Appendix O

Restoring Tidal Flow Assessment

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Restoring Tidal Flow to the SEPP 14 Wetland

O.1 Background

Currently, the levee created by Government Road blocks tidal flow from Back Creek (South West Rocks Creek) entering the SEPP 14 Wetland on the subject site. An existing floodgate on a 375 mm pipe beneath Government Road allows flood or stormwater flows to discharge out of the subject site into Back Creek. It is noted the existing floodgate is currently broken, allowing a limited amount of tidal flow into the site.

O.2 Objectives

The general objective of restoring tidal flow to the SEPP 14 wetland within the site is to re-establish a healthy saline wetland ecosystem. James Warren & Associates have indicated that re-establishment of saltmarsh community is a high priority which would necessitate replicating tidal variations similar to downstream of the existing floodgate.

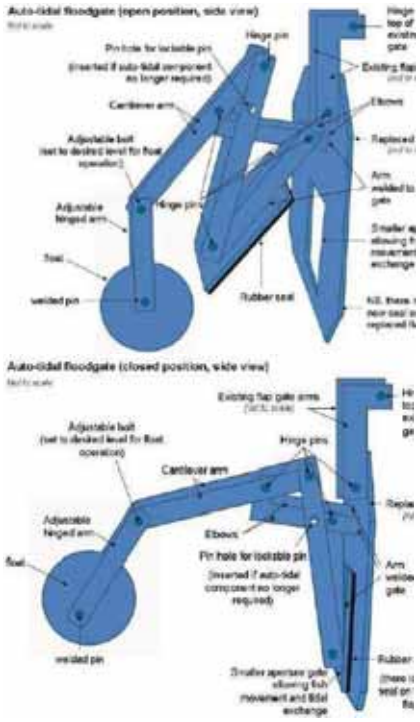
In the Wetland Management Plan, Sainty suggests "a trial period of tidal inundation placing a boundary to the extent of vegetation with a full salt tolerance" (James Warren & Associates, 2010:9). This boundary is estimated to be approximately equivalent to the 0.4 m AHD contour based on comparison of vegetation mapping and survey data.

O.3 Proposed Works

It is proposed that tidal flow will be restored to the SEPP 14 wetland within the site by construction of a new 900 mm diameter culvert pipe beneath Government Road (adjacent to the existing pipe). The new pipe will be fitted with an automatic tide floodgate similar to the design shown in **Plate O.1**. The automatic tide floodgate includes a secondary gate with an aperture that opens and closes with an adjustable floating arm to allow a degree of tidal flushing and fish passage whilst providing flood protection.

The opening and closing of the aperture on the secondary gate is triggered by the water level on the downstream side (north side) of the system. When the water level drops below the float during low tide events, the weight of the float arm causes it to fall and the secondary gate to open, resulting in the exchange of water. This continues until the incoming tide lifts the float to its maximum height and causes the gate to seal. The gate is held closed by the rising action of the float and the back pressure applied to the gate once overtopped, providing protection against flood water flowing upstream (NSW Department of Industry and Investment, 2009:17).

The secondary gate can be manually adjusted to set the level at which the aperture closes during an incoming tide. This provides control on the amount of tidal inflow and the subsequent extent of inundation of the SEPP 14 Wetland in the subject site.



Source: NSW Department of Industry and Investment (2009)

Plate O.1 Indicative Examples of an Automatic Floodgate

The initial phase of the floodgate operation will involve restricting the amount of tidal inflow to confine tidal inundation of the SEPP 14 Wetland in the subject site to the extent of vegetation with a full salt tolerance (approximately the 0.4 m AHD contour). If it is considered appropriate to increase the extent of tidal inundation of the SEPP 14 Wetland then the following strategy can be staged:

- remove the floodgate from the existing 375 mm pipe to convert it to an open pipe culvert for tidal flow exchange;
- remove the automatic floodgate from the new 900 mm pipe to also convert it to an open pipe culvert for tidal flow exchange.

