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Our Ref: MEW: L.N1514.005

16 December 2010

Great Lakes Council
PO Box 450
FORSTER NSW 2428

Attention: Roger Busby

Dear Roger

RE: MYALL RIVER DOWNS, TEA GARDENS – ADDITIONAL REVIEW OF FLOODING, STORMWATER AND GROUNDWATER ASSESSMENTS

BACKGROUND

A Local Environmental Study (LES) for the Myall River Downs site was prepared in 2003 by Parsons Brinckerhoff (PB). The LES considered a range of environmental issues including flooding, stormwater and groundwater. Since the preparation of the LES, significant changes in flood policy/guidelines to take account of climate change have occurred. In addition, stormwater quality and quantity management policies, guidelines and practices have progressed. Following the LES preparation in 2003, additional reports addressing flooding and stormwater quality for the site were prepared by Worley Parsons (WP) in 2006 (by the former Patterson Britton and Partners) and 2008.

Changes in guidelines, policies and practices resulted in a number of findings of the LES flooding and stormwater assessments being superseded. Importantly, event-based flooding, hydrologic and hydraulic modelling undertaken for the LES has largely been superseded following the latest directions from DECC and NSW Department of Planning on consideration of climate change impacts. The assessment undertaken by WP in 2008 has identified that the flood levels for planning purposes will be dominated by the predicted elevated water levels in the estuary under the climate change scenarios.

BMT WBM and Environ completed an independent review of the flooding, stormwater and groundwater assessments prepared by WP for the above site on behalf of Great Lakes Council in 2008. The outcomes of this review are detailed in BMT WBM letter L.N1514.003 dated 1 October 2008. Following WP's consideration of these comments, BMT WBM and WP met on 7 November, 2008 to discuss the flooding and stormwater assessment comments to agree on a way forward. These discussions are summarised in BMT WBM letter L.N1514.004 dated 14 November 2008. Since November 2008 further investigation and modelling has been completed by WP to address the flooding and stormwater issues discussed during the meeting between BMT WBM and WP.

A meeting was held at Great Lakes Council on 6 August 2010 which was attended by representatives of Council, RPS Harper Somers O'Sullivan, Myall River Downs Pty Ltd, BMT WBM, WP and Martens Consulting Engineers (MCE). During this meeting an update was provided on the additional investigations completed for the site. Following this meeting, the Water Management Report (WMR) and conceptual Groundwater Management Plan (GMP) reports were updated by WP and MCE. An updated WMR and GMP were issued to BMT WBM on 18 October, 2010 by RPS Harper Somers O'Sullivan for review.

This letter report outlines the results of a review of the updated WMR and GMP. The flooding, drainage and stormwater quality issues reviewed are those identified during the 7 November, 2008 meeting as requiring further investigation. The numbering system applied within this review is consistent with the numbering used in the earlier review.

The groundwater review considered the comments provided in the original review (L.N1514.003 dated 1 October 2008) that were not discussed during the 7 November, 2008 meeting.

Our comments on the unresolved issues are provided in the following sections. The original comments are shown in *italicized* text and our comments based on consideration of the latest reports are shown in normal text.

FLOODING AND DRAINAGE – UNRESOLVED ISSUES

6 *The WP report does not include a summary of estimated 20yr and 100yr ARI flows at key locations along the main watercourses within the site for both the existing and developed conditions. Peak flows are presented in the Appendix A of the WP report for individual sub-catchments, but cumulative flows at critical locations along the eastern and western branches were not provided. Critical locations would include culverts/road crossings and discharge points from the site into the adjacent wetlands. It is considered that this information should be provided within the report.*

Peak flows at key locations along the drainage channels have been provided by WP within the revised WMR and cover the critical locations.

8 *The WP reports do not present existing scenario design flood level estimates for the site. The modelling appears to have focused on developed scenario flooding and ensuring that these flows can be accommodated within proposed drainage corridors. The assessment of the existing flood levels is important to satisfy Council's LES assessment requirement that the proposed development would not have an impact on upstream/adjacent development during the 1% AEP design event and an extreme event.*

The revised WMR includes discussion of the flooding impacts of the development on existing development during the 1% AEP design event. This assessment indicates that the ground level in the existing industrial development is approximately 3.75m AHD and the 100 yr (1% AEP) flood level at the boundary between the site and industrial land (including consideration of climate change) is 3.01m AHD. The results of this assessment indicate that the development would not increase flooding impacts within the existing industrial development.

13 *WP has proposed revision of the freeboard requirements for the site based on the most extreme level of climate change assessed (30% increase in rainfall intensity, 0.91m increase in the downstream water level boundary condition (100yr ARI receiving water level)). WP has recommended that the minimum flood planning level (minimum floor level) be set approximately equivalent to the estimated flood levels for the most extreme climate change scenario modelled in the lower reaches of the floodways. In the upper reaches where the predicted increase in flood level was less than 300mm WP has recommended that the previous freeboard and flood planning levels be adopted. It is our understanding that in addition to potential climate change impacts, freeboard includes allowance for factors including uncertainties with the modelling approach / input data, local factors and future floodplain modifications. Based on the WP flood level estimates, it is our opinion that the minimum floor level requirement should be increased by significantly more than has been recommended to allow for these additional uncertainties. The magnitude of the additional freeboard required would need to be confirmed by Council in accordance with their flood planning policy.*

WP indicated during the 7 November, 2008 meeting that separate discussions would be held with Council to address climate change considerations for flooding within the site. The revised WMR includes consideration of the 2009 NSW Department of Planning Guideline "*Draft NSW Coastal Planning Guideline: Adapting to Sea Level Rise*" that followed on from the 2007 DECC guideline *"Floodplain Risk Management Guideline: Practical Consideration of Climate Change"* that was considered when the previous WMR was prepared. WP has proposed the following flood planning levels:

- Lots to be filled to a minimum level equivalent to the 100yr ARI flood level including allowance for a 0.9m sea level rise.
- Habitable floor levels to be at a minimum level equivalent to the 100yr ARI flood level including allowance for a 0.9m sea level rise and 0.5m freeboard.
- Roads to be constructed at a minimum level equivalent to the 100yr ARI flood level + 0.3m freeboard.
- Evacuation routes to have a flood depth not greater than 0.3m during the 100yr ARI event (including 0.9m sea level rise).

The proposed planning levels do not include allowance for increased rainfall intensities during design rainfall events. Sensitivity modelling was completed by WP to evaluate the impacts of 30% increased rainfall intensities and it was estimated that this would result in an increase in flood level of less than 0.1m for most of the site.

The results presented within T.2.6. of the revised WMR indicate that the above planning requirements would result in the following outcomes for most of the site:

- Lots filled to the 100yr ARI flood level (no climate change) + up to 0.4m.
- Minimum habitable floor levels set to the 100yr ARI flood level (no climate change) + up to 0.9m.
- Roads constructed to the 100yr ARI flood level (no climate change) + 0.3m.

The above criteria could result in some lots required to be filled to a level below the adjacent road. It is suggested that the lot criteria be adjusted to ensure that lot levels are not lower than the adjacent roads.

14 *The flood management strategy includes a proposal to excavate along the key drainage pathways by up to 2m to reduce flood levels and reduce the extent of filling required in the lower sections of the site. Based on the revised design scenario modelling results that incorporate climate change considerations, it is expected that additional excavation would have minimal impact on reducing flood planning levels which are dominated by the receiving water level. It is considered that the proposal to excavate may have impacts on the groundwater flow/quality and the performance of any stormwater quality measures provided in the excavated channel.*

WP has confirmed that excavation potentially will be up to 3m in areas where permanent storage for constructed wetlands is to be formed below the base of the channel. The excavation depths are shown on Figure E4 in the revised WMR. The excavation is likely to intercept the groundwater table and the impacts of this have been assessed by Martens and Associates and are discussed further below.

15 *It is unclear if in principle approval from DWE to excavate within a watercourse under the Water Management Act has been received. This will be important to ensure the proposed flood and water quality management strategies incorporating excavation of the watercourses are achievable.*

Excavation below the invert of the drainage channels is proposed in order to form the on-line constructed wetlands. The revised WMR indicates that the drainage channel invert will be formed at a minimum level of RL 1.4m AHD with the wetlands excavated up to 1.5m below this depth to RL -0.1m AHD. The revised WMR outlines the following advice we understand was provided by NoW to WP regarding the management of stormwater:

"Any runoff from the development entering wetlands or channels which extend into groundwater, the runoff quality should be equal to or better than the quality of groundwater".

The revised WMR suggests that groundwater within the site has a naturally high nutrient concentration. This conclusion is based on two samples collected during the earlier LES groundwater investigations and five samples collected from the adjacent Riverside Estate in July 2009. Whilst these samples indicate that nutrient levels are elevated, it is considered that the results of grab samples from two local sites are insufficient to reach this conclusion for the entire site. Since the limited data available suggests that concentrations are very high, it is recommended that further sampling be completed to confirm that the sampled groundwater quality is representative of groundwater quality conditions across the entire site.

16 *Limited information is provided in the report regarding the dimensions of the modelled channels. Depths and side slopes are provided, but no details on the modelled widths are provided. The report indicates that 'channel widths were estimated from the masterplan'. It is considered that this information should be provided in the report.*

Channel dimensions have been provided in Appendix 1 of the revised WMR.

17 *Constructed wetlands are proposed to be formed within the invert of the main channel. The constructed wetlands were modelled in MUSIC with a 1m deep permanent storage and 0.3m deep extended detention storage. Based on Diagram 2.4 presented in the WP report, it appears that provision of the constructed wetlands within the main channel has not been incorporated into the hydraulic models.*

WP has revised the constructed wetland configuration to remove the extended detention storage. The constructed wetlands are now proposed to be constructed entirely below the invert of the drainage channels and it is agreed that no modification of the hydraulic models is now necessary to address this comment.

18 *The drainage concept outlined in the 2006 and 2008 WP reports includes eastern and western branch lines that each commence at the north-eastern corner of the site. The western branch is aligned with an existing constructed drain that is proposed to be bifurcated just upstream of a former sand mine pit. A minor branch connects the main western branch to the sand mine pit. It appears that flow will initially be diverted to the former sand mine pit. Based on estimates in the LES, the sand mine pit has a capacity of approximately 300ML. Diversion of runoff into the former sand mine pit may impact on environmental flows to the adjacent wetlands. It is unclear if the harvestable rights for the catchment and potential impacts of the storage on environmental flows to the receiving wetlands have been assessed.*

The concept in the previous WMR outlined a proposal to initially direct all flow along the main east-west channel into the sand mine pit with discharge to the downstream environment only occuring when the pit is full. The revised WMR describes a proposal to only utilise the sand mine pit for storage during events that exceed the 1yr ARI design event. This would maintain flow to the existing wetlands located to the west of the site. Although this revised approach is indicated in the text of the report, the concept shown in Figure E2 suggests that flow will initially be directed into the sand mine pit. WP should confirm the drainage approach in this area.

STORMWATER QUALITY AND QUANTITY – UNRESOLVED ISSUES

22 *Flow targets to manage stream erosion and wetland hydrology (which was identified as being important to the Wallum Froglet habitat in the wetlands) are not proposed for the site. It is considered that flow objectives and targets should be set to address Council's requirement that 'discharge patterns are maintained' under developed conditions. This is considered to be particularly important for this site due to the apparent ecological sensitivity of the receiving wetlands.*

The revised WMR does not provide further details of how flow regimes to the downstream wetlands are proposed to be achieved. The modelling results indicated that surface discharge to the downstream wetlands would increase by more than 100% following development.

23 *The impact of elevated receiving water levels on the ability of the ecology of the wetlands to adapt to climate change is also considered to be an important issue for this site. Following development, the reduced buffer width to the wetlands may limit the potential for migration of wetland habitats. This ultimately may be more significant to the long-term survival potential of wetland flora/fauna at this site than immediate hydrologic changes due to development.*

The revised WMR outlines a proposal to regrade the western part of the site to provide a range of vegetation communities to improve habitat. The concept plan indicates this area as a "wetland transition zone". It is considered that if regraded and vegetated appropriately, this area could provide an important buffer to the existing SEPP14 wetlands located to the west. Further details would be required at a later stage for managing the hydrology in this area, but at this stage the provision of this buffer is considered to have merit for protection of the downstream wetlands. It is recommended that further consideration of this issue be undertaken by Council's ecologists.

25 *A one year period of rainfall data from the Williamtown station was adopted for the MUSIC models. It is considered that this short period is insufficient for simulating a range of event durations and intensities likely to be experienced at this site. A five year minimum modelling period is considered more appropriate for simulating longer term conditions. The adopted modelling period should include a sample of wet, dry and average rainfall years.*

The revised WMR indicates that the modelling period has been increased from one to five years and the average annual rainfall for this modelling period is close to long-term averages near the site. The adopted period is considered to be reasonable.

27 *The rainfall-runoff parameters adopted in the MUSIC models were modified from the default values. It is considered that the adopted parameters may not appropriately represent the existing site hydrology. Although the estimated Cv of 0.21 for the site appears appropriate for the site characteristics, it is considered that the distribution of surface runoff and base flow that comprise the total runoff for the site may not be reflective of the existing catchment conditions. It is considered that further justification for modifying the default rainfall-runoff parameters should be provided.*

WP has modified the rainfall-runoff parameters for the revised WMR. The revised rainfall-runoff parameters result in the following site water balance:

Existing – 15% surface runoff, 15% baseflow, 67% evapotranspiration, 3% deep seepage
Developed (no treat.) – 40% surface runoff, 9% baseflow, 49% evapotranspiration, 2% deep seepage

The revised rainfall-runoff parameters for the site are considered to provide a reasonable estimate of the site water balance based on the existing and developed site conditions.

30 *Stormwater pollutant concentration parameters input to MUSIC were adopted from Stormwater Flow and Quality and the Effectiveness of Non-proprietary Stormwater Treatment Measures (Fletcher et al, 2004). Values are presented in the report and these appear to be the adopted storm flow concentrations. Adopted concentration parameters for base flow should also be provided in the report.*

Adopted base flow parameters have been provided in the revised WMR and these are considered to be appropriate.

32 *The previous land uses (pine forest plantation, sand mining, waste disposal facility) within the site appear to have contributed to higher than typical concentrations of TP and TN in the groundwater (based on limited monitoring undertaken). Groundwater quality monitoring undertaken for the LES indicated the presence of elevated organic nitrogen concentrations which were attributed to past land uses. Although further monitoring data would be required to confirm, it is considered that the adopted TN and TP storm flow and base flow concentrations for modelling may be lower than the existing site conditions. Therefore the adopted concentrations for the existing scenario model may be conservative and this is considered to be a reasonable approach*.

During the initial review, WP indicated that further site investigations were being completed to confirm groundwater quality conditions. No additional monitoring data appears to be included in the revised WMS to provide further support that current groundwater quality within this site is poorer than typical conditions. We understand that further consideration of this issue was completed as a component of the groundwater modelling and further comments on this issue are provided below within the groundwater modelling review.

Existing Scenario Model

34 *Sub-catchments for the MUSIC modelling (which differ from the flooding assessment sub-catchments) are shown on Figure 5 (Catchment Plan) within the 2006 WP report. The configuration of the sub-catchments within the site appears reasonable. It is considered that the catchment plan should also*

include the sub-catchments in the forested area to the north of the site to appropriately simulate the on-line constructed wetlands that form a component of the developed (with measures) scenario.

The MUSIC models have been modified to include the existing industrial and forested catchments to the north of the site.

