Tillegra Dam – Response to DoP Questions

Project No. 003618/01/08/06
DoP Ref: 09/00891

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Hunter Water Corporation

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APPENDIX A

Objective of Report

The objective of this report is to provide a succinct response to questions from NSW Planning (letter reference 09/00891), relevant to potential impacts of Tillegra Dam on the hunter estuary.

1 Background

NSW Planning has commissioned 5 different independent reviews of project documentation tendered by HWC, which consider the merits of the Tillegra Dam proposal. The reviews are as follows;

- Justification for Tillegra Dam – by SMEC
- Socio-economics – by CIE
- Hydrological modelling – by Bewsher Consulting
- Hydrodynamic modelling – by Water Research Laboratory (UNSW)
- Wetland ecology – by Cumberland Ecology

As of October 2010, a range of supplementary issues or questions have been raised by WRL, Cumberland Ecology, and Bewsher.

Hunter Water's response to these questions is arranged in this report, under the respective reviewer headings.

2 Report Focus

To simplify the response, this report focuses almost solely in responding to the expressed concerns, as they relate to the designated Ramsar wetland site.

3 Water Research Laboratory (WRL) 13 September 2010

3.1 Dam Filling

The WRL review identified that the modelling undertaken does not include a detailed assessment of the resultant hydrological and water quality impacts of the dam filling period.

The first round of modelling was undertaken using the ELCOM model. The purpose of the model is twofold. Firstly it comparatively determines if the estuary is sensitive to changes in flows, as may result from the construction of Tillegra Dam and secondly, if more modelling was required, it proves the mixing status of the estuary and therefore the applicability of a 2D model.

The sensitivity analysis using ELCOM examined a range of differing scenarios for pre and post Tillegra Dam. It also included a range of flow variables for Seaham Weir of interest to the NSW Office of Water. It also included a fill up scenario.

The ELCOM model result demonstrated that the estuary was not sensitive to changes in flow, as may be derived by either fill up or operational modes.

Despite the fact the modelling served its purpose showing that the estuary was not sensitive to changes in flow, in response to representations from NSW Office of Water and NSW Planning, HWC was required to commission and run additional modelling 2D modelling at considerable expense to rate payers, despite the fact that it was known that the additional modelling would not provide any more meaningful information than that garnered from the ELCOM results which was satisfactory for the purpose it was used (sensitivity analysis).

In determining what scenarios to consider for modelling effects on the Hunter River Estuary using the 2D Tuflow model, after considering the ELCOM results, Hunter Water and its consultants came to the conclusion that the first filling phase was not critical.

By assuming that the first filling phase should be modelled, Planning and a number of its review consultants are adopting a default position rather than critically reasoning what scenarios are relevant to the specific proposal being assessed.

Consider the following;

The first filling phase of a dam is characterised by a long period during which no water flows over the spillway and the only flows from the dam are those intentionally released through the outlet works. However, long periods of zero flow over the spillway are not only limited to the first filling phase. During the operation of the dam, there will be periods of drought during which the water level is declining and no water flows over the spillway. Once the drought breaks, there will be a period of refilling, also involving no flows over the spillway.

When comparing the first filling phase of Tillegra Dam with it operating at full capacity, one must also consider the significant difference in water being extracted for supply to customers and hence not reaching estuary.

The ELCOM modelling presented in the EAR took this into account and showed that the first filling phase was not a critical scenario compared to scenarios involving extractions at peak demand. Consequently we concluded that including first fill scenarios in further analysis was unnecessary and would be a waste of time and effort.

As a very simplistic illustration of the scale of the effect of extractions for customers at full demand, consider the following. Assume that the first filling at current demand takes 5 years. The volume of water prevented from reaching the estuary would be equal to 450 GL (the volume of the reservoir) plus a small volume which evaporated from the reservoir as it filled. Now consider a scenario where the dam has been virtually completely emptied by drought and is re-filling under maximum demand, 61GL/yr greater than current demand. To fill the dam in the same 5 year period would take the volume of the reservoir (450 GL) plus the volume of additional water extracted to meet demand (61 GL/yr x 5 yrs = 305 GL) plus the evaporation. This is obviously not a proof as to which scenario represents the worst case but should illustrate how dangerous it would be to assume that first filling is the critical case.

Hunter Water is adamant that the first fill period is not critical and that this is a rational conclusion reached from the evidence previously presented. Planning has not indicated any specific deficiency in our rationale and we can only assume that Planning and its consultants are working on a preconception that first filling is critical rather than reaching a conclusion based on the evidence.

Our response to a detailed analysis of a “dam filling period” therefore relates to a question of relevance. Currently, HWC has spent somewhere in the vicinity of $500k on modelling and estuarine ecological analysis. Because modelling is both very expensive and time consuming, our view is that only model runs that are informative should be undertaken.

In summary, if further modelling of “fill up” stages is required, it can be undertaken, however, although counter intuitive to some, as previously detailed, the concept of a “first filling stage” has no bearing on potential environmental impacts of the dam, as opposed to any other time period within the dam’s operational life. Indeed, if at anytime an impact was to occur to end of system flows to the estuary, this would be most likely to occur when the dam was operated at yield.

3.2 Flood Calibration

The WRL review identified that there was a significant issue with the flood calibration of the Hunter Estuary which was used by BMT WBM in its flood assessment.

The implication of this statement in the manner put by NSW Planning is that the flood model is not reliable and therefore cannot be used to assess impacts from flooding within the Ramsar Wetlands. This is not true.

The issue raised by the reviewer, relates primarily to the matching of the flood recession curve at Raymond Terrace. This limitation is noted by BMT WBM (2010) on page 56 of the collated assessment report and relates to scaling of the flood hydrographs for the Hunter River by previous investigators.

This identified issue by both the report authors and subsequently, the independent reviewer has absolutely no bearing on the flooding inundation extents or depths relevant to the Ramsar wetlands. The recession curve issue only applies to Raymond Terrace, some 16 kilometres upstream of the Ramsar wetland site.

If NSW Planning consults figure 4-5 on page 56 of the collated assessment report, as referenced by WRL when discussing the issue, it shows the flooding calibration to have a good accuracy at Hexham, 3 kilometres upstream of Ramsar boundary and at Stockton, on the downstream edge of the Ramsar boundary, the calibration is excellent.

Specifically;

The observed peak flow at Hexham for the calibration event is 1.64m AHD and the modelled peak is 1.7m AHD. There is a difference of 6 centimetres in real and modelled flood heights in absolute terms and the relativities as shown by figure 4-5 are reasonably preserved over the 128 hour period.

At Stockton, the observed peak flow for the calibration event is 1.08m AHD and the modelled peak is 1.1m AHD. There is a difference of 2 centimetres in flood height in absolute terms and the relativities as shown by figure 4-5 are exceptionally well preserved over the 128 hour period.

As demonstrated in the reports, NSW Planning can rest assured that there are no significant issues with the flood modelling calibration that would prevent it providing an excellent insight to potential affects on flooding in the Ramsar wetlands.

It is noted that the flood model is not new. It was previously used by the RTA to assist with the design of significant civil engineering works on the Pacific Highway. The consultant, BMT WBM has significant experience in flood modelling and has a long standing involvement in environmental assessments of the Hunter River, including that relevant to estuary management planning and most recently the Flood study for the Hunter. These are all commissions unrelated to HWC.

Based on the significant experience of BMT WBM and the previous use of the model in other major projects, HWC has no reason to consider that the model may have any significant deficiency relevant to this study and indeed, the issue of the flood recession curve which is the issue raised by the reviewer and also raised in the first instance by the report authors, has been demonstrated to be restricted to Raymond Terrace, many miles away from the wetlands. At the calibration points in the lower estuary which are in close proximity to the Ramsar wetlands, the results indicate that the model works well and provides good representative relative data, necessary for a satisfactory assessment.

3.3 Upper Estuary

The reviewer concludes that the neither the ELCOM model nor the TUFLOW FV model can be relied upon to predict dry weather inflows and salinity intrusion into the Upper Estuary.

It is noted that the Tillegra Dam proposal does not affect dry weather inflows to the estuary and consequently salinity intrusion. Seaham weir currently blocks low flows (dry weather flows) from entering the estuary from the Williams River. This occurs with or without Tillegra Dam. Modelling of this existing process and further, whether the model adequately represents any effect, therefore, does not significantly add value to the environmental assessment process as related to understanding impacts within the Ramsar wetlands which are not located in the upper estuary.

Not withstanding, a response detailing the models performance including its applicability to the upper estuary is included in appendix A.

3.4 Quantifying Impacts

The reviewer identified that the assessment in the proponents collated report is descriptive, rather than providing quantifiable impacts (such as providing appropriate mapping of quantifiable changes to flows, flooding, and salinity changes in the estuary) particularly those that are relevant for key ecological processes and with a focus on Ramsar wetlands.

The modelling provides quantifiable data. All of the quantifiable data is given in the report through a variety of illustrative mechanism such as mapping, figures and tables. The quantifiable changes in abiotic parameters are so minor that they have no implication for the ecological assessment. The data from an ecological perspective shows that there are no meaningful quantifiable impacts to flows, flooding and salinity in the vicinity of the Ramsar wetlands. Hence a descriptive discussion is given because extensive mapping beyond that given is redundant or otherwise unnecessary.

For example, consider changes in flooding. The model results show that depth of flooding may change but as noted in the report, there is no discernable difference to flooding extents pre and post Tillegra when presented graphically. Flood depth maps were therefore produced. Maps showing changes to spatial extents were not. Per request of NSW Planning, the flood inundation extents for pre and post Tillegra have now been mapped in any case. This mapping provided, as previously noted in the text, clearly shows no meaningful change to extents.

In certain circumstances, such as with the Elcom model, the data given provides an indication of relative changes based on a steady state analysis. The estuary of course is dynamic. The results are therefore not absolutes. Graphical mapping of such outcomes in absolute terms is not appropriate and would be interpreted erroneously.

Consider tables 5.9 and 5-10 in the Collated Assessment Report detailing long section water level profile impacts from the ELCOM model. The majority of the quantifiable modelling results show changes less than 0.5 millimetres, however in a few distinct cases mainly related to low flow periods, changes are recorded mostly around ~ 7 millimetres. Is this change significant and can it be mapped? To answer this question compare the pre-dam low and high scenarios data in the report and consider;

- Static translation of a negative 7mm change in tidal height may only affect flooding extents by a few centimetres or a few metres at most, depending on the topography of the exact area in question.

- The natural variation in antecedent flow conditions into the estuary can affect the tidal height across the estuary by approximately 50mm (the affect is greater the distance from the ocean)

- The effect of wind and fetch across the surface of the water that can drive waves greater than 300mm high through fringing mangroves and into saltmarsh areas.

- That since the announcement of Tillegra Dam in 2006, sea level has risen in Newcastle harbour by 5.9mm[1] and this trend is continuing.

- That sedimentation rates in the Ramsar wetlands including saltmarsh can range from 2mm to 5mm per year.

- That elevation of saltmarsh areas can also rise and fall through the process of compaction and changes to groundwater levels by several millimetres per year.

- That the tidal prism and amplitude is dynamic, responding to infilling from upstream sediments sources and major dredging works undertaken in the port.

Mapping the changes in the long section profile is practically impossible and will not change our understanding of the potential impacts of Tillegra Dam. The potential for impacts on these quantifiable but exceedingly minor changes are nil because any effects are swamped by natural background variations. Mapping the data presented in the tables is realistically, not achievable and further, will not change the outcomes of the environmental assessment undertaken by the consulting ecologists. They have examine the data and provided an expert opinion.

Further consider tables 5.11 and 5-12 which details ELCOM model results for salinity. The majority of results under the different scenarios vary by a fraction of a part per thousand. The results are in fact recorded in increments of 1 part per million (0.001ppt). Recording salinity levels to three decimal places, for an ecological assessment in an estuary, an environment with widely fluctuating salinity conditions is completely unnecessary. Small variances recorded in increments of 1ppm have nil implications for estuarine ecology. In fact, such small changes are hardly relevant to consider even in freshwater aquatic ecosystems, unless the background salinity was already significantly high and close to the limits of tolerance for some species. Therefore there may be quantifiable changes in some steady state scenarios by a few hundred ppm, but when considering the effect of such changes in the context of ecological consequences within a dynamic estuarine system, these may as well be regarded as nil changes.

There is no point in presenting detailed mapping showing nil changes. That is, how salinity in an estuary may change by a few fractions of a part per thousand. These deviations although quantifiable by the modelling are in the real world, undetectable. The deviations are so small they are meaningless in terms of understanding potential impacts. Consider how mangroves and saltmarsh would respond to a change in salinity of this magnitude. These plants may have preferential distributional ranges in the tidal and supra-littoral zone, however they can tolerate both freshwater during a flood and at the other end of the spectrum, hyper saline conditions during a drought. Mapping or illustrating non meaningful change in salinity will not change our understanding of the potential ecological impacts of Tillegra Dam.

3.4.1 Further consideration of flooding

We agree with the reviewers and NSW Planning that the intuitive expectation should be that as flood depths decrease, spatial extent of flooding should contract, as flood water does not flow as far across the upward sloping elevations of any adjacent floodplain. Consequently we understand that the mapping which shows no real changes to flooding extents may have been counter intuitive to normal expectations.

