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### Publication date

2014

### Document Version

Final published version

### Citation (APA)

Duong, T., Ranasinghe, R. W. M. R. J. B., Luijendijk, A., Walstra, D. J., & Roelvink, D. (2014). *A qualitative assessment of climate change impacts on the stability of small tidal inlets via schematised numerical modelling*. Poster session presented at 34th International Conference on Coastal Engineering, Seoul, Korea, Republic of.

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# A QUALITATIVE ASSESSMENT OF CLIMATE CHANGE IMPACTS ON THE STABILITY OF SMALL TIDAL INLETS VIA SCHEMATISED NUMERICAL MODELLING

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## Research Questions:

1. Are currently available predictive tools capable of simulating CC impacts on more commonly found small tidal inlet (STI) systems?
2. Nature and magnitude of full range potential CC impacts on these systems?

## Modelling approach:

| Present condition simulation (PS)                                                                                                             | Climate Change simulations (CS)                                                                                                                                                                                                                                |
|-----------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| - schematised monthly averaged wave and riverflow forcing; simplified tidal forcing, representing contemporary conditions at the study areas. | - Varying MSL (i.e. SLR), wave, riverflow; <b>in-isolation (G1) and in combination (G2)</b> .<br>+ SLR (by 2100): 1m<br>+ $H_s$ , $\theta$ and $R$ vary (from PS values)<br>- Simulation duration: same as PS<br>- Basin infilling included in SLR simulations |

## Methods:

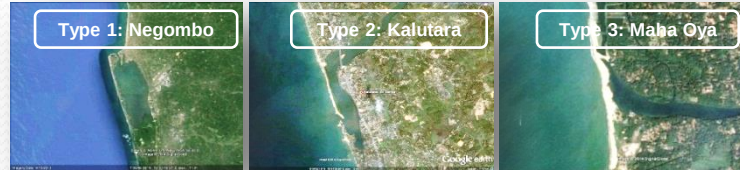
- Series of strategic idealised model applications, using Delft3D.
- Schematised inlet/forcing conditions representing 3 main inlet morphodynamic characteristics:

Type 1: Permanently open, locationally stable inlet

Type 2: Permanently open, alongshore migrating inlet

Type 3: Seasonally/Intermittently open, locationally stable inlet

- Representative sites: Type 1 – Negombo lagoon; Type 2 – Kalutara lagoon; Type 3 – Maha Oya river (Southwest coast of Sri Lanka).



## Model Results: Inlet stability indicator: $r=P/M_{tot}$

(Bruun, 1978:  $M_{tot}$ =annual littoral drift ( $m^3/year$ ),  $P$ = tidal prism ( $m^3$ ))

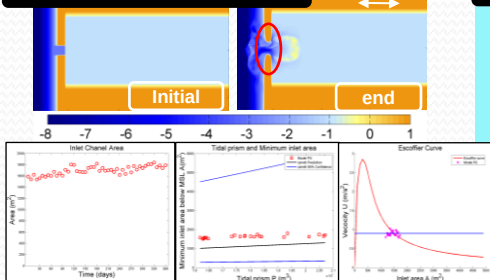
| $r=P/M_{tot}$         | > 150 | 100 – 150 | 50 – 100     | 20 – 50 | < 20     |
|-----------------------|-------|-----------|--------------|---------|----------|
| Bruun Classifications | Good  | Fair      | Fair to poor | Poor    | Unstable |

### Type 1: Stable Inlet

### Type 2: Migrating inlet

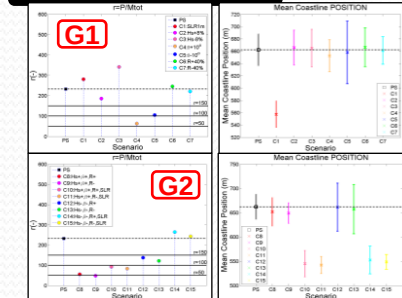
### Type 3: Intermittently Closing Inlet

#### 1. Present Simulation



- Inlet locationally, cross-sectionally stable,  $r=233$  (consistent with Bruun criteria)
- Model results agree with Jarrett 1976 AP relationship and Ebb-flood curve