37 *The estimated existing average annual loads of TSS, TP and TN presented in T.3.6 within the report appear to be within the appropriate range for the existing site conditions. Although, it is considered that the recommended modifications to the existing scenario MUSIC model described above be undertaken to ensure that both the hydrology and pollutant concentration inputs are reasonable as these form the basis for the developed scenario models.*

WP has presented revised estimates of the TSS, TP and TN loads following modification of the existing scenario model in T.3.6 in the revised WMR. The results include estimates of the total load of pollutants within surface runoff, base flow and deep seepage. The revised estimates are considered to be within appropriate bounds.

Developed Scenario Model

39 *The total modelled effective impervious proportion for the developed site was approximately 45%. The adopted impervious fractions for each sub-catchment are presented in T.3.7 within the report and these typically appear to be slightly high (which is a conservative and therefore a reasonable approach). It is considered that the sub-catchment imperviousness in Sub-catchment A13 (Lake) should be increased to allow for direct rainfall on the relatively large lake surface area. It is also considered reasonable to allow for a 20% 'impervious' proportion in the drainage corridors to allow for direct rainfall on the significant areas of wetland proposed.*

The MUSIC models were appropriately updated to include additional 'imperviousness' due to direct rainfall on the proposed water bodies.

40 *The estimated existing average annual loads of TSS, TP and TN presented in T.3.8 within the report are considered to be within reasonable bounds for the developed site conditions. Although, it is considered that the recommended modifications to the developed scenario MUSIC model described above be undertaken to confirm that both the hydrology and pollutant concentration inputs are reasonable.*

WP has presented revised estimates of the TSS, TP and TN loads following modification of the existing scenario model in T.3.8 in the revised WMR. The results include estimates of the total load of pollutants within surface runoff, base flow and deep seepage. The revised estimates are considered to be within appropriate bounds.

Developed (With Treatment) Scenario Model

41 Infiltration measures were simulated (as bioretention measures in MUSIC) to manage stormwater from future residential lots and public streets. The infiltration measures were simulated adopting a seepage loss of 54mm/hr and this has resulted in approximately 75% of surface runoff and base flow generated by the source nodes being 'lost' from the modelled system through infiltration. In addition to losing flow volume, the pollutant loads conveyed within this flow are also lost. The modelled flow for the existing scenario is approximately 580ML/yr and the developed (with treatment) scenario is approximately 365ML/yr. It is unlikely that the total runoff volume for the developed scenario can be reduced below existing conditions for the indicated water management strategy.

WP has modified the tabulation of results for the developed (with treatment) scenario to include consideration of estimated pollutant loads contained within the flow infiltrated through the base of bioretention measures towards the groundwater table. It is considered that the results outlined in T.3.9 provide an improved estimate of the total pollutant load conveyed in surface runoff and base flow following treatment.

The results in T.3.9 suggest that the TP and TN loads discharged from the bioretention measures would increase after passing through the constructed wetlands which suggest that the constructed wetlands would provide limited benefit (from a stormwater quality management perspective) to the WMR.

45 *Estimated lifecycle costs for the developed with treatment scenario were not provided.*

WP has provided a discussion of maintenance requirements within the revised WMR. Preliminary lifecycle cost estimates were provided in an earlier draft copy of the revised WMR (WP report 301010-01753-EN-TEN-001 dated 9 July 2010). .

GROUNDWATER ASSESSMENT – MARTENS CONSULTING ENGINEERS STUDY

A review has been undertaken of the *Preliminary Hydrogeological Study and Concept Groundwater Management Plan* prepared for Myall River Downs by Martens Consulting Engineers (final report dated August 2010). The report has been assessed against Council requirements for LES investigations, Department of Environment, Climate Change and Office of Water (DECCW) review comments (March 2010).

47 *PB indicates the depth to groundwater varies between 0.60m to 1.50m below ground level (bgl) within medium grained sand. PB indicates that rainfall is the dominant recharge process due to the shallow groundwater levels which is considered to be a reasonable assumption.*

MCE have completed additional field investigations that included a single manual measurement and 5 weeks of continuous level data logging for three existing piezometers. They also completed supplementary slug testing to improve understanding of hydraulic conductivity. This is considered adequate for the LES stage of development.

48 *The groundwater levels were determined from site investigations, including drilling and installation of 6 monitoring wells to depths of around 1.5m bgl, groundwater sampling of two of the monitoring wells and excavation of 20 test pits, with the depth to groundwater noted for each test pit. Environmental logs detailing the installation of monitoring wells MW1 to MW6 were reportedly included in Appendix B of the LES, but only the test pit logs were included.*

MCE identified limitations of this data in their study and has subsequently collected a small amount of additional data for 3 bores to rectify in terms of groundwater levels. However, there is still a reasonable level of uncertainty associated with aquifer materials or properties. This uncertainty has been acknowledged by MCE. Additional geotechnical investigation should be undertaken at the DA stage to improve understanding of aquifer properties beyond 1.5m bgl.

49 *PB indicates the subsurface sands form an unconfined aquifer that extends to an assumed maximum depth of 18m. The reason for this assumption is not stated and further clarification of this should be provided.*

MCE has revised the depth to aquifer basement to RL -10 m AHD (13 metres deep) but no explanation for the basis of this has been provided. This assumed depth is considered at the shallow end of typical depths in these environments. As such it will add some conservatism to the magnitude of impacts predicted in the modelling. It is recommended that additional geotechnical investigations be completed at the DA stage to confirm depth to aquifer basement.

50 *PB indicates groundwater flows are hydraulically connected with Pindimar Bay to the south, Kore Kore Creek to the west and the Myall River to the east. Groundwater contours were provided for review and confirm the flow direction.*

The MCE study and modelling has improved understanding of hydraulic pathways for groundwater within the study area. The conceptual model formed as part of the modelling is considered broadly appropriate for the study.

51 *Five falling head tests were completed to assess hydraulic conductivity. The method for the falling head test was included and falling head test calculation sheets were included in Appendix E. The hydraulic conductivity values reported ranged from 1.3m/ day to 5.3m/ day which is consistent with the strata encountered.*

Further slug testing has been undertaken by MCE to provide additional guidance for representative hydraulic conductivity values. Values summarised in Table 8 are considered appropriate.

52 *Two groundwater samples were analysed for total nitrogen, total phosphorous, cations and anions at a NATA accredited laboratory. Field measurements of pH and electrical conductivity were also collected. A discussion of groundwater quality results was included and indicated that the groundwater is very low in dissolved salts and is slightly acidic. The groundwater also contains elevated Total Kjeldahl Nitrogen (TKN) and phosphorous concentrations suggesting some low level contamination from past land uses. It is noted that the TKN and phosphorus results have not been compared to any guidelines*.

MCE have provided limited additional grab sample data for groundwater quality from a nearby development (Riverside Estate) obtained on 6 July 2009 (Table 4). While these values are generally comparable to the results from the study site collected by PB in 2000, insufficient evidence has been provided to confirm that elevated nutrient concentrations are background in-situ (or "natural") values for the site as suggested by MCE. Given the site's history as a forestry plantation and waste disposal site, further characterisation is warranted before making this assumption. The nutrient concentrations listed in Table 3 and 4 of the MCE report are higher than typical values observed in comparable coastal sand aquifers on the NSW coast. This includes sites within the Great Lakes LGA. Given the expected low long-term groundwater flow velocities (in the order of 0.02 – 0.05 m/day) it is feasible that contamination from past land use is yet to be flushed into the estuary (a process that can take decades to centuries).

The proposed development is likely to reduce groundwater nutrient concentrations over the long-term however, the concentrations presented in the MCE study may represent a degraded groundwater resource rather than an undisturbed system. It is recommended that further work be undertaken prior to the DA stage to improve understanding of the source of high nutrient concentrations in groundwater. More detailed assessment of the impacts of an altered groundwater water balance on nutrient dynamics should also be completed.

53 *No records of the field quality assurance methodologies and field quality program implemented (if any) have been provided.*

MCE has undertaken additional field investigations that supersede PB work.

54 *Impacts to groundwater were assessed through the conceptual stormwater management strategies which were developed for two development scenarios. Both development scenarios included an increase in impervious area across the site, which PB indicated would result in an alteration to the groundwater flow regime. The effect of the development scenarios on the groundwater flow regime was assessed using predictive groundwater modelling. Inputs to the model included hydraulic conductivity of 5m/day (based on the falling head test results), transmissivity of 50 square metres per day, a specific yield of 0.1 and recharge rates ranging from 27% to 77% of the average annual rainfall of 1292mm. Justification of the amount of recharge used is required as this is considered to be a very high amount. Coffey Rock was noted at 0.3m above the water table, but this does not appear to have been modelled. This rock may be the reason why excessive recharge was required to calibrate the groundwater model*.

MCE has completed revised groundwater flow modelling for three scenarios (existing, post-development and post-development with sea level rise). Their approach is a significant improvement on the previous PB modelling and adopts a simplified approach consistent with good practice. As acknowledged by MCE however, modelling is preliminary and parameterisation has been based on the limited information already available or obtained during field investigations. A model appraisal has been completed by BMT WBM in accordance with the Murray Darling Basin Commission (MDBC) *Groundwater Flow Modelling Guideline* which is considered the best practice national guideline.

Overall, the modelling is considered satisfactory for assessment of the proposal at the LES stage. However, a number of issues were identified that need to be considered should the development progress further.

- No clear water balance was presented for modelling scenarios. Rather, specific elements were extracted to demonstrate changes in flow to the SEPP14 wetlands. Analysis of the models by BMT WBM has identified some inconsistency between the surface water and groundwater balances derived through MUSIC and MODFLOW modelling respectively. Given the limited water balance data provided, there is some uncertainty surrounding the implications of the development on site water balance.
- Steady state recharge values adopted for developed and undeveloped zones (125 and 62.5 mm/year) were the primary calibration parameter. These values are toward the lower end of expected values (explained as the result of high ET rates due to shallow groundwater).
- Calibration of M1 (existing case) used the manual groundwater level observations obtained during MCE field investigations on 27 March 2009. These levels were preceded by a period of low rainfall (~25

percentile for the preceding 6 months) and followed by a clear rise (~1m) in groundwater levels across the site as a result of sustained rainfall. This is likely to have contributed to the relatively weak calibration achieved and means predicted groundwater levels may be lower than expected. No sensitivity testing of different climatic conditions was undertaken.

- To achieve the reported calibration (Normalised RMS 28%), MCE created three zones of hydraulic conductivity with a three orders of magnitude variation across the site. Modelled groundwater contours for all scenarios suggest that these hydraulic conductivity zones create some unusual results in the areas surrounding MW4 where a value of 0.1 m/day was adopted. No basis for nomination of these hydraulic conductivity zones is provided in the report or PB reports. The high NRMS, unusual predicted groundwater contours surrounding MW4 and uncertainty around recharge values combine to create some uncertainty in model predictions. MCE acknowledge this in their report.
- Modelling results for developed scenarios (M2 and M3) are dominated by the drain boundary conditions. Given that a steady state modelling approach has been adopted, models eventually solve the numerical flow equation to the assumed invert of wetland/basins wherever the water table is intercepted. This is the primary explanation for the limited change in groundwater flow to SEPP14 wetlands predicted in modelling. Effectively all of the increased recharge associated with the proposed surface water management strategy (~1850 ML/year) exits the groundwater models (M2 and M3) as a point source surface water discharge.
- The water quality and ecological impact of this increase point surface discharge has not been assessed at this stage. It is also not clear how this 1850 ML/year of combined groundwater/surface runoff discharge to drains integrates with the surface water balance for the developed (with controls) scenario.
- The uncertainty surrounding the quarry water levels and hydraulic outputs (assumed to be evaporation and pumping) reported by MCE may have implications for the existing scenario. Modelling results suggest the dominance of drain outputs for developed scenarios limits the influence of the quarry. Predicted groundwater contours surrounding the quarry would require a substantial level of water extraction.
- While BMT WBM support the steady state approach to modelling in light of limited information, some uncertainty exists in transient groundwater response to rainfall and point source recharge associated with the developed (with controls) scenarios. Model results and preliminary finished surface levels were assessed and it was found that groundwater was not predicted to intercept wetland/basins in a number of locations. The short-term impacts of rapid raising of the water table through point source recharge should be evaluated at the DA stage.

55 *PB indicates that groundwater was modelled with recharge by rainfall. The development will decrease the area available for recharge, resulting in reduced groundwater recharge and changes in groundwater flow regime. Groundwater contours of a typical future groundwater regime were presented in the report and appear reasonable but the above clarification on the adopted recharge rates is required before further comment can be provided.*

See above.

56 *PB indicates that the designed stormwater drainage system will use elongated water bodies for drainage to be constructed without a lining to allow cross connection with groundwater, resulting in the continual exchange of groundwater and surface water through these bodies. It is considered that it would be preferable to line stormwater management measures to minimise the potential for cross connection.*

The viability of the proposed unlined wetland/basins currently hinges on the high concentrations of nutrients in existing groundwater. DECCW require stormwater discharge to groundwater to be of equivalent or better quality than groundwater. In principle, if the impacts of increased point surface discharge of groundwater (via drains) are within acceptable limits, interception of groundwater via the wetland basins is potentially a viable strategy.

57 *Impacts of filling and excavation on groundwater*

Following a review of PB investigations, preliminary developed surface terrain and predicted groundwater elevation, BMT WBM recommend that further assessment of transient groundwater conditions be undertaken at the DA stage for a small number of representative recharge events. Potential for exposure of acid sulphate soils (ASS) should also be assessed given the predicted lowering of the water table and reported presence of potential ASS in the LES investigation.

CONCLUSIONS

BMT WBM has completed a review of the revised flooding, stormwater and groundwater assessments provided for the proposed Myall River Downs development. The revised water management strategy allocates 2.8% of the development area outside drainage channels to bioretention measures and 1.4% of the development area within drainage channels to constructed wetlands for the purpose of stormwater quality management. Therefore, a total area equivalent to 4.2% of the development area would be provided for stormwater quality management. Based on our experience, this would result in best practice management of stormwater quality within the development. The latest concept has also introduced additional “secondary” lateral drainage channels to direct flow to the main drainage channels. This has assisted with reducing the fill requirements, improving the drainage strategy and providing further opportunities for stormwater quality management.

Excavation up to 3m deep would be required to construct drainage channels and on-line constructed wetlands within the development site. This excavation will result in the groundwater table being intercepted at locations along the drainage channels. The groundwater modelling results indicate that groundwater flow through the existing aquifer towards the natural wetlands would be similar to current levels following development. It is our understanding that this would primarily be achieved by groundwater levels and flow being regulated through groundwater discharge to the excavated drainage channels. The excavated channels would intercept groundwater, treated stormwater and surface runoff, and convey this flow to the downstream wetlands. Based on data provided in the revised stormwater and groundwater assessment reports, it is estimated that approximately 1850ML/yr of surface runoff would discharge at point locations into the downstream wetlands. It is estimated that this represents an increase of more than 100% in surface runoff discharge to the downstream wetlands when compared to existing conditions.

Limited groundwater quality data is currently available for the development site and adjacent development. The data indicates that the total nitrogen and phosphorus concentrations are elevated above those typically observed in similar environments. The concentrations may be representative of natural conditions or past land uses. Due to the limited groundwater quality data available, and absence of data on past site activities, it is our opinion that no firm conclusions can be drawn from this data. Excavation to form the drains will result in groundwater being intercepted and discharged as point surface flows to the natural wetlands at the end of the constructed drainage channels. If existing concentrations of nitrogen and phosphorus in groundwater are high, the more efficient connection of groundwater to the wetlands may initially result in increased loads of nutrients being discharged to the wetland following development. It is expected that these concentrations would reduce in the future as the groundwater is diluted by the treated stormwater which may have a significantly lower nutrient concentration than the observed groundwater quality.

