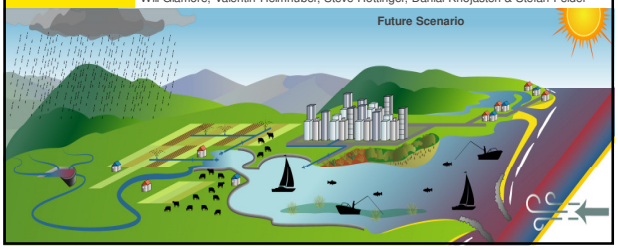
Water Research Laboratory | School of Civil & Environmental Engineering

Climate Change in Estuaries: Moving Beyond the High Tide

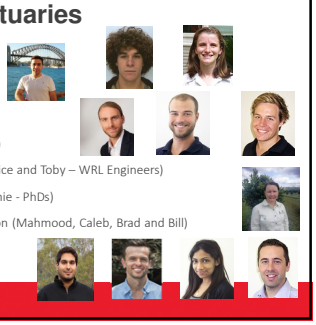
Will Glamore, Valentin Heimhuber, Steve Hottinger, Danial Khojasteh & Stefan Felder



Climate Change in Estuaries

Research on:

- Estuary hydrodynamics (Danial - PhD)
- Entrance dynamics (Steve - Masters)
- Hydro-ecological dynamics (Tino – Post Doc)
- Restoration and climate change (Duncan, Alice and Toby – WRL Engineers)
- Water quality, Estuaries & SLR (Kate and Jamie - PhDs)
- Vegetation, Blue Carbon and Tidal restoration (Mahmood, Caleb, Brad and Bill)



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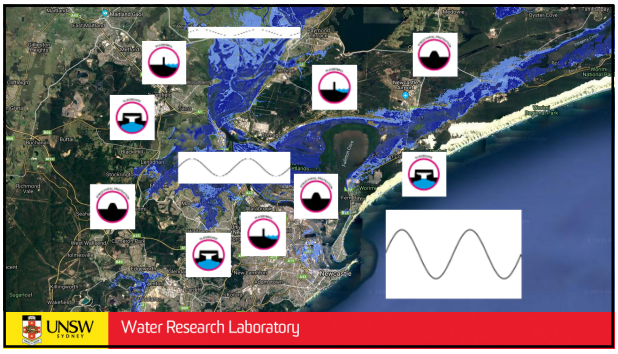

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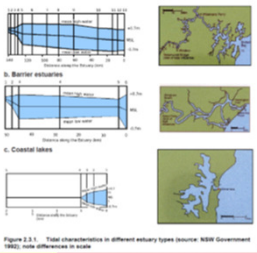
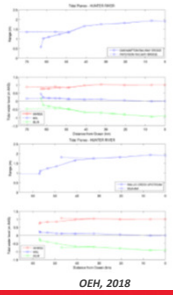
Tides & SLR in Estuaries





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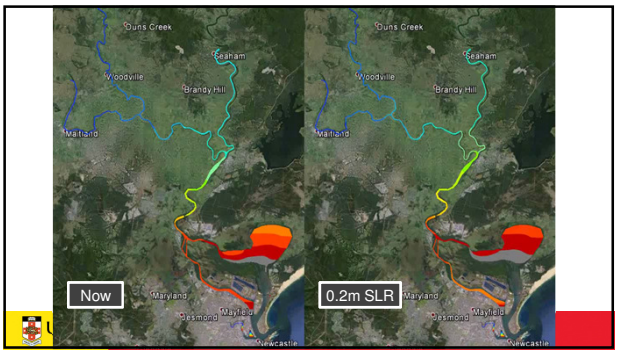
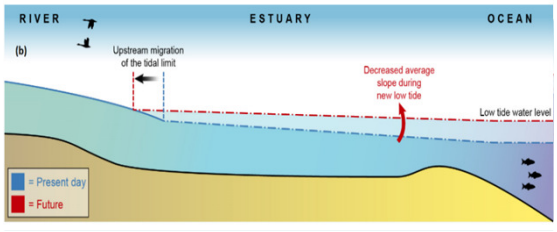


Tidal Dynamics Under SLR



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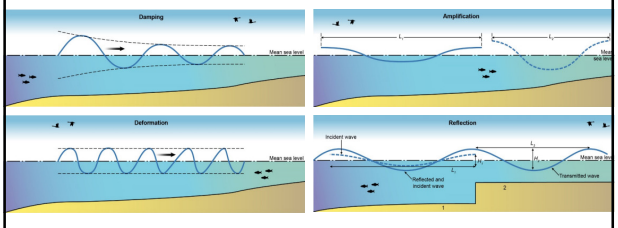
The tidal wave is dynamic…



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Why should I care?