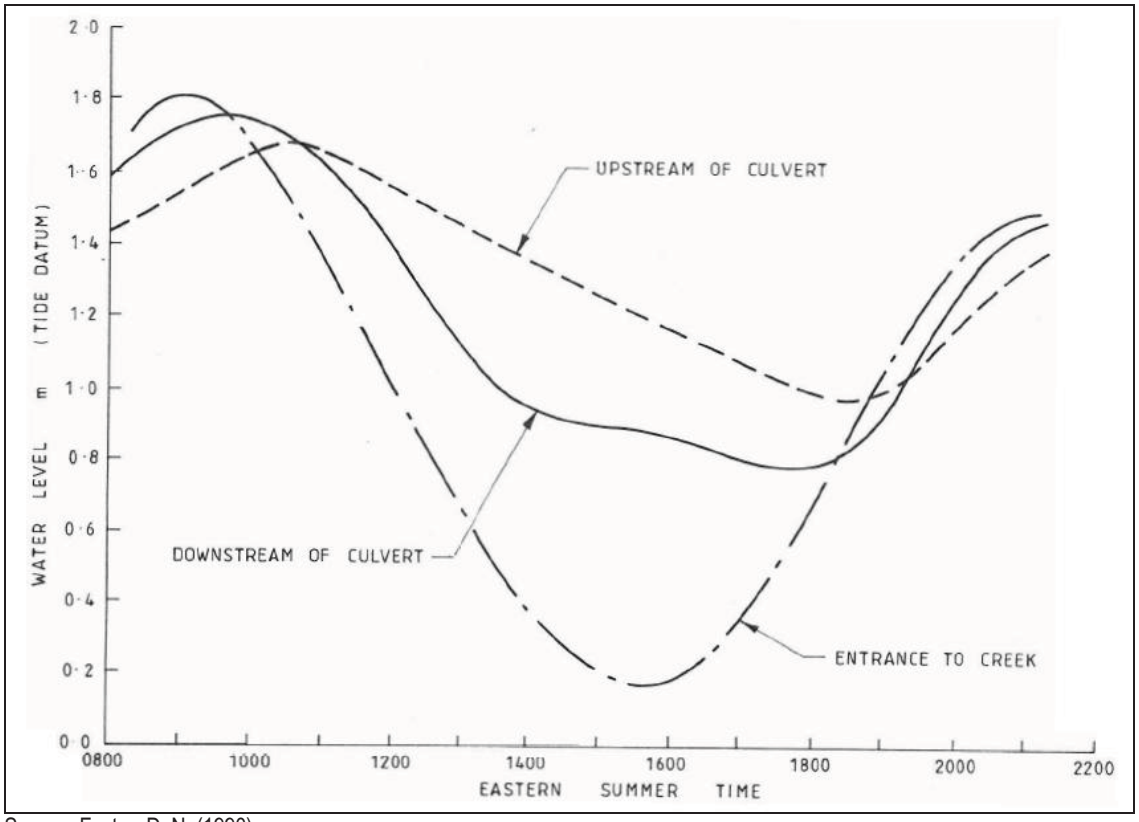
These options are modelled in the following section.

O.4 Methodology for Modelling Tidal Flows

Preliminary modelling of tidal restoration to the subject site has been undertaken using a spreadsheet analysis of tidal flows over a period of one month at a time interval of 20 minutes. The purpose of the modelling is to provide an estimate of the degree of tidal exchange within the site for various culvert and floodgate configurations. The steps involved in the modelling are described below.

O.4.1 Modelling Tide Levels in Back Creek

Tide level data is based on tide data for South West Rocks for October / November 2010 which has been modified to replicate the dampened tidal range in Back Creek at Government Road. This 'dampening' of the tidal range is estimated from information obtained from a previous study addressing tidal flows in Back Creek (*South West Rocks Fishing Port Siltation Investigation* by Foster, D. N., 1990). Refer to **Plate O.2** which shows the relationship between tide levels in Back Creek (upstream of the culvert beneath New Entrance Road) and tide levels at South West Rocks.



