TOMAGO WETLAND REHABILITATION PROJECT: INTEGRATED, INNOVATIVE APPROACHES

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Abstract

Tomago Wetland is a 450 hectare wetland located within the Hunter Wetlands National Park on the northern shore of the Hunter River estuary, New South Wales (NSW), Australia. Prior to European settlement, Tomago Wetland was an estuarine wetland with significant areas of saltmarsh and mangroves. Since the construction of a flood levee and drainage system, what was once an important aquatic food source and nursery habitat for fish has been isolated, drained and dominated by pasture grasses and weeds. The two sets of floodgates at Tomago Wetland have been identified as the 2nd and 3rd highest priority floodgates to remediate and the wetland is the second highest acid sulfate soil priority area within the Hunter Region.

In 2007 the western floodgates were modified through the installation of SmartGates, which control tidal flushing based on water levels. This restored fish passage and tidal flushing to the western section of Tomago Wetland and effectively rehabilitated that region. However the larger eastern section remained in poor condition and isolated from the river and tide.

Here we describe the processes and innovative aspects of the mutli-stage collaborative project to open the eastern floodgates at Tomago Wetland and restore connectivity and tidal flushing to the remaining area within the bounds of the National Park and Ramsar Listed Wetland. These works have included:

- Hydraulic modelling to calculate the optimal volume of water required to rehabilitate the wetland and areas of inundation.
- Inventing, fabricating and installing a new design of auto-tidal floodgates able to withstand large hydraulic stresses.
- Earthworks to re-establish water movement through natural drainage channels without exacerbating acidic problems.
- Protecting neighbouring private farmland from inundation.

So far these works have re-established fish passage and conditions suitable for saltmarsh habitat across an additional 312ha of wetland. On-ground monitoring programs are underway to ensure the site is adaptively managed.

Introduction

Tomago Wetland is a 450 hectare wetland located within the Hunter Wetlands National Park on the northern shore of the Hunter River estuary, to the west of Fullerton Cove. The site is characterised by low lying land (0.0 to 0.8m AHD), with over 200 hectares of the site below 0.2m AHD. Early crown land subdivision maps indicate that saltmarsh vegetation dominated the site up until the 1950's (Winning 1996).

Between 1913 and 1928 land reclamation, initially for grazing, was achieved through the construction of a levee and internal drainage system around Fullerton Cove, including the Tomago area (Rayner and Glamore 2011). Between 1968 and 1980 the levee bank, single long ring drain and other internal drains were further enlarged by the NSW Public Works Department as part of the Williamtown - Long Bight - Tomago Drainage Scheme, (MacDonald *et al*. 1997). Floodgates were installed in two locations on the western side of Fullerton Cove on the Tomago land during the 1970's. The main objective of these further works was to direct water from smaller floods downstream within the confines of the river, to provide a flood detention basin during large floods to help protect Newcastle, and further protect and promote agriculture in the areas behind the levees (National Parks and Wildlife Service 1998). Later the internal ring drain was blocked about 3km to the east of Tomago Wetland, effectively separating the drainage on either side of Fullerton Cove.

Since the construction of the flood levee and drainage system, what was once an important and productive migratory bird feeding and roost site, aquatic food source and nursery habitat for fish has been tidally isolated, drained, dominated by pasture grasses and weeds (Winning 1996) and impacted by grazing and the effects of acid sulfate soils (ASS) (DPI 2008). As the residual salinity has been leached from the soil, the original saltmarsh species have been out-competed by less salt tolerant species. This has resulted in much of the previous saltmarsh area being replaced by 'saline pasture' and *Phragmites australis* reedmarsh, with an increase also in the area of *Casuarina glauca* forest. Freshwater coastal wetlands, previously occurring on the periphery of the coastal saltmarsh, have encroached into the site (Winning 2000).

Lowering of the groundwater table has also oxidised sub-surface ASS in the wetland causing soil acidification and poor water quality. A recent study into the risk posed by ASS to the Lower Hunter Estuary (DPI 2008) revealed that Tomago Wetland is the second highest ASS priority area in the Lower Hunter. Sulfides have been observed on the soil surface in waterlogged sections of the wetland (DPI 2008). Potential ASS has been located 1-1.4m below the surface (DPI 2008). In another study, DPI (2007), identified the two sets of floodgates at Tomago Wetland as the 2nd and 3rd highest priority floodgates to remediate within the Hunter Region to dilute and neutralise ASS discharge from the wetland as well as reinstate fish passage.