It is important to appreciate however that the Hunter Estuary and its wetlands occur in a highly modified landscape that is atypical to a normal estuarine environment. Specifically, almost the entire Hunter estuary Ramsar site is surrounded by levee banks and floodgates or

[1] Long term eustatic sea level trends since satellite altimeter measurements commenced from 1990 are estimated by CSIRO to be 3.2mm/yr. Sea level rise and its distribution affected by annual variations in global sea temperature. For the purpose of this paper we have adopted conservative sea level rise rates of 1.18mm/yr as recorded from the Newcastle Ocean Gauge and 0.33mm/yr at the Hexham gauge observed since the 1970's, as cited by Rogers (2004)

other engineered structures. These impede the free flow of water and restrict the wetlands into narrow tidal margins along the main watercourse. The flooding is constrained within these restricted areas.

In practical terms this means that tidal waters are restricted by the presence of the levee banks. When a flood occurs, it cannot extend further onto the floodplain because the levee banks hold the water in the main channel, generally around the existing mean high water extent delineated by the embankment (some levee banks were extended into the main channel and backfilled). The flood simply rises or falls almost vertically, hard up against the structures, without changing spatial extents. The inset photos in figure one (a), show the types of structures that cause this effect in the North Arm of the estuary. Figure one (b) shows the significant flood levee and ring drain surrounding Fullerton Cove.

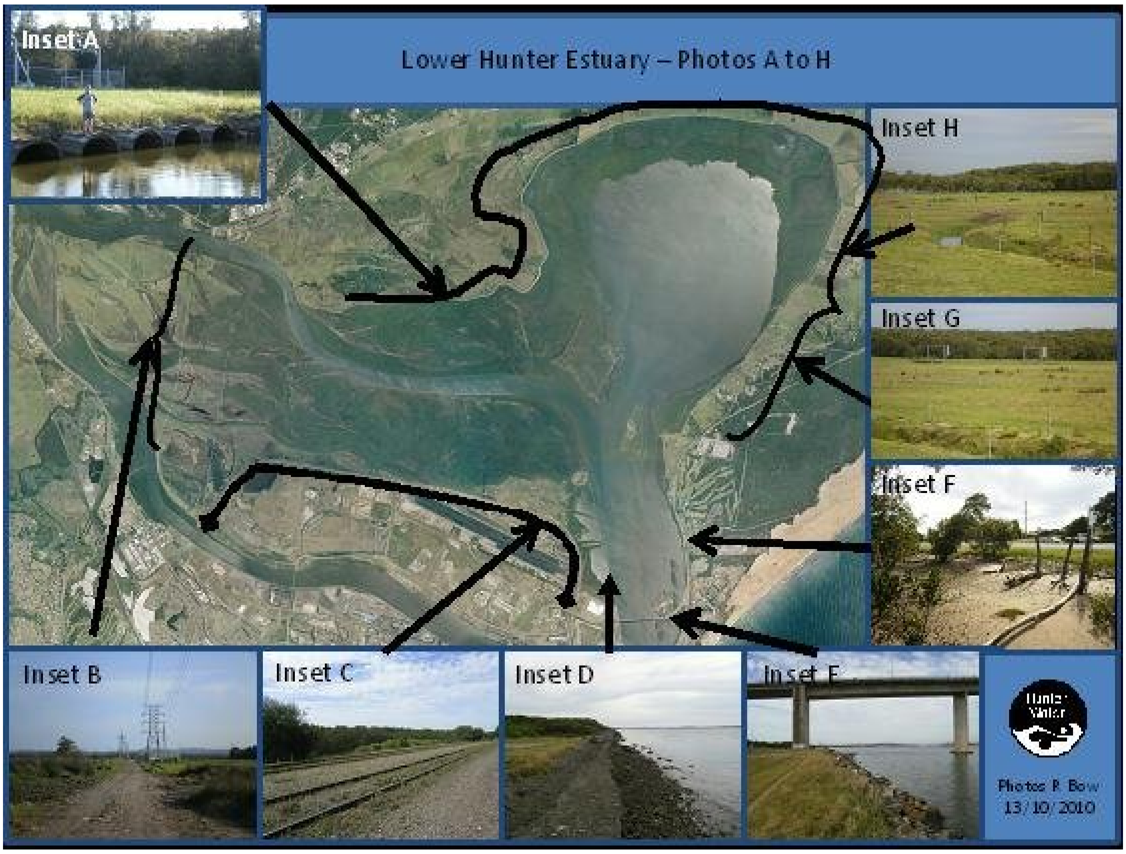


Figure 1a – Typical structures affecting flooding in the lower estuary.

Figure 1b – Fullerton Cove ring drain and levee bank

A description of the inset photos detailing a number of relevant structures is as follows;

Photo A - This shows a typical floodgate (upstream side) which is part of the levee bank, ring drain and access road to the North West of the Hunter River Estuary Wetlands. These drainage and flood control works were constructed in the 1970's. It encircles all of Fullerton Cove, isolating the entire north western section of the Hunter estuary wetlands, from the adjacent Tomago wetlands and industrial development lands.

Photo B - This shows the electricity easement and service road embankment that delineates Kooragang Island from Ash Island. The easement and road acts as a minor flood bank across the western fringe of the Ramsar wetlands. There are small culverts that allow tidal flows across into Ash Island, for a salt marsh regeneration project overseen by the HCRCMA. There are several high voltage lines and service easements of this type elsewhere across Ash / Kooragang Island that have similar effects.

Photo C - This shows the rail embankment that can service heavy industry and the port of Newcastle on Kooragang Island. It is located behind the coal loaders on the southern side of the island. The embankment has been constructed on fill over the wetlands, and is about 2m in height. The rest of Kooragang Island has been filled southwards, back from this point. The embankment acts as a substantial levee bank along the southern boundary of the Ramsar wetland site.

Photo D - This is a photo of Kooragang dykes, one of the more important bird roosting areas in the lower Hunter estuary. The dykes appear to be constructed from blast furnace slag dumped from the old Newcastle steel works. They run for several kilometres along the southern bank of the north arm of the river. There are several breaches in the dykes that allow water to flow through behind to the railway on a rising tide. Although the dykes have been breached, they still attenuate the free flow of water from the main arm of the river. The main drainage point of the mangrove wetlands behind the dykes is in actual fact further west back up the river towards Ash Island.

Photo E - This photo shows the northern bank of the north arm of the river, looking back to Stockton Bridge. Note that the banks are quite steep and rock armoured, typical of much of the lower estuary. Even the most extensive flood flows are unlikely to overtop this bank.

Photo F - This photo shows the Fern Bay road from Stockton Bridge. The roadway is by default a levee embankment that constrains the estuary to the west of this location for about a kilometre to Fullerton Cove.

Photo G - Northwards from Fern Bay Road, this photo shows the floodgates and levee banks typically found fringing Fullerton Cove as noted within photo A. The embankment in this photo next to the flood gates is approximately ~2m in height if not greater. All flooding is effectively controlled at this location except that caused by localised rainfall prior to discharge through the drains and flood gates.

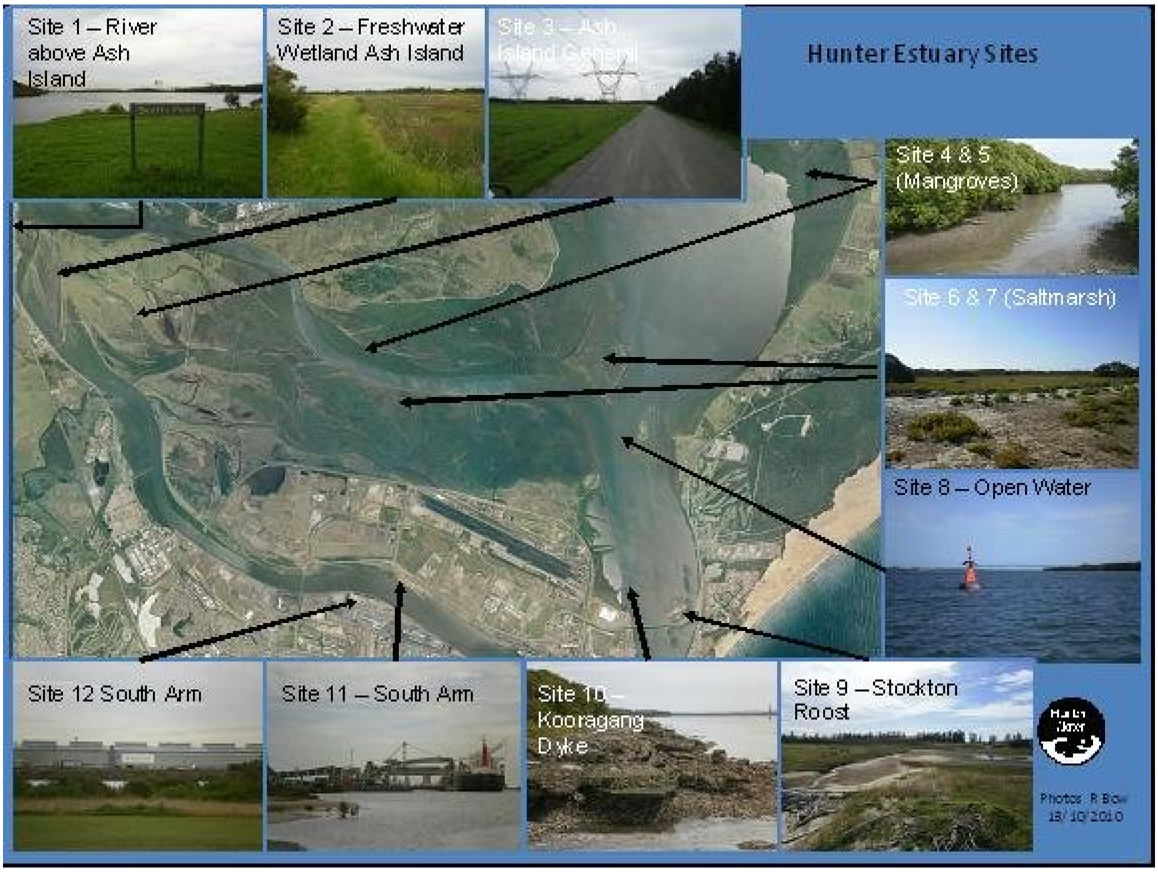
Photo H - This photo shows the continuance of the levee banks at Fullerton Cove. A typical agricultural drain installed in what would otherwise be wetlands behind the embankment is also shown in the photo (pre-farm development). Note the straight lines (almost hexagonal around the Ramsar wetlands) delineating the mangroves against the pasture on the main 1:25,000 aerial photograph. Such delineation between the vegetation types is clearly non natural. This indicates just how far the embankment extends around Fullerton Cove, constraining the wetlands in the Ramsar site.

3.4.2 Specific Site Analysis of Hydrodynamic Model Outputs

Whilst it is difficult for Hunter Water and its consultants to provide additional “mapping” as requested by NSW planning and its reviewers, we have selected several representative sites within the lower estuary to illustrate the on ground characteristics of the wetland with photographs to illustrate the character of the Ramsar wetlands and further discuss the results of the modelling at a micro level.

This should provide a more fulsome understanding of why HWC’s consultants have concluded that should Tillegra Dam be approved, there would be nil meaningful changes to the systems ecology.

These sites have been selected as representative of the characteristics of the lower Hunter Estuary in or adjacent to Kooragang Island, Ash Island, Fullerton Cove and in general, the Hunter estuary Ramsar wetlands site. The locations of each site are depicted in figure two.



<u>Figure 2</u> – Sites in the Hunter Estuary for Impact Assessment Discussion

It is noted that estuaries are highly dynamic, variable environments. Plant and animal species have evolved to tolerate extreme fluctuations in water levels, salinity, temperature and general water quality parameters. They are not sensitive, rather, the fact that after several hundred years of industrial and agricultural development they are still present, bears testament to how resilient these ecosystems actually are.

3.4.3 Site 1 – Tip of Ash Island Looking to Hexham Bridge

This site is open water habitat in the river adjacent to the northern western most point of Kooragang / Ash Island, approximately two kilometres upstream of the Ramsar wetland boundary. The banks of the Island are up to 1m higher than MHW. The banks are well grassed with improve pasture and there are Casuarinas planted along the foreshore several rows deep. The North and South arms meet at this point. The river is approximately 100m wide. Fringing mangroves are apparent on the far bank. The full size photographs of the site is shown below.

Figure 3 Confluence of North and South Arms, Hunter River, adjacent to Ash Island

Salinity

The isohaline profile figures derived from the Tuflow FV model are shown at page 152, 153 and 154 of the collated assessment report. They show the relative distribution of salinity isohalines in the estuary during the decade commencing in 1940. Essentially a long term time period that includes a prolonged drought, more frequent flows from the Williams and Patterson as opposed to the Hunter River, combined with episodic floods.

Compare scenarios 1 (pre Tillegra) with scenario 4 (post Tillegra) the plotted frequency curves are almost identical to each other. This indicates that there will not be significant deviance from baseline conditions, should Tillegra Dam be constructed.