Source: Foster, D. N. (1990)

Plate O.2 Tide Levels in Back Creek – 26 February 1979

For the purpose of this report, the tide levels on the upstream side of the culvert beneath New Entrance Road is considered a good approximation of the tide levels on the downstream side of Government Road (the distance between these two locations is approximately 800 m – refer to **Illustration O.1**).

To adjust the tide level data for South West Rocks to replicate tide levels in Back Creek at Government Road, a ratio of 0.4 was applied to the South West Rocks tidal range (based on the ratio estimated from **Plate O.2**). The estimated high tide level in Back Creek was reduced by approximately 0.2 m from the ocean levels during spring tides. This results in significantly higher low-tide levels in the creek compared to ocean levels which is typical of tidal rivers. **Plate O.3** compares ocean tide levels (dotted line) to the estimated tide levels for Back Creek at Government Road (solid line).

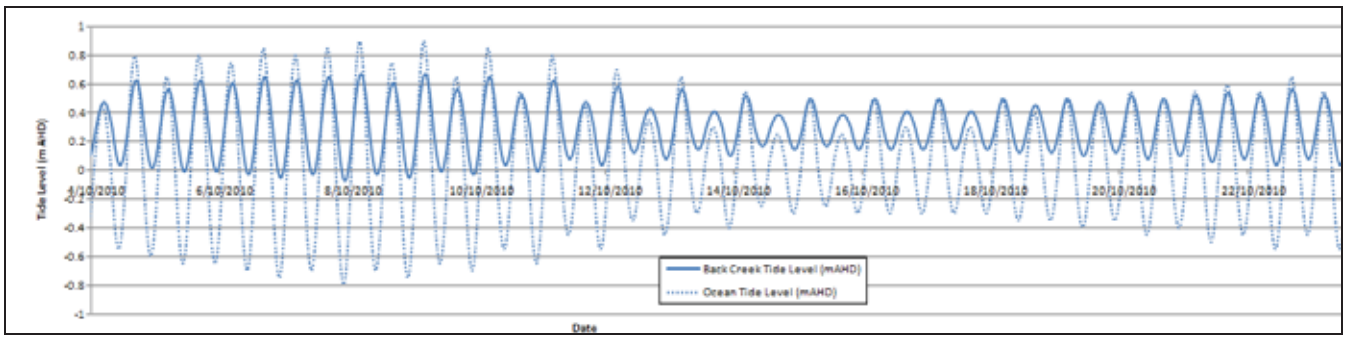


Plate O.3 Comparison of Ocean Tide Levels and Estimated Tide Levels in Back Creek over the Period 4th to 22nd October 2010

O.4.2 Modelling Tidal Flows through Automatic Floodgates

Modelling flows through the aperture of the proposed automatic floodgates was calculated using the following equations:

- Flow over a rectangular sharp-crested weir when the upstream water level is below the top of the aperture (both submerged and unsubmerged weir equations have been used based on the downstream water level);

  Unsubmerged Flow:

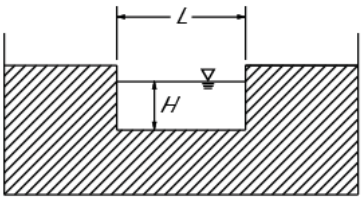
  $Q_1 = L\ C_w\ 0.67\ \sqrt{(2g)}\ H^{1.5}$

  where L = width of aperture;

  C_w = weir coefficient = 0.0605 + 0.08 (H/P) + 0.0001H;

  H = height of water above bottom of aperture;

  P = height of aperture opening above pipe invert;



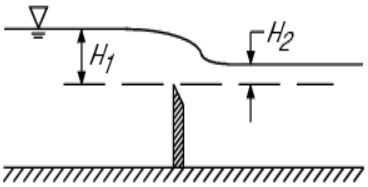
  Submerged Flow:

  $Q = Q_1\ [1 - H_2/H_1)^{1.5}]^{0.385}$

  where Q_1 = flow for unsubmerged case;