The Kooragang Nature Reserve (later part of the Hunter Wetlands National Park), including Tomago Wetland was gazetted in 1983. Much of the Kooragang Nature Reserve property at Tomago was transferred to the National Parks and Wildlife Service (NPWS) in 1985 from BHP for the purposes of nature conservation, specifically as compensation for losses of migratory shorebird habitat elsewhere in the estuary (NPWS 1998). In 1993 the Kooragang Wetland Rehabilitation Project (KWRP) was formed to rehabilitate coastal wetlands of the Hunter including Tomago Wetlands, but most early effort was directed to planning and on-ground works at other locations in the estuary. In 1998 the Plan of Management for Kooragang Nature Reserve was approved by the NPWS, which outlined the reinstatement of tidal flows as a long term objective for the rehabilitation of the area.

Early plans for the rehabilitation of the Tomago area were prepared by KWRP and NPWS from 1993 to 2006, accommodating a number of project revisions due to changes in land use planning at Tomago and throughout the estuary. This resulted in two draft Environmental Impact Statements (being prepared but not released) and a final approved Review of Environmental Factors (REF). The plans identified the proposed works and desired environmental outcomes at various sites across Tomago

Wetland, and at an estuary wide scale. The final REF was approved by NPWS in 2006 and works began shortly after to implement the plans (NPWS 2005; DEC 2005).

In summary, the aims were to:

- Create night time roosting areas, including shallow lagoons and saltmarsh, for shorebirds
- Improve fish passage into and out of the Tomago lands.
- Encourage the return of a self-designing mosaic of typical lower Hunter estuary ecosystems, including saltmarsh, shallow lagoons, mudflats, reed beds and tidal creeks (although actively discouraging mangroves).
- Manage hydrology to avoid negative impacts to neighbouring properties, infrastructure, estuary water quality or fresh water aquifers.
- Foster an inclusive, adaptive management approach to the rehabilitation of the site, including effective monitoring of changes.

Methods

Reinstating the hydrology of the site was the primary tool used to achieve the suite of environmental outcomes required of the area. After a fortuitous but unplanned flooding of the Tomago area in late 2004 due to the vandalism of two floodgates, an estimation of the area to be re-wetted and/or protected was gained by site managers and proved an impetus for on-ground works to begin in earnest.

Through literature searches, details of the physical on-ground attributes required to achieve the desired ecological results were determined, such as water depths and salinity levels conducive to saltmarsh re-colonization and water velocities through culverts for maximum fish survival. As per Howe (2008) and Spencer and Howe (2008), a key factor in restoring saltmarsh habitat is to limit the inundation to ensure floodplain depths did not exceed 0.3 m. Depths greater than 0.3 m would promote mangrove habitat, reducing the areas of desired saltmarsh.

Combined with on-ground elevation and existing infrastructure data (floodgates, constructed drains), the ecological requirements were used by the Water Research Laboratory (WRL) at the University of New South Wales to develop a series of hydrological models for the site. The models identified the optimum amount of tidal water to be reintroduced to the wetland during each stage of the project and likely sites for on-ground works, while maintaining the ability to control upstream high water levels and prevent small-medium Hunter River floods from entering the site (Figure 1).

Suitable attributes, locations and methods for monitoring the site during each stage were determined. Instruments to log physical parameters such as water level, quality and velocity were installed at key locations. Facilities for long term fauna and flora studies and floodwater extent were created such as reference sites and monitoring cameras.