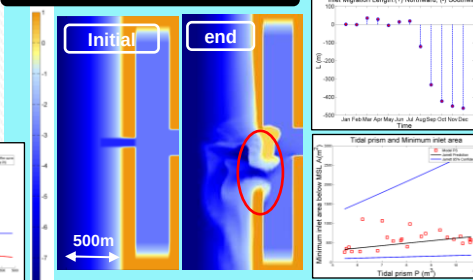
#### 2. CC Simulations



### 3. Conclusions

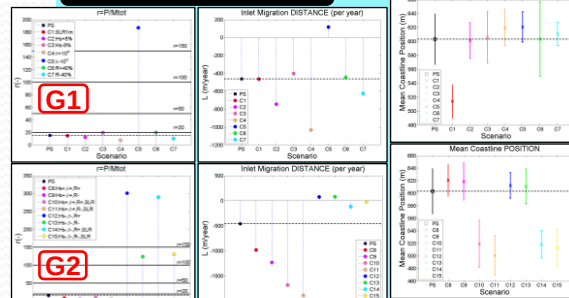
- Type 1 inlet does not change** its behavior significantly (does not change type) due to CC driven variations in system forcing but its stability can change significantly ( $r$  changes classes in Bruun criteria: from good to fair or fair to poor; but not to the lower, more unstable classifications,  $r$  still always > 50).
- Responses of inlet to the different CC forcing scenarios:
  - A change in wave direction ( $\theta$ ) alone (northerly/southerly shift of direction  $+10/-10^\circ$ ), both leading to an enhancement of littoral drift, can have a significant impact on inlet stability ( $r$  changes significantly from good ( $>150$ ) to fair (100-150) or fair to poor (50-100) class).
  - Changes in riverflow ( $\pm 40\%$ ),  $H_s$  ( $\pm 8\%$ ) or SLR alone have insignificant impact on inlet stability ( $r$  always > 150, inlet in 'good' Bruun classification).
  - Enhancement of littoral drift (by  $H_s + 8\%$ ,  $\theta + 10^\circ$  or  $H_s + 8\%$ ,  $\theta + 10^\circ$ ) can result in  $r$  values from >150 to 50 (but not below 50).
  - Scenarios with SLR or higher riverflow ( $R$ ) generally increases  $r$ .
  - SLR of 1m results in significant mean coastline recession (up to  $\sim 120m$ ).
- Other CC driven changes in system forcing do not result in significant coastline recession/progradation.
- Coastline variability (spatial) is maximum when  $\theta$  becomes more southerly (std of  $\sim 10m$ ).
- Inlet does not change type in all tested CC scenarios, implying that even under the most extreme projected CC driven variations in forcing, Type 1 inlet will not change its general behavior.

#### 1. Present Simulation



- Inlet migrates 460m Southward (in one year),  $r=16$  (consistent with Bruun criteria, unstable inlet)
- Model results agree with Jarrett 1976 AP relationship

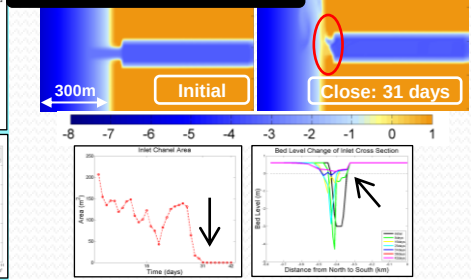
#### 2. CC Simulations



### 3. Conclusions

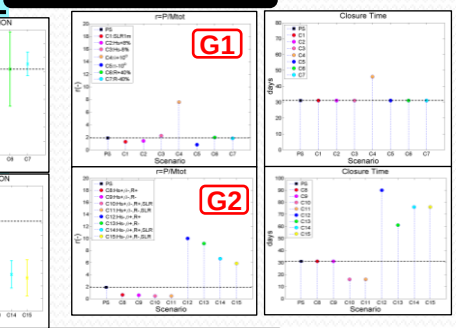
- Type 2 inlet can change** its behavior significantly due to CC driven variations in system forcing (i.e. inlet can change to Type 1 stable inlet,  $r$  changing from unstable to fair or good in Bruun criteria).
- Inlet responses to the various CC forcing scenarios show:
  - A change in wave direction by a southerly shift ( $\theta - 10^\circ$ ) alone, leading to a reduction of littoral drift can have a significant impact on inlet behavior ( $r$  can change significantly from 16 to >150, changing type from unstable to a Type 1 stable inlet).
  - Changes in riverflow ( $\pm 40\%$ ),  $H_s$  ( $\pm 8\%$ ), northerly shift of wave direction ( $\theta + 10^\circ$ ) or SLR alone have insignificant impact, i.e. inlet does not change type ( $r$  varies in the range (5-20)).
  - Enhancement of littoral drift ( $H_s + 8\%$  and  $\theta + 10^\circ$ ) does not change inlet behavior ( $r$  reduces slightly but in the range (5-10)). When SLR is combined with enhanced littoral drift, inlet migration is maximum.
  - When  $H_s$  and  $\theta$  both change such that littoral drift is reduced ( $H_s - 8\%$  and  $\theta - 10^\circ$ ) inlet changes type to Type 1 stable inlet ( $r$  increases to >150).
  - SLR of 1m results in significant mean coastline recession (up to  $\sim 100m$  in C11). Other CC driven changes in system forcing do not result in significant coastline recession/progradation.
  - Coastline variability (spatial) is maximum when Riverflow changes (std of  $\sim 10m$ ).

#### 1. Present Simulation



- Inlet completely closes when riverflow is small (after 31days),  $r=2$  (consistent with Bruun criteria, unstable inlet).

#### 2. CC Simulations



### 3. Conclusions

- Type 3 inlet does not change** its behavior significantly due to any CC driven variations in system forcing (i.e. inlet does not change type, inlet always closes,  $r$  always < 20 in unstable Bruun category).
- However, under individual CC forcing scenarios, the inlet response varies:
  - Reduction of littoral drift (by more northerly wave direction  $\theta + 10^\circ$ ) alone results in a significantly slower inlet closure (time taken to close is 46days, 48.4% > than PS).
  - Changes in riverflow ( $\pm 40\%$ ) or  $H_s$  ( $\pm 8\%$ ) or enhancement of littoral drift (southerly shift of wave direction  $\theta - 10^\circ$ ) or SLR alone seems to not affect inlet behavior significantly (i.e. time taken to close more or less the same as present situation PS).
  - When  $H_s$  and  $\theta$  both change such that littoral drift is enhanced ( $H_s + 8\%$  and  $\theta - 10^\circ$ ) inlet behavior remains unchanged. But When SLR is combined with enhancement of littoral drift, inlet closes faster (16days, % change in closure time = 50 compared to PS).
  - Regardless of whether SLR is present or not, inlet closes slower (% change in closure time maximum 200 compared to PS) when  $H_s$  and  $\theta$  both change such that littoral drift is reduced ( $H_s - 8\%$  and  $\theta + 10^\circ$ ).
  - Inlet does close in all tested CC scenarios, implying that even under the most extreme projected CC driven variations in forcing, general behavior of intermittent closure will not change at Type 3 inlets.