It is our opinion that increased groundwater and/or surface water flows are unavoidable for this development proposal due to the increase in catchment imperviousness from approximately 10% to over 40%, and the related reduction in the soil water storage available for evapotranspiration. The groundwater report indicates that groundwater discharge through the aquifer to the natural wetlands would be maintained at current conditions. To achieve this, the surface water discharges to the natural wetlands would increase. It is our opinion that a preferable outcome would be to distribute the increased flows between groundwater and surface water discharges to balance the risk to the receiving waters. This could potentially be achieved by more strategic infiltration of surface runoff from particular sub-catchments within the development to direct some increased flow to the wetlands whilst reducing the groundwater flow to the channels. Consideration could also be given to reducing the permeability of the base and lower side slopes of the lower sections of the drainage channels to minimise the inflow of groundwater to the channels. It is also recommended that appropriate options to maximise harvesting and evapotranspiration of the additional runoff be considered within the site at DA stage to minimise the increase in discharge to the wetlands. Whichever option is adopted, it is considered important that the ecological impacts of increased groundwater and/or surface water discharges to the receiving waters be assessed.

Yours Faithfully

BMT WBM Pty Ltd

Mark Wainwright, Associate

Appendix 5 - Martens Consulting Engineers, Preliminary Hydrogeological Study and Concept Groundwater Management Plan (August 2010)

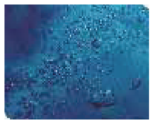
Worley Parsons

Preliminary Hydrogeological Study and Concept Groundwater Management Plan, Myall River Downs, Tea Gardens, NSW

martens consulting engineers

ENVIRONMENTAL

WATER

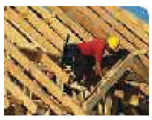


WASTEWATER

GEOTECHNICAL

CIVIL

PROJECT MANAGEMENT



P0902346JR2V03
August 2010

Limitations Statement

The sole purpose of this report and the associated services performed by Martens & Associates Pty Ltd is to undertake a Preliminary Hydrogeological Study and Interim Concept Groundwater Management Plan in accordance with the scope of services set out in the contract / quotation between Martens & Associates Pty Ltd and Warley Parsons (hereafter known as the Client). That scope of works and services were defined by the requests of the Client, by the time and budgetary constraints imposed by the Client, and by the availability of access to the site.

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Document and Distribution Status									
Author(s)			Reviewer(s)		Project Manager		Signature		
NF, BR, DM			Dr D. Martens		Dr D. Martens				
Revision No.	Status	Release Date	Document Location						
			File Copy	MA Library	Client	Void	Void	Void	
A	Draft	05.07.2010	1E	1H	1E				
B	Final	17.08.2010	1E	1H	1E				

Distribution Types: F = Fax, H = hard copy, P = PDF document, E = Other electronic format. Digits indicate number of document copies.

All enquiries regarding this project are to be directed to the Project Manager.

Contents

1 Overview

1.1 Project Background

This report outlines preliminary groundwater investigations and the development of a Concept Groundwater Management Plan (CGMP) to inform and assist the rezoning of land at Tea Gardens, NSW, for the proposed Myall River Downs (MRD) development.

As part of the rezoning proposal, a Local Environmental Study (LES) was prepared by Parsons Brinkerhoff (2003) for Great Lakes Council to meet the requirements of Section 117 of the Environmental Planning Act, 1979, and assess the capability of the site for future urban development. Within the LES, Parsons Brinkerhoff investigated water cycle (stormwater, groundwater and flooding) components of the site and subsequently developed a baseline water management strategy.

Since the 2003 LES, there has been ongoing discussion with the NSW Office of Water (NOW, formerly known as NSW Department of Water and Energy) in regard to the management of groundwater at the site. This report seeks to extend the previous LES work and provide preliminary assessment of outstanding issues and management requirements.

1.2 Study Area Description

The site forms part of a much larger, approximately northeast – southwest aligned Pleistocene and Holocene coastal barrier mass. The MRD site consists typically of low-lying land (<5 mAHD) bound by the Port Stephens estuary to the south, Kore Kore Creek and Pindimar Bay to the west, and the Myall River to the east. A site location plan is presented in Figure 1.

Margins of the site bordering Port Stephens are subject to tidal inundation and are designated wetlands under State Environmental Planning Policy (SEPP) 14.

The site is sparsely developed. Vehicular access roads exist across the site, coupled with engineered drainage channels and culverts. While the site is typically of low relief, as a series of low N-S aligned ridges and swales is present on the site. Vegetation consists of a variety of coastal vegetation communities.

Apart from a number of small engineered drainage channels, no natural water courses traverse the site, drainage is essentially 'internal' with low lying areas forming likely points of increased groundwater recharge during rainfall / runoff events. Given that the site is characterised by Pleistocene and Holocene sand dominant lithology, runoff of incident rainfall is only likely to occur under extreme events.

The western portion of the site contains a pit relating to sand mining operations at the site. The excavation pit covers an area of approximately 10.5 ha and extends to depths of approximately 4 to 5 m below natural ground level (subject to further survey). Pit walls indicate the development of coffee rock within the sand profile. Observations also indicate that the pit is in contact with the aquifer, with groundwater flows discharging into the pit from immediately above the coffee rock level. Typical background water levels (levels outside times of pumping or high rainfall) within the pit are of the order of -1.7 mAHD based on anecdotal evidence provided by the site owner. Recent (28.05.2010) survey of the pit's water level produced a level of -1.64 mAHD.

We note that the precise mechanism for development of low water level within the quarry pit is not currently well understood. It is postulated that levels are likely to be the result of groundwater inflow balancing with evaporative losses. Equilibrium levels are achieved when sufficient local head develops to meet evaporation losses.

1.3 Development Proposal Description

The proposal involves the following key elements:

1. Site area is approximately 346 ha of which some 106.22 ha is proposed for residential purposes.

2. Integration of both open space and built upon area as an ecologically sustainable development, including existing wetland areas, existing buffer zone and squirrel glider management zone.

3. Development is proposed to consist of water management and open space corridors, community pocket parks, sporting and playing fields. Low density tourist loggings, conference and community facilities associated with low-rise town houses, and a light industrial subdivision are proposed for inclusion.

4. Surface water management system designed by Worley Parsons.

The origin and general form of the development comes about from the Concept Plan (MRD-03) for the site (prepared by Crighton Properties; dated June 2007).

1.4 Proposed Surface Water System

The proposed surface water system has been designed by Patterson Britton and Partners (PBP, now Worley Parsons) and consists of the following features:

1. Constructed wetland systems to improve the quality of stormwater runoff via filtration, pollutant uptake, and deposition of sediments.

2. Use of vegetated swales to remove gross pollutants through physical entrapment and nutrient uptake by plants.
3. Infiltration areas / basins which filtrate stormwater removing pollutants typical of urban runoff. A drainage system constructed beneath the infiltration area will allow groundwater recharge.
4. Use of rainwater tanks on residential lots to capture roof runoff for beneficial non-potable reuse.

The following section briefly summaries the key objectives and the conceptual design of the proposed surface water management strategy for the MRD site, developed by Parson Brinkerhoff (2003). Proposed surface water management system is detailed in Figure 15.

1.4.1 LES 2003 Water Management Objectives

Key objectives outlined by Parson Brinkerhoff (2003) for the water management strategy for the MRD site are as follows:

1. Drainage from developed areas that does not compromise public safety and minimise flooding;
2. Maintain peak runoff from site at existing levels for minor and major storm events;
3. Ensure that flooding upstream of the site is not worsened or is improved;
4. Water quality discharge to sensitive downstream waterways is not compromised. Water quality should be maintained at baseline levels, being a function of adopted management and treatment techniques;
5. Minimisation of groundwater impacts; and
6. An allowance for the maintenance of the system to ensure performance.

1.4.2 PBP Conceptual Water Management Strategy 2006

The conceptual surface water management strategy for the site identified the following structures for utilisation:

1. Development of offline wetlands with the capability of capturing the first 10 mm of runoff from developed areas of the site. Excess runoff from incident rainfall would discharge directly to the trunk drainage system. The linear wetland would comprise of a (1) deepwater zone, a (2) macrophyte zone, and an (3) outlet zone.
2. The truck drainage system would consist of elongated water bodies with maximum permanent water depths of 2.5 m.

1.4.3 *NSW Office of Water Letter October 2010*

Following a period of consultation and site meetings with the NSW Office of Water (NOW), NOW prepare a groundwater management principles letter in relation to the Myall River Downs at Tea Gardens Rezoning (dated 4th March, 2010). Key recommendations of this letter included the following:

1. Groundwater systems should be managed such that their most sensitive beneficial use or environmental value is preserved.
2. The development shall have a neutral or beneficial impact on groundwater resources.
3. Groundwater quality shall be maintained or improved. This means that site stormwater shall be treated to a level equal to or better than existing groundwater quality prior to discharge at any proposed infiltration basins / water table 'windows'.
4. Maintain where possible, natural patterns of groundwater flow and not disrupt groundwater levels that are critical for ecosystems.

1.5 Study Scope

The project scope is summarised as follows:

1. A review of existing groundwater data relating to the proposed surface water management strategy;
2. General site inspection including the location and inspection of existing bores;
3. Various preliminary discussions with NOW in regard to groundwater management;
4. Prepare preliminary groundwater budgets based upon the current proposed master plan (MRD-03) and current surface water management system. Works include the following:
   i) Prepare a preliminary MODFLOW groundwater model updating the LES model.
   ii) Calibrate model against limited existing well data.
   iii) Prepare post-development model based on expected development footprint.
   iv) Preparation of pre and post-development mass budgets and flows.
   v) Assess the impact of potential climate change induced sea level rise.
5. Preparation of an interim Conceptual Groundwater Management Plan (CGWMP) covering the following:
   i) Aquifer characteristics.

ii) Management objectives.

iii) Management methods for aquifer recharge and adopted surface water management strategy.

iv) Post-development monitoring and contingency planning.

v) Water quality trigger values for management.

2 Hydrogeological Investigation

2.1 Regional Groundwater Background Information

2.1.1 Karuah Alluvial Resource

We note that the site is positioned within an area mapped as the Karuah Alluvial Resource (Figure 5). However, there is no effective hydraulic connectivity between the site and the Karuah Aquifer which is located to the north and separated by a significant bedrock controlled east-west aligned ridgeline. The groundwater catchment to the site is limited to surface runoff from the small catchment draining the ridgeline surrounding the development area.

2.1.2 Water Bearing Strata

Water bearing strata consist generally of unconfined medium grained quartz coastal sand, although the likely presence of semi-confined systems can occur in small isolated areas due to humic deposits in sand layers (Australian Natural Resource Atlas, 2009).

2.1.3 Permeability and Infiltration Rates

A summary of relevant previously reported data in relation to aquifer permeability and surface infiltration rates is provided in Table 1. Parameters reported by Coffey Partners (1996) and Coffey Geotechnics (2007) relate to the Myall Quays and Riverside developments situated < 1.0 km to the east of the MRD site within a similar geological / hydrogeological setting, while Bish (1995) data are from a nearby Hawks Nest aquifer with similar ground characteristics.

Table 1: Summary of reported local permeability and infiltration data.

Parameter	Bish (1995)	Coffey Partners International (1996)	Parsons Brinkerhoff (2003)	Coffey Geotechnics (2007)
Transmissivity (m^2/d)	-	110	20 - 50	200
Hydraulic Conductivity (m/d)	0.7 – 36.5	12	1 - 20	8
Surface Infiltration Rate (m/d)	-	2	-	2

2.2 LES Investigation

2.2.1 Overview

A previous investigation of prevailing groundwater conditions was undertaken by Parson Brinkerhoff (2003) as part of Local Environmental Study (LES) for the Myall River Downs site.

Groundwater information pertaining to the Parsons Brinkerhoff (2003) LES is briefly summarised in the following sections.

2.2.2 Sub-surface Materials

While a thorough geotechnical investigation of sub-surface lithology was not undertaken as a part of the LES, an investigation into the land use capability of the sub-surface lithology and pertinent geomorphic process was undertaken.

The LES indicated that the site is likely to be underlain by a variety of Pleistocene and Holocene sediments, chiefly of marine, aeolian, estuarine, and fluvial origin (Table 2).

Review of data collected by Parsons Brinkerhoff (2003) indicates a typical profile characterised by sands, with minor horizons of coffee rock. Parsons Brinkerhoff (2003) outline that total sand thickness below the site is assumed to vary up to 20 m (although significantly less in places), with this figure derived from information obtained on the neighbouring Myall Quays development (Coffey Partners, 1996).

Table 2: Typical sub-surface conditions.

Unit	Source	Typical Depth (m)
1	TOPSOIL – SAND, fine to medium grained, dark grey to brown, with some silt, with roots present	0.15 – 0.5
2	SAND - medium to coarse grained, grey to white or cream.	Variable to 2.3
3	Coffee Rock - occasional hard pan or coffee rock horizons, orange or red-brown to black	Variable

A preliminary assessment of Acid Sulfate Soils (ASS) was under taken as part of the LES. Only field screen testing of soils was performed on soil samples, however this indicated that potential ASS are like to exist at the site at depth ranging between 0.0 – 1.50 m below ground level.

2.2.3 *Water Bearing Strata*

The unconfined aquifer is assumed to extend to a depth of ~ 18 m (Parsons Brinkerhoff, 2003). Depth to groundwater is variable across the site, ranging between 0.6 – 1.5 m below ground level (mBGL).

2.2.4 *Salinity*

Based on data from on-site and neighbouring localities, salinity for the aquifer underlying the MRD site is likely to range between 190 – 13,900 mg/L (Coffey Partners, 1996; Parsons Brinkerhoff, 2003; and Coffey Geotechnics, 2007).

2.2.5 *Recharge*

No published values of groundwater recharge were available for the aquifer underlying the site. However, based on our assessment of similar aquifer systems, annual recharge as a proportion of annual rainfall is likely to be of the order of 5 to 15%. This relatively low percentage is expected given the site's groundwater regime is likely to be strongly influenced by evapotranspiration (ET) due to the groundwater's shallow depths below surface level. No further background research with regards to recharge was undertaken as this parameter is calibrated in the site groundwater model.

2.2.6 *Hydraulic Conductivity (K)*

Aquifer(s) in the region of the site are characterised by medium to high K values which are typical of medium grained quartz sand. Parson Brinkerhoff established K values for the MRD aquifer within the range of 1.3 - 5.3 m/d. However, based on previous investigation undertaken by Coffey Partners (1996) on the adjacent Myall Quays development, PB reported that K values likely range between 1 – 20m/d.

Field testing for this study obtained K values from 3 monitoring bores previously installed by PB across the MRD site. Data analysis identified K values ranging between 4.4 – 12.8 m/d.

Groundwater modelling conducted by Coffey Geotechnics (2007) on the adjacent Riverside Development utilised a K value of 8 m/d which was based on field testing.

Review of available literature indicates likely K values for medium grained sand is 8 – 18 m/d and 18 – 80 m/d for course sand (Bair and Lahm, 2006).

Based on the above, K can be expected to typically be of the order of 1 – 20 m/d over the broader region and that this is a suitable range for undertaking calibration of the preliminary MODFLOW groundwater model.

2.2.7 *Groundwater Levels*

Groundwater levels at the MRD site were investigated by Parsons Brinkerhoff (2003). Groundwater levels were investigated via the construction of five groundwater monitoring bores (M1 to M5) and the excavation of twenty test pits (TP1 to TP20) across the site. Groundwater levels at the site were observed in a one-off event (19.01.2000). Temporal observation of groundwater was not undertaken during the investigation by Parsons Brinkerhoff.

At the time of preparing this report, monitoring data pertaining to groundwater monitoring bores, M1 to M5, identified in the Parsons Brinkerhoff (2003) report were not available.

While test pits excavated across the site provide groundwater levels, inaccuracies relating to test pit locations and elevation data for test pit locations render the data not useful for further investigations and is therefore not considered further in this preliminary investigation.