Coastal Properties	Estuary Properties
Now: 250	Now: 8,500
2100: 3,300	2100: 50,700

Source: NSW Estuary Tidal Inundation Exposure Assessment

Important for:

- Drainage/Inundation
- Planning
- Water quality (turbidity, salinity, etc)
- Extraction & Discharges
- Groundwater
- Ecology

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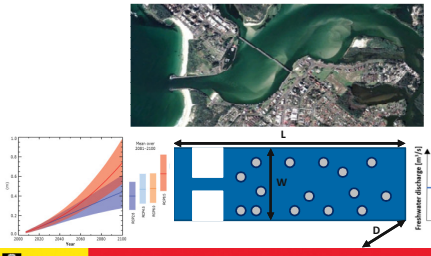
Estuaries and SLR



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Methodology

154 simulations performed

Main parameters analysed	Other parameters used
• Tidal range • Flow velocity • Tidal duration asymmetry • Tidal current asymmetry	• Tidal prism • Froude number • Phase difference • Min/max water surface elevation

Parameters	Scenarios
Estuary length	40, 60, 80, 100, 160 [km]
Estuary width	1 [km]
Estuary depth	- 2, 3, 4, 5, 6 [m]
Inlet restriction width	0, 40, 50, 60, 70, 80, 90 [%]
Inlet restriction length	500, 1500 [m]
SLR	0, 1, 2 [m]
Tidal range	0.5, 1, 4 [m]
Tidal period	12.5 [hr]
Rugosity (Manning)	0.03 [s/m$^{1/3}$]
$\frac{Freshwater\ inflow}{Tidal\ prism}$	0 , 0.1

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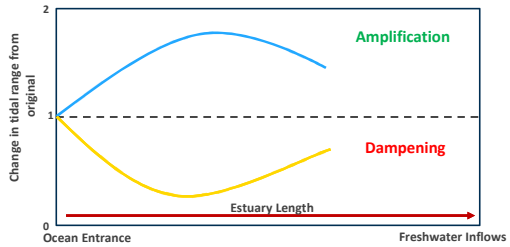
SLR in Estuaries: Friction, Resonance, Reflection



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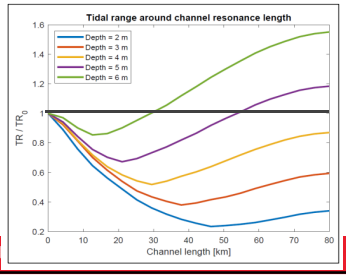
Reflection, Resonance & Friction

Amplification

At unity, bucket models apply.

Dampening



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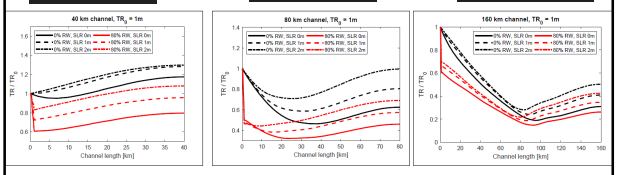
40 km estuary | **80 km estuary** | **160 km estuary**



*Short rivers are dominated by **reflection***
*Longer estuaries are dominated by **friction***
SLR decreases friction

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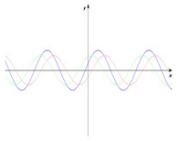
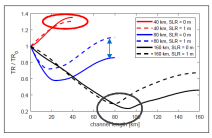
Tidal Resonance





- ***Weak tidal forcing***
  - → *Resonance effects*
- ***Strong tidal forcing***
  - → *No resonance effects*

Tidal forcing	Channel length		
	Short (40 km) *Below resonance length*	**Intermediate (60-100 km)** *Around resonance length*	**Long (160 km)** *Above resonance length*
Micro (0.5 m)	TR decrease with SLR	TR higher increase due to SLR than for other channel lengths	Nodes are shifted downstream
Meso (1 m)	Lower TR increase with SLR than for other channel lengths	Higher TR increase with SLR than for other channel lengths	Nodes are shifted downstream
Macro (4 m)	Non-visible resonance effects	Non-visible resonance effects	Non-visible resonance effects