The summary of maximum and minima salinities for the scenarios at this site is given in table 5.13 of the collated assessment report (approximated as Hexham). There is a quantifiable change of 0.1ppt on the maximum daily salinity at this point between the pre and post Tillegra Scenario. The implication of a 0.1ppt change (100ppm) on the systems ecology is estimated to be nil.

The ELCOM steady state simulations are in agreement with the Tuflow FV model results. ELCOM shows that at this site, 19km from the mouth of the ocean, there are no meaningful changes to salinity (refer table 5-11 in the collated assessment – distance 19285m).

Specifically, salinity may vary by a few fractions to a bit more than a part per thousand under low, median, median fill up and high flow scenarios. The deviations however are so small that it is impossible to describe the potential impacts.

For example, with all antecedent environmental characteristics of the estuary being assumed equal the model shows that under low flow conditions, salinity may change from 21.599ppt to 21.278ppt post Tillegra Dam (a difference of - 0.321ppt). The salinity actually decreases minutely at this location as part of the project proposal is to moderately increase flows over Seaham Weir through the construction of a new fishway, to improve system connectivity between the estuary and the Williams. With a fresh in the Williams, salinity could change between 7.109ppt and 8.648ppt (a difference of 1.539ppt).

The deviations are all within the range of existing natural, background variations that could be expected to occur at any time. The impact of a - 0.321ppt change to salinity to the ecology of the river under low flow conditions or 1.539ppt with a fresh in the river is from an ecological perspective, nil.

NSW Planning and the independent reviewers are asked to bear in mind that the ELCOM model is a steady state simulation that effectively isolates the system dynamics to allow a comparative analysis of relativities between the pre – post flow scenarios. The ELCOM model is not providing an absolute reference to a static salinity level for any site in the river.

Obviously in the real world the estuary is a dynamic environment. Salinity at this location may in fact fluctuate between 5ppt and 30ppt depending on the level of antecedent freshwater flow in the rivers and the tidal stage. This is why estuarine plants and animals have evolved to withstand severe osmotic stress and why, from an ecological perspective, a change of 0.321ppt during low flow or 1.539ppt during a fresh event, is a meaningless change when compared to the natural background variation that can occur at this point in the estuary.

Changes to estuary water levels under normal flow conditions
The ELCOM steady state simulations also show differences in water level profiles of between - 6 millimetres (low flow conditions) and +2 millimetres (higher flow conditions). Against steep under cutting banks at this location, of about 1 metre in height, there is no change to habitat from an increase or decrease in wetted area perimeter. The deviations are also within the range of existing natural, background variations that could occur over time. The modelled changes are so slight that an analysis of impacts would be impossible at this location as there is no cause from which to measure an effect.

Changes to estuary water levels under flood flow conditions
The Tuflow flood model mapping indicates that during a 1 in 5 year flood, there may be up to a 10mm change in flood depth (from a flow of ~ 0.9m going to ~ 0.89m depth, about the width of an average person's fingernail). The flood hydrograph given on page 107 of the collated assessment report shows that whilst the peak discharge of the flood event is reduced, changes to flood duration is not significantly affected (there is minor lag on the recession but not outside of likely natural variation). Because of the bathymetry of the river and topography at this site, the spatial extents are not materially affected.

The Tuflow flood model mapping indicates that during a 1 in 10 year flood, there may be a reduction of about 40mm in flood depth (from 1.2m to about ~ 1.16m). The flood hydrograph given on page 108 of the collated assessment report shows that whilst the peak discharge of the flood event is reduced, flood duration is not significantly affected (there is minor lag on the recession but not outside of likely natural variation). The spatial extent of flooding does not change. A flood of this magnitude will effectively inundate most of Ash Island with or without Tillegra Dam.

Other larger flood events are affected in a similar and relative manner. Further discussion on the potential changes are not given here however, as they would not contribute to the discussion of derived impacts.

Summary

An analysis of potential changes at this site, show that the implications of Tillegra Dam being constructed for this site are as follows;

- nil appreciable change to salinity
- nil meaningful change to normal water level
- nil meaningful change to flood height
- nil meaningful change to flood extent
- nil meaningful changes to flood duration

The ecological implication of Tillegra Dam to this site is therefore likely to be nil, reflective of the general observations made by the consulting ecologists for the entire lower estuary and wetlands area.

3.4.4 Site 2 –North Western Ash Island freshwater wetlands

This site covers north western most point of Kooragang / Ash Island, approximately one kilometre upstream of the Ramsar wetland boundary. The island is well grassed with improved pasture. There is the occasional incidence of fireweed typical to the Hunter. A number of low lying depressions and wetland swales cut through the pasture. The predominate plant within the swales are the reed, *Phragmites australis.*

Figure 4: Freshwater wetlands on Ash Island

Magnitude and Frequency of Salinity at this Site
The wetlands are isolated from the river. They are freshwater wetlands that are charged from localised rainfall and runoff from the adjacent pasture land. As they are isolated from the river, Tillegra Dam cannot affect the salinity of this site.

Changes to water levels under flood flow conditions
The Tuflow flood model mapping indicates that during a 1 in 5 year flood, there may be up to a 10mm change in flood depth (from a flow of ~ 0.9m going to ~ 0.89m depth, about the width of an average person's fingernail) however a flood of this magnitude either pre or post Tillegra Dam can be expected to fill the swales and depressions on the island with freshwater.

The flood hydrograph given on page 107 of the collated assessment report shows that whilst the peak discharge of the flood event is reduced, changes to flood duration is not significantly affected (there is minor lag on the modelled recession but not outside of likely natural variation). Because of the bathymetry of the swales and general topography at this site, the spatial extents are not materially affected.

Other larger flood events are affected in a similar and relative manner. Further discussion on the potential changes are not given here however, as they would not contribute to the discussion of derived impacts.

Summary
The implications of Tillegra Dam being constructed for this site are as follows;

- nil appreciable change to salinity – the area is not tidal
- nil meaningful change to normal water level - the area is not tidal
- nil meaningful change to flood height – the swales will be inundated on a 1 in 5 event with or without Tillegra Dam.
- nil meaningful change to flood extent – the topography of the swales dictates the area of flooded.
- nil meaningful changes to flood duration

In effect, the wetland swales are effectively drains for the adjoining pasture land, with freshwater levels determined by localised rainfall and runoff. The ecological implication of Tillegra Dam to this site is therefore likely to be nil, reflective of the general observations made by the consulting ecologists for the entire lower estuary and wetlands area.

3.4.5 Site 3 – Ash Island, Kooragang City Farm and infrastructure supporting the Kooragang Wetlands Rehabilitation Project

This part of Ash Island is above the highest astronomical tide. The only affect that Tillegra Dam could have on this part of the Island is that related to impacting upon higher recurrence interval flood events. Photo's of this main part of the island is shown in figure 5.

Figure 5: Ash Island (General)

Per discussion on flooding in at Site 1 and 2, the changes to flood heights are extremely minor and the implications for Tillegra Dam being constructed for this site is as follows;

- nil appreciable change to salinity – the area is not tidal
- nil meaningful change to normal water level - the area is not tidal
- nil meaningful change to flood height – the swales will be inundated on a 1 in 5 event with or without Tillegra Dam.
- nil meaningful change to flood extent – the topography of the swales dictates the area of flooded.
- nil meaningful changes to flood duration

The ecological implication, as well as the socio economic implication of Tillegra Dam to this site is therefore likely to be nil, reflective of the general observations made by the consulting ecologists for the entire lower estuary and wetlands area.

3.4.6 Site 4 and 5 - Mangroves in Ramsar wetland.

These two sites are generally representative of mangrove wetlands within the north arm of the Hunter. Within Fullerton cove there are extensive fringing stands of the grey mangrove, *Avicennia marina* which extend the full circumference of the cove and are also present on a series of smaller inter tidal islands.

In the main channel of the Hunter, the stands of grey mangrove tend to be taller and denser, with seedlings trapping sediment and moving into the main channel. Behind the main mangrove stands, the community appears to intergrade frequently with saltmarsh EEC.

Further up the river towards the north western boundary of the Ramsar site, the occasional river mangrove *Aegiceras corniculatum* can be found, normally higher in the tidal zone and on occasion, within saltmarsh areas. Photo's typical of the mangrove habitat within the river and wetlands are shown in figure 6.

Figure 6: Typical mangrove habitat of the lower Hunter Estuary

Salinity
The isohaline profile figures derived from the Tuflow FV model are shown at page 152, 153 and 154 of the collated assessment report. They show the relative distribution of salinity isohalines in the estuary during the decade commencing in 1940. Essentially a long term time period that includes a prolonged drought, more frequent flows from the Williams and Patterson as opposed to the Hunter River, combined with episodic floods.

Compare scenarios 1 (pre Tillegra) with scenario 4 (post Tillegra) the plotted frequency curves are almost identical to each other. This indicates that there will not be significant deviance from baseline conditions, should Tillegra Dam be constructed.

The summary of maximum and minima salinities for the scenarios at this site is given in table 5.13 of the collated assessment report (approximated as North Arm (Upstream). It is acknowledged that the salinity distribution may be slightly different for Fullerton Cove. There is a quantifiable change of 0.3ppt on the maximum daily salinity at this point between the pre and post Tillegra Scenario and 0.1ppt on the minima. The implication of a 0.3 & 0.1ppt change (between 100ppm and 300ppm) on the systems ecology is estimated to be nil. Interestingly, scenario 6 within table 5.13 (inclusion of 2.5GL ECA) shows that the adoption of such a release strategy could reduce the scope of the deviations by 0.1 to 0.2ppt.

The ELCOM steady state simulations are in agreement with the Tuflow FV model results. ELCOM shows that at Fullerton Cove, approximated at the mouth of the cove some 10km from the mouth of the ocean, there are no meaningful changes to salinity (refer table 5-11 in the collated assessment – distance 9922m).

Under low flow conditions, salinity is normally 32.964ppt and this will not change post Tillegra Dam. With a fresh in the Williams, post Tillegra, as more water is extracted from the Williams, salinity could slightly increase from 28.013ppt to 29.007 (a difference of 0.994ppt).

Further upstream in main north arm of the Hunter River, 15km from the ocean (at 14949m in the table) under low flow conditions, salinity is normally 28.541 and this may change by – 0.321ppt post Tillegra. With a fresh in the Williams, post Tillegra, as more water is extracted from the Williams, salinity could slightly increase from 17.943ppt to 19.466 (a difference of 1.523ppt).

These differences are well within the limits of tolerance for mangroves that can grow in a variety of estuarine environments. The salinity differences at either location are so marginal that they would not have any discernable impact on the growth or survival of either known species. The natural background salinity in the river and within Fullerton Cove is of course, dynamic and highly variable. The variances noted by the steady state modelling are insignificant in terms of the substantial natural background variation.

Changes to estuary water levels under normal flow conditions
The ELCOM steady state simulations also show differences in water level profiles of between - 7 millimetres (low flow conditions) and -1 millimetres (higher flow conditions). Within the preferred intertidal zone of both species of mangroves the deviations are extremely small. They are also within the range of existing natural, background variations that could occur over time. The modelled changes are so slight that an analysis of impacts would be impossible at this location as there is no cause from which to measure an effect.

Changes to estuary water levels under flood flow conditions
The Tuflow flood model mapping (represented by sites 7 in Fullerton Cove and site 12 North Arm, Table 5.6) indicates that during a 1 in 5 year flood, there may be up to a 3mm change in flood depth within Fullerton Cove (from a flow of ~ 0.709m going to ~ 0.706m depth. Approximately 5 kilometres upstream the difference may be up to 12mm (0.866m going to a depth of 0.854m). Changes to other larger recurrence interval floods are relatively similar.

The flood hydrograph given on page 107 of the collated assessment report shows that whilst the peak discharge of the flood event is reduced, changes to flood duration is not significantly affected (there is minor lag on the recession but not outside of likely natural variation).

Because of the bathymetry of the river and topography at this site, the spatial extents are not materially affected.

Summary

An analysis of potential changes at this site, show that the implications of Tillegra Dam being constructed for this site are as follows;

- nil appreciable change to salinity
- nil meaningful change to normal water level
- nil meaningful change to flood height
- nil meaningful change to flood extent
- nil meaningful changes to flood duration

The ecological implication of Tillegra Dam to this site is therefore likely to be nil, reflective of the general observations made by the consulting ecologists for the entire lower estuary and wetlands area.

3.4.7 Site 6 and 7– Saltmarsh in Ramsar wetland.

The main saltmarsh areas within the lower estuary occur at the juncture of the North Arm of the Hunter and Fullerton Cove. There are also significant areas within the north western segment of Kooragang Island, near the upstream boundary of the Ramsar wetlands. Typical saltmarsh habitat including open salt pans, Samphire and couch are shown in figure 7.

Figure 7: Typical saltmarsh habitat of the lower Hunter Estuary (photos from Fullerton Cove and the north western boundary of the Ramsar wetlands on Kooragang Island)

As the most considerable portions of saltmarsh in the Hunter Estuary occur between Fullerton Cove and the north western portion of the Ramsar wetlands, between 10km and 18km upstream from the ocean, the same environmental conditions described in section 4.4.6 (mangroves) can be considered to apply, and therefore will not be repeated here.