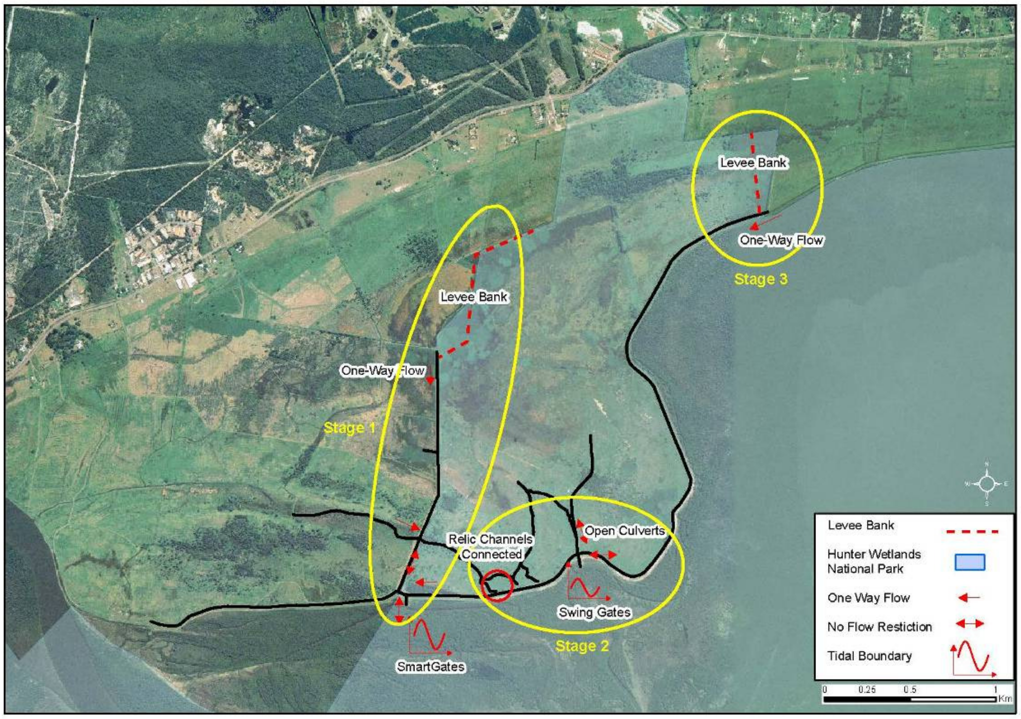


Figure 1. Staged works plan for Tomago Wetland (WRL)

On-ground works to support the Stage 1 opening of the western floodgates included the construction of a 1.8 kilometre levee across the upstream boundary and the installation of floodgate flaps and culverts prevent water from entering private land to the north and west, the eastward part of the ring drain or overland to eastern areas of the Park. The ring drain was cleared and minor earthworks carried out to existing levees and drain banks to direct the tidal water overland. Exotic and undesired vegetation such as swamp oak (*Casuarina glauca*) was cleared over approximately 10 hectares to improve the shorebird roosting qualities of the wetland. A floating boom was placed either side of the floodgates and remnant mangroves upstream were mulched to minimise future mangrove colonisation of the restored floodplain.

For Stage 1, in the west of the wetland, a One-Dimensional (1-D) RMA suite of numerical hydrodynamic models was used (Glamore *et al*, 2005) to simulate the reintroduction of tidal exchange at the site and to determine the likely configuration of on-ground structures. Once key on-ground works had been implemented a trial opening of the floodgate was undertaken to further calibrate the hydrological model, refine water volumes required and provide detail for any additional floodplain works to prevent private property impacts prior to the main floodgate opening.

Following several years of preparatory works, four of the five western floodgates were opened in 2008 to permit tidal exchange via the installation of the SmartGate Environmental Control System (or SmartGate), with funding from the Hunter-Central Rivers Catchment Management Authority. The SmartGates automatically control the amount of water within the wetland by monitoring real-time environmental parameters (in this case upstream water level) via a datalogger. Pre-determined water levels trigger the automated opening or closing of a sluice gate over an aperture in the modified floodgate allowing a precisely controlled amount of water into the wetland. The SmartGates are solar powered and self-contained and remote telemetry can be used to retrieve data, view current conditions or change trigger values. A dial-in and dial-out facility was also incorporated to ensure the SmartGates could be manipulated and monitored remotely during flood events and send alarms to managers if faults occurred (WRL Website).

In 2010-11 Two-Dimensional (2-D) MIKE flood modelling tools were used for the planning of Stages 2 and 3 (Rayner and Glamore 2011) of the rehabilitation works. These models were linked to the previous 1-D Stage 1 model and data gathered from the results of that stage were used to verify the new model. The entire area was investigated together (Stages 1-3) to ensure all aspects of hydrological connectivity across the site were considered and included in the model. This ensured that future works would not detrimentally affect previous habitat improvements and that the Staged approach to the on-ground works could be adequately managed across the landscape. The 2-D modelling techniques and more detailed field data (including LiDAR) enabled a significantly improved tidal exchange model to be developed than in Stage 1 (Rayner and Glamore, 2011) and trial openings were not required prior to completing the investigation.

