

DESIGN OPTIONS FOR MARINE INFRASTRUCTURE IN THE FITZROY RIVER DELTA

Senarath Weerakoon and Peter Wood, Queensland Department of Transport and Main Roads, szweera@msq.qld.gov.au
Michael Sun and Weidong Zeng, Arcadis Australia, michael.sun@arcadis.com

ABSTRACT

This paper discusses the challenges in designing public boating infrastructure in vast tidal flood plains, including the different construction techniques used, lessons learned in design and construction and how they have been adapted in other projects. The case study focuses on two recreational public boating infrastructure projects at Inkerman Creek and Casuarina Creek, located in the flood plain delta of the Fitzroy River in the Central Queensland region.

INTRODUCTION

The Port Alma public boat ramp, located within the Port Alma bulk cargo handling facility, was constructed in 1982 for the use of recreational and commercial fisherman in the region. The port now primarily handles cargoes consisting of class 1 explosives, ammonium nitrate, bulk tallow and equipment used in support of military exercises held at Shoalwater Bay. The presence of a busy public boat ramp within the explosive handling port is considered as a safety risk and the management authorities of the boat ramp and the port wanted to relocate the boat ramp outside the explosive handling zone. However, access to Port Alma is through a 23km long causeway constructed over the vast tidal delta of the Fitzroy River. The two sites selected for relocating the existing boat ramp are within the creek system of the delta, but also on this vast tidal plain, causing significant design and construction challenges.

Due to the restricted tidal accessibility, a single lane boat ramp and small Car Trailer Unit (CTU) park at Inkerman Creek was planned. The largest of the two facilities was planned for Casuarina Creek where a very deep tidal creek and full tide accessibility to Keppel Bay is available for any type of recreational vessel. For this site, a two-lane boat ramp, a floating walkway and a larger CTU park was planned. However, the creek bank where the boat ramp site is planned has been experiencing erosion at various times over the last 25 years. From historical aerial images and Lidar surveys carried out in the area, it was estimated that on average 0.5m/ year erosion is taking place. Therefore, some hydrodynamic modelling of the creek system was required to determine the impact to the shoreline erosion due to the construction of the facility and to study the shoreline behavior during the life of the structure.

Based on the modelling results, additional bank protection works were designed for the upstream and downstream area of the creek bank to ensure that the structure can perform its services throughout its design life.

DESIGN ELEMENTS

The major elements of the new facilities include:

- Reclaiming an area with a fill height of approximately 1m on the tidal flood plain
- Form a carpark whose finished surface should be equal or above 3.41m RL which is 0.2m above the HAT (Highest Astronomical Tide)
- Floating walkway horizontally restrained by driven steel piles (Casuarina Creek facility only)
- Boat ramps connecting the creeks and reclaimed fill
- Fish passage culverts/and other utilities
- Erosion and scour control measures

The acceptable post-construction settlement criterion for carpark is set as 250mm within 40 years operation.

GEOTECHNICAL CONDITIONS

Geotechnical Investigations utilising both boreholes and CPTu were carried out to characterise the subsurface ground conditions. The results of this can be summarised as follows:

- 10m thick, very soft to soft estuarine mud, overlying stiff to very stiff alluvium clay
- the very soft to soft estuarine mud is slightly over-consolidated due to multiple processes such as erosion, rising of water table, chemical changes in the soil and aging effects
- the very soft to soft estuarine mud displays linearly increasing strength/cone resistance with depth
- no bedrock was encountered at 12m depth of borehole.

The interpretations from CPTu tests and oedometer tests indicated that the undrained strength of the estuarine mud is approximately 15kPa at the existing surface and that it increases approximately linearly with depth.

An oedometer test was undertaken on the undisturbed soil sample retrieved from 3.5m depth, which indicated a pre-consolidation pressure of 70kPa.

DESIGN OF INKERMAN CREEK FACILITY

The delivery time and cost were primary factors for consideration in the design. Recreational boating facilities are often considered as a non-critical infrastructure, therefore investing heavily on geotechnical treatments was not considered as suitable. Operational traffic loading on boat ramps and associated infrastructure are very low compared to that of roads and bridges. Therefore, the main consideration was the construction traffic and the self-weight of the structure for the assessment of post construction settlement.