As a summary however, simply focusing on salinity and tidal height, the ELCOM results show that under median flow conditions, when the dam is operating at yield, changes to water level heights range between +/- 0.1mm and 0.5mm. Under a fill up scenario (but with the Williams running at a moderate fresh) the results associated with relative changes are almost identical. These changes are so slight that the differences in water level and subsequent inundation would not be distinguishable with the human eye across the gradual slope of a wetland saltmarsh area.

Below the 25th percentile of occurrence of flows, the relative differences in observed versus expected water level heights could change by - 6 to 7mm. Given that saltmarsh species generally inhabit the mid tidal range to the spring high water mark, and may be found on flats with gradients of approximately 1 in 100 (although they are often found in more restricted, steeper rising elevations in bands behind fringing mangroves), in theory the tidal extent of inundation across such flats could be reduced by a few centimetres to a few metres, depending on the exact topography of the site.

The consequences of these changes however are undetectable with the scope of natural background variations that may be experienced within the estuary. Section 4.4 of this report discusses the confounding factors that prevent these small changes being effectively distinguished within these typical habitat areas.

Because salt marsh is an endangered ecological community that has suffered significant declines, this issue is worthy of further scrutiny. Accordingly we have discussed this matter robustly in Section 5.5 of this report (quantifying species specific impacts). Readers are referred to this section for more information.

3.4.8 Site 8 – Open water habitat at the junction of North Arm Hunter and Fullerton Cove

The site is representative of open water estuarine habitat within the middle of the lower Hunter estuary Ramsar wetlands. Water depth is relatively shallow, about three to four metres in the deepest part of the channel. The water is highly turbid all year. There is no seagrass. The channel is a benthic environment mainly consisting of finely worked sediment (mud).

This site is estimated to be 10 kilometres upstream of the Pacific Ocean. Photo's of the site are given in figure 8.

Figure 8: Typical open water habitat of the North Arm of the Hunter River (photo's taken adjacent or close proximity to the junction of Fullerton Cove and North Arm)

Salinity

The isohaline profile figures derived from the Tuflow FV model are shown at page 152, 153 and 154 of the collated assessment report. They show the relative distribution of salinity isohalines in the estuary during the decade commencing in 1940. Essentially a long term time period that includes a prolonged drought, more frequent flows from the Williams and Patterson as opposed to the Hunter River, combined with episodic floods.

Compare scenarios 1 (pre Tillegra) with scenario 4 (post Tillegra) the plotted frequency curves are almost identical to each other. This indicates that there will not be significant deviance from baseline conditions, should Tillegra Dam be constructed.

The summary of maximum and minima salinities for the scenarios at this site is given in table 5.13 of the collated assessment report (approximated as North Arm Upstream). There is a quantifiable change of 0.3ppt on the maximum daily salinity and 0.1ppt minima at this point between the pre and post Tillegra Scenario. The implication of a +0.3 / -0.1ppt change on the systems ecology in the minimum and maximum range is estimated to be nil.

The ELCOM steady state simulations are in agreement with the Tuflow FV model results. ELCOM shows that at this site, 10km from the mouth of the ocean, there are no meaningful changes to salinity (refer table 5-11 in the collated assessment – distance at 9922m).

Specifically, the deviations are so small that it is impossible to describe the potential impacts. For example, with all antecedent environmental characteristics of the estuary being equal the model shows that under low flow conditions, salinity is normally 32.964ppt and this will not change post Tillegra Dam. With a fresh in the Williams, post Tillegra, as more water is extracted from the Williams, salinity could slightly increase from 28.013ppt to 29.007 (a difference of 0.994ppt).

Again, NSW Planning and the independent reviewers are reminded that the ELCOM model is a steady state simulation. The real life fluctuations in salinity at this site over any tidal cycle as well as in response to antecedent flow conditions can be significant. The deviations therefore are not meaningful as they are all within the range of existing natural, background variations that could be expected to occur at any time. There are no low flow impacts and the difference of a 0.994ppt with a fresh in the Williams river is from an ecological perspective, nil. Salinity levels at this location are dominated by the downstream marine environment.

Changes to estuary water levels under normal flow conditions
The ELCOM steady state simulations show differences in water level profiles of between - 7 millimetres (low flow conditions) and +0.1 millimetres (higher flow conditions). In the middle of the river in the open water habitat, against the background of the normal tidal range, the deviations are minor. The modelled changes are so slight that an analysis of impacts would be impossible at this location as there is no cause from which to measure an effect.

Changes to estuary water levels under flood flow conditions
The Tuflow flood model mapping indicates that during a 1 in 5 year flood, there may be up to a 3mm change in flood depth (from a flow of ~ 0.709m going to ~ 0.706m depth. The flood hydrograph at this location is more likely to reflect that given for Stockton Bridge as shown on page 107 of the collated assessment report. It shows that whilst the peak discharge of the flood event is reduced, a change to flood duration does not occur.

The Tuflow flood model mapping indicates that during a 1 in 10 year flood, there may be a reduction of about 11mm in flood depth (from 0.842m to about ~ 0.831m). The flood hydrograph given on page 108 of the collated assessment report shows that whilst the peak discharge is reduced, a change to flood duration does not occur.

Other larger flood events are affected in a similar and relative manner. Further discussion on the potential changes are not given here however, as they would not contribute to the discussion of derived impacts.

Summary
An analysis of potential changes at this site, show that the implications of Tillegra Dam being constructed for this site are as follows;

- nil appreciable change to salinity
- nil meaningful change to normal water level

- nil meaningful change to flood height
- nil meaningful change to flood extent
- nil meaningful changes to flood duration

The ecological implication of Tillegra Dam to this site is therefore likely to be nil, reflective of the general observations made by the consulting ecologists for the entire lower estuary and wetlands area.

3.4.9 Site 9 and 10 – Migratory bird roosting habitats at Stockton and Kooragang Dykes

The Stockton diurnal roosting site is on the south eastern downstream boundary of the Ramsar wetland site. It can best be described as a small mounded intertidal flat surrounded by an artificially created moat excavated from the surrounding sand spit. The entire site is approximately 2 hectares in size. The moat is connected to the main channel of the north arm of the hunter via an engineered channel for tidal flow. The mouth of the channel is screened with a rock weir and pool fencing as well as being screened by a floating boom to prevent the recruitment of mangrove seedlings into the habitat. The surrounding sand spit is periodically cleared by the NPWS and the Hunter Bird Observers Club to remove mangroves to improve predator sight lines for the migratory birds.

Kooragang Dykes are on the Southern Bank of the north arm of the Hunter River. The dykes are effectively training walls for the river of about 1.5 to 2 kilometres in length. The dykes are constructed from a material similar to pumice, which is assumed to be blast furnace slag historically sourced from the now defunct Newcastle steel works.

Figure 9 provides photos of both roosting areas. Both these sites are estimated to be 7 kilometres upstream of the Pacific Ocean.

Figure 9: Photographs of the roosting sites of the Kooragang Ramsar Wetlands (North Stockton and Kooragang Dykes)

Salinity
The isohaline profile figures derived from the Tuflow FV model are shown at page 152, 153 and 154 of the collated assessment report. They show the relative distribution of salinity isohalines in the estuary during the decade commencing in 1940. Essentially a long term time period that includes a prolonged drought, more frequent flows from the Williams and Patterson as opposed to the Hunter River, combined with episodic floods.

Compare scenarios 1 (pre Tillegra) with scenario 4 (post Tillegra) the plotted frequency curves are almost identical to each other. This indicates that there will not be significant deviance from baseline conditions, should Tillegra Dam be constructed.

The summary of maximum and minima salinities for the scenarios at this site is given in table 5.13 of the collated assessment report (at this location the North Arm Downstream site, although slightly further downstream is approximated as being reasonably representative). There is a quantifiable change of 0.1ppt on the maximum daily salinity and 0.3ppt on the minima at this point between the pre and post Tillegra Scenario. The implication of a +0.1 / -0.3ppt change (100 to 300ppm) in the minimum and maximum range, on the systems ecology, including the use of either north Stockton or the dykes as roosting habitat by migratory wading birds is estimated to be nil.

The ELCOM steady state simulations are in agreement with the Tuflow FV model results. ELCOM shows that at this site, 7km from the mouth of the ocean, there are no meaningful changes to salinity (refer table 5-11 in the collated assessment – distance 7571m).

Specifically, the deviations are so small that it is impossible to describe the potential impacts. For example, with all antecedent environmental characteristics of the estuary being equal the model shows that under low flow conditions, salinity is normally 33.611ppt and this could change post Tillegra Dam to 33.621, a difference of 0.010ppt. With a fresh in the Williams, post Tillegra, salinity could change from 30.999ppt to 31.487 (a difference of 0.488ppt).

Again, NSW Planning and the independent reviewers are requested to keep in mind that the ELCOM model is a steady state simulation. There are real life fluctuations in salinity at this site over any tidal cycle as well as in response to antecedent flow conditions. The deviations therefore are not meaningful as they are all within the range of existing natural, background variations that could be expected to occur at any time.

Realistically, there are no low flow impacts and the difference of a 0.488ppt with a fresh in the Williams river is from an ecological perspective, nil. Salinity levels indicate that this location is marine dominated.

Changes to estuary water levels under normal flow conditions
The ELCOM steady state simulations also show differences in water level profiles of between - 7 millimetres (low flow conditions) and + 0.8 millimetres (high flow conditions). Against the background of the normal tidal range, the deviations are minor.

The modelled changes are so slight that an analysis of impacts would be impossible at Kooragang Dykes as there is no cause from which to measure an effect.

The potential affect to the North Stockton artificial migratory bird roosting habitat is slightly more difficult to assess. Beyond median flows, there is in all practicalities nil effect, however at low flows, a change of 7mm depth has the ability to change flows moving through restricted channels with flow control barriers such as weirs.

In the case of North Stockton however, the rock weir is porous, being designed to allow water to flow through the structure. Its purpose is not necessarily to control water height and flow. Rather its purpose is to screen young mangrove seedlings from entering the habitat. On this basis, the minor change in very low flow conditions will not significantly change the flow through and over the weir, the hydrologic performance of the moat and therefore the existing characteristics of the roosting habitat.

This position is further supported by the fact that since the projects announcement (2006) and the planned construction of Tillegra Dam (2013) with sea level rise of 1.3mm, there will actually be a positive change in water height by 2.4mm through sea level rise (sea level rise of 9.44mm less 7mm reduction by Tillegra Dam). Sedimentation and compaction rates are not known for this area; however, sea level rise is not predicted to be incrementally linear in nature. The rate of sea level rise will subsume these sedimentation / compaction rates which are likely to be around net +1mm/yr at this location, and rapidly increase thereafter.

Changes to estuary water levels under flood flow conditions
It is noted that during a flood of any of the design magnitudes, the roosting habitats (reported as sights 1 & 3 in table 5-6 of the collated assessment report) are not inundated until a flood greater than the 20 year ARI occurs (it is noted that flood waters will penetrate into the moat at the Stockton site). When this does occur the changes in depth are minimal to what would occur naturally, being around 7mm on the 1 in 20 year event at the dykes. The flood hydrograph at this location will reflect that given for Stockton Bridge as shown on page 107 of the collated assessment report. It shows that whilst the peak discharge of the flood event is reduced, a change to flood duration does not occur.

The spatial extent of flooding at these two sites is not affected. Flood water of any of the design floods used in the analysis are constrained by the railway embankment behind Kooragang Dykes. At the North Stockton roost site, all of the floods are constrained by the rock armouring of the banks near the bridge, and the steepness of the banks of the river carried around to Fern Bay road.

Summary
An analysis of potential changes at this site, show that the implications of Tillegra Dam being constructed for this site are as follows;

- nil appreciable change to salinity
- nil meaningful change to normal water level
- nil meaningful change to flood height
- nil meaningful change to flood extent
- nil meaningful changes to flood duration

The ecological implication of Tillegra Dam to this site is therefore likely to be nil, reflective of the general observations made by the consulting ecologists for the entire lower estuary and wetlands area.

3.4.10 Site 11 & 12 – Riverine Habitat on Southern side of Kooragang Island

These two sites are not located within the lower Hunter estuary Ramsar wetlands; rather they are representative of the remainder of the lower estuary outside of the wetland site. They are depicted in figure 10 and are useful to consider as the ecological character of the Ramsar site is dependant on the entire health of the lower estuary not just that which falls within arbitrary cadastre described on the information sheet.

The South Arm of the Hunter River is bounded by significant port reclamation and dredging works. Site 9 on Kooragang Island is subject to significant development for ship berthing and coal loading. The banks are up to 3m high, with rock revetments holding them in place.

At Site 10, significant filling and reclamation has occurred in the vicinity of the steel works and surrounding industrial lands. The banks are extremely steep, often rock armoured and greater than ~ 5 metres in height.

Figure 10: South arm riverine environment

Salinity
The report has not plotted the isohaline profiles for the South Arm; however the frequency profiles would not be dissimilar to that reported to other locations. That is the plotted frequency curves would be almost identical to each other. The summary of maximum and minima salinities for the South Arm scenarios at this site is given in table 5.13 of the collated assessment report (approximated as South Arm – the reporting point is just downstream of the Tourle Street Bridge). There is a quantifiable change of 0.2ppt on the maximum daily salinity and 0.2ppt minima at this point between the pre and post Tillegra Scenario. The implication of a +0.2 / -0.2ppt change on the systems ecology in the minimum and maximum range is estimated to be nil.