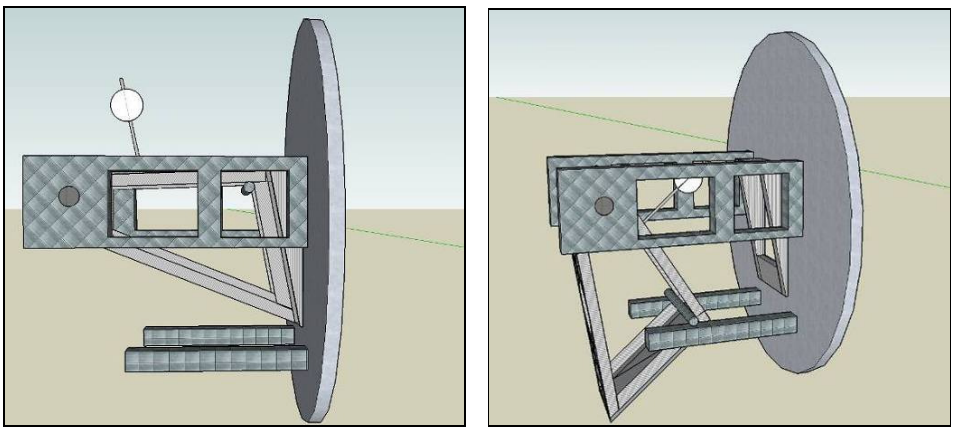
Due to funding constraints and a precautionary approach to potential impacts on upstream landholders works for Stages 2 and 3 were separated. On-ground works for Stage 2 were undertaken in 2011 with funding from Commonwealth Governments ‘Caring for Our Country’ program and the NSW Recreational Fishing Trust. These works included temporarily fitting flaps to existing culverts on the internal ring drain immediately to the east of the eastern floodgates. This prevented water from the Stage 2 works affecting upstream private property prior to additional water control infrastructure being installed at the Hunter Wetlands National Park boundary as part of Stage 3.

Figure 2. SwingGates being installed

Figure 3. Installed SwingGates in closed (left) and open (right) positions.

Once this precautionary infrastructure was in place the four existing floodgate flaps on the eastern Tomago floodgates (previously one way flaps) were replace with modified Swing Gates (Figure 2) in 2011. These allowed a limited amount of tidal flushing (up to 0.7m AHD) through the gates, before closing to prevent excess water entering the site (Figure 3).

The SwingGates (Figure 4) were developed by WRL to accommodate two common auto-tidal gate problems. Firstly, ensuring an environmentally sensitive flow of water (velocity and pressure) through the apertures to minimise the risk of damage to larval biota; this is overcome by having large apertures in the floodgate flaps. However, large auto-tidal doors are subject to significant drag forces as the water moves past. Typical auto tidal floodgates use a buoy to open and close the aperture door. The buoy must large enough not only lift the door infrastructure, but also counter the drag forces of inflowing water pulling the door closed. Large volumes of water were required to achieve the desired floodplain water levels at Tomago. Calculations for the eastern Tomago floodgates indicated that impractically large buoys would be needed to counter the drag forces from the inflows required so a new solution was required.



Closed **Open**

Figure 4. Diagram of SwingGate (W. Glamore)

The SwingGates were developed, designed and field tested during Stage 2 of the Tomago Wetland rehabilitation project. The new design of the SwingGate moved the location of these drag forces on the structure and allowed adequate and automatic gate control via inbuilt buoyancy and small floats, which close the gates at a set water level on the rising tide. On the ebb tide, once downstream water level reaches a pre-determined point, the SwingGates main face plate follows the natural falling of the tide allowing it to fall away from a large aperture cut into the flap gate and re-establish connectivity between the wetland and Hunter River estuary. Fish passage is inversely related to flow velocity (Castro-Santos 2005). The water velocity flowing through the SwingGates is below 0.3m/s, well below critical values.

The main advantages of the SwingGates are:

- It allows large volumes of water into a site at a low velocity/turbulence. As the force of the water is on the pinon trust and not the face plate, the gate cannot be shut by the force of the water.
- Its opening and closing levels can be easily set and adjusted in the field to fine tune the opening and closing levels.
- It is made from light weight marine grade aluminium and the overall gate structure is typically lighter than standard iron floodgates.
- It has only 1 moving part and requires no power to open/close.