  H_1 = height of upstream water level above bottom of aperture;

  H_2 = height of downstream water level above bottom of aperture;



- Flow through an orifice when the upstream water level is above the top of the aperture (both submerged and unsubmerged orifice equations have been used based on the downstream water level);

  $Q = C_d\ C_v\ A\ \sqrt{(2gH)}$

  where C_d = 0.6 and C_v = 1.0;

  A = cross-sectional area of aperture opening;

  H = difference in upstream and downstream water levels for a submerged aperture;

  H = height of upstream water level above centre of aperture opening for unsubmerged case

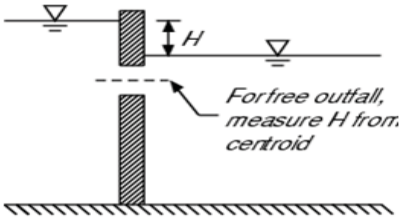


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Illustration O.1 Local Features

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Drawn by: AMM Reviewed by: RE Date: November 2010
Source of base data: Kempsey Shire Council

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O.4.3 Modelling Tidal Flows through Open Pipe Culverts

The option of removing floodgates has been assessed. Modelling flows through open pipe culverts was calculated using the following equations:

- For $0 < H/D < 0.8$:
  $Q = 0.48\ D^2\ \sqrt{(gD)}\ (S_0 / 0.4)^{0.05}\ (H/D)^{1.9}$ where $(S_0 / 0.4)^{0.05} = 0.9$ for square edges
  where D = pipe diameter; and
  H = height of water above pipe invert;
- For $0.8 < H/D < 1.2$:
  $Q = 0.44\ D^2\ \sqrt{(gD)}\ (S_0 / 0.4)^{0.05}\ (H/D)^{1.5}$ where $(S_0 / 0.4)^{0.05} = 0.9$ for square edges.

O.4.4 Determining Water Level in SEPP 14 Wetland

Using the estimated tide levels in Back Creek and the previous aperture and pipe culvert flow calculations, the flow rate and corresponding volume flowing through the aperture gate / pipe culvert was calculated for each 20 minute time step. The flow volume was then used to calculate the water level within the SEPP 14 wetland based on the water level : volume relationship (shown in table below) which was calculated in CivilCAD using the detailed survey data for the site.

Table O.1 Water Level : Volume Relationship in SEPP 14 Wetland

Water level in SEPP 14 wetland (m AHD)	*Volume in SEPP 14 wetland (m^3)*
0.0	0
0.1	150
0.2	1,740
0.3	6,530
0.4	13,780
0.5	24,690
0.6	38,080

O.4.5 Modelling Assumptions

Other assumptions used in the modelling include:

- Invert level of new culvert pipe = 0.0 m AHD;
- Bottom of aperture opening is 100 mm above pipe invert;
- No stormwater / rainfall inputs have been modelled.

O.5 Modelling Results

The following pipe and floodgate scenarios were modelled to provide an estimate of the extent of tidal inundation in the SEPP 14 wetland in the subject site:

1. installation of a new 900 mm diameter pipe with automatic tide floodgate adjoining the existing 375 mm pipe beneath Government Road;
2. in addition to the above scenario, the existing 375 mm pipe was modelled as an open pipe culvert with the existing floodgate removed (ie open for tidal flow exchange);
3. in addition to the above scenario, the new 900 mm diameter pipe was modelled as an open pipe culvert with the automatic tide floodgate removed for greater tidal exchange (ie both the existing 375 mm pipe and the new 900 mm diameter pipe open for tidal flow exchange)

O.5.1 Stage 1: Install New 900 mm Diameter Culvert Pipe with Automatic Tide Floodgate

This option involves:

- retaining the existing 375 mm diameter pipe and floodgate; and
- installation of 1 x 900 mm diameter pipe with automatic tide floodgate. The aperture size on the automatic tide floodgate is assumed to be 300 mm wide and 450 mm high based on discussions with Greg Beckerell at Armon Engineering in Kempsey. This size is the maximum size aperture opening that could be readily manufactured for a 900 mm diameter pipe.