The ELCOM steady state simulations show that at this site, approximated as 8km from the mouth of the ocean, there are no meaningful changes to salinity (refer table 5-12 in the collated assessment – distance 8278m).

Specifically, the deviations are so small that it is impossible to describe the potential impacts. For example, with all antecedent environmental characteristics of the estuary being equal the model shows that under low flow conditions, salinity is normally 33.735ppt and this will change to 33.721ppt post Tillegra Dam. With a fresh in the Williams, salinity could change from 29.823ppt to 30.677 (a difference of 0.854ppt).

The deviations are not meaningful as they are all within the range of existing natural, background variations that could be expected to occur at any time. There are no low flow impacts and the difference of a 0.854ppt with a fresh in the Williams river is from an ecological perspective, nil. Salinity levels indicate that this location is marine dominated.

Changes to estuary water levels under normal flow conditions
The ELCOM steady state simulations also show differences in water level profiles of between - 5 millimetres (low flow conditions) and +0.9 millimetres (higher flow conditions). Against the background of the normal tidal range, the deviations are minor. The modelled changes are so slight, particularly considering these changes are constrained against steep banks and rock revetments that an analysis of impacts would be impossible at this location as there is no cause from which to measure an effect.

Changes to estuary water levels under flood flow conditions
The Tuflow flood model mapping indicates that all flood events remain in channel, which is not surprising given the extent of reclamation and rock armouring of the adjoining river banks. Up to a 1 in 10 event, there is nil change to flooding depth. Very large events (> 1 in 20) can be attenuated at this location by about 10mm at the top of a flood event. The implications of this change in terms of affect on habitat inundation is nil, as the flood waters simply rise marginally against the banks on either side of the river.

Summary
An analysis of potential changes at this site, show that the implications of Tillegra Dam being constructed for this site are as follows;

- nil appreciable change to salinity
- nil meaningful change to normal water level
- nil meaningful change to flood height
- nil meaningful change to flood extent
- nil meaningful changes to flood duration

The ecological implication of Tillegra Dam to this site is therefore likely to be nil, reflective of the general observations made by the consulting ecologists for the entire lower estuary and wetlands area.

3.5 Checking of Estuary Inflows

The review identified that the catchment hydrology should be verified through checking total volumes of freshwater flowing into the Williams River and lost by evaporation against volumes shown in the Bewsher Report

Tillegra Dam will have a surface area of around 21.5km^2. With pan evaporation being around 1250mm/year, and a pan to open water coefficient of around 0.8, the expected open water evaporation from Tillegra Dam is expected to be around 21.5GL/year, which is very close to the estimate provided in Bewsher (2010) Table 2.

The increased evaporation will be offset somewhat by the fact that rain direct on the lake surface will produce more water than would have been produced by rainfall on the catchment area that will be inundated. This interaction leads to an expected increase of around 5.8GL/year of freshwater inflow compared with the pre-dam situation. The net result is that the existence of the dam will lead to around 15.7GL/year reduction in freshwater flowing into the Williams.

The increase in supply associated with Tillegra Dam is around 45GL/year above the existing supply rate of 75GL/year. Combining the increase in town usage with the net increased losses associated with the dam, it is expected that total freshwater flow to the estuary will drop by around 61GL/year, which compares favourably with Item H in Table 2 of Bewsher (2010). Please note that the modelling used in the Tillegra Dam EAR (as presented in Table 2 of Bewsher) is more comprehensive than this estimate, but the closeness of the result demonstrates that no gross errors have been made in the estimation of increased evaporative losses from the Williams Valley associated with the Tillegra Dam proposal.

3.6 Other matters raised by the reviewer

Hunter Water has requested specific feedback from its primary modelling consultant BMT WBM as related to the performance of the ELCOM, TUFLOW and TUFLOW FV in response to observations made by WRL.

Advice was specifically sought on;

- use of the manning's *n* roughness co-efficient for long term modelling,
- water calibration at Morpeth, Hinton and Bolwarra,
- reviewer observations of over and under salinity predictions
- scaling of flood hydrographs

The response from BMT WBM is provided in appendix A. Hunter Water has reviewed the response by BMT WB and is satisfied that the models used are well calibrated and capable of providing an excellent simulation of pre and post dam scenarios for the purpose of the environmental assessment, in all parts of the estuary, including the upper tidal pool.

4 Cumberland Ecology

4.1 Consideration of the most recent ECD of the Kooragang Wetland

The Ecological Character description presented by the proponent for the Kooragang Wetland has not considered the information presented in the most recent report by Hydro-Electric Corporation (2010) such as the known cumulative changes within the Kooragang Wetland.

This is because the work undertaken by HWC and its consultants was substantially completed in 2009. We thank the reviewer for noting that this ECD was not available at the time the work was completed. It is neither fair nor reasonable to expect HWC or its consultants to consider a report in its assessment, prior to it being written and made publicly available.

Further, it is noted that the ECD prepared by Brereton and Taylor Wood (2010) for DEWHA has not been formally released into the public domain. We do not have access to a copy. The DEWHA advice from their website is only that a new ECD has been prepared and this is under consideration.

Ultimately the purpose of the HWC commissioned reports is to determine whether the construction of Tillegra Dam will materially affected the ecological character of the Kooragang Wetlands.

The legal definition of the ecological character is technically that supplied to the Ramsar secretariat on listing or as otherwise updated by the Ramsar manager. In the case of the Hunter Ramsar wetlands, as there is no formal ECD (with the 2010 update still being in prep or under consideration by DEWHA). The default description from which to make an assessment of impacts from, is therefore the Ramsar Information Sheet (RIS) prepared in 2002.[2]

The RIS for the Hunter wetlands is a short summary of the wetlands characteristics and values. It does not provide a quantitative description of every part of the wetlands from which to provide a substantive assessment. Hence the inclusion of additional information regarding the ecological character, in the assessment reports by HWC's consultants.

Ultimately, because the hydrological and hydrodynamic characteristics of the estuary are not predicted by Hunter Water's consultants to change in any material way, beyond normal background variations, within *reasonable limits* the fine detail of the ecological character is fundamentally irrelevant. No matter what its character, if the dam does not fundamentally change the existing hydrological and hydrodynamic parameters in the estuary, it cannot change the ecological character, no matter what refinements are proposed to the ECD.

4.2 Lack of Certainty in Risk Assessment

The proponent's assessment should acknowledge that the existing reasons for the decline of the wetland flora and migratory seabirds are not known, and also given consideration to how the project would impact on the existing decline.

Logically, if the existing reasons for the decline of wetland flora and migratory seabirds are not known, it would be impossible for HWC to also give consideration to how the project would impact on this existing decline (given the apparent lack of knowledge surrounding the effect).

Not with standing this fundamental problem put forward, the existing reasons for the decline of wetland flora and migratory seabirds, on the balance of probabilities, are in fact actually well known. We agree with the reviewer however that they are not known *"…..with precision or within absolute terms"*, because existing historical data prevents conclusions being drawn on absolute terms, beyond all reasonable doubt.

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[2] The Shortland Wetland Centre has a plan of management for their site and an updated ECD. However the Shortland wetlands, part of the Hunter Ramsar assemblage, are not a focus of the assessment as they are comparatively hydrologically disjunct from the estuary.

On balance however, Hunter Water is comfortable with the observations made by its consultants which indicate that habitat destruction is one of the key reasons for migratory bird decline. In regards to the saltmarsh, the same reason holds true. Significant amounts of saltmarsh habitat have been destroyed by draining and reclamation projects within the Hunter estuary. There are some 200 + levy banks and floodgates throughout the lower hunter.

The most recent losses of saltmarsh through mangrove colonisation is however a much more difficult matter to consider with certainty as although sea level may be rising, this may not currently exceed the rate of sediment deposition occurring within the areas, and consequently ascribing the cause of the impact is certainly far more complicated.

The HWC commissioned reports clearly show that the project would not have any fundamentally effect on the existing hydrological and hydrodynamic parameters in the estuary. Consequently we conclude that it can neither contribute to nor arrest the existing decline in migratory shorebirds or wetland flora. We further conclude that should the NSW Government's or the IPCC forecasts for climate change and subsequent sea level rise be realised, the impacts for the lower Hunter estuary will be beyond anything previously seen by modern man, with the fundamental ecological characteristics of the wetlands irretrievably and detrimentally altered. This is certain to occur with or without Tillegra Dam.

4.3 Updating the Limits of Acceptable Change

The proponent's assessment does not include quantifiable LAC as provided by the Hydro Electric Corporation (2010). The term "significant" is not appropriate when evaluating impacts of the "controlled action" as all variables in the "LAC" need to be a quantifiable variable.

It appears that both NSW Planning and the reviewer have formed the conclusion that because the action has been declared a controlled action, it must have associated detrimental impacts requiring control and that these therefore, must not exceed or otherwise be kept within the "limits of acceptable change".

The designation of an action as controlled however does not necessarily mean that it will automatically have adverse affects on the matter; rather it is an administrative mechanism that compels a proponent to extensively research the matter and provide additional information for consideration of the controlling authority.

In this regard, the term "significant" is entirely appropriate to use when evaluating impacts of a controlled action. The legislation itself makes specific reference to the term. As a matter of subordinate policy, DEWHA defines a significant impact as;

> "A significant impact is an impact which is important, notable, or of consequence, having regard to its context or intensity. Whether or not an action is likely to have a significant impact depends upon the sensitivity, value, and quality of the environment which is impacted, and upon the intensity, duration, magnitude and geographic extent of the impacts."

The Tillegra Dam project was designated as a "controlled action" on the basis that it would, or was likely to have impacts on the "*quality, quantity and hydrological flow regimes of surface and groundwater flow*" on Hunter estuary Ramsar wetlands and such would have a significant impact on the ecological character of the wetlands.

Hunter Water's consultants have found no evidence that confirms the hypothesis by the Commonwealth, that there would be an impact on the quality and quantity of flows to the estuary that would have a demonstrable, notable, important consequential affect on the ecological character the wetland.

What this means in practical terms, is that there is no basis for the "controlled action" status and the status of the action should be reviewed by the Minister pursuant to S78 of the EPBC Act. Further, as no change would be caused by Tillegra dam, any "limits to acceptable change” which facilitates some long term natural variance in the wetlands occurring under the ECD, is technically irrelevant.

Not withstanding the above commentary, quantifiable variables when considering any LAC’s for the management of the wetland would be sensible as suggested by the reviewer; however, the current legal framework within which HWC is compelled to work relates back to the RIS as the existing ECD. HWC cannot legally update to a new ECD prior to DEWHA confirming that this is to be adopted and it is formally lodged. Finally, as observed by the reviewer quantifiable LAC’s are difficult to construct around the RIS. The existing RIS is broad, which hampers the construction of meaningful measures.

4.4 Addressing Issues about Modelling

(highlighted list point by NSW Planning within its attachment)

Hunter Water is unaware of any issues related to “modelling” that affects the veracity of the existing assessment. Whilst the reviewers have tendered a range of commentary on the various models used, the reviewers have concluded that the models are satisfactory for use in the lower estuary (where the Ramsar wetland sites are located). Further, although not relevant to the Ramsar wetland assessment, HWC and its consultants dispute the concerns raised related to the application of the ELCOM and Tuflow FV models in the upper estuary.

Hunter Water is further satisfied with the construct and application of its hydrological model, but acknowledges that there are several different ways the modelling could be undertaken. Of all of the appropriate techniques, HWC’s model is conservative in terms of understanding potential estuarine impacts and further, the relativities of change pre and post Tillegra, are appropriately represented.

4.5 Species Specific Assessment

The proponent’s assessment does not provide a species specific impacts assessment including a detailed analysis of the use of the wetlands. Impacts of changes to salinity and flows on sensitive wetland vegetation (specifically saltmarsh), migratory wading birds and on invertebrates within the wetland needs to be addressed for the filling and operational periods. Also the proponent’s assessment does not examine the species or plant communities that are of greatest risk.

Hunter Water agrees with the reviewer’s observation that there have been no species specific impact assessments or assessments of plant and animal communities nor specific consideration of those that are of greatest risk, within the EIA documentation.

Hunter Water’s assessment shows that there would be effectively no changes to the estuaries environmental characteristics as a result of the dam. For example, even the most sensitive estuarine organisms, which would be macro-invertebrates, would not be impacted by a change in salinity of a few fractions of a part per thousand. This is particularly the case where such animals have actually evolved and adapted to wide ranging and rapid changes in salinity, as have all species that substantively spend most of their life cycles within an estuary.

Consider also as an example, that flooding at Kooragang Dykes and at Stockton Bridge within the roosting habitat will not change except in the most exceptional floods greater than 1 in 20 ARI and then by only by a few millimetres. This would be unlikely to cause any different in affect than say, a 1 in 19.5 year flood naturally occurring as opposed to the 1 in 20 year event. The likely impact is unquantifiable and a specific consideration for flooding impacts on every known wading bird known to use the sites would simply consume considerable time, resources and effort, without being able to provide a meaningful answer beyond that which has been established.