Other works were implemented as part of Stage 2 included earthworks to reconnect natural relic channels to the north of the ring drain and assist in delivery of tidal water to the centre of the wetland. This involved the construction of a rock lined dish shaped drain between relic wetland channels and the ring drain (Figure 5). Acid sulfate soil issues were a risk at this location and designs for these earthworks were in accordance with the Acid Sulfate Soil Management Guidelines (Robertson *et al,* 1998). Minimum existing water levels on the wetland side were maintained at 0.2m AHD to ensure oxidation of the ASS was avoided.

Figure 5. Dish drain at low tide retaining relic drain water levels (left) and reconnecting relic channels at high tide (right)

In 2012 the final stage (Stage 3) of the proposed works was undertaken with funding from the Hunter Central Rivers CMA and NSW Parks & Wildlife. This involved the construction of a new set culverts with one way flaps on the ring drain approximately 2km upstream (to the north east) of the eastern floodgates (Figure 6), and a 650m low level levee bank north of the new culverts to approximately 1m AHD. This infrastructure isolated properties outside the National Park boundaries from tidal waters. Once these works were completed, the flaps installed on the ring drain culverts during Stage 2 were permanently opened to reconnect the ring drain to tidal flushing and permit flows up to the north-eastern parts of the wetland.

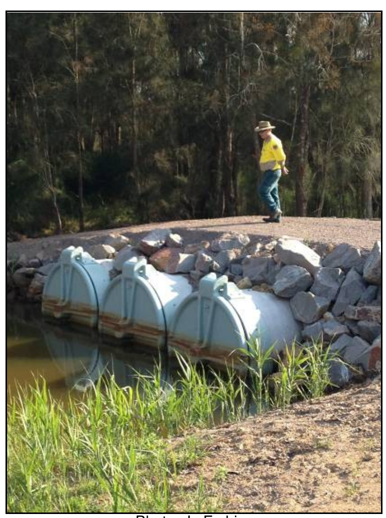


Photo: Jo Erskine

Figure 6. Stage 3 Eastern culverts and floodgates

Results

Ongoing monitoring across the whole wetland, including the area affected by these works is being undertaken by the National Park managers. This monitoring includes water level and quality parameters, and periodic flora, fauna and flood area surveys. Results from the Stage 1 area show the site has now begun to stabilize with minor changes in pH, salinity and turbidity being recorded from natural disturbances only, such as increased decomposition rates in warmer months or lower salinity levels only after heavy rainfall. To assist with monitoring the long-term evolution of the site and allow for offsite management, a digital camera was installed atop an 18 m tall pole in February 2009 overlooking the main Stage 1 recovery area. The camera is in a fixed position and currently takes images 5 times per day. Onsite field measurements of discharge and water level are being used in conjunction with the camera to determine the flux of key surface water quality constituents. The images are also available on a website http://www.wrl.unsw.edu.au/site/projects/tomago-wetland-remote-monitoring/ and are currently being used for several purposes, including:

- Assessing the coverage of tidal water with time
- Determining the hydroperiod and related plant species
- Determining how the dendritic channel network evolves with time
- Assessing the type and quantity of birds onsite throughout the day
- Determining the impact of large rainfall events on the site and drainage patterns
- Assessing whether the SmartGates should be operated based on real-time onsite conditions
- Reducing vandalism onsite
- Calculating the evolution of saltmarsh using red shift filters
- Determining if cattle or other unwanted species are gaining access to the site

Historical reports showed that the saltmarsh on the Tomago site was an important high tide roost for migratory shorebirds (Clarke and van Gessel 1983). However results of later, post floodgate installation studies reflected the changed environmental conditions at the site, with it no longer being a significant area for waterbirds (Kingsford 1997) but supporting species that commonly prevail in grasslands, Casuarina forests, reeds and parts of wetlands (Winning 2000).