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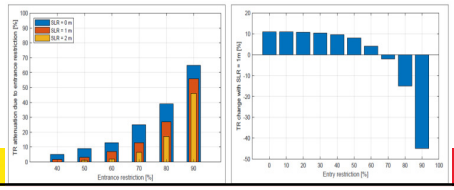
SLR and entrance restriction

- → *As sea levels go up, entrance losses go down (less friction)*
- → *Tidal range goes up by 10% with 1m SLR, until entrance restrictions cause tidal range to decay (due to more friction)*



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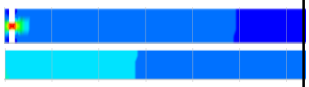
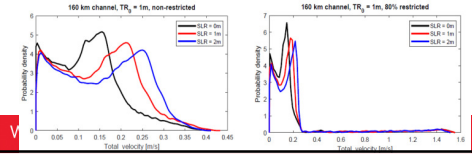
Velocity & entrance restriction

1. *SLR changes velocity*
2. *SLR acts on **velocity distribution***
3. *Potential impact on erosion and sediment distribution*





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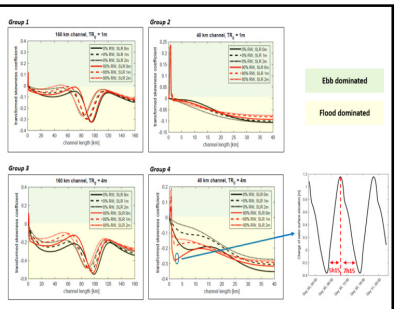
Tidal Asymmetry

- *NSW Estuaries are flood dominated*
- *SLR decrease this flood domination*
- *Potential impact on erosion and sediment distribution*



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Summary

Initial research suggests that SLR is likely to:

- **Expect altered tidal patterns** due to changes in friction, reflection and resonance.
- Importance of controlling factors: **(1) Tidal range, (2) Channel length, (3) SLR amount, (4) entrance width and (5) restriction length**.
- Can result in **higher tidal ranges** (if entrance is open >50-80%) but pattern is not linear.
- Changes to entrance **velocity**, changes velocity distributions upstream.
- Decrease **flood tide dominance may** shift sediment transport regime.
- So… **future decisions need better planning tools!**

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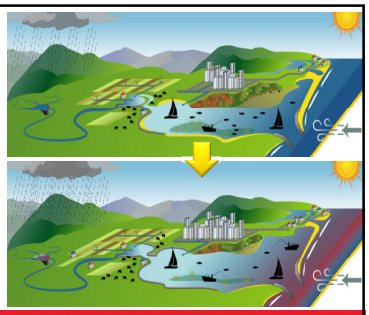
Questions?



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Introduction | Methodology | Estuarine Physics | **Results/Discussion** | Conclusion

Discussion

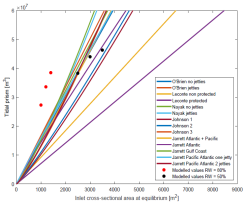
Inlet stability

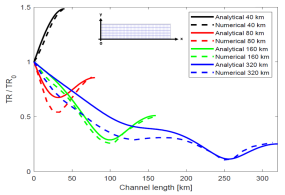
- *Morphodynamics equilibrium according to O'Brien*

$$A = 6.56 \cdot 10^{-5} \cdot P$$

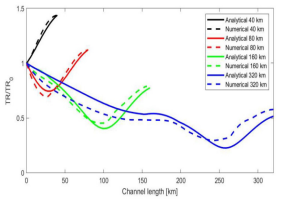
	Current restriction cross-sectional area [m2]			O'Brien equilibrium restriction cross-sectional area [m2] according to the simulated tidal prisms		
	SLR = 0 m	SLR = 1 m	SLR = 2 m	SLR = 0 m	SLR = 1 m	SLR = 2 m
50% restricted inlet	2500	3000	3500	2510	2890	3040
80% restricted inlet	1000	1200	1400	1790	2210	2530

- *80% restricted channels are not in equilibrium*
- *Results realistic if inlets occurs between solid banks*
- *Other $A = f(P)$ relationships*





$$n_{r,f} = 0.5\overline{n}_h (f_s)^{-1} [e^{-\beta(x-L)} \cos(\omega t - k(x-L)) + e^{\beta(x-L)} \cos(\omega t + k(x-L))]$$



$$n_{r,f} = 0.5\overline{n}_h (f_s)^{-1} [e^{\beta(x+L)} \cos(\omega t - k(x-L)) + e^{\beta(-x-L)} \cos(\omega t + k(x-L))]$$