Consider also as an example, the specific potential effect of a reduction of long section tidal water profile impacts on the distribution and abundance of wetland and saltmarsh plants such as Samphire *Sarcocornia quinqueflora,* salt couch *Sporobolus virginicus,* the grey mangrove, *Avicennia marina,* and the river mangrove, *Aegiceras corniculatum.*

The most considerable portions of saltmarsh in the Hunter Estuary occur in the north western portion of the Ramsar wetlands, between 10km and 18km upstream from the ocean. The ELCOM results show that under median flow conditions, when the dam is operating at yield, changes to water level heights range between +/- 0.1mm and 0.5mm. Under a fill up scenario (but with the Williams running at a moderate fresh) the results associated with relative changes are almost identical. These changes are so slight that the differences in water level and subsequent inundation would not be distinguishable with the human eye across the gradual slope of a wetland saltmarsh area.

Further, the grey and river mangroves can exploit a wide range of ecological niches and are relatively well distributed through the mid to high tidal ranges. The changes of the magnitude described are also without consequence.

Below the 25th percentile of occurrence of flows, the relative differences in observed versus expected water level heights could change by 6 to 7mm. Given that saltmarsh species generally inhabit the mid tidal range to the spring high water mark, and may be found on flats with gradients of approximately 1 in 100 (although they are often found in more restricted, steeper rising elevations in bands behind fringing mangroves), in theory the tidal extent of inundation across such flats could be reduced by a few centimetres to a few metres, depending on the exact topography of the site.

Consider however that 75% of the time, vertical tidal water level extents are not affected (+/- 0.1 to 0.5mm) and therefore tidal flooding of the full extent of the marsh will still occur with regular frequency. Further the marsh will still be subject to salt spray and hyper saline conditions will prevail, preventing the invasion of the marsh by terrestrial plants.

Further sediment accretion may be moderately slowed in the last few affected centimetres or metres (depending on site topography) of the saltmarsh for a year or two with slightly less inundation events (reduced by 25% of the time), until such time as sea level rise moves the system back to equilibrium with a few years (sea level is rising as previously noted by 1.3mm/yr at the Newcastle Ocean gauge). Consider also that the marsh may rise and fall by a few millimetres in any given year depending on groundwater swelling, water logging and conversely, drying, subsidence and compaction. A full list of the confounding factors of concern is given in S4.4 of this report (Quantifying impacts).

On this basis it is reasonable to reach a conclusion that a minor shift in tidal height of a few millimetres combined with natural background processes is unlikely to cause any detectable variance in the either the extent of the saltmarsh, nor cause a shift in the vertical species zonation within the salt marsh.

Overall there are several hundred different plant and animal species that would inhabit the lower estuary. There would also be several distinct ecological communities. Undertaking specific impact assessments on all of them, when there are no impacts of substance to the abiotic characteristics of the estuary, which is an extremely variable and dynamic system, would be an extremely time consuming and as demonstrated, a futile exercise. The changes forecast by the models are infinitesimal in an ecological sense. It is therefore impossible to estimate or establish a causative link to how ecological systems may respond. Therefore it is impossible to predict any individual or collective impact.

This is why Hunter Water's consulting ecologists have reached a conclusion that there would be no significant impact to the lower Estuary and the lower Hunter Estuary Ramsar wetlands as a consequence of Tillegra Dam.

On this basis, HWC believes that the position put by NSW Planning and the reviewers is unreasonable. That is, it is Hunter Water's firm belief that no ecologist no matter what their experience and expertise, would be able to distinguish an impact from the changes given in the modelling results. This is why undertaking a species specific assessment of impact from an altered hydrological regime, when no meaningful change to the regime has been identified, cannot be facilitated.

4.6 Ecological Assessment of Filling Phase

The proponent's assessment does not include an assessment of the filling period on sensitive wetland communities such as saltmarsh, and also migratory waders.

This is not correct. The ELCOM assessment includes a consideration of a pre / post Tillegra Dam fill up sequence on the hydrodynamics of the estuary. The fill up scenario demonstrates that the estuary is as equally insensitive to changes during a filling period as it is to operation at full demand.

As previously noted to NSW Planning, dams fill, spill, decline, and refill. They do not produce water by their own mechanisations after the "first fill". This means that impacts are not only limited or restricted to "a first filling phase". NSW Planning and its independent reviewers are referred to the advice given on this matter at the start of the report.

4.7 Accuracy of Assessment

The proponent has not demonstrated for the operational impact assessment and filling phase, the potential impacts of flooding level changes on migratory bird species, vegetation communities and macro-invertebrate species within the wetland.

The ELCOM model clearly shows negligible changes to water levels (less than 1 in 1 ARI) for filling and operational scenarios. The changes are so minor that in the majority of cases they are difficult to differentiate between the natural "background noise" of water movement as it ebbs and flows around the estuary.

Changes in larger flood depth in larger floods (> 1 in 5 ARI) are shown by the Tuflow flood model. The modelling shows that the flood durations are unaffected. The spatial extent to flooding is unaffected. The flood hydrographs show only minor variations on the peak of the event, for a period of only 24 hours and typically by less than 10mm in a one in five year event.

Neither HWC nor its consultants can demonstrate potential impacts of flooding changes to any part of the estuary's ecology as requested as the changes are so minimal that it is not possible to undertake a meaningful assessment.

4.8 Quantifying Impacts

The proponent has not quantified the impacts through defining and mapping the area of potential impacts on wetlands under different filling and flooding scenarios and transparently showing how the findings from the Hunter Estuary modelling (such as changes to freshwater flow, flood extents, heights and salinity movement within the estuary) potentially impacts on the ecology and specific species (key flora and fauna of the wetland)

Hunter Water rejects the imputation that potential changes to the estuary have not been presented transparently. It would be worthwhile for both NSW Planning and its reviewers to look back through the reports again. Within the collated assessment report, the necessary data to complete the assessment is contained in figure 5.9, table 5.6, figures 5.10 to 5.13, tables 5.9 to 5.12, figure 5.40 to 5.45, Table 13 etc.

The report shows that there will be no meaningful changes to the environmental characteristics of the estuary. Certainly, some of the data has not be illustrated in visually appealing maps, however, if there are no meaningful changes deviating from baseline, then in a practical sense, these cannot be mapped or the mapping is a pointless endeavour. The flood inundation extent mapping undertaken recently on request, illustrates this case in point.

4.9 Consideration of Hydrological Changes on Migratory Waders

The proponent has provided insufficient detail on the changes in hydrological inputs (including minor changes) and potential impacts on migratory waders.

Many migratory waders are reliant on salt marsh as important habitat. The most considerable portions of saltmarsh in the Hunter Estuary occur in the north western portion of the Ramsar wetlands, between 10km and 18km upstream from the ocean. The ELCOM results show that under median flow conditions, when the dam is operating at yield, changes to water level heights range between +/- 0.1mm and 0.5mm. These changes are so slight that the differences in water level and subsequent inundation would not be distinguishable with the human eye across the gradual slope of a wetland saltmarsh area.

Further, if one considers the natural variation in water level by comparing any of the relative outputs of the ELCOM model for pre Tillegra (Table 5.9, Scenario 1, 6, 11 and 13) it is apparent that the water levels can naturally vary up to 18mm (potentially up to 50mm in other parts of the estuary) depending on antecedent flow conditions in the estuary, if not greater (the model has not considered a 1 percentile steady state scenario to compare against a 100 percentile steady state scenario so the full range of natural variance cannot be described on a relative basis). Clearly however, minor variations of between +/- 0.1mm to 0.5mm on any particular post Tillegra scenario are incomprehensibly minor compared to the natural bounds of variation indicated within the modelling.

Because natural variation in water level heights under natural flow conditions are at least an order of magnitude higher than any apparent effect that would be derived from Tillegra Dam, Hunter Water can safely conclude that there would be no impacts on habitat and therefore migratory waders.

Clearly, because in practical terms the differences are so minimal, providing additional detailed and specific impact assessment data on what could only be described as the non existent effects of Tillegra dam would be an inherently unproductive activity to undertake.

In short, without cause there is no effect. An assessment of no cause but with the anticipation of effect is not predicated on a logical, systematic and sound approach to impact assessment. Rather it would be an emotive approach based on preconceived notions or apprehended bias. Hunter Water does not endorse such an approach being taken within a merit based assessment.

4.10 Cumulative Water Quality and Hydrological Inputs

The proponent has provided insufficient information on the cumulative changes to water quality, water inputs, cumulative impacts of Tillegra Dam (on top of past changes) and consideration of the potential implications for future development.

The assessment shows that Tillegra Dam will have no impact of note to the estuaries water quality or quantity. Therefore Tillegra Dam cannot add to any pre-existing change in a meaningful manner. Further, from a technical legal standpoint (although this is somewhat a sad state of affairs from a management perspective) the cumulative impacts to the estuary up until 2002 and the formulation of the RIS, actually define the ecological character of the Ramsar wetlands, rather than impact upon it. Cumulative impacts only occur after the date of listing and formulation of the RIS or ECD.

Obviously however from an overall wetland ecosystem conservation perspective outside of the EPBC legislative framework, the cumulative impact of 200 years of urban, industrial and agricultural development has been extreme. The technical legal standpoint does not do justice to the degradation of the existing Hunter river environment.

It is acknowledged that there have been significant water allocations upstream that have irretrievably changed the character of the estuary, complimented by significant detrimental change to the natural character of the estuary through development of the port, training of the river, dredging of the water way, reclamation of the entirety of the middle estuary to form Kooragang Island and destruction of thousands of hectares of mangroves and saltmarsh by the construction of floodgates and levee banks.

For example, figure 11 shows the extent of saltmarsh destruction in the Hunter Estuary (from Burns & Davey 2010). The mapping shows almost the complete loss of saltmarsh in the estuary. The primary cause is the installation of floodgates around Fullerton Cove and at Tomago that has caused the consequent destruction of salt marsh habitat by its replacement with pasture. The placement of floodgates on Ironbark Creek has also destroyed significant saltmarsh wetland areas in the western side of the estuary. These losses have been further compounded by the filling of the majority of Kooragang Island for industrial land.

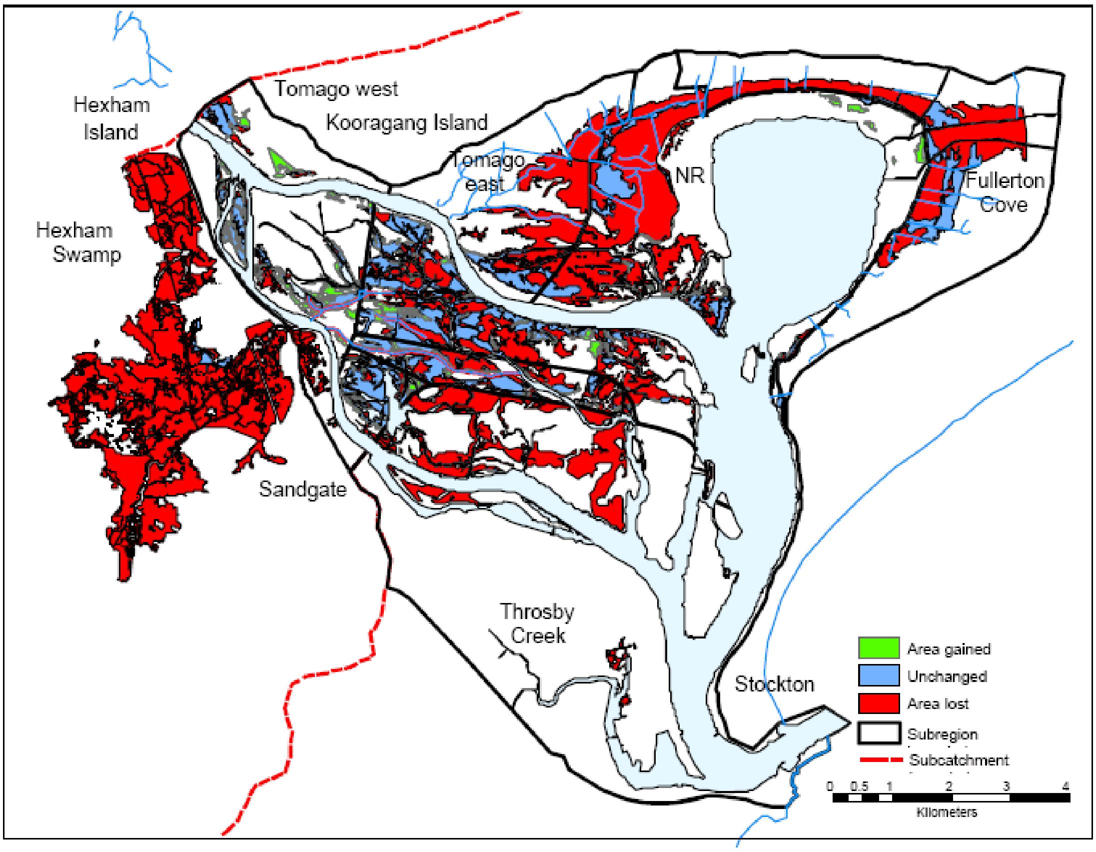


Figure 11 – Historical saltmarsh loss in the Hunter Estuary (from Burns and Davey 2010)

This is why Hunter Water and its consultants can quite clearly state, that on balance, the biggest and most severe challenge for migratory and intertidal wading birds in the Hunter Estuary has been habitat destruction. The independent reviewer has noted that there have been significant reductions since the 1970's in bird populations in the estuary, which interestingly, coincides with the significant reclamation and flood control works which were also undertaken progressively at that time.