The Hunter Bird Observers club regularly conducts bird surveys in the affected area of the wetland. In recent years, following recovery of saltmarsh in the western portion of the National Park (near the north-south drain) as a result of Stage 1 works, their monthly surveys have revealed use of the wetland by migratory birds once again as both a feeding and night roosting area (A. Lindsey pers. comm. 2012, J. Erskine pers. comm. 2012). Recent surveys in the Stage 2 area have also recorded use of this area by Black-winged Stilt (*Himantopus himantopus*), Sharp-tailed Sandpipers (*Calidris acuminate*), Black-fronted (*Elseyornis melanops*) and Red-kneed Dotterels (*Erythrogonys cinctus*).

Estuarine wetlands are important nursery habitat for juvenile fish and invertebrates (Beck *et al.* 2001; Sheaves 2005) enhancing their survival (Boesch and Turner 1984; Kneib 1997) and playing a major role in estuary (and fishery) productivity through a variety of processes (Jordan, Smith and Nestlerode 2009). As such, a loss of connectivity between wetlands and the rest of an estuary can compromise ecological function (Meynecke 2009).

Fish are extremely mobile, and it has been shown that they will quickly move into new habitats as they become available (Peterson and Bayley 1993; Sheldon and Meffe 1995). Boys *et al* 2012 and Able *et al.* 2008 demonstrated that restoration of connectivity in tidal creeks through regular and frequent opening of floodgates leads to a strong, rapid and sustained recolonisation of habitats and an increase in the number of estuarine-marine aquatic species. Although not specifically monitored at Tomago, similar results could be expected from the rehabilitation works there. In addition as commercial fish catches are often correlated with estuarine habitat availability and connectivity (Blaber 2009; Turner 1992; Manson *et al.* 2005; Meynecke, Lee and Duke 2008), including those in NSW (Saintilan 2004), the improvements at Tomago Wetland will also have economic benefits to the fishing industry.

Salinity and water level monitoring was carried out before and after the installation of the SwingGates and other works for Stage 2. Changes to both parameters have been recorded, particularly at monitoring sites close to the floodgates, but to a lesser degree at more distant locations. The changes followed the predicted outcomes from the hydraulic modelling with diurnal tidal changes now clearly reflected in the water levels immediately upstream of the gates and in the reconnected relic channels and connected wetlands. Salinity levels also fluctuate more at these locations than prior to the gate opening. Both water level and salinity are still influenced by the local rainfall and freshwater inflows from outside the Park.

So far these works have re-established fish passage and conditions suitable for saltmarsh habitat and shorebird use across an additional 312ha of wetland (Figure 7). Outcomes of the long term monitoring will determine what future adaptive management strategies are adopted.

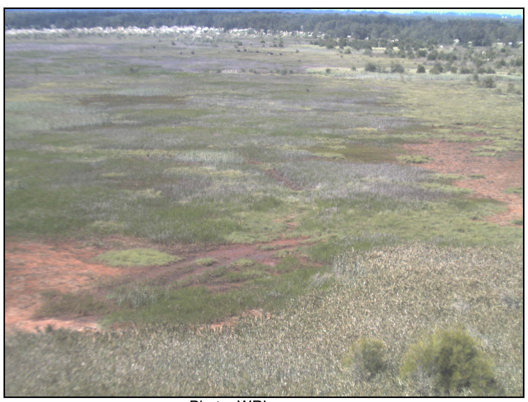


Photo: WRL

Photo: Doug Beckers

Figure 7. Examples of Tomago vegetation before (left) and after (right) Stage 1-2

Discussion

Since European settlement large changes to New South Wales' (NSW) estuarine wetlands and their hydrology have occurred (Williams *et al* 2000; West *et al* 1985), particularly through the use of levees, floodgates and culverts, which restrict saline water ingress, tidal amplitude and fragment habitats (Daiber 1986; Streever 1997). This disturbance has been well documented and is highly detrimental to estuarine biodiversity, sustainability and productivity (Vitousek *et al.* 1997; Pollard and Hannan 1994; Kroon and Ansell 2006; Raposa and Roman 2001) through degraded habitats (Chambers, Meyerson and Saltonstall 1999), reduced connectivity (Eberhardt, Burdick and Dionne 2011) and mobilization of acid sulphate soil products (Sammut *et al.* 1995).