The water level fluctuations in the SEPP 14 wetland for Stage 1 are shown in **Plate O.4**. The plate shows the downstream Back Creek tide level (dotted) and the restored tide level in the SEPP 14 wetland (solid line). The aperture gate was modelled as fully open for all tide levels.

The modelling shows the tidal levels in the SEPP 14 wetland generally vary between 0.33 and 0.41 m AHD with the higher levels corresponding to the higher spring tide periods. The limit of tidal inundation is shown on an aerial photo of the site in **Illustration O.2**. Closing the aperture gate at a tide level of 0.7 m AHD or higher does not alter the water levels in the SEPP 14 wetland (in comparison to the fully open aperture scenario). If the aperture gate is set to close at a tide level of 0.5 m AHD or less the water level variations in the SEPP 14 wetland vary between 0.30 and 0.35 m AHD with the higher levels corresponding to the smaller neap tide periods (due to the gate being open for a longer period with the smaller tide levels).

O.5.2 Stage 2: In Addition to Stage 1, Remove the Floodgate from the Existing 375 mm Pipe

This option involves:

- retaining the new 1 x 900 mm diameter pipe with automatic tide floodgate from the previous stage;
- removing the floodgate from the existing 375 mm diameter pipe to create an open pipe culvert for tidal exchange.

The water level fluctuations in the SEPP 14 wetland for Stage 2 are shown in **Plate O.5**. The modelling shows the tidal levels in the SEPP 14 wetland generally vary between 0.30 and 0.44 m AHD with the higher levels corresponding to the higher spring tide periods. The limit of tidal inundation is shown on an aerial photo of the site in **Illustration O.2**.

O.5.3 Stage 3: In Addition to Stage 2, Remove the Automatic Floodgate from the 900 mm Pipe

This option involves:

- retaining the existing 375 mm diameter pipe as an open pipe culvert from the previous stage;
- removing the automatic tide floodgate from the existing 900 mm diameter pipe to also create an open pipe culvert for tidal exchange.

The water level fluctuations in the SEPP 14 wetland for Stage 3 are shown in **Plate O.6**. The modelling shows the tidal levels in the SEPP 14 wetland generally vary between 0.27 and 0.48 m AHD with the higher levels corresponding to the higher spring tide periods. The limit of tidal inundation is shown on an aerial photo of the site in **Illustration O.2**.

The water level variations in the SEPP 14 wetland are summarised in **Table O.2**. The table shows a range of percentile water levels for each stage. For example, the 95th percentile water level (eg. 0.39 m AHD for Stage 1) is the water level that is higher than 95 percent of the other water levels for that stage.