The thick very soft to soft estuarine mud poses the following risks to the proposed facilities, including:

- Tidal fluctuation leading to inundation at HAT during

construction

- Trafficability
- Settlement (up to 1m of settlement)
- Stability (bearing and global stability)

A working platform in the form of 250mm thick rock fill has been adopted to improve trafficability and enable the reclamation. A flatter slope has been adopted for the reclamation to ensure that the required Factor of Safety (FoS) against overall slip failure (FoS of 1.3 for temporary and 1.5 for permanent) can be achieved.

For post-construction settlement control, various options such as stone columns, deep mixing and controlled modulus columns have been considered. Preloading has been selected as the most cost-effective method in view of the remoteness of the project site, local availability of the equipment, skilled personnel and project budget.

In the design, prefabricated vertical drain (PVD) on 1.0m x 1.0m grid in the structural zone to 1.5m x 1.5m grid in the non-structural zone was proposed to expediate the dissipation of pore water pressure present in the deep very soft and soft alluvium.

OBSERVATIONS DURING CONSTRUCTION

The construction works of the Inkerman Creek facility started in October 2021. PVD installation, reclamation and surcharge fill was completed in mid-January 2022 (Figure 1). Installation of the drains required a thicker working platform than what was originally anticipated in the design and an additional high strength geotextile layer, which lead to increased construction time and cost. Settlement activities are monitored throughout the settlement period by taking fortnightly readings on settlement plates installed on the reclamation area (Figure 2).



Figure 1 - Inkerman Creek Boat Ramp Project - Initial reclamation and surcharge fill

The following have been observed during the construction:

- Settlement of up to 500mm at around 180 days since reclamation. The plot of the observed settlement data vs predicted, shows that a longer consolidation time is needed to reach the primary consolidation. This suggests that the installation of PVDs provided limited benefit for this type of structure when compared to the increased cost/time

to install them. (Figure 3)

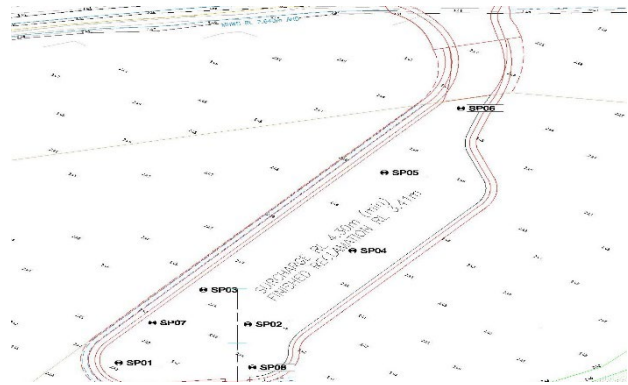


Figure 2- Locations of Settlement Plates

- Stability - no overall stability issue was observed except for minor local slumping during the placement of rock fill at the boat ramp.

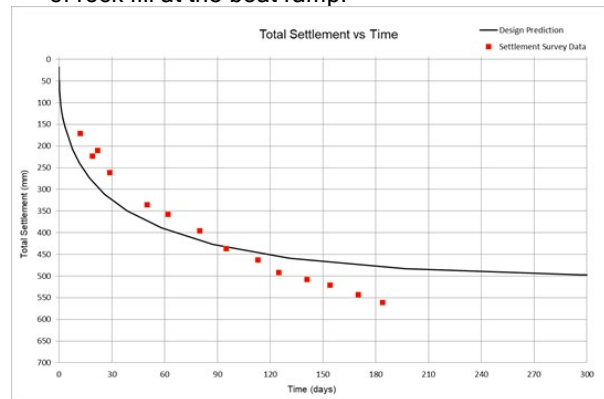


Figure 3 - Plot of predicted settlement vs observed settlement

It was also observed that there was a vast amount of ground water retained in the tidal plane through a near impermeable barrier created at the mangroves belt along the creek bank. This was a local feature on the site created by heavy rainfall received in the region during the few months prior to construction starting. Because of this, it was observed that the behavior of the fill is not as predicted in the geotechnical model initially until the water was drained off.

DESIGN OF CASUARINA CREEK FACILITY

The Casuarina Creek site is also under very similar geotechnical conditions but also on a rapidly retreating creek bank. Therefore, special erosion protection measures have been combined with geotechnical treatments in the design. The preliminary settlement behavior of the Inkerman Creek site during and after construction have been carefully monitored and the observations were utilised to determine the best geotechnical treatment option for the site.

