Long-term Impacts of Bypassing on Sediment Transport in Tidal Estuaries

An introduction to Doctorate research at the Griffith Centre for Coastal Management

Queensland Coastal Conference, Airlie Beach, September 2017

Jemma Purandare
Griffith Centre for Coastal Management
(PhD Candidate – Coastal Sedimentology)
Presentation Structure

- **Background**
  - Purpose and relevance of the research
  - Prior work
  - Gold Coast Broadwater and Seaway

- **Literature Review**
  - Findings to date
  - Knowledge gaps

- **Upcoming work**
  - Research tasks
  - Project outputs
Introduction

- Tidal Entrances
  - Recreation
  - Navigation
  - Highly dynamic

- Engineering
  - Fixing
  - Dredging
  - Bypassing
  - Beach management

City of Gold Coast, 2015
Tidal Entrances – Globally Significant

- East Coast US (Hayes, 1979)
- Guadiana estuary, Portugal (Garel et.al., 2014)
- Kennebec River entrance, Maine (FitzGerald et.al., 2000)
- New England, USA (FitzGerald et.al., 2002)
- Golden Gate inlet, San Francisco Bay (Erikson et.al., 2013; Elias & Hansen, 2013)
- Dutch Wadden Sea, the Netherlands (Dissanayake et.al., 2009; van Leuwen et.al., 2003; van der Vegt et.al., 2009)
- Danshui River estuary, Taiwan (Chen et.al., 2015)
- Currumbin Creek, Gold Coast (Castelle et.al., 2007)
- Obidos lagoon, Portugal (Bruneau et.al., 2011)
- Dyfi Estuary, UK (Brown & Davies, 2010)
- Canaceral Entrance, Florida (Bodge, 1993)
- Jiaozhou Bay, China (Wang et.al., 2014)
- Nerang River inlet (Broadwater), Gold Coast (Whitlow, 2005; Sennes et.al., 2007; Ryan et.al., 2003; Robinson et.al., 2006; Mirfenderesk et.al., 2007)
The Broadwater, Southport, Gold Coast

- Semi-enclosed tidal estuary (Sennes et al., 2007)
- Highly dynamic prior to engineering intervention (Whitlow, 2005)
  - Seaway training walls
  - Sand bypassing system
  - Initial capital dredging: Wave Break Island
  - Maintenance dredging
- Coomera and Nerang River catchments
- Highly developed and urbanised
The Broadwater – Highly Studied

- Delft Hydraulic Laboratory (1970 – 1985 prior to construction; modelling ongoing)
- Notional Seaway EIS (GHD) (2006)
- Broadwater Cruise Ship Terminal EIS (2014/2015)
- Numerous research projects
- BMT WBM (Ongoing modelling)
- City of Gold Coast (Ongoing)
- Griffith Centre for Coastal Management (Ongoing)
- International researchers and institutions (Ongoing)
Sediment Dynamics in the Broadwater

Cross-section

<table>
<thead>
<tr>
<th>Location</th>
<th>Littoral Transport in cu.yd/year</th>
<th>Upcoast (+)</th>
<th>Downcoast (-)</th>
<th>Net Transport</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Spit</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inside Breaker zone</td>
<td></td>
<td>+ 1,000,000</td>
<td>- 365,000</td>
<td>+ 635,000</td>
</tr>
<tr>
<td>Outside breaker zone</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Palmbeach near</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tallbudgera Creek</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inside breaker zone</td>
<td></td>
<td>+ 215,000</td>
<td>- 125,000</td>
<td>+ 340,000</td>
</tr>
<tr>
<td>Outside breaker zone</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tugun</td>
<td></td>
<td>+ 115,000</td>
<td>+ 115,000</td>
<td>+ 230,000</td>
</tr>
<tr>
<td>Inside breaker zone</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outside breaker zone</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>South of Tweed River</td>
<td></td>
<td>+ 265,000</td>
<td>+ 360,000</td>
<td>+ 625,000</td>
</tr>
<tr>
<td>Inside breaker zone</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outside breaker zone</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Sand Bypassing

- Feeds sediment from one side of a tidal entrance to the other
- Broadwater – Southport Spit to South Stradbroke Island
- Constructed with the Seaway in 1984-1986
- Approximately 630,000m³/year
- Sediment leakage and potential contribution from the Broadwater
- Gold Coast ‘bookended’ by bypass systems
Shifting Sediment Transport

- Historically flood-dominant
- Recent studies show shift to ebb-dominance
- Potential for loss of sediment from the Broadwater
  - Impacts to dynamics and geomorphology
- Sediment contribution from catchments not fully understood
- Further work to understand shift, cause and potential impacts

