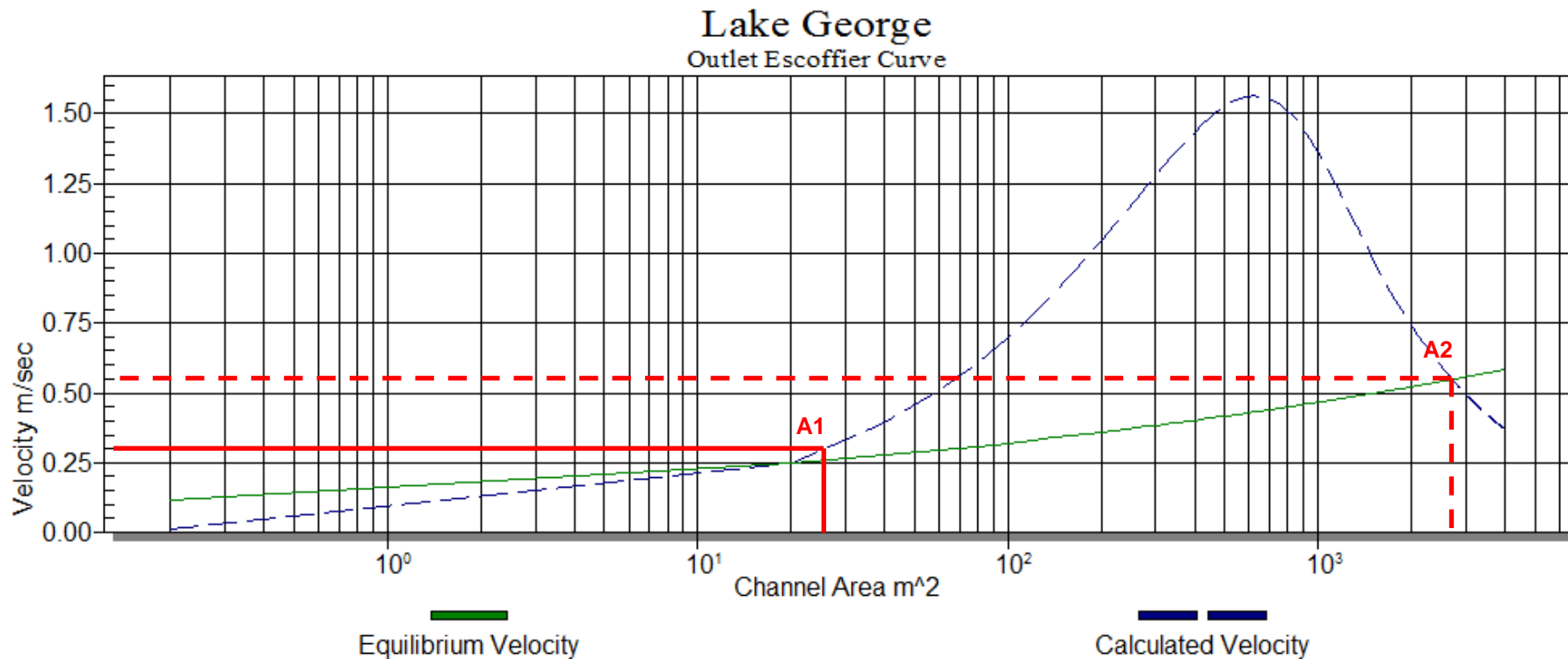


Figure 3 – Escoffier curve for Lake George outlet



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2 REFERENCES

Escoffier, F. F. (1940) The Stability of Tidal Inlets. Shore and Beach, Vol. 8, No. 4, pp 114-115

O'Brien, M. P. (1969). "Equilibrium Flow Areas of Inlets on Sandy Coasts," Journal of the Waterways and Harbors Division, American Society of Civil Engineers, No. WWI, pp 43-52.