Illustration O.2 Predicted Tidal Flow Inundation Levels

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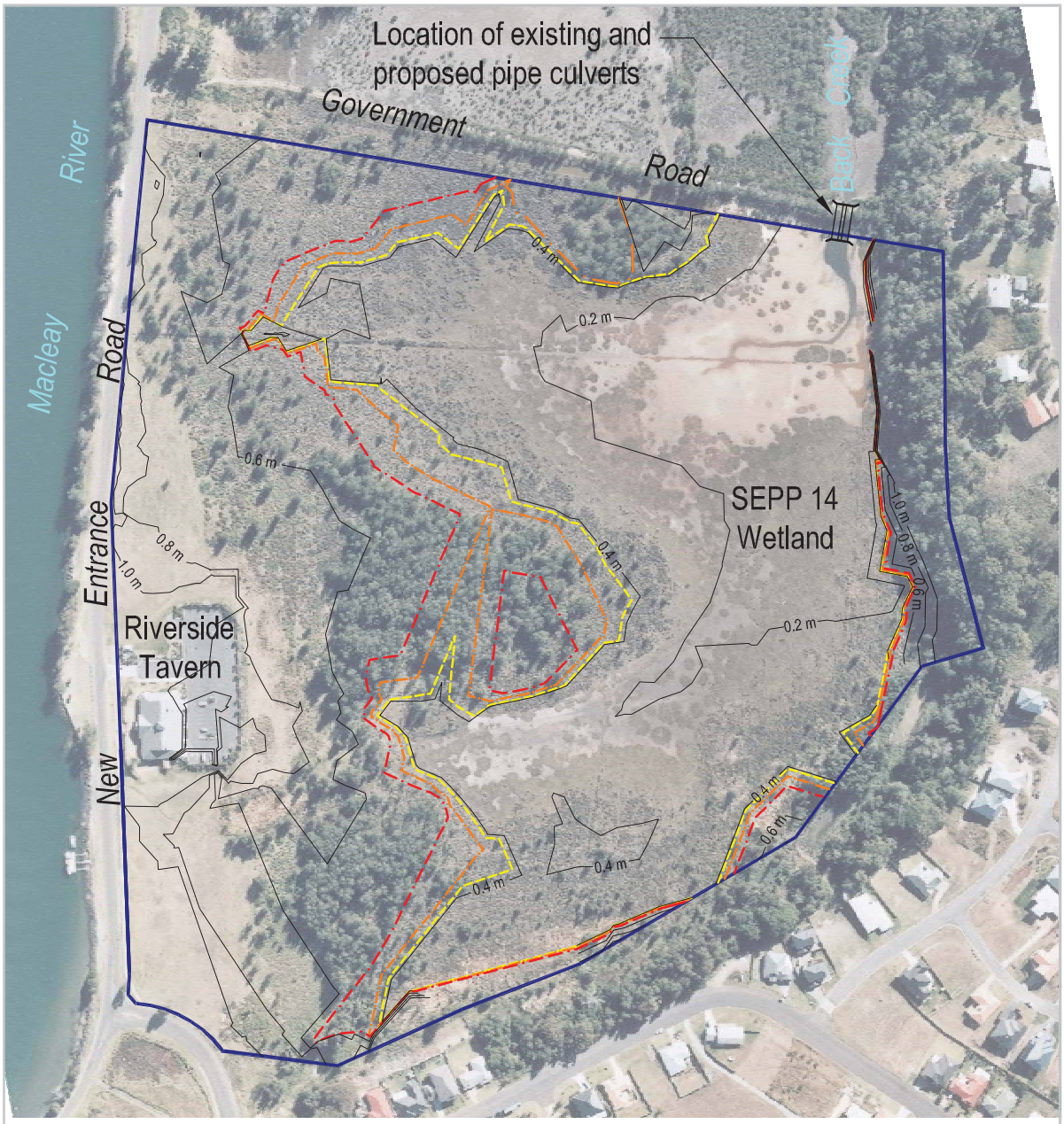
Drawn by: MVE Reviewed by: RE Date: November 2010

Information shown is for illustrative purposes only

Source of base data: Aerial from NSW LPI Aerial Photograph, survey information from Amos & McDonald Surveyors



Extent of Tidal Inundation

Stage 1	0.41 m AHD	(1 x 900Ø pipe with tidal floodgate)
Stage 2	0.44 m AHD	(as above plus 1 x 375Ø pipe with floodgate removed)
Stage 3	0.48 m AHD	(floodgates removed from both 900Ø and 375Ø pipes)

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Predicted Tidal Flow Inundation Levels

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Illustration O.2

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Table O.2 Restored Tide Levels in SEPP 14 Wetland for Proposed Stages

Stage	*Percentile Water Level in SEPP 14 Wetland* [1]						
	10 %ile	*25 %ile*	*50 %ile*	*75 %ile*	*90 %ile*	*95 %ile*	*100 %ile*
1	0.33	0.34	0.36	0.37	0.38	0.39	0.41
2	0.30	0.32	0.35	0.38	0.40	0.41	0.44
3	0.27	0.30	0.34	0.38	0.41	0.43	0.48

Note: 1. The percentile water level is determined by the percentage of all water levels that are smaller than a specific value. For example, a water level that is higher than 95 percent of the other water levels is in the 95th percentile (eg. 0.39 m AHD for the case of 1 x ø900mm pipe)

O.6 Conclusions

The general objective of restoring tidal flow to the SEPP 14 wetland within the site is to re-establish a healthy saline wetland ecosystem. The proposed installation of a new 900 mm diameter culvert pipe with automatic tide floodgate beneath Government Road provides a system that can be manually adjusted to slowly introduce tidal flows to the site.