Location of LES test pits and groundwater bores is presented in Figure 6.

2.2.8 *Groundwater Quality*

Parsons Brinkerhoff (2003) reported limited groundwater quality data for the site based on measurements made at 2 separate boreholes during January 2000 (Table 3). Groundwater quality data indicates generally acidic fresh water with elevated nutrient (TKN and phosphorus) content.

While the source of nutrients in groundwater was not determined, Parsons Brinkerhoff (2003) assume nutrient levels to be representative of low level contamination from past land use. However due to the site being largely undeveloped, it is possible that these values may represent background *in-situ* conditions at the time of investigation.

While NOW regard the existing aquifer as a potential potable water supply, preliminary groundwater quality data indicates that pH and TDS properties of the aquifer exceed NHMRC (2004) Human Health Guidelines for drinking water. We note that at this stage, further groundwater quality data would be required to further characterise the aquifer and determine its future potential value as a water resource.

Table 3: Site groundwater quality data collected January 2000 (Parsons Brinkerhoff, 2003).

Parameter	MW2	MW5	Average
Nutrients			
Nitrate (inorganic) (mg/L)	<0.01	<0.01	<0.01
Nitrate (organic) (mg/L)	<0.01	<0.01	<0.01
TKN (mg/L)	7.8	14	10.9
Total N (mg/L)	7.8	14	10.9
Total P (mg/L)	1.31	1.01	1.16
Major Ions			
Sodium (mg/L)	15	32	23.5
Potassium (mg/L)	0.6	0.9	0.75
Calcium (mg/L)	0.9	0.9	0.9
Magnesium (mg/L)	2.2	4.0	3.1
Sulfate (mg/L)	8	11	9.5
Chloride (mg/L)	23	51	37
Carbonate Equilibrium			
Hydroxide (mg/L)	< 1	< 1	< 1
Carbonate (mg/L)	< 1	< 1	< 1
Bicarbonate (mg/L)	< 1	< 1	< 1
Alkalinity (mg/L)	< 1	< 1	< 1
Total Hardness	11	19	15
pH	5.57	5.00	5.28
TDS (mg/L)	602	1304	953
Conductivity (µS/cm)	920	2050	1485

In addition to the above data, groundwater quality sampling data collected from the Riverside Estate immediately to the east of the site were reviewed (Table 4). These showed similar nutrient and salinity levels to those observed at the site.

Table4: Groundwater 'grab' sample mean data for Riverside Estate (5 boreholes sampled on 6th July, 2009).

Sample site	Units	Average
pH	pH Units	5.4
Electrical Conductivity	µS/cm	236
Total Dissolved Solids	mg/L	145.2
Total Nitrogen	mg/L	8.50
Total Phosphorus	mg/L	2.41

2.3 Supplementary Field Investigations

2.3.1 *Field Works*

Given that bore data were not available and test pit groundwater data were not useful in preparing the preliminary groundwater model, additional information was collected from 3 existing groundwater monitoring bores identified at the MRD site. The following works were conducted:

1. Walk over by an experienced hydrogeologist of the site and inspection of existing monitoring piezometers previously installed by Parsons Brinkerhoff in 2000;
2. Manual dip measurement of groundwater level at 3 existing groundwater monitoring bores (MW2, MW4 and MW5); and
3. Installation of 3 high resolution continuous groundwater level data loggers ('Divers') at piezometers MW2, MW4, and MW5. The monitoring period for these Divers was 28 March 2009 to 5 May 2009.

Piezometer installation data are outlined in Table 5.

Table 5: Site monitoring piezometer network details (Parson Brinkerhoff, 2003).

Site	Surface Elevation (mAHD)	Top of Piezometer Casing (mAHD)	Total Borehole Depth (mBGL)	Screen Interval (mBGL)	Screened Inserted Into
MW2	2.51	3.46	3.43	Unknown	Unknown
MW4	2.24	3.20	3.23	Unknown	Unknown
MW5	2.17	3.11	3.45	Unknown	Unknown

Groundwater levels utilised in this assessment were collected by Martens and Associates from three previously installed monitoring well boreholes (MW2, MW4, and MW5) for the period 28.03.2009 – 05.05.2009. The location of previously installed monitoring bores MW1 and MW3 were not identified during the MA site visit. Recorded groundwater level observations for 27/3/2009 are given in Table 6.

Table 6 Summary of observed site groundwater levels for 27.03.2009.

Groundwater Bore No.	Approx RL (mAHD)	Groundwater Level (mAHD)
MW2	2.51	1.56
MW4	2.24	1.59
MW5	2.17	1.15

2.3.2 *Continuous Level Measurements*

During the 36 day monitoring period, approximately 267.6 mm of rain fell over the site, enabling an assessment of the impact of rainfall on transient groundwater conditions. Monitoring also enabled the influence of tidal cycles to be observed on site ground water conditions.

Results of the monitoring are provided in Figure 2 which provides a plot of groundwater level at each monitoring station together with a plot of daily rainfall received at the site. Rainfall data were taken as 24 hour rainfall totals at 9am from the Nelson Bay Meteorological Station which is located approximately 6.0 km SSE from site.

In addition to the raw data plot, Figure 3 provides a plot of mean daily groundwater residual levels (ie. level relative to mean monitoring period level and excluding tidal effects) in order that data can be easily compared. Comments on the data are as follows:

1. Rainfall appears to have a significant effect on groundwater level at each of the monitoring sites. During the monitoring period, six (6) spikes in groundwater level relating to incident rainfall were identified. The largest increase in groundwater levels occurred during the 72 hr period of 31 March to 2 April, when approximately 113mm rainfall resulted in an increase in groundwater level of between 750 to 1000 mm increases across the three (3) monitoring piezometer sites.
2. Several smaller rainfall events ranging between approximately 4 and 19 mm were also identified. These events resulted in a rise of between approximately 100 - 350 mm in water table height at all observation sites. It is noted that variation in groundwater response behaviour (per event) exists for some monitoring piezometer sites following incident rainfall. This indicates that rates of groundwater recharge across the site are temporally inconsistent, and periodically other factors likely influence the rate of groundwater recharge.
3. Data indicates an inherent and rapid groundwater response to incident rainfall at the MRD site, with an interval of lag between rainfall and groundwater response, conceivably at an interval of <6 hrs. Specific Yield (S_y) is estimated (by back calculation) to be of the order of ~0.10 – 0.15.

4. Tidal influence on groundwater level was observed at all monitoring sites. The influence was most marked at piezometer MW5 which showed semi-diurnal groundwater level fluctuations in the range of 50 mm/day, while tidal influences of 10 mm/day were observed at MW4. These tide related fluctuations are attributed to changing ocean levels affecting local hydraulic gradients and therefore

groundwater discharge rates.

5. The presence of a strong tidal signal throughout the site reflects the high hydraulic conductivity of the underlying aquifer

A summary of the continuous groundwater monitoring levels are presented in Table 7.

Table 7: Summary of continuous groundwater level monitoring data from date: 28.03.2009 – 05.05.2009.

Groundwater Monitoring Bore No.	Surface Elevation (mAHD)	Max Level (mAHD)	Min Level (mBGL)	Fluctuation Range (m)	Median Level (mAHD)
MW2	2.51	2.486	1.473	1.013	2.089
MW4	2.24	2.238	1.516	0.722	1.956
MW5	2.17	2.128	1.182	0.946	1.674

2.3.3 *Hydraulic Conductivity*

Supplementary slug testing was undertaken within monitoring piezometers MW2, MW4, and MW5 on 27 March 2009. Tests were undertaken by either adding or withdrawing 20 L to / from the aquifer. All responses were monitored automatically using an in-borehole Diver. Results are provided in Table 8 and while slightly higher, are comparable to previous site testing reported by Parson Brinkerhoff (2003).

Table 8: Slug testing results for 27.03.2009.

Groundwater Monitoring Bore No.	K Estimate (m/d)	Parsons Brinkerhoff K Estimates (m/d)
MW2	12.8	4.8
MW4	4.4	1.3
MW5	N/A [1]	4.8

Note: [1.] Test value not reported due to suspected well screen clogging.

2.4 Groundwater Modelling

2.4.1 *Model Development Approach*

To assist with determining the spatial extent and variability of groundwater resources below the site, a series of preliminary groundwater models of the study area were developed using Visual MODFLOW 2009.1 Pro, which updates the previous Parson Brinkerhoff work. MODFLOW is a 3D modelling platform that is capable of simulating groundwater flow through porous media under both steady state (ie. fixed time instance) and transient (ie. time varying) boundary conditions. In this instance, the modelling is considered preliminary given the limited extent of geotechnical and piezometer network data.

The following scenarios were modelled as part of this investigation:

Model 1 (M1): Pre-development Conditions (steady state)
Using available site geotechnical data, a calibrated single layered steady state model M1 was developed. The primary purpose of the model was to provide a base case for development footprint and climate change impact assessment purposes.

Model 2 (M2): Post - development Conditions (steady state)
Model M2 was developed to provide a preliminary assessment of the likely impact of the proposed development footprint on steady state groundwater conditions. In particular, model M2 reduced recharge rates over the proposed development and locally increased recharge rates at each of the site sub-catchment discharge locations.

Model 3 (M3): Post-development Conditions (steady state)
Model M3 was developed using the developed conditions as documented in model M2, but modified to examine the impact that potential climate change induced sea level rise of 0.9 m would have on groundwater levels within the development footprint (including the proposed surface water management system).

2.4.2 *Model Discretisation*

Model discretisation is summarised in Table 9.

Table 9: MODFLOW model discretisation.

Property	Value / Details
Model Area	1920ha
Grid cell size	50 x 50 m (refined to 12.5 x 12.5 m over site)
Layer thickness	~13 m (base level set at ~ -10 mAHD)
Topography	Adapted from site survey data / proposed developed terrain
Calibration Period	2009 (steady state model M1)

2.4.3 *Boundary Conditions for Model M1*

Constant Head Boundaries

a) 0.7 mAHD based on lagoon water level monitoring at the eastern lagoon (Figure 7 – G).
b) -1.7 mAHD based on anecdotal survey data at the western quarry pit (Figure 7 - H).
c) 0 mAHD at Kore Kore Creek and Pindimar Bay (Figure 7 - I).

Surface Drains

a) Drain A - B (Figure 7).
b) Drain C - D (Figure 7).
c) Drain E – F (Figure 7).

Drain conductance estimates were based on K = 5 m/d, drain width of 6 m. Levels were estimated based on available survey data.

2.4.4 *Calibration of Model M1*

Steady state calibration of model M1 was undertaken through iterative convergence methods. Initially a homogeneous bulk K zone of 5 m/d was applied across the model domain along with 2 recharge zones, namely a zone for developed areas and a zone for undeveloped areas. Recharge for the developed zone was set at a rate 50% lower than the undeveloped zone to take into account the impact of pervious areas. Recharge was the primary calibration parameter as K values were assigned based on test estimates (Section 2.3.3).

Calibration results with the homogeneous bulk K zone of 5 m/d produced a maximum residual of -0.46 m, minimum residual of -0.07 m and absolute residual mean of 0.27 m (Figure 8a). In light of the models low degree of parameterisation, these results indicate that the model provides a reasonable prediction of the groundwater surface. However, as expected, these results suggest that K values are likely to be somewhat heterogeneous over the site.

Final calibration (Figure 8b) required a relatively low K zone of 0.1 m/d to be applied in the vicinity of MW4 and a relatively high K zone of 35 m/d to be applied in the vicinity of MW2. This resulted in a maximum residual of 0.13 m, minimum residual of -0.09 m and absolute residual mean of 0.12 m.

Calibrated net recharge values were 125 mm/yr and 62.5 mm/yr for the undeveloped zones and developed zones respectively. For the undeveloped zone this represents approximately 9% of mean annual rainfall (1348.9 mm at Nelson Head, station 61054). These values are expected given that the site's groundwater regime is likely to be strongly influenced by evapotranspiration (ET) due to consistently shallow depths to groundwater.

In light of the available data, modelling results indicate that the steady state model (M1) is sufficiently calibrated to allow its use for preliminary assessment. We note that supplementary monitoring bores for areas located outside of the existing 3 groundwater monitoring bores [used for M1 calibration] would further improve model M1 accuracy.

2.4.5 Boundary Conditions for Models M2 and M3

Boundary conditions utilised in M1were modified as follows:

<u>M2</u>

a) M2 recharge was decreased by 50% within the proposed development footprint to simulate decreased recharge due to increased impervious areas.

b) Surface runoff estimates from impervious areas (provided by Worley Parsons) conveyed to the site stormwater basins/wetlands were represented as local increases in groundwater recharge [where recharge depth was determined based on annualised runoff volume over receiving area].

Drain boundary conditions were assigned to stormwater basins/wetlands to replicate removal of groundwater from the basin/wetland due to conveyance. Drain levels for the basins were assigned based on invert levels provided by Worley Parsons. High drain conductance estimates were used to ensure full removal of water from swales during conveyance.

c) A preliminary developed surface terrain file was prepared by Tattersall Lander Pty Ltd.

<u>M3</u>

a) Boundary conditions generally remained as per M2 with the following modifications.

b) A constant head boundary condition of 0.9 mAHD was applied at Kore Kore Creek and Pindimar Bay to simulate climate change induced sea level rise. The constant head boundary was also relocated to the 0.9 m site contour to simulate the effect of ocean transgression through the site.

c) The western lagoon constant head (Figure 7 – G) was increased to 0.9 mAHD to coincide with its connection with Pindimar Bay under sea level rise conditions.

d) The eastern quarry standing water level was raised by 0.9 m to – 0.8 m AHD to model the impact of potential climate change induced sea level rise. This approach maintains a similar head differential between current sea level and mean quarry standing water level. This is taken as a reasonable interim assumption in light of the limited information [regarding quarry water levels and groundwater processes] available at the time of report preparation.

e) Drain boundary conditions within M1 were adjusted in order to maintain a drain level of 0.9 mAHD at the final discharge point (Kore Kore Creek and Pindimar Bay).

2.4.6 Modelled Groundwater

Steady state groundwater modelling results are discussed below:

Model 1 (M1): Existing Conditions (steady state)

Simulation results are provided in Figure 9 which indicate the presence of a groundwater divide within the central portion of the site, being aligned approximately in a N – S direction. Groundwater reaches maximum mean levels of approximately 2.2 mAHD at the divide within the central area of proposed site development and flows either to Kore Kore Creek and Pindimar Bay to the west to south-west or in a general easterly direction toward the Myall River.

Model 2 (M2): Developed Conditions (steady State)

Simulation results are provided in Figure 10 which indicates that under developed conditions there will be negligible changes to groundwater flow direction at the site boundaries and within adjoining wetlands.

Figure 11 provides a drawdown (ie. water table difference) plot between developed and existing conditions and indicates that groundwater levels are likely to generally lower over the site by depths ranging from 0.1 to 0.8 m.

There is no modelled groundwater level change at the fringing SEPP 14 wetlands.

Model 3 (M3): Developed Conditions with Sea Level Rise (steady State)

Simulation results are provided in Figure 12 and indicate that a sea level rise of 0.9 m will not significantly alter groundwater levels within the development footprint.

Figure 13 provides a drawdown plot between developed conditions and developed conditions with sea level rise and indicates that groundwater levels are likely to increase by 0.1 m in the west of the site.

On this basis, we do not expect that there will be any significant change in the operation and efficiency of the proposed surface management system (as prepared by Worley Parsons).

2.4.7 Preliminary Zone Budgets

The site was separated into the following zones for water budgeting assessment purposes.

1. MRD Zone – this zone comprises the development site and external areas within the model domain which are not occupied by wetland.