Several settlement assessment options were undertaken for this site with the knowledge that creep

settlement will occur over the time in the soils irrespective of whether PVDs are installed or not when the ground is filled with a 1.5m high embankment. For a 50-year design life, this settlement is estimated to be around 400mm. Therefore, some level of intervention would be required in the midlife of the structure to correct the finished levels. Therefore, following scenarios have been used in the settlement and stability analysis:

- Option 1: Fill only to the required finished platform level of RL 3.42 m AHD and top up with additional fill as required when the level drops in the order of 400 mm over 40 years.
- Option 2: Fill to about RL 4 m AHD, with resultant settlement over 40 years allowing the platform to drop to about RL 3.42 m AHD. The use of lightweight fill could also be implemented in this option to reduce the total settlement.
- Option 3: Install Prefabricated Vertical Drains (PVDs) at 2 m equilateral spacing and fill to about 4.3 m for around 6 months. After 6 months, remove excess fill so that the finished platform is at about RL 3.42 m. Topping up with fill will be required after approximately 1 year, 3 years, and 24 years.

However due to Option 1 and 3 both needing intervention with fill levels earlier in the design life of the facility, Option 2 was selected for slope stability analysis and to be included in the final design.

EROSION PROTECTION AT CASUARINA CREEK
 Historical aerial images and Lidar surveys carried out for the Casuarina Creek site gives a conservative estimate of 0.5m/year shoreline retreat for the baseline scenario (no boat ramp). Hydrodynamic modelling carried out for the creek suggested that, at the proposed location, bed shear stresses during peak flood and ebb currents of the tidal circle exceeds the threshold value for the creek bank particles to initiate movement thus creating natural meandering of the creek.

With the construction of the boat ramp into the tidal water, the hydrodynamic model predicted that the tidal flows will be intersected and diverted to the middle of creek with a reduction of bed shear stresses. However, it was found that the residual values at the creek bank could still cause erosion. Also, there is an increased threat of undermining to the toe of the structure due to increase in bed shear stresses at the ramp toe area.

Therefore, installation of grout filled mattresses to the banks of the creek up to 50m of either side and to the toe of the boat ramp extending to the deepest part of the creek was suggested as the long-term erosion response. This proposed solution has been modelled with 0.5m/year base case shoreline erosion rate to ensure that the facility can meet its 50-year design life (Figure 5). The model also allowed the designers to predict landform buildup during the life of the structure. This could then be used for planning of more eco-friendly coastal protection works such as planting mangroves to increase the biodiversity of the creek.



Figure 4 - Casuarina Creek Boat Ramp Project, Central Queensland, Australia- Eroding shoreline

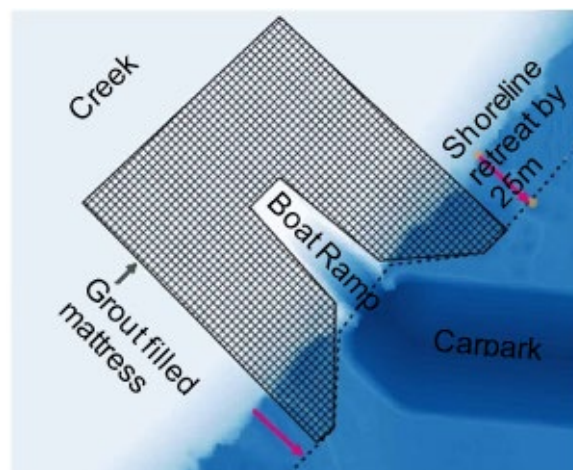


Figure 5- Coastal Protection works modelled for 50-year design life for Casuarina Creek site.

CONCLUSIONS

Several factors contributed to the accurate prediction of soft soil settlement analysis for Fitzroy River delta. This includes accurate, sufficient, and representative geotechnical investigation, correct determination of pre-consolidation pressure and practical use of Prefabricated Vertical Drains. The counter productive use of vertical drains can cause disturbance effect to the surrounding soil and without adequate stresses induced by the loading operation, settlements will be excessive and take a longer period to reach 90% consolidation (T_{90}).

REFERENCES

Sun, Khing (2020): Inkerman Creek Boating Facilities Geotechnical Design Report, WSP Australia

Sun (2021): Casuarina Creek Geotechnical Investigations Report, Arcadis Australia

Kitchen. R (2022): Basis of Design Report- Casuarina Creek Boat Ramp, Projex Partners Ltd

Baum M (2022): Coastal Modelling for the Casuarina Creek Boat Ramp Project, BMT Australia.