The Tillegra Dam project will not add to the environmental degradation previously experienced by land clearing, filling, reclamation and dredging in the estuary as described above.

Further development of the Hunter Catchment, whether for agriculture or for mining is not a matter that is related to the construction and operation of Tillegra Dam. Hunter Water has no control over these activities and the approval of Tillegra Dam, given the lack of meaningful change caused by the dam, does not represent an opportunity cost for the future development in the region.

In summary, past changes to the Hunter Estuary (clearing of vegetation in the catchment, dredging, reclamation, water abstraction upstream) predominately occurred prior to the Ramsar wetlands being declared and the RIS submitted (2002). Despite being unpleasant, the truth is that the ecological character of the wetlands is in effect a result of these past practices cumulative or otherwise. The effect of Tillegra Dam cumulatively, post the Ramsar listing is not definable, because we cannot identify any impacts resulting from the dam project in its own right. Tillegra dam is the only significant project related to water supply that has been proposed, since the Ramsar wetlands were listed.

4.11 Analysis at Different Time Scales and Worst Case Scenario

The proponent has not provided a detailed analysis of migratory species and wetland types to indicate which species / communities could be most at risk from hydrological and salinity changes under annual, seasonal, monthly, daily, drought conditions and worst case scenarios such as a protracted filling period (coinciding with a drought)

The reviewer has not appreciated the fact that the ELCOM model provides a steady state, relative analysis that is independent of temporal variability. This allows the natural dynamic “background noise” of the estuary to be isolated so that it becomes possible to identify changes that may be attributed to an altered hydrological regime, and therefore determine whether the estuary is sensitive to any change derived from Tillegra Dam. The ELCOM model clearly shows that the estuary is not sensitive to any changes in water abstraction from the Williams River.

Further, it appears that the reviewer has not appreciated the fact that the TUFLOW FV model uses daily time step data to analyse a decade of historic flow, during a time of severe drought in the Hunter catchment, during which the dam declines and then fills at yield, a situation that is far more representative of a worst case scenario than any other which we can conceive.

It is also apparent that the reviewer has formed a conclusion that the flood modelling is poorly calibrated, where in actual fact, the flood modelling provides and excellent overview of the effects of flooding in the lower estuary including the Ramsar wetlands. The commentary from Dr Peirson related to the model relates to its functionality at Raymond Terrace, some 30 kilometres upstream of the ocean, not those areas of specific interest to the ecology of the lower estuary. It appears to HWC that this information from WRL may have been taken out of context and a re-examination of this issue is advisable.

Hunter Water can only ask that NSW Planning and the reviewer critically re-examine the reports which clearly show that the models function well, and that the results of the modelling work show that there are no detectable changes predicted for the hydro-dynamic characteristics of the estuary of any meaningful scope, scale, frequency or magnitude.

Further, Hunter Water notes that without being able to identify potential changes to the hydrodynamics of the estuary of sufficient magnitude to be of concern, postulating what ecological components may be of most risk is a redundant action.

4.12 Monitoring

The review recommends that the proposed monitoring of impacts be revised once individual species and communities at risk have been determined through further assessment as outlined above. Additionally trigger points for the determination of impacts need to be quantifiable not qualitative statements.

Hunter Water and its consultants are unable to implement this recommendation as there is no potential for impacts in the Hunter Estuary. Without being able to identify potential linkages or causative agents for impact, the species and communities most at risk cannot be identified.

In relation to the key performance indicators put forward by the reviewer, Hunter Water notes that even in their current form, these are excellent indicators for holistic management of the

Ramsar wetland site. For Hunter Water to agree to undertake any substantive monitoring of note relevant to these KPI's however, the following factors would need to be identified;

a) That Tillegra Dam would be likely to cause change.
b) That any change caused by Tillegra Dam would be distinguishable from other detrimental affects, such as may occur from ongoing industrial and urban development in the catchment, or for example, that may be caused by industrial port development, or for example that may occur through the introduction of a noxious species, or that which may occur from climate change and sea level rise.

Ultimately Hunter Water is not a key wetland manager. Our legislative brief is to supply water and waste water services to the people of the Hunter. As a water utility, Hunter Water does not have the authority to implement management arrangements for the wetlands nor does the Corporation have the delegated authority to provide regulatory oversight to factors that may impact on the health of the wetlands.

Hunter Water can only raise funding from the public to implement water and waste water services. Hunter Water cannot use rate payers funding to address environmental issues that are unrelated to the activities of the organisation. IPART would never allow funding to be raised to cross subsidise environmental works, that are unrelated to the organisation and are not our responsibility any more than the Director General of the Department of Environment, Climate Change and Water would allow budgeted allocations for the conservation of wetlands in NSW to be spent on water or waste water treatment plants in the Hunter.

On this basis, Hunter Water is substantially concerned by the monitoring arrangements put forward by the independent reviewer. The management of the wetlands are a state and commonwealth government responsibility. These responsibilities should not be abrogated with the expectation that the regional water and waste water service provider should fill the management vacuum created.

5 Bewsher Report

5.1 Improvements to the Calculations of Inflows

The Bewsher review has concluded that the Glen Martin residual inflows (from the ungauged catchments upstream of Glen Martin and Seaham Weir have reduced the validity, accuracy, and precision of the modelling because they have not been properly verified against recorded streamflows. The review also concluded that a correct model (for the entire period of record) will likely change some of the conclusions drawn to date such as the relative contribution of the Williams River flows to the estuary and an increased water supply to the existing system.

The issue of verification of streamflow in the Williams River is a moot point. HWC supplied evidence in the report titled *Précis of Tillegra Dam EAR Hydrological Modelling* in the form of numerous modelled vs observed streamflow plots to verify that modelled streamflow is a close representation of observed streamflow. These plots include both flow duration curve comparisons as well as time series comparisons.

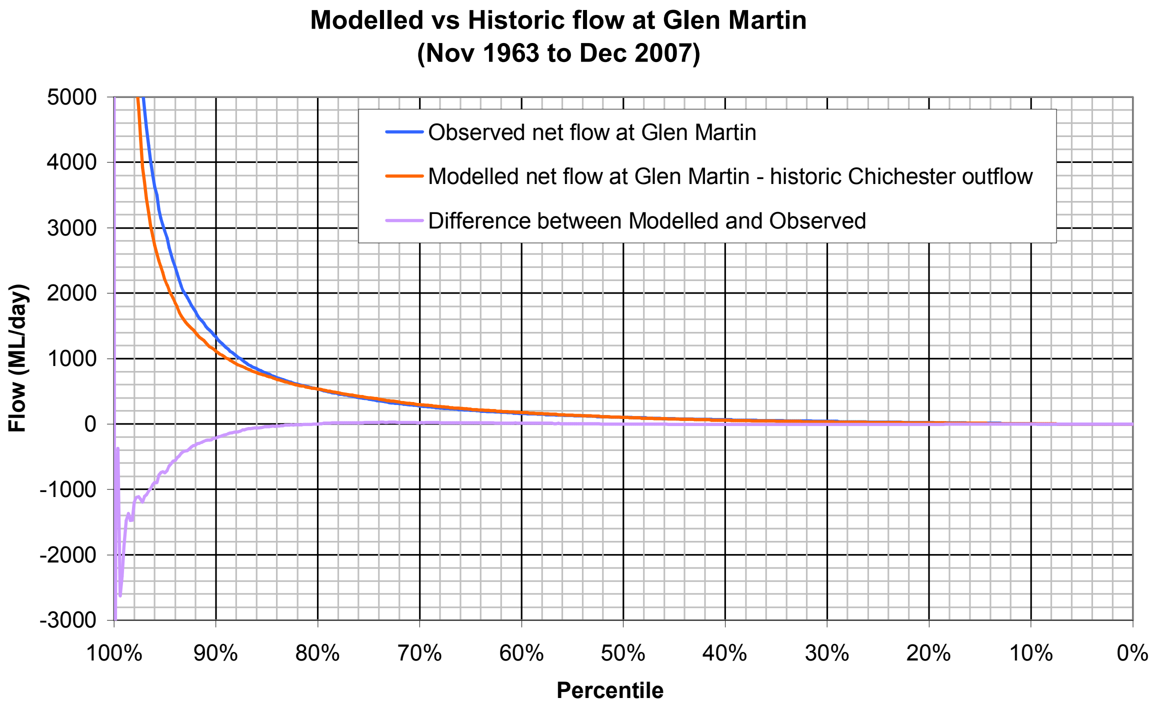
The primary concern expressed in the Bewsher report is that HWC did not attempt to match the average annual streamflow at Glen Martin. This is true. HWC's aim in developing the dataset was to characterise those aspects of streamflow that are important when calculating system yield and other impacts pre and post Tillegra Dam. The model calibration process that HWC adopted included simultaneous optimisation of model performance against daily and monthly flow volumes, but not annual, with HWC being satisfied that monthly calibration would be sufficient to preserve volumetric mass balance. HWC believes that differences between its approach and Bewsher's recommended approach are not material in terms of the assessment of system yield pre and post Tillegra Dam and similarly will have little (or zero) impact on the assessment of environmental and social impacts associated with the proposed Tillegra Dam.

Our analysis shows that the HWC model has excellent agreement when representing flows on a daily and monthly basis. On occasion, the model may under represent a high flow (flood) event and cumulatively this may differ from gauged flows at Glen Martin. This does not affect the environmental assessment work undertaken, the yield calculations or the estimate of flow changes to the estuary by any significant nature. Hunter Water strongly recommends that NSW Planning read the modelling précis provided to Bewsher Consulting in regards to the modelling accuracy and precision.

5.2 Implications of the Underestimated Flows on other Assessments

The Bewsher review has noted that there are potential implications for the other environmental assessments such as geomorphology, aquatic ecology, water quality etc which have relied on the modelled streamflow which is understated (from Glen Martin down to the estuary).

The difference between the modelled and observed streamflow distribution at Glen Martin has been quantified and is shown below.



The blue line shows the distribution of observed daily river flow and the orange line shows the corresponding distribution of modelled river flow. As can be seen from the above graph the difference between observed and modelled flow is greatest for the 14% of time that river flow is above around 800ML/day, with little difference for the remaining 86% of time when flow is below 800ML/day. The purple line shows the magnitude of the difference relative to flow percentile.

It can be concluded from the above graph that river flow modelling by HWC provides a highly accurate representation of river flow for the 86% of the time that river flow is below around 800ML/day. This means that HWC will have accurately presented the potential impacts of Tillegra Dam on 3rd party water users because access to water at the rates and times that they need it has been accurately represented. It also means that HWC has accurately represented environmental flow release strategies which are all associated with flows considerably lower than 800ML/day.

Bewsher (2010) notes that the HWC model may lead to an over estimation of relative flow reductions, related to end of system flow to the estuary. If this is the case, this would simply result in a conservative assessment wherein any hydrodynamic impacts would be over emphasised. The Tillegra Dam impact assessment, if anything, errs on the side of caution. This is supported by Pierson (2010) who finds that the difference between modelled and observed flow at Glen Martin would no greatly change the study conclusions with respect to salinity modelling in the estuary.

In terms of yield calculations, when flow is above 800ML/day, the actual size of flow is only relevant to HWC extraction when it is also less than 1650ML/day, which is the capacity of Balickera Pumping Station. Based on the above graph, flow is between 800ML/day and 1650ML/day for around 7% of the time, or 25 days per year.

In addition to the impact being limited to specific flow conditions; it is also limited to days when there is space in Grahamstown Dam to receive the flow. HWC has now cross checked the correlation between the occurrence of river flow in the range of 800ML/day to 1650ML/day and space in the dam, and it was found that the three conditions occur simultaneously around 1.2% of time, or 4.5 days per year on average. On these 4.5 days per year the observed flow is around 20% higher than modelled flow, and HWC could therefore have potentially harvested slightly more water than was calculated in its modelling. In other words, the HWC model gets it right 98.8% of the time and for the other 1.2% of time the model takes at least 80% of the water that could have been accessed. It is not surprising, therefore, that the approach used by HWC has very little impact on yield estimation. HWC has calculated that the difference between modelled and historic flow at Glen Martin could influence yield by around 0.4GL/year, both pre and post Tillegra Dam being constructed.

As noted by Bewsher, models are only approximations of reality. Hunter Waters view is that the HWC model provides an excellent representation of reality, particularly in reference to the recording of daily and monthly flows, for pre and post Tillegra in relative terms.

5.3 Confirmation of Assessment of Worse Case Scenario

Bewsher recommends that examining a period of relatively high flows in the Williams River with coinciding low flows from the Patterson and Hunter rivers could lead to a number of worst case scenarios. Please advise and reference if such scenarios have been considered.