2. Wetland Zone – this represents wetland areas within the model domain.

Zone locations are provided in Figure 14. Zone budget results were developed based on model M1 and M2 results and are provided in Table 10.

Comments are as follows:

1. On the basis of current groundwater data, there is likely to be a minor reduction (-0.66 %) in net groundwater recharge to the fringing wetland. This is well within expected existing annual water balance fluctuations and comes about through a marginal decrease in net recharge within the development site.

2. On balance, and given the level of accuracy inherent within the modelling, we do not expect that there will be any significant or in fact observable change to groundwater flow or recharge conditions to the fringing SEPP 14 wetlands or the river as a result of the development proposal.

Table 10: Average annual wetland groundwater zone water budgets (ML/year)

Zone	Existing Conditions (Model M1) (ML/year)	Developed Conditions (Model M2) (ML/year)	Net Change (%)
Wetland Zone Inflow	753	748	- 0.66

2.4.8 *Preliminary Nutrient Fluxes*

Using the zone water budgets defined above, nitrogen and phosphorus fluxes were estimated based on the limited existing groundwater chemistry data. Results are provided in Table 11 with comments as follows:

1. Results provide an overview of mass transport rates to the fringing wetlands and hence to the receiving waters.

2. Developed conditions show negligible differences in nutrient fluxes.

3. Impacts of stormwater and recycled water loads to the groundwater system have not at this stage been included in the nutrient flux analysis but should be included in the more detailed modelling at a later stage.

Table 11: Average annual nutrient fluxes for wetland groundwater zone.

Zone	Existing Conditions (TN / TP tonnes/year)	Developed Conditions (TN / TP tonnes/year)	Net Change (TN / TP%)
Wetland Zone	8.21 / 0.87	8.15 / 0.87	- 0.73/ 0.0

Note: Total Nitrogen (TN), Total Phosphorous (TP)

2.4.9 *Groundwater pH*

Existing groundwater pH levels at the site are variable (as they are to the east at the Riverside Estate site) and may range between say 4.5 and 6.5 depending on specific location, local soil and geology, and antecedent rainfall conditions.

Rainfall pH levels for coastal NSW are generally acidic due to the disassociation of CO_2 to form carbonic acid and may range between say 5.5 and 7.0. Lower levels [to say pH of 4.5] can be experienced in coastal areas near larger urban centres or closer to industrial centres (such as Newcastle in the case of this site) (Bridgman, 1989).

Contrasting the depressed pH of rainfall, urban runoff, notably from concrete and other pavement surfaces, has the potential to maintain a slightly elevated pH of say 6.5 – 7.5. In the case of this development, we do not expect any changes to background groundwater pH levels at the fringing wetlands for the following reasons:

1. There will be minimal concrete pavements / surfaces within the development relative to other surfaces (ie. pervious surfaces and roofs) and therefore limited potential for significant production of alkaline urban runoff.

2. Rainwater will remain the primary source of acidity within urban runoff and there will continue to be significant opportunity within the development footprint and within the proposed surface drainage system for contact between rainwater and *in-situ* soil prior to percolation to the groundwater system.

3. Local soils within and adjoining the fringing wetlands have a significant capacity to maintain stable pH levels given the high levels of organic matter and buffering capacity of local soils (Murphy, 1995).

2.4.10 Modelling Refinements

We recommend that preliminary modelling undertaken as part of this investigation can be further refined as follows:

1. Expanding the existing piezomenter monitoring network to include supplementary monitoring locations and transient groundwater level data so transient conditions can be better evaluated.
2. Supplementary geotechnical investigations to improve the understanding of aquifer material properties. This should include some testing of site coffey rock. A review of the preliminary MODFLOW model set-up should be completed following delivery of any additional geotechnical information.
3. Incorporate improved details of water level processes in the existing western sand quarry.
4. Supplementary groundwater quality sampling to more fully characterise local groundwater quality.

3 Preliminary Concept Groundwater Management Plan

3.1 Overview

This preliminary concept groundwater management plan provides advice on the following:

1. Existing aquifer characteristics
2. Potential aquifer risks
3. Risk management objectives
4. Risk management methods
5. Further Investigation Requirements

3.2 General Aquifer Characteristics

Based on limited investigation and modelling of the aquifer, the following interim characteristics define the MRD site aquifer:

1. The aquifer is sand-dominated and highly permeable;
2. The groundwater system is coupled with the Port Stephens estuary and is responsive to tidal fluctuations;
3. The aquifer is highly responsive to recharge events. Reasonably rapid groundwater level fluctuations in the order of 750 – 1,000mm can occur in response to rainfall;
4. Aquifer recharge is local and is predominantly controlled by incident rainfall; and
5. Based on limited groundwater quality data, groundwater is likely to be of a low-value resource due to TDS and pH.

3.3 Primary Risk Identification

Whilst this document does not present a comprehensive analysis of risks to the sites aquifer, the following broad scale risks are identified in association with the release of urban land.

1. Untreated stormwater discharge to groundwater resulting in groundwater contamination.

2. Changes to groundwater level which come about through modifications to surface infiltration and recharge properties at the site.

3. Changes to groundwater flow direction which come about through modifications to surface infiltration and recharge properties at the site.

4. Significant modifications to groundwater flow budgets to groundwater dependent ecosystems and the receiving waters.

5. Locally increasing groundwater levels though excessive recharge resulting in surface water losses from the groundwater system.

3.4 Risk Management Objectives

On the basis of identified risks, the following risk management objectives are provided:

1. Development is to be undertaken in such a way so as to ensure that groundwater table drawdown is minimised.

2. Development should not result in a degradation of the existing aquifer water quality.

3. Development should not significantly alter the flow directions of ground water at the site.

4. Insure the surface and groundwater system is maintained such that the integrity of groundwater dependent ecosystems is preserved or enhanced.

3.5 Risk Management Methods

The following methods are recommended in order that the risk management objectives can be met:

1. Ensure all stormwater management systems treat stormwater to a level equal to or better than existing groundwater quality prior to discharge to any groundwater body.

2. Minimise [but do not necessary preclude] the exposure of groundwater to surface water systems.

3. Ensure that where groundwater recharge has been locally reduced, that recharge is increased in other areas of the site to compensate for any potential water budget short falls.

4. Recharge treated stormwater throughout the site in such a way so as to enable distributed recharge rather than single point recharge. This will ensure that groundwater flow gradients, levels and directions are maintained at pre-development levels.

3.6 Recycled Water Usage

We provide the following preliminary comments in relation to the risks that any potential irrigation of recycled water over the site would pose.

1. Indicative nutrient concentrations in recycled water would be 6 mg/L TN and 2.2 mg/L TP. These values are comparable to existing groundwater conditions, particularly nitrogen levels. We note there may be scope to reduce these concentrations with additional water treatment.

2. On the basis that lots will be of the order of 600 m^2 with irrigated garden beds being in approximately 200 m^2, some 90-100 KL/ET/year (say 100 KL/dwelling/year) of recycled water would be expected to be used for outdoor purposes (assuming a total water consumption rate of 210 KL/ET/year).

3. Irrigation nutrient loads to the yard areas will therefore be of the order of 0.60 kg/year TN and 0.22 kg/year TP. It is important to note that these loads would be irrigated during dry times and generally onto unsaturated soils and not directly into the groundwater system. During times of high groundwater, there would be no need to provide additional irrigation water. Risks of direct recharge are therefore negligible.

4. Broad acre nutrient consumption rates for lawns and landscaped gardens are of the order of 200 kg/ha/year and 15 kg/ha/year phosphorus. On this basis, demand for nutrients in irrigated yard and landscaped areas will be of the order of 4 kg/year TN and 0.3 kg/year TP.

5. The above demonstrates that demand for nutrients in garden areas alone far outstrips that which can be supplied by the recycled water. In the case of nitrogen, demand is 660 % of expected supply, and in the case of phosphorus, demand is 136 % of expected supply. In the case of phosphorus, these preliminary estimates do not account for the significant sorption of phosphorous that would occur within soils.

6. The preliminary calculations are conservative as they do not account for the opportunity for nutrient update in areas outside those being irrigated, nor do they account for nutrient transformation which will occur within the unsaturated and saturated portions of the soil (eg. denitrification losses).

4 References

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5 Attachment A – Figures

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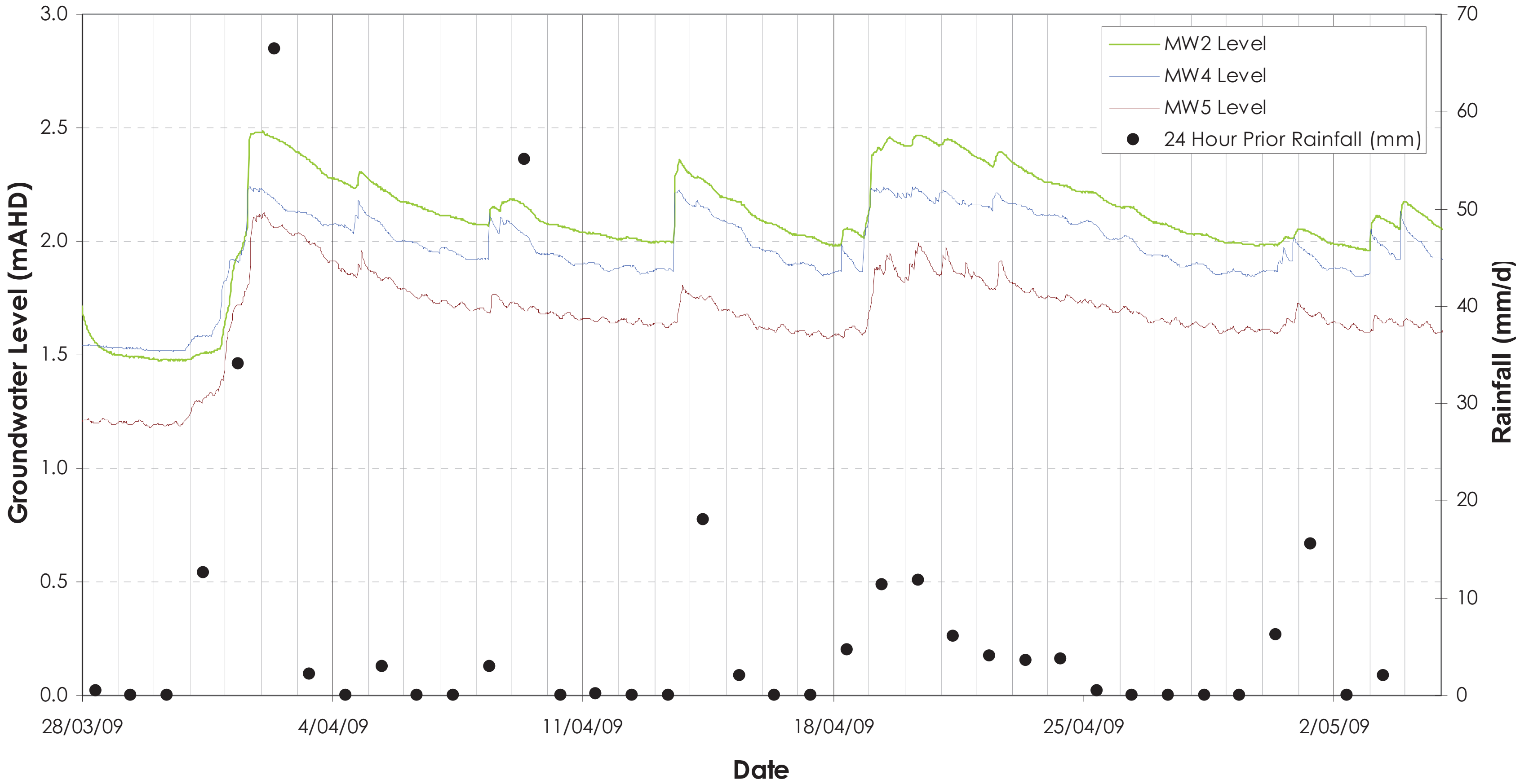
Martens & Associates Pty Ltd ABN 85 070 240 890		Environment | Water | Wastewater | Geotechnical | Civil | Management	
Drawn:	NF	**MYALL RIVER DOWN STUDY AREA LOCATION AND SITE BOUNDARY**	Drawing No: **FIGURE 1**
Approved:	DMM		
Date:	02.02.2010		
Scale:	Approx. 1: 22,000		Job No: P0902346



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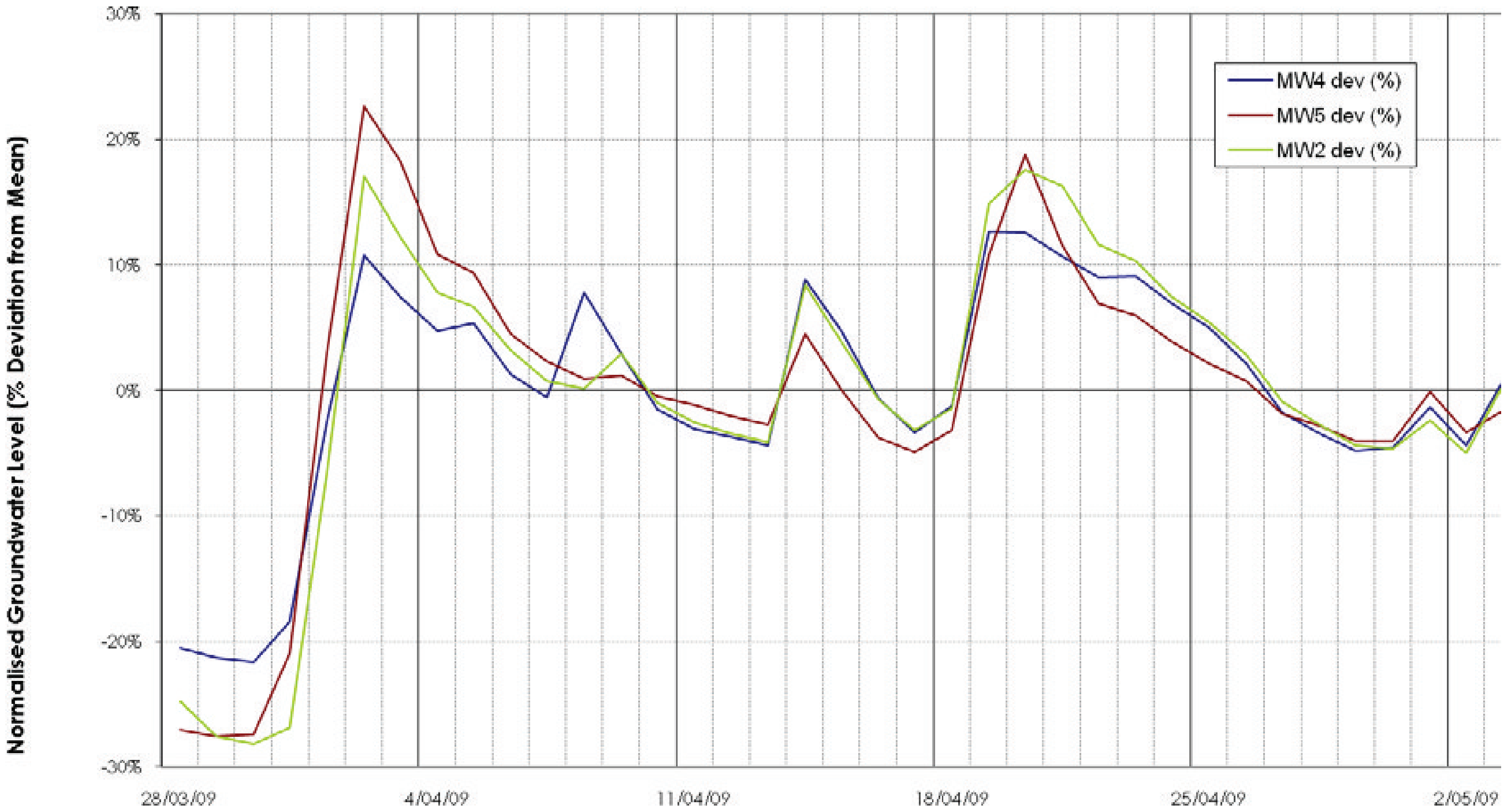
Martens & Associates Pty Ltd ABN 85 070 240 890		**Environment | Water | Wastewater | Geotechnical | Civil | Management**	
Drawn:	NF	**DETAILED GROUNDWATER LEVEL OBSERVATIONS: MW2, MW4, and MW5 PERIOD: 28.03.09 – 05.05.09**	Drawing No: **FIGURE 2**
Approved:	DMM		
Date:	02.02.2010		
Scale:	N/A		Job No: P0902346