Modelling indicates that with a fully open aperture gate in the automatic tide floodgate a maximum tide level of 0.41 m AHD can be achieved on spring tides in the site. This corresponds to the existing extent of vegetation with a full salt tolerance which is the boundary for initial tidal inundation suggested by Sainty in the Wetland Management Plan (James Warren & Associates, 2010).

Tide levels in the site generally follow the same pattern as the tidal variations on the downstream side of Government Road with a fully open aperture gate. However the magnitude of the tidal variations in the site is reduced due to the dampening effect of flow restriction through the aperture gate. This is beneficial for restricting tidal inundation levels the existing extent of vegetation with a full salt tolerance.

Following monitoring of the response of the SEPP 14 wetland to tidal inundation it is possible to utilise the existing 375 mm diameter pipe for further tidal exchange by removal of the existing floodgate. This will the magnitude of the tidal variations in the site with an increase in the limit of tidal inundation to approximately 0.44 m AHD. If deemed appropriate, the automatic tide floodgate on 900 mm diameter culvert pipe could then be removed to further increase the limit of tidal inundation to approximately 0.48 m AHD.

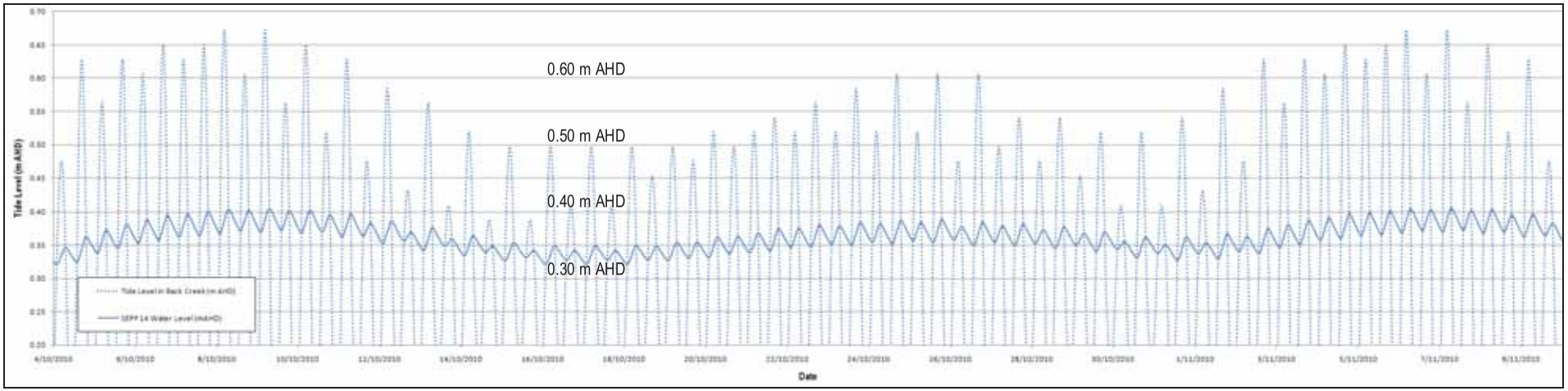

Plate O.4 Stage 1: Restored Tide Levels with 1 x 900mm Pipe Culvert with Automatic Tide Floodgate