Bewsher has suggested that the worst case scenarios would occur during periods that relatively high flows in the Williams River coincide with relatively low flows in the Hunter and Paterson Rivers. The method that HWC used, in conjunction with NOW, to determine the worst case scenario for the FVM salinity modelling of the estuary was not dissimilar to that proposed by Bewsher. It was considered by the two organisations that a focus on the streamflows recorded in the 1940s would provide a suitable dataset that includes periods of time when the Hunter Estuary receives low flows from the Hunter and Paterson Rivers, and moderate flows from the Williams.

To confirm the hypothesis held by NoW and HWC that the 1940’s drought period was the worst period for flows to the Hunter estuary, and in particular, the tidal pool BMT WBM completed a spells analysis of the full 67 years of records available, to confirm which ten year period was most sensitive to high salinity concentrations in the tidal pool. The process is described in full at S 5.4.1.1 (page 139) within the collated assessment report).

As has been stated previously, the reason that a 10 year period was selected for the FVM detailed salinity modelling rather than the entire period of record was that running the FVM model for the full 70 years was found to be unwieldy due to the length of run times. Instead it was decided to use a representative 10 year period with a bias to choosing a 10 year period that represented dry periods in the Hunter and Paterson that coincide with inflows from the Williams. It was found that any given “10 year” period from history includes periods of high and low flow combinations, and that a small number, including the 1940s, contained a number of significant low flow events in the Hunter and Paterson Rivers. While some other decades also contained significant dry periods, it would be hard to argue that the decade chosen is not suitable to represent the impact of the dam on the types of extended low flow periods that can occur in the Hunter and Paterson Rivers, and are precisely types of periods during which the impact of the dam will be most severe.

The decade from the 1940's onwards is a time during which in relative terms flows from the Hunter / Paterson are minimal compared to their normal behaviour and a large proportion of flows occurred from the Williams. This is exactly the type of scenario recommended by Bewsher as worthy of examination as the worst case.

6 References

Bewsher, D. (2010) *Independent Review of the Tillegra Dam Hydrology*. Draft Report. 24 August 2010

Burns, C and Davey, G. (2010), *NSW Marine Habitat Mapping Project*, excerpt as shown on the Marine Education Society of Australasia Website, http://www.mesa.edu.au/seaweek2010/saltmarsh.asp

Peirson, W (2010) *Second Independent Review Tillegra Dam: Hydrological and Water Quality Impacts on Hunter Estuary*. Final Report. 13th September 2010

Rogers, K (2004) *Mangrove and Saltmarsh Surface Elevation Dynamics in Relation to Environmental Variables in South Eastern Australia.* PhD, School of Earth and Environmental Sciences. University of Wollongong. http://ro.uow.edu.au/theses/653

APPENDIX A

BMT WBM response to WRL reviewer comments and questions raised by NSW Planning

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Our Ref: LJK: L.N1651.011.docx

22 October 2010

Hunter Water Corporation
36 Honeysuckle Drive
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Attention: Roland Bow

Dear Roland

RE: RESPONSE AND CLARIFICATION TO COMMENTS RAISED BY SECOND INDEPENDENT REVIEW

The following provides clarification to a number of comments raised by the second independent review of estuary modelling undertaken by BMT WBM. Following our appraisal, we offer the following as a response to the following technical aspects highlighted by the independent review:

a) use of the Manning's *n* roughness co-efficient for long-term modelling;

b) water level calibration at Morpeth, Hinton and Bolwarra;

c) apparent over prediction of salinity intrusion by the model TUFLOW-FV;

d) apparent under prediction of salinity intrusion by the model ELCOM; and

e) scaling of flood hydrographs used by TUFLOW flood model calibration.

a) The reviewer notes (Lines 30-35) that the Manning's n value of 0.010 specified for waterways channels for upstream rivers is implausibly low and below the formal range of applicability of Manning's n.

Practical numerical modelling often requires compromises regarding the representation of the physical processes occurring in reality. For instance 1D modelling does not explicitly account for many of the energy loss mechanisms associated with 2D and 3D flow fields. The calibrated Manning's *n* coefficients in these models are therefore required to account for a range of energy loss processes other than purely bed friction.

The scope of the modelling investigations undertaken for the Project required a system that could model tidal hydrodynamics and salinity advection-dispersion for the full tidal extent of the Hunter River Estuary over time scales extending from minutes to decades. The TUFLOW-FV two-dimensional scheme used in the Project has successfully achieved this difficult task, however compromises regarding model resolution have been required to achieve a tractable solution. Higher resolutions pay a simulation time penalty both in terms of increasing the number of computation cells and in terms of reducing the timestep required for stability of the numerical scheme (i.e. the Courant–Friedrichs–Lewy (CFL) condition).

The model resolution in the upper reaches of the Hunter River is coarser than would ideally be the case if the overall domain size was not so large and the simulation length requirements were not so high. The relative coarseness of the resolution in the highly sinuous upstream channel results in additional "numerical" energy losses due to the flow "seeing" abrupt changes in channel direction rather than the smooth transitions seen in the actual physical system. The calibration process undertaken as part of the model development identified that using more typical values of the Manning's *n* Roughness (~0.020) resulted in excessive damping of the tidal signal in the upper reaches of the Hunter River Estuary. The calibration process furthermore demonstrated that a lower Manning's *n* Roughness of around 0.010 compensated for the numerical losses induced due to the relatively coarse mesh. With the tidal signal well represented in the calibrated model, the tidal-prism and advection-dispersion predictions of the model should be reasonably accurate.

b) The reviewer notes (Lines 37-39) specific problems with the model calibration in the upper estuary.

During the development of the numerical model and its bathymetry it was indentified that a number of sills or other bathymetric features (e.g. shoals / sediment deposition areas) control water levels in the upper reaches of the Hunter River particularly between Bolwarra and Morpeth. Model bathymetry has been defined using a Digital Elevation Model (DEM) prepared from cross section data collected by Department of Commerce (DoC), which inherently incorporate assumptions relating to the channel condition and conveyance between cross sections. As noted by BMT WBM (2010), discrepancy between observed and modelled flow at Hinton, Morpeth and Bolwarra are likely attributed to such features which control flow in these upstream areas. In the absence of more comprehensive bathymetry data, and consideration of limitations imposed by timestep constraints (as described above), the numerical model provides a good representation of the System. Consequently, the level of calibration achieved for these areas and resolution of the model is considered adequate for long-term assessment of flow and salinity regimes on an estuary wide basis.

c) The reviewer notes (Lines 41 to 43) that TUFLOW-FV appears to over predict salinity intrusion during and after the flood event on the 19-22 March 2001.

Salinity calibration results referred to by the reviewer (i.e. Figure 4-44) show the daily maximum (green line) and daily minimum (red line) salinity to be less than the measured (blue line) salinity profile. It is assumed that the reviewer intended to note that the TUFLOW-FV model under predicts rather than over predict salinity intrusion. As discussed by BMT WBM (2010), the model TUFLOW-FV under predicts salinity intrusion as a result of assumptions relating to depth-averaged representation of hydrodynamics and advection-dispersion (i.e. it is a two dimensional model). As such the model does not account for stratification effects caused by density gradients between freshwater and saltwater and destratification effects as a result of vertical mixing and turbulent processes occurring within the water column. The effect of density anomalies under high river flow conditions is important as illustrated by ELCOM validation results (refer Section 4.3.6 of BMT WBM (2010)), which show freshwater (lower salinity) at the surface and a source of saltwater (higher salinity) near the bed further upstream, which is subject to vertical mixing processes following the flood event.

d) The reviewer notes (Lines 49-54) three specific limitations of the model ELCOM.

The first comment relates to the turbulence formulation of ELCOM which is assumed to be primarily from wind energy. This comment may be related to interpretation of the following line:

> *"Turbulence was modelled using the mixed-wind layer model including mixing energy transport as recommended by Hodges and Dallimore (2006)".*

This is considered to be a result of a miscommunication by the report. ELCOM includes a "mixed layer model" of which wind is one component. Further details of the mixing model are discussed by Hodges and Dallimore (2006). However, the statement in the review letter noting that:

> *"It is apparent that ELCOM has been formulated for conditions in which wind energy is the primary source of turbulence"*

is not considered accurate, although it is not uncommon for wind to be a key driver in many ELCOM applications. The model ELCOM accounts for all turbulence generation mechanisms, and conserves and transports the Total Kinetic Energy (TKE). The TKE is generated through wind, shear between layers, bottom drag and convection. This is somewhat different from how other 3D numerical models may treat such processes, however the present approach has been developed for stratified lakes and estuaries (e.g. the Swan Estuary which arguably has a tighter stratification than the Hunter River Estuary) since typical k-epsilon schemes used in classic models tend to be overly diffusive of stratification. Chapter 6 of Hodges and Dallimore (2006) outlines the generation terms and approach in detail.

The second point relates to the numerical diffusion of the model being high. This comment is likely to be in response to the statement:

> *"A horizontal diffusivity of zero was adopted on the basis that numerical diffusivity adequately accounts for diffusive processes".*

While ELCOM differs from most models in terms of its vertical dynamics, the horizontal dynamics are based on a classic Reynolds-Averaged Navier Stokes (RANS) type approach, and the ULTIMATE-QUICKEST scheme for scalar transport which is respected for not being too diffusive, so there is no particular difference of ELCOM to other model codes in this respect. The accurate predictions of stratification and salinity evolution during a flood indicate this is in fact not a major issue in this analysis. The ELCOM simulations have also not been run for a long time, where problems with diffusivity can manifest greatly.

The qualitative cross-section (curtain) comparison plots of the ELCOM validation (refer Section 4.3.6 of BMT WBM (2010)) demonstrate that the formation of stratification is comparable to that observed in data, and in particular during high freshwater flows. Based on validation results obtained, the diffusivity is not considered unreasonable, with any over diffusivity potentially a result of coarse vertical grid resolution rather than the numerical approach used to model the system. Further, it is possible that these curtain plots have been interpreted incorrectly by the reviewer, since his statement "*In contrast with TUFLOW-FV, ELCOM under predicts the intrusion of salinity following the flood event (see Figures 4-33 and 4-34)*". On close inspection of the stations in these plots, the model is performing exceptionally well in matching the toe of the salt wedge, and the extent the freshwater is reaching on the surface. It is possible that these plots have been mistakenly assumed to be on the same horizontal scale (which they are not), and that station abbreviations to be read from the ELCOM plots are perhaps difficult to read.

Finally, with respect to the issue of drag characterisation within the estuarine environment as evidenced by the poor tidal calibration, this has been discussed to some extent by BMT WBM (2010). The issued raised by the reviewer is not due to bottom drag, but numerical drag which is an artefact of structured grid models where abrupt changes in flow direction (particularly in the riverine reach before the river opens out into the estuary) can affect energy and momentum of the system which is seen as a reduction in the tidal signal. It is noted that the focus of these model simulations was stratification in the lower estuary area and as such is not considered to be a significant issue or limitation of the investigations.

e) The reviewer notes (Lines 154-170) irregularity of the deviation of the flood hydrograph for the 1990 flood event and suggests that scaling of recorded hydrographs as part of the calibration process as being unsatisfactory.

The limitations of the calibration process adopted for the study is a function of the piece-wise development of hydraulic models along various reaches of the Hunter River system between Singleton and Newcastle. There has been no detailed continuous model routing of flows through the system that would provide for derivation of appropriate boundary conditions at the upstream boundary of the study area model (i.e. Green Rocks). For major flood events, the boundary conditions at the upstream model boundary (which is situated between gauge locations) is further complicated by the unknown distribution of flow between the channel and the floodplain. A continuous flood model between an upstream gauge location (e.g. Singleton or Oakhampton) to Newcastle Harbour would be required for accurate flood routing, which is beyond the scope of previous flood assessments in the Lower Hunter. Even still however, model calibration/validation will be problematic given the scarcity of recorded flood level data and the complexity of the channel/floodplain flow distribution which is not evident from gauge water level data.

As previously noted by BMT WBM (2010), the peak of the 1990 flood event in the Lower Hunter downstream of Raymond Terrace is dominated by Williams River inflows with an adequate peak flood level calibration achieved. Accordingly, the hydrodynamic performance of the developed model is considered fit for purpose. The scaling of the Hunter River inflow contribution (which is post-peak flood level at Raymond Terrace) is expected to have minimal influence on peak flood levels. The uncertainty in the hydrograph recession and total flood volume for the adopted 1990 conditions has limited relevance to peak flood level conditions in the Lower Estuary and relative impact of the Tillegra Dam for design event scenarios considered.

I trust the above information will provide sufficient clarification on a number of technical aspects discussed within the independent review and will further assist the Department of Planning with their review and appraisal of the estuary modelling investigations.

Should you have any questions please do not hesitate to contact the undersigned.

Yours Faithfully
BMT WBM Pty Ltd

Luke Kidd
Senior Environmental Engineer

References

BMT WBM, 2010. Estuarine Impacts of the Proposed Tillegra Dam: A collated Assessment. Report prepared for Hunter Water Corporation, August 2010.

Hodges B. and Dallimore C., 2006. Estuary, Lake and Coastal Ocean Model: ELCOM v2.2. Science Manual, Centre For Water Research University of Western Australia, June 15, 2006.