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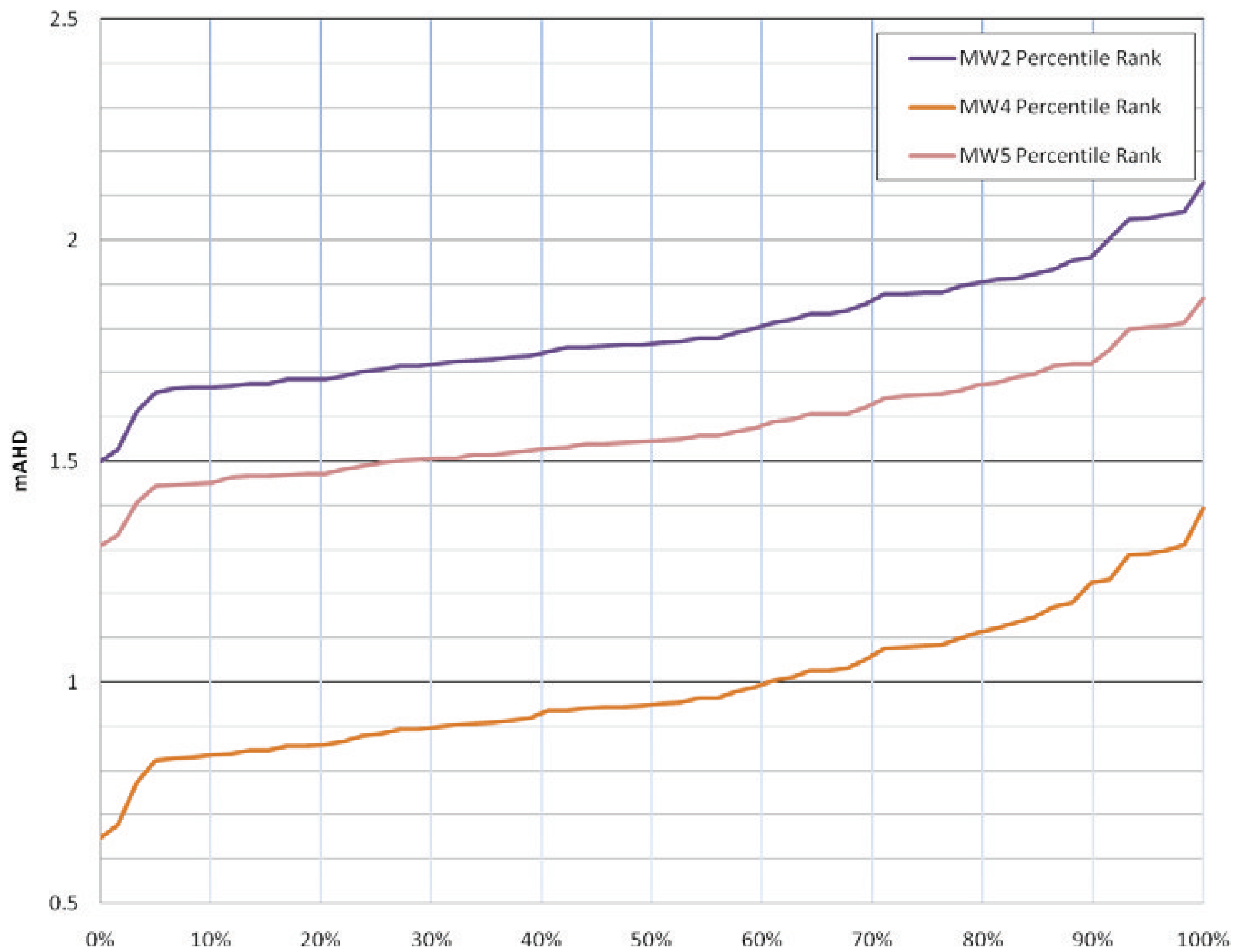
Martens & Associates Pty Ltd ABN 85 070 240 890		Environment | Water | Wastewater | Geotechnical | Civil | Management	
Drawn:	NF	**NORMALISED GROUNDWATER LEVEL OBSERVATIONS: MW2, MW4, and MW5 (% DEVIATION FROM MEAN) PERIOD: 28.03.09 – 05.05.09**	Drawing No: **FIGURE 3**
Approved:	DMM		
Date:	02.02.2010		
Scale:	N/A		Job No: P0902346



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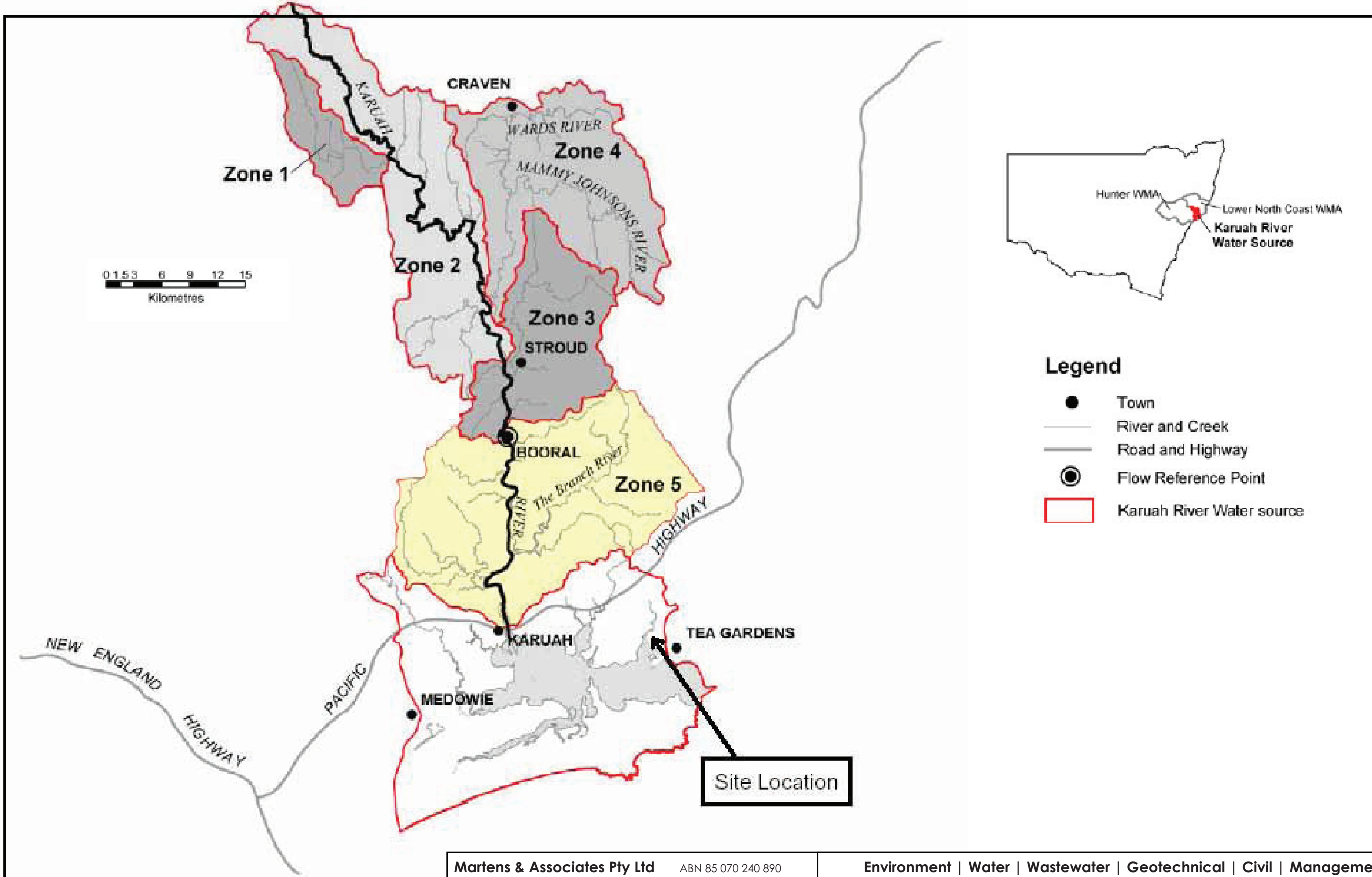
Martens & Associates Pty Ltd ABN 85 070 240 890		Environment | Water | Wastewater | Geotechnical | Civil | Management	
Drawn:	NF	CUMULATIVE FREQUENCY CURVE FOR POST-DEVELOPMENT (M4) MODELLED GROUNDWATER ELEVATIONS FOR MW2, MW4, AND MW5 (PERIOD 1950 – 2009)	Drawing No: FIGURE 4
Approved:	DMM		
Date:	02.02.2010		
Scale:	N/A		Job No: P0902346



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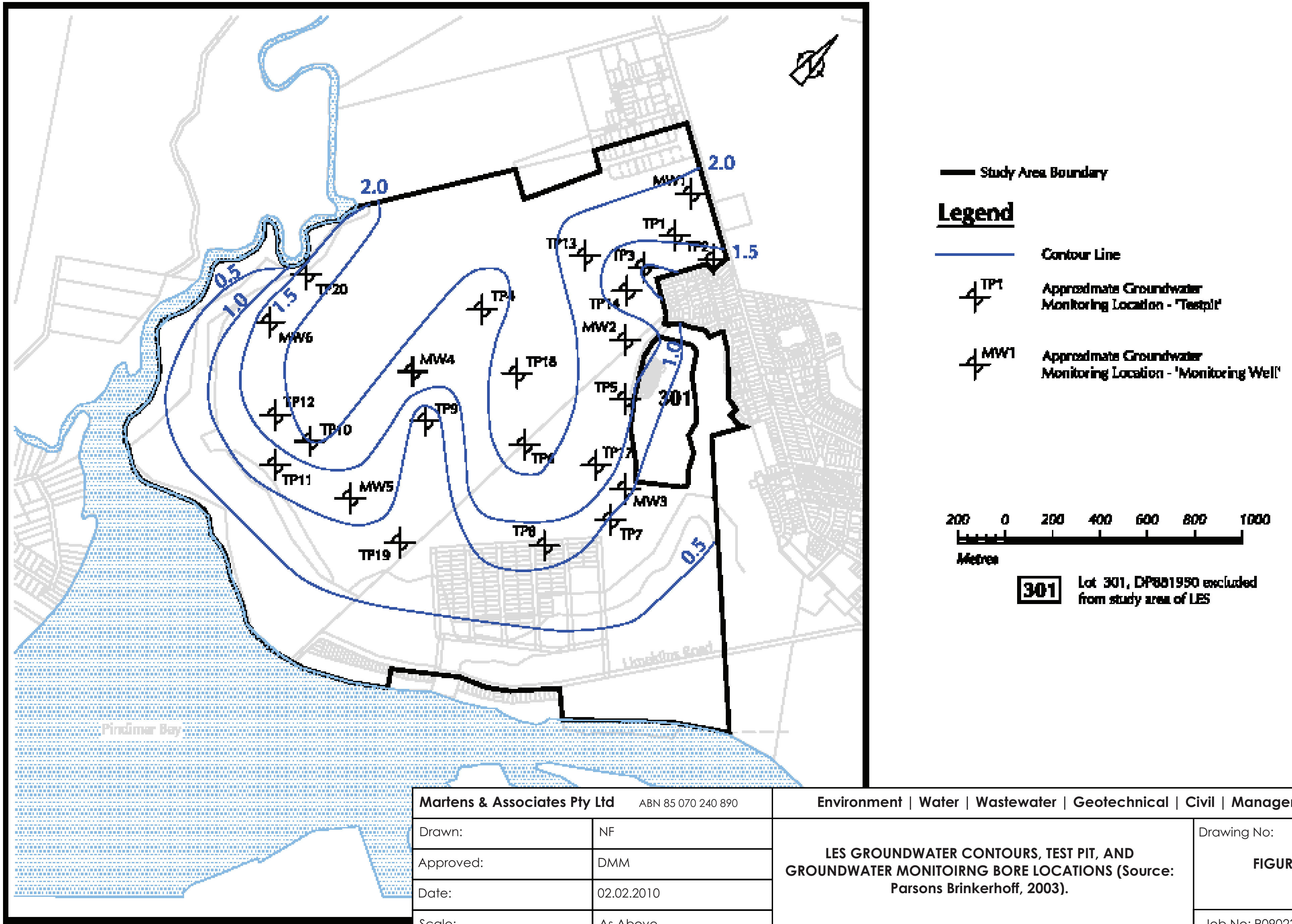
Martens & Associates Pty Ltd ABN 85 070 240 890		Environment | Water | Wastewater | Geotechnical | Civil | Management	
Drawn:	NF	KARUAH RIVER WATER SOURCE AND MYALL RIVER DOWNS LOCATION IN WATER SOURCE AREA	Drawing No: FIGURE 5
Approved:	DMM		
Date:	02.02.2010		
Scale:			Job No: P0902346



Martens & Associates Pty Ltd ABN 85 070 240 890		Environment | Water | Wastewater | Geotechnical | Civil | Management	
Drawn:	NF	LES GROUNDWATER CONTOURS, TEST PIT, AND GROUNDWATER MONITOIRNG BORE LOCATIONS (Source: Parsons Brinkerhoff, 2003).	Drawing No: FIGURE 6
Approved:	DMM		
Date:	02.02.2010		
Scale:	As Above		Job No: P0902346