Chapman, 1980
## Sand Bypassing – Global Examples

<table>
<thead>
<tr>
<th>Location</th>
<th>Country</th>
<th>Type of Bypass System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nerang River Entrance, Queensland</td>
<td>Australia</td>
<td>Trestle and jet pump system (fixed)</td>
</tr>
<tr>
<td>Boca Raton, Florida</td>
<td>USA</td>
<td>Weir training wall and trap with conventional dredging</td>
</tr>
<tr>
<td>Channel Islands Harbour, California</td>
<td>USA</td>
<td>Detached breakwater and sand trap with biannual dredging and pumping</td>
</tr>
<tr>
<td>Dawesville, Western Australia</td>
<td>Australia</td>
<td>Crawler excavator (mobile) and crawler mounted pump system</td>
</tr>
<tr>
<td>Indian River Inlet, Delaware</td>
<td>USA</td>
<td>Jet pump and crane (mobile)</td>
</tr>
<tr>
<td>Oceanside Harbour, California</td>
<td>USA</td>
<td>Jet pumps and fluidisers (fixed)</td>
</tr>
<tr>
<td>South Lake Worth Inlet, Florida</td>
<td>USA</td>
<td>Fixed hydraulic suction dredge with a rotating boom (fixed)</td>
</tr>
<tr>
<td>Tweed River Entrance, New South Wales</td>
<td>Australia</td>
<td>Sand trap and jet pump system (fixed)</td>
</tr>
</tbody>
</table>
Research Hypothesis and Questions

**Sediment transport dominance has shifted from flood-dominant to ebb-dominant in the last 30 years as a direct result of the training and sand bypassing of the Seaway**

1. Has the sediment transport dominance shifted in the Broadwater?
2. Where has the unaccounted sediment gone?
3. What has caused the shift?
4. Can we confirm the impact sand bypassing has had on sediment dynamics?
5. What does these impacts mean for future management?
6. Can theories be applied to other bypassed systems?
Literature Review

Allen, M. & Callaghan, J., 1999
Australian Bureau of Statistics, 2012
Bertin, X. et al., 2005
BMT WBM, 2014
BMT WBM, 2013
Bowra, K. et al., 2011
Bruneau, N. et al., 2011
Bureau of Meteorology, 2017
Cechet, B. et al., 2011
Chapman, D.M., 1981
City of Gold Coast, 2016
City of Gold Coast, 2015
City of Gold Coast, 2011
Delft Hydraulics Laboratory, 1976
Delft Hydraulics Laboratory, 1970a
Delft Hydraulics Laboratory, 1970b
Delft Hydraulics Laboratory, 1970c
Delft Hydraulics Laboratory, 1970d
Delft Hydraulics Laboratory, 1965
Geoscience Australia, 2004
GHD, 2006
Gold Coast Waterways Authority, 2009
Government of New South Wales, 2017
Griffith Centre for Coastal Management, 2008
Hughes, M., 2016
Kench, P.S., 1999
Master Builders Queensland, 2016
Mccauley, E. & Tomlinson, R., 2006
Mccfenderesk, H. & Tomlinson, R., 2009
Mccfenderesk, H. & Tomlinson, R., 2007
Mccfenderesk, H. & Tomlinson, R., 2008
Queensland Government Office of Economic and Statistical Research, 1996
Robinson, D. et al., 2006
Sedigh, M. et al., 2016
Sedigh, M. et al., 2015
Sedigh, M. et al., 2016
Shand, T.D. et al., 2010
Sennes, G. et al., 2007
Sennes, G. et al., 2007
Splinter, K.D. et al., 2011
Voisey, C. & Robinson, D., 2006
Water Research Laboratory and Griffith University for Gold Coast City Council, 1998
Whitlow, R., 2005

And so on…
Literature Review

- Discrepancies in the littoral drift calculations
- Consideration of system changes
- Ebb-tide delta
- Limited understanding of catchment sediment
- Bypass system studies and changes
- Conceptual model
- Consolidation of knowledge
- Paper to be published 2017

Robinson et al. 2006
Data Availability

- Sand bypass system data
  - TRESBP and Nerang pumping data

- Survey data
  - Gold Coast Waterways Authority
  - Publically available consultancy data (e.g. BMT WBM, DHL)
  - Griffith Centre for Coastal Management
  - City of Gold Coast

- Modelling data
  - Griffith Centre for Coastal Management
  - Gold Coast Waterways Authority
  - Publically available consultancy data

- Field observations
  - City of Gold Coast
  - Publically available consultancy data
  - Individual

- Technical reports and published papers
  - Griffith Centre for Coastal Management
  - Gold Coast Waterways Authority
Intended Outputs and Ongoing Work

- Further data and literature analysis specific to the potential impact of engineering infrastructure
- Confirm the shift in sediment transport dominance
- Combined sediment budget for the Broadwater, including contributions from the catchment (Nerang and Coomera Rivers)
- Impact of urbanisation and engineering on the sediment volumes and dynamics – specifically sand bypassing
- Development of a conceptual model
- Communicated via published papers, conference presentations and the final thesis
Key Output – Conceptual Model

- ‘Conceptual’ model
- Decision making tool for determining the potential impacts to sediment transport dynamics
- Engineering scenarios
- Application of findings from the Broadwater study to other tidal inlet examples where sand bypassing may be an option
- Works to determine impacts to sediment transport dynamics from sand bypassing using additional mechanisms
- Mechanism currently in development – likely MS Excel and ArcGIS based
- Cumulative impact considerations - quantified by order of magnitude of impact
Application of Conceptual Model

- Can the model be applied to tidal entrance with different characteristics?
- Applied to other tidal entrance examples
  - No bypassing system
  - Other engineering interventions
  - Different sources (e.g. single catchment, undeveloped catchment, highly urbanised)
- Determine the extent of scope for the model
- Inform management strategies
Thank you

Jemma Purandare
PhD Candidate
jemma.purandare@gmail.com
Griffith Centre for Coastal Management
Gold Coast, Australia