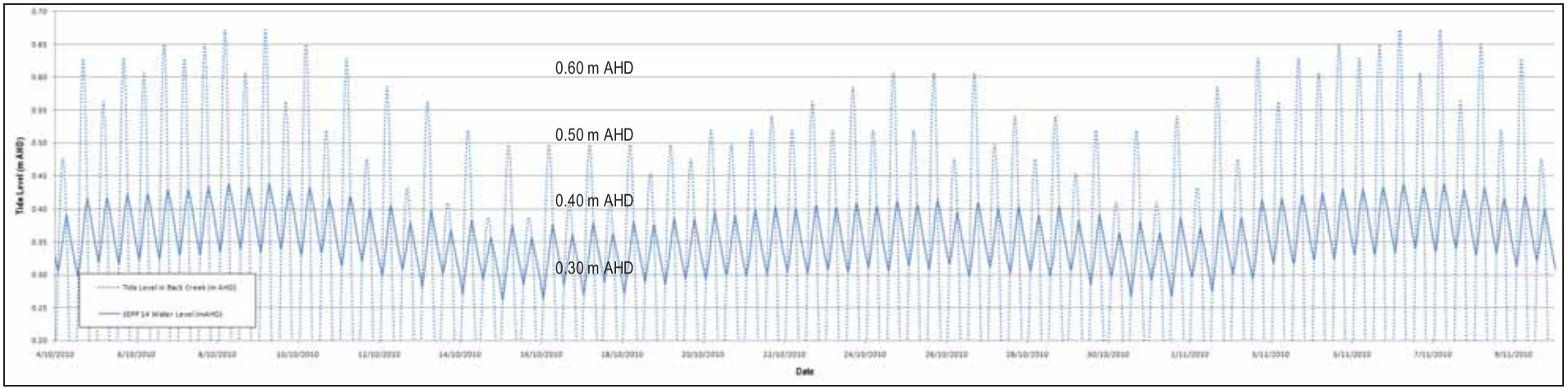

Plate O.5 Stage 2: Restored Tide Levels with 1 x 900mm Pipe Culvert with Automatic Tide Floodgate plus Open 375mm Pipe Culvert

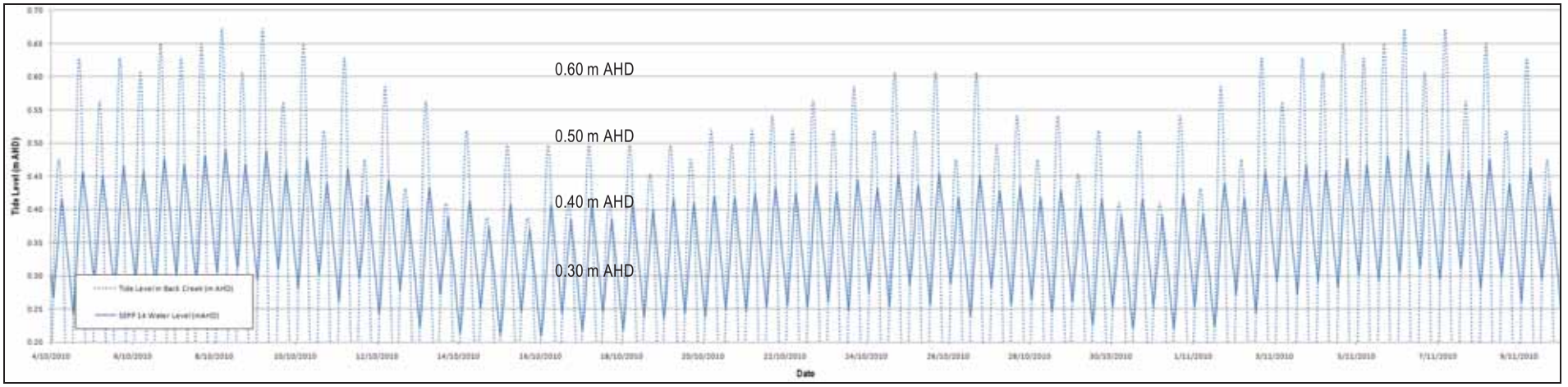

Plate O.6 Stage 3: Restored Tide Levels with 1 x 900mm Open Pipe Culvert and 1 x 375mm Open Pipe Culvert