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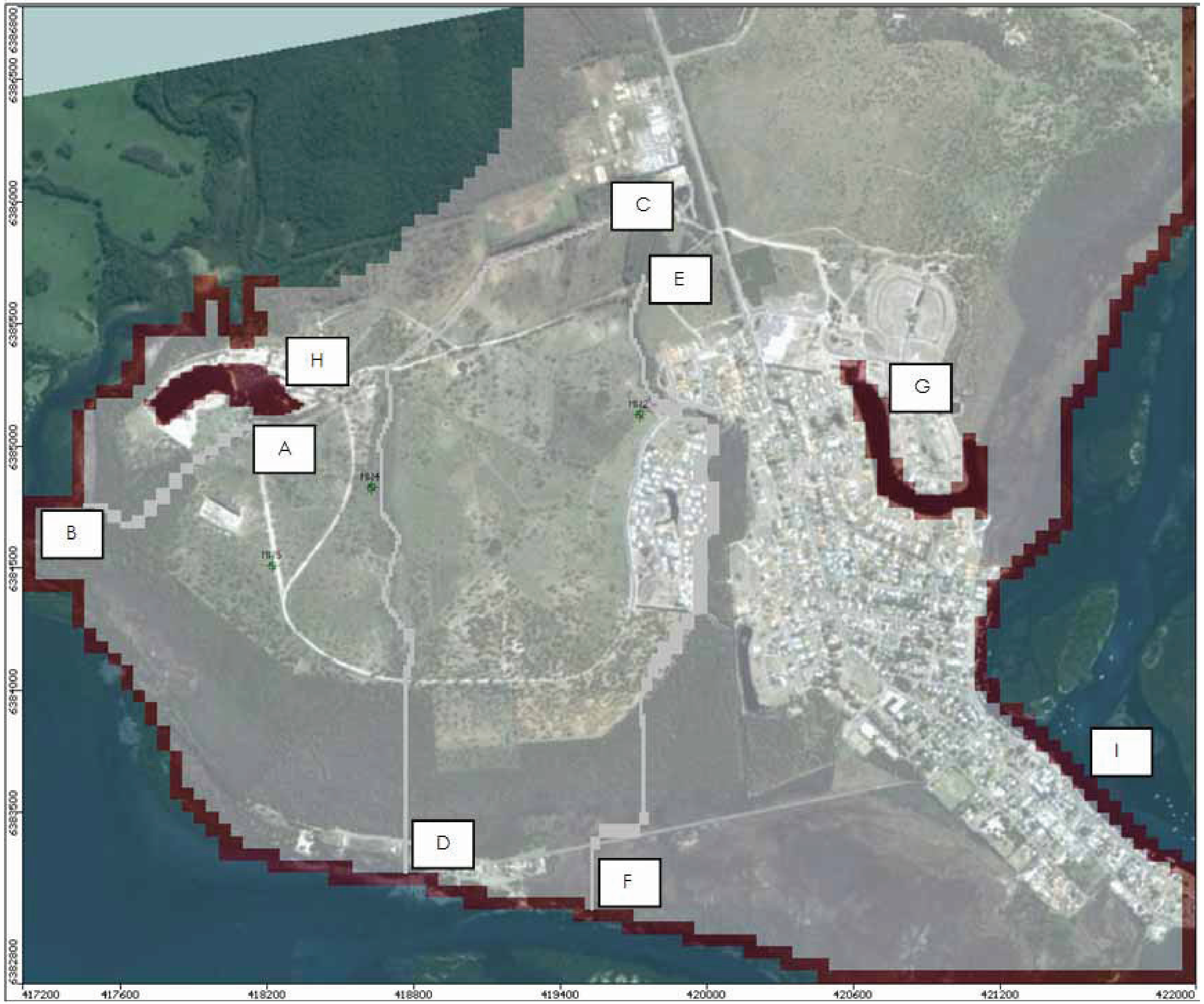

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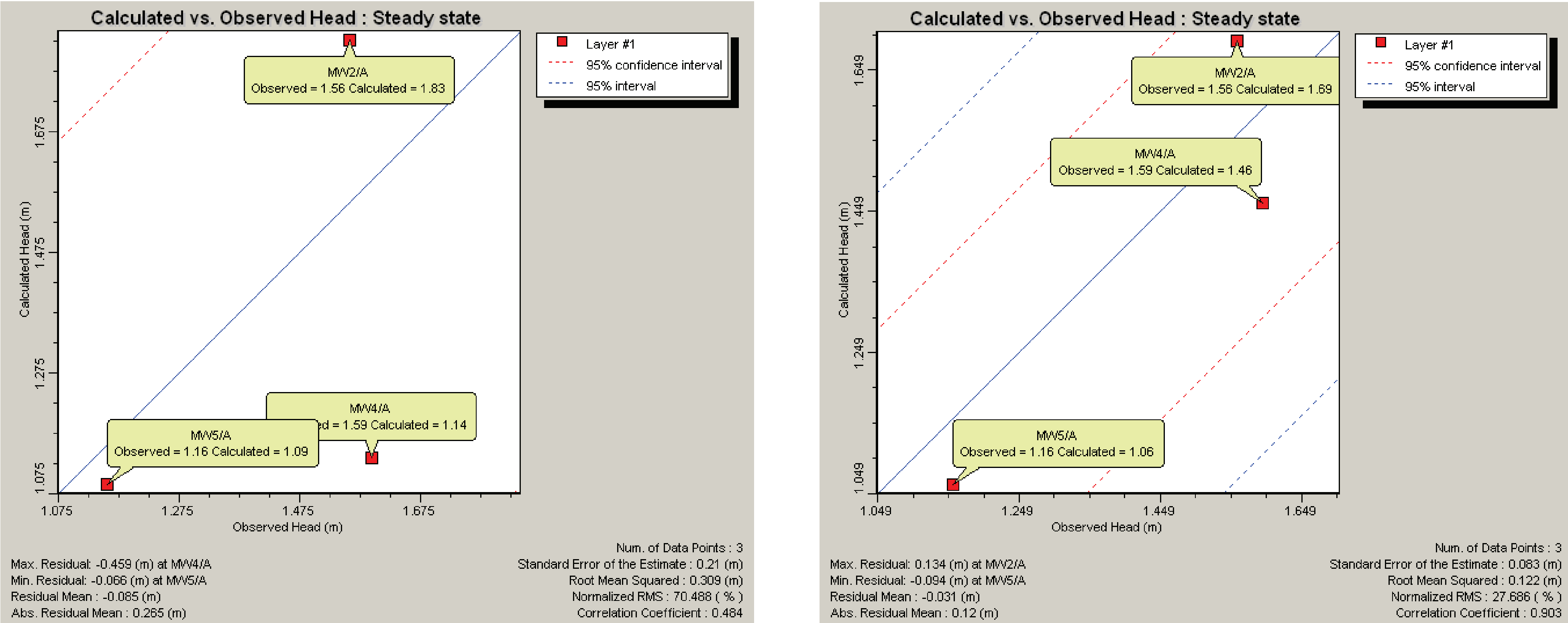
Martens & Associates Pty Ltd ABN 85 070 240 890		Environment | Water | Wastewater | Geotechnical | Civil | Management	
Drawn:	BR	MODFLOW MODEL (M1) – MODEL DOMAIN AND BOUNDARY CONDITIONS.	Drawing No: FIGURE 7
Approved:	DMM		
Date:	18.06.2010		
Scale:	REFER X,Y COORDINATES		Job No: P0902346

Key:
Red – Constant head boundary
Silver – Drain boundary
Aqua – Inactive flow



(a) M1 preliminary calibration with homogeneous K = 5 m/d.

(b) M1 final calibration with heterogeneous K zones.

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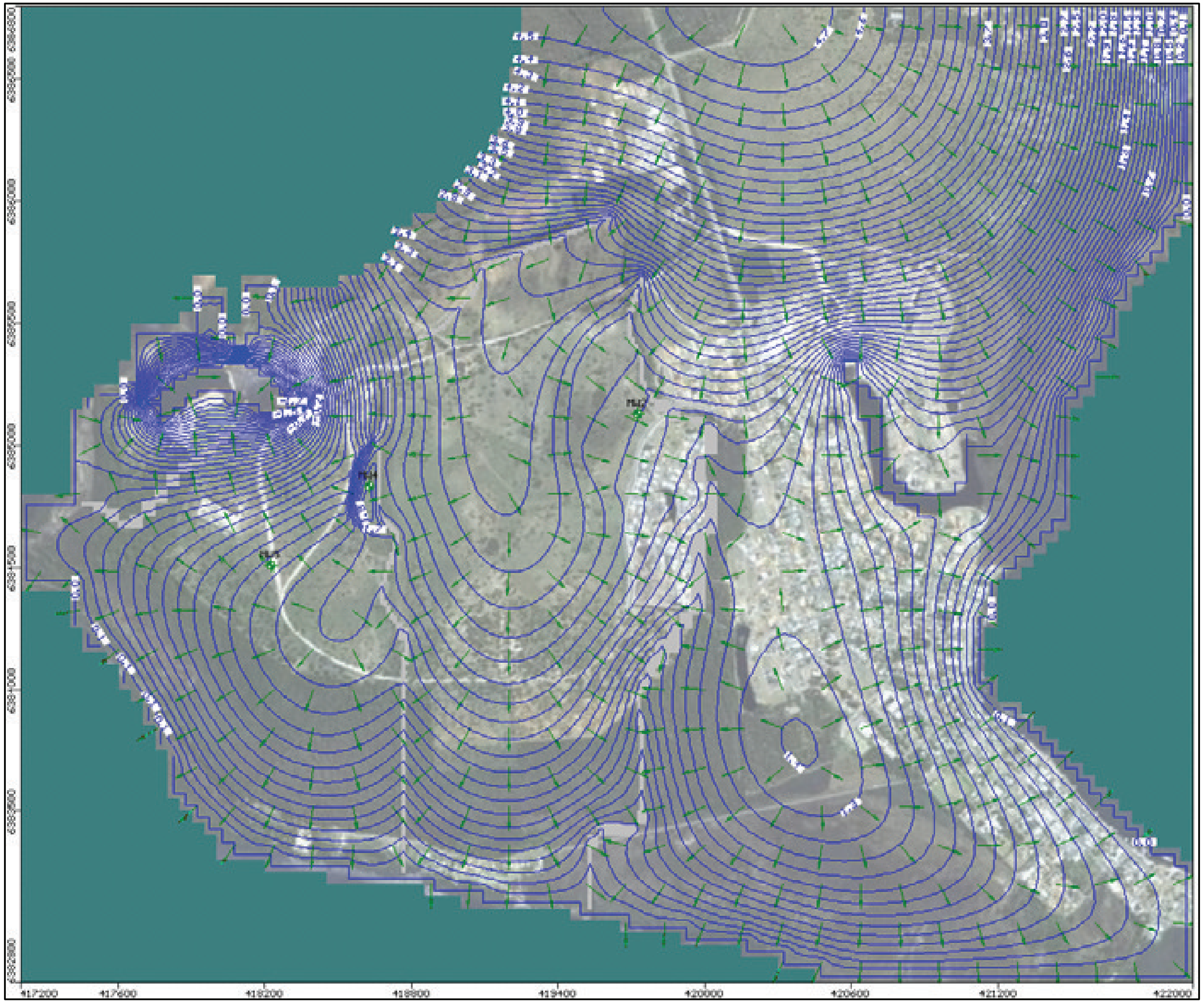
Martens & Associates Pty Ltd ABN 85 070 240 890		**Environment | Water | Wastewater | Geotechnical | Civil | Management**	
Drawn:	BR	**STEADY STATE CALIBRATION (MODEL M1) CALCULATED HEADS VERSUS OBSERVED HEADS**	Drawing No: **FIGURE 8**
Approved:	DM		
Date:	18.06.2010		
Scale:	NA		Job No: P0902346



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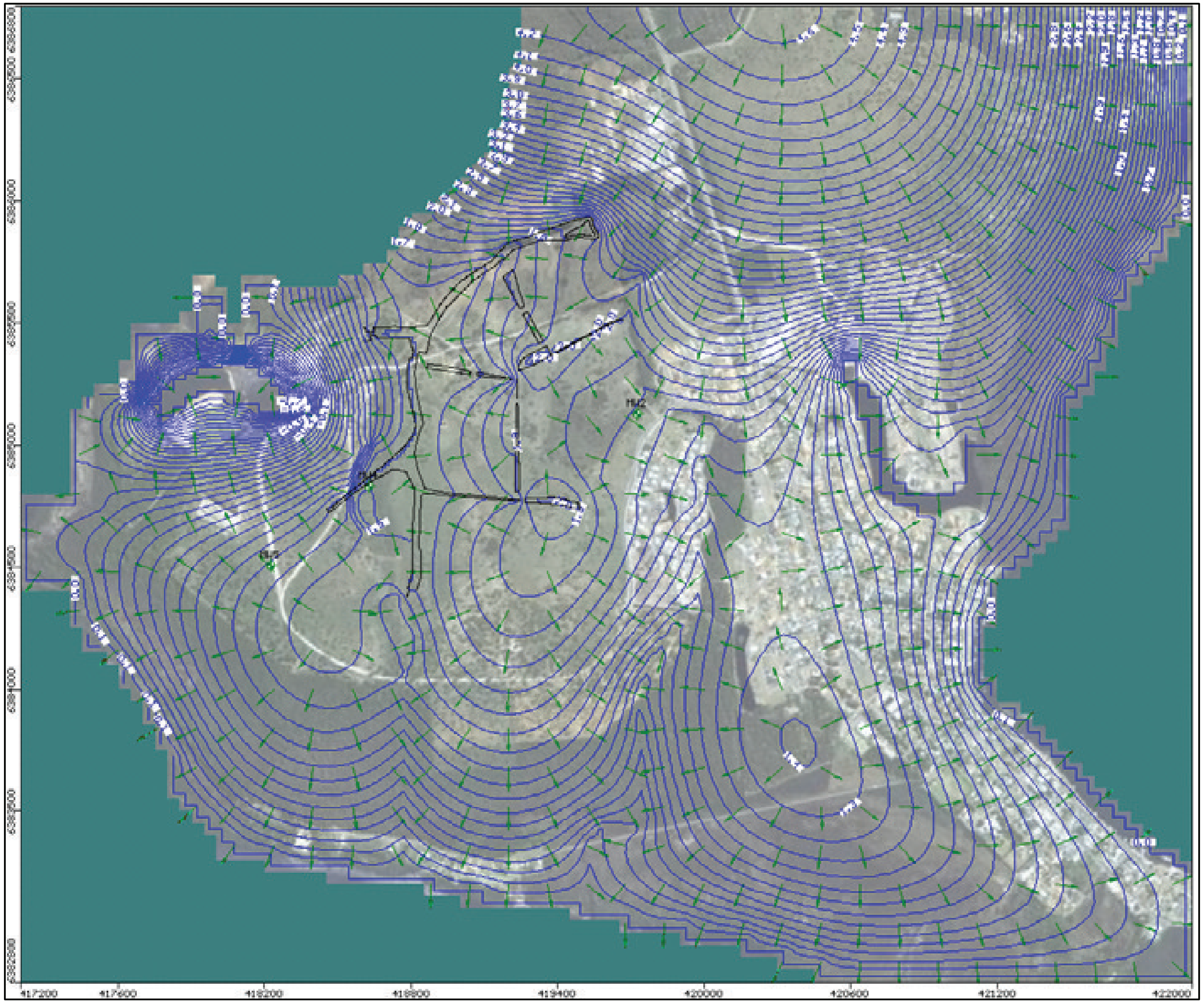
Key
Blue lines - Head equipotential (0.1 m contour interval)
Green Flow direction

Martens & Associates Pty Ltd ABN 85 070 240 890		**Environment | Water | Wastewater | Geotechnical | Civil | Management**		
Drawn:	BR	**MODFLOW MODEL M1- EXISITNG CONDITIONS: STEADY STATE PIEZOMETRIC SURFACE**	Drawing No: **FIGURE 9**	
Approved:	DMM			
Date:	29.06.2010			
Scale:	REFER X,Y COORDINATES		Job No: P0902346	

N



Key

Blue — Head equipotential (0.1 m contour interval)
Green — Flow direction
Black — Site drainage channels

Martens & Associates Pty Ltd ABN 85 070 240 890		**Environment | Water | Wastewater | Geotechnical | Civil | Management**	
Drawn:	BR	**MODFLOW MODEL M2 – DEVELOPED CONDITIONS: STEADY STATE PIEZOMETRIC SURFACE**	Drawing No: **FIGURE 10**
Approved:	DMM		
Date:	29.06.2010		
Scale:	REFER X,Y COORDINATES		Job No: P0902346

Key
Brown Drawdown contours
(0.1 m interval)

Martens & Associates Pty Ltd ABN 85 070 240 890		Environment | Water | Wastewater | Geotechnical | Civil | Management	
Drawn:	BR	**DRAWDOWN PLOT BETWEEN DEVELOPED (M2) AND EXISITNG (M1) CONDITIONS**	Drawing No: **FIGURE 11**
Approved:	DMM		
Date:	29.06.2010		
Scale:	REFER X,Y COORDINATES		Job No: P0902346

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Key

Blue	Head equipotential (0.1 m contour interval)
Green	Flow direction
Black	Site drainage channels

Martens & Associates Pty Ltd ABN 85 070 240 890		**Environment | Water | Wastewater | Geotechnical | Civil | Management**	
Drawn:	BR	**MODFLOW MODEL M3 - DEVELOPED CONDITIONS WITH 0.9 m SEA LEVEL RISE: STEADY STATE PIEZOMETRIC SURFACE**	Drawing No: **FIGURE 12**
Approved:	DMM		
Date:	29.06.2010		
Scale:	REFER X,Y COORDINATES		Job No: P0902346

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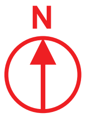
Key

Brown lines	Drawdown contours (0.1 m interval)
Shading	0.9 mAHD constant head zone

Note:
Surface levels over existing development in the south east portion of the model domain which have been conservatively assigned the 0.9 mAHD constant head boundary should be confirmed with further survey.