The Hunter estuary is a good example of this scenario with large land use changes, and associated significant flood mitigation infrastructure throughout the catchment. There has been considerable alteration of natural estuarine habitat in the Hunter (Williams *et al* 2000; Winning 1996). Significantly, broad areas of saltmarsh have been lost, while increases in mangroves and brackish reed swamp have occurred, particularly since the 1950's (Williams *et al* 2000; West *et al* 1985; Winning 1996). These vegetation changes have had detrimental environmental impacts on shorebirds fish and other aquatic organisms (Spencer 2010; Boys and Williams 2012). Coastal saltmarsh in the NSW North Coast, Sydney Basin and South East Corner bioregions has been listed as endangered ecological community under the NSW Threatened Species Conservation Act 1995 since 2004.

Tomago is one of numerous Hunter estuarine wetlands previously disconnected from the estuary and adversely affected by these large land use changes. The ultimate objective of the Tomago Wetland rehabilitation program was to reverse this disconnection by re-introducing a controlled amount of tidal exchange to areas of this wetland cut off by the flood control infrastructure. The reinstatement of a more natural hydrological regime was the key to obtaining many of the other ecological outcomes desired at this site. Using minimal on-ground works and altering the management of existing infrastructure to achieve these hydrological regimes, changes to the site are gradual, natural and relatively inexpensive.

Due to funding constraints and concerns about impacting upstream landholders, the Stage 1 on-ground works in 2007 were designed to ensure that only the western portion of Tomago Wetland was restored. Approximately 250 hectares was inundated as part of Stage 1, covering a mixture of introduced pasture, remnant coastal saltmarsh and freshwater wetlands in the western side of the Park. The larger eastern section remained in poor condition and isolated from the river and tide. Subsequent stages, in 2011 and 2012 restored tidal flushing to another 62ha in the east of the Park, while ensuring no detrimental effects, such as changes in hydrology, occurred to the west or on neighboring property. Rainwater drainage from neighbouring property has been maintained and the effects of the restoration activities are confined to within the Hunter Wetlands National Park boundaries.

Results have achieved and will continue to achieve increased salt marsh coverage, additional migratory bird feeding and roosting areas, improved fish passage and access to wetland habitat and will help ameliorate ASS and water quality problems. This 'soft' hydrological change method is in contrast to large scale earth works or engineering options often proposed to achieve similar outcomes which can be disruptive, destructive, expensive and potentially environmentally risky.

Throughout the project, but particularly for the first stage when relationships were being formed, engagement and involvement of local neighbours and stakeholders was very important. These communication efforts and ensuring there remained the ability to reverse the operation of any activities in the event of any unforseen negative outcomes, facilitated trust and confidence between the parties.

Numerous NSW Government agencies have some involvement or jurisdiction over various aspects of infrastructure or outcomes at Tomago Wetlands. Because of this the success of the project depended on a high level of communication and co-operation between the agencies, integrating the outcomes of the rehabilitation project with the requirements of their activities.

Central to the project as the landholders and managers of the wetland are the Parks and Wildlife Group (previously NPWS), currently part of the Office of Environment and Heritage (OEH). Other stakeholders were the Department of Primary Industries(DPI) Fisheries regarding the fish habitat, resources and water quality benefits, and funding through a Recreational Fishing Trust grant; the Water Administration Ministerial Corporation, owners of the Hunter Valley Flood Mitigation Scheme (HVFMS); other sections in OEH responsible for managing HVFMS infrastructure including the levee, floodgates and some drains at Tomago; the Hunter-Central Rivers Catchment Management Authority which provided funding for the works and some on-going maintenance costs. The Soil Conservation Service, also within DPI, contracted by OEH to perform HVFMS infrastructure maintenance. A formal Operation and Maintenance Agreement for the western floodgates (FG 3.180) was signed by required parties in 2011.

Close communication with and ongoing involvement of contractors, particularly WRL, over all stages of the project has lead to a continuity of experience with the site. The development of the innovative SwingGates for the Stage 2 works to practically cope with the hydrological demands at the site was crucial to the success of the project. Other large scale wetland rehabilitation sites may also benefit from their application as an auto-tidal gate able to deliver large volumes of water in a controlled, ecologically sympathetic manner.

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Dredging and reclamation earthworks in waterways required for this project were permitted under Part 7 of the *Fisheries Management Act* 1994 by Permit P07/135 (Stage 1) and P11/2026 (Stages 2 and 3). All works were approved through routine environmental regulation processes, including the production and approval of a Review of Environmental Factors.

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