Martens & Associates Pty Ltd ABN 85 070 240 890		**Environment | Water | Wastewater | Geotechnical | Civil | Management**		
Drawn:	BR	**DRAWDOWN PLOT BETWEEN DEVELOPED (M2) AND DEVELOPED WITH SEA LEVEL RISE (M3) CONDITIONS**		Drawing No: **FIGURE 13**
Approved:	DMM			
Date:	29.06.2010			
Scale:	REFER X,Y COORDINATES			Job No: P0902346



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Martens & Associates Pty Ltd ABN 85 070 240 890		Environment | Water | Wastewater | Geotechnical | Civil | Management	
Drawn:	BR	**GROUNDWATER WATER ZONES DELINEATED FOR WATER ZONE BUDGETING**	Drawing No: **FIGURE 14**
Approved:	DMM		
Date:	18.06.2010		
Scale:	REFER X,Y COORDINATES		Job No: P0902346

Martens & Associates Pty Ltd ABN 85 070 240 890		Environment | Water | Wastewater | Geotechnical | Civil | Management	
Drawn:	NF	LOCATION OF WETLANDS, INFILTRATION BASINS, AND VEGETATED SWALES - SURFACE WATER MANAGEMENT STRATEGY FOR THE MRD SITE (Source PBP, 2006)	Drawing No: FIGURE 15
Approved:	DMM		
Date:	02.02.2010		
Scale:	NA		Job No: P0902346

6 Attachment B – Supplementary Slug Test Data

Single Bore Slug Test (Rising or Falling)

Method ST-13 Revised 7.3.2007

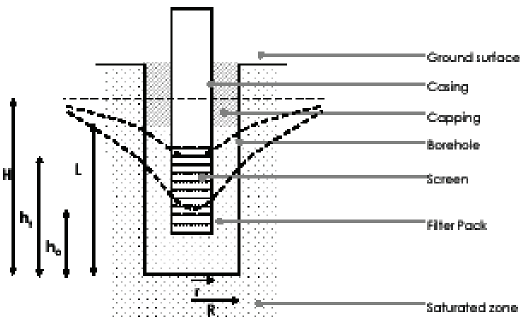
Notes: 1. water level values = direct pressure reading from logger/100 and are relative levels which do not relate to any datum. 2. Screen interval assumed as no bore construction data was available

PROJECT DETAILS

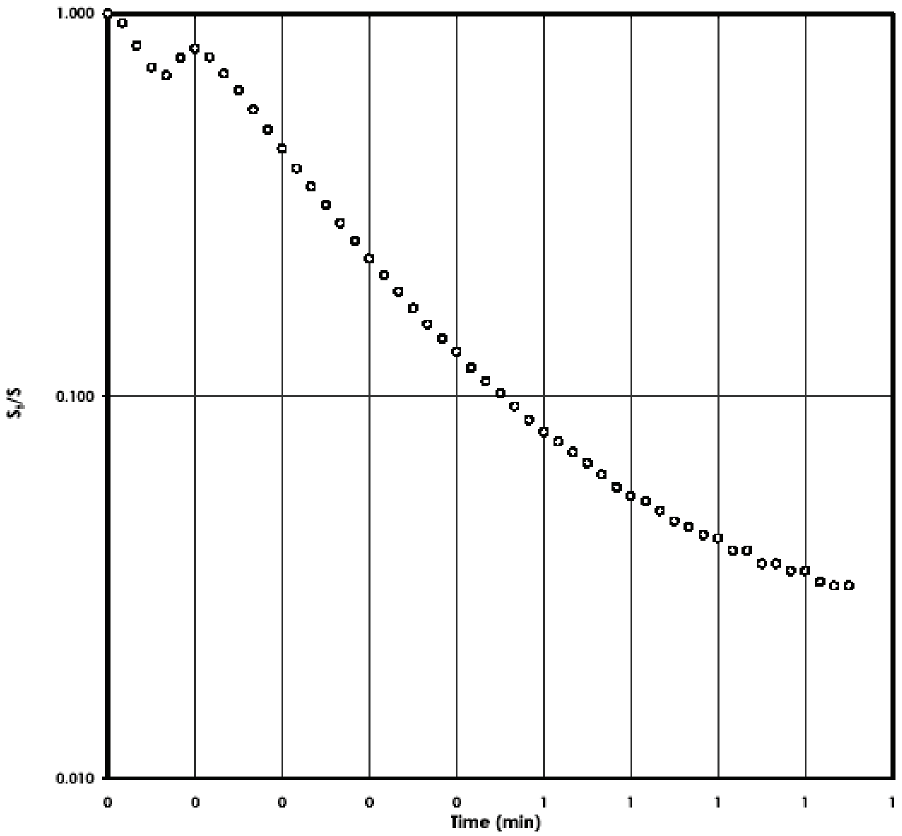
Project	Myall River Downs Groundwater Investigation	Test Date	27.03.2009
Project Ref	P0902346JS04_V1	Field Testing	B. Rose
Borehole Ref	MW2	Data Analysis	B. Rose
Method	Hvorslev (1981)	Reviewed	D. Martens

FIELD TEST DATA

FACTOR	Enter Data	Unit
H - Initial water level reading (depth)	11.5	m
h_o - Water level reading at time = 0 (depth)	12.8	m
r - Casing radius	0.025	m
R - Bore radius	0.025	m
L - Length of open screen	0.50	m
T_o - Length of characteristic time	0.21	minutes
K_{sat} - Saturated hydraulic conductivity	12.754	m/d



DATA PLOT



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Single Bore Slug Test (Rising or Falling)

Method ST-13 Revised 7.3.2007

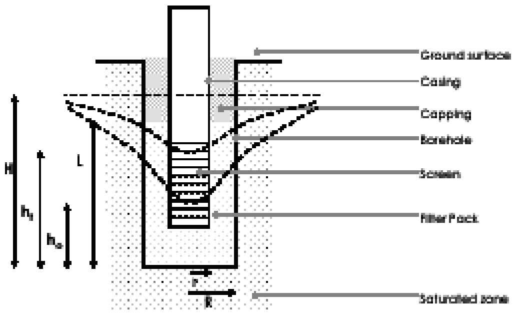
Notes: 1. water level values = direct pressure reading from logger/100 and are relative levels which do not relate to any datum. 2. Screen interval assumed as no bore construction data was available

PROJECT DETAILS

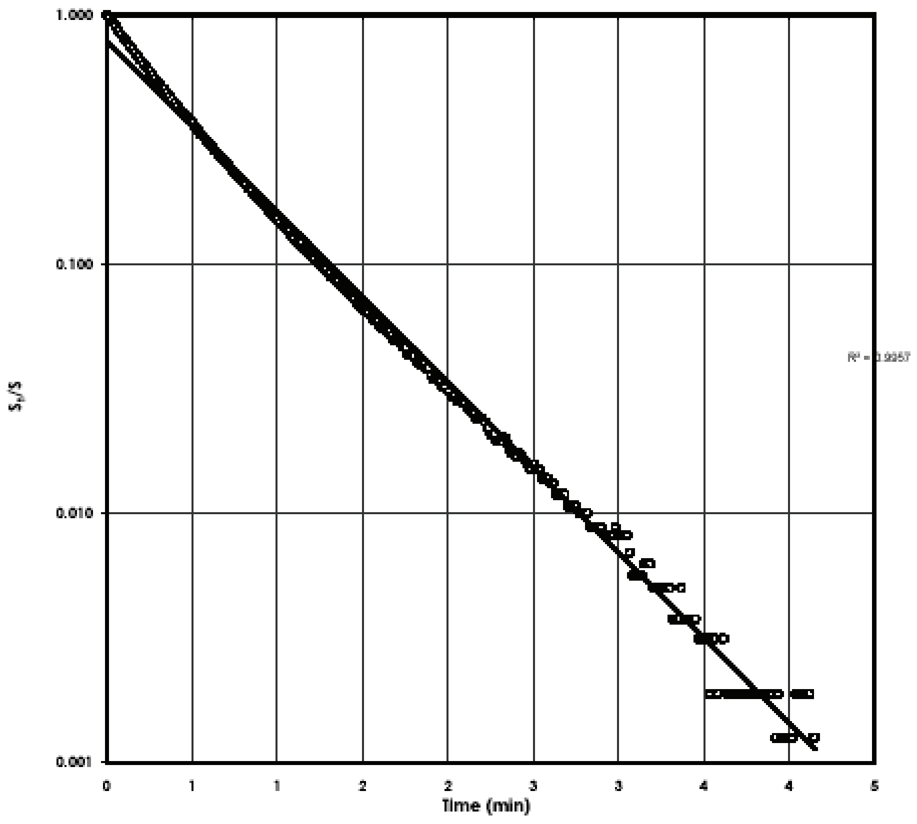
Project	Myall River Downs Groundwater Investigation	Test Date	27.03.2009
Project Ref	P0902346JS05_V1	Field Testing	B. Rose
Borehole Ref	MW4	Data Analysis	B. Rose
Method	Hvorslev (1981)	Reviewed	D. Martens

FIELD TEST DATA

FACTOR	Enter Data	Unit
H - Initial water level reading (depth)	11.587	m
h_o - Water level reading at time = 0 (depth)	13.173	m
r - Casing radius	0.025	m
R - Bore radius	0.050	m
L - Length of open screen	0.50	m
T_o - Length of characteristic time	0.47	minutes
K_{sat} - Saturated hydraulic conductivity	4.364	m/d



DATA PLOT



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Single Bore Slug Test (Rising or Falling)

Method ST-13 Revised 7.3.2007

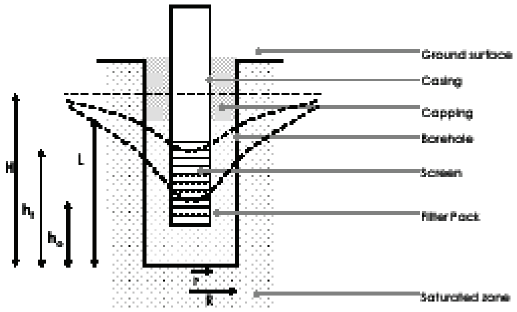
Notes: 1. water level values = direct pressure reading from logger/100 and are relative levels which do not relate to any datum. 2. Screen interval assumed as no bore construction data was available

PROJECT DETAILS

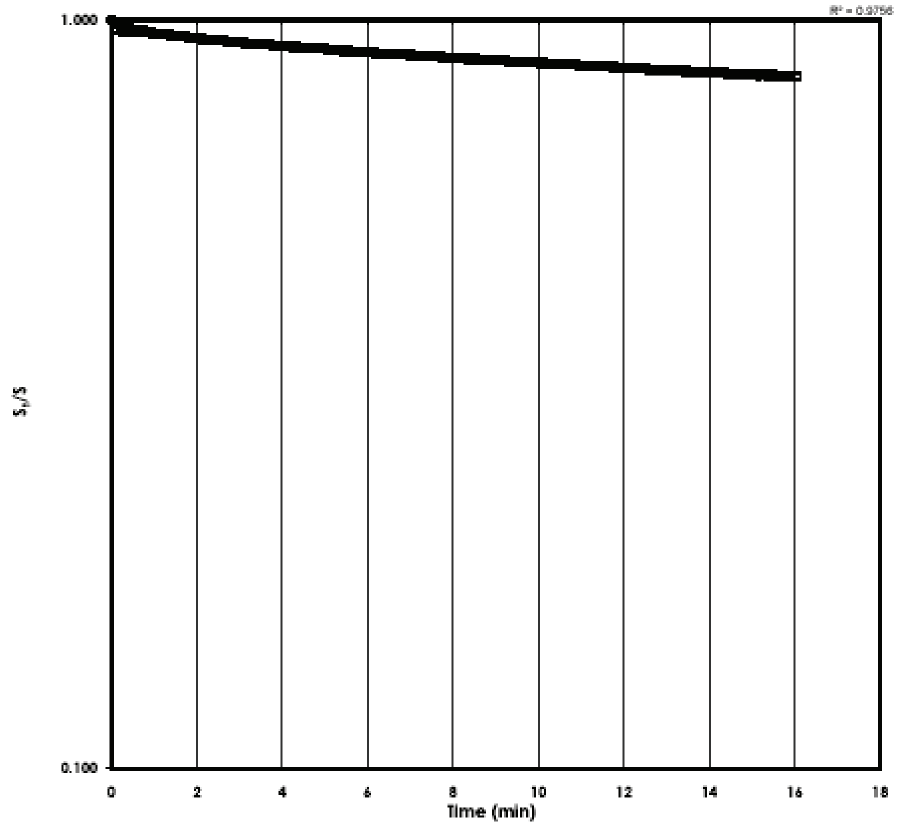
Project	Myall River Downs Groundwater Investigation
Project Ref	P0902346JS06_V1
Borehole Ref	MW5
Method	Hvorslev (1981)
Test Date	27.03.2009
Field Testing	B. Rose
Data Analysis	B. Rose
Reviewed	D. Martens

FIELD TEST DATA

FACTOR	Enter Data	Unit
H - Initial water level reading (depth)	11.474	m
h_o - Water level reading at time = 0 (depth)	13.370	m
r - Casing radius	0.025	m
R - Bore radius	0.050	m
L - Length of open screen	0.50	m
T_o - Length of characteristic time	106.18	minutes
K_{sat} - Saturated hydraulic conductivity	0.020	m/d



DATA PLOT



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Appendix 6 - Martens Consulting Engineers, Supplementary Groundwater Assessment Comments (April 2011)

Worley Parsons

martens consulting engineers

Supplementary Groundwater Assessment Comments, Myall River Downs, Tea Gardens, NSW

ENVIRONMENTAL

WATER

WASTEWATER

GEOTECHNICAL

CIVIL

PROJECT MANAGEMENT

P0902346JR04V01
April 2011

Limitations Statement

The sole purpose of this report and the associated services performed by Martens & Associates Pty Ltd is to provide supplementary groundwater assessment comments in accordance with the scope of services set out in the contract / quotation between Martens & Associates Pty Ltd and Worley Parsons (hereafter known as the Client). That scope of works and services were defined by the requests of the Client, by the time and budgetary constraints imposed by the Client, and by the availability of access to the site.

Martens & Associates Pty Ltd derived the data in this report primarily from a number of sources which may include for example site inspections, correspondence regarding the proposal, examination of records in the public domain, interviews with individuals with information about the site or the project, and field explorations conducted on the dates indicated. The passage of time, manifestation of latent conditions or impacts of future events may require further examination / exploration of the site and subsequent data analyses, together with a re-evaluation of the findings, observations and conclusions expressed in this report.

In preparing this report, Martens & Associates Pty Ltd may have relied upon and presumed accurate certain information (or absence thereof) relative to the site. Except as otherwise stated in the report, Martens & Associates Pty Ltd has not attempted to verify the accuracy of completeness of any such information (including for example survey data supplied by others).

The findings, observations and conclusions expressed by Martens & Associates Pty Ltd in this report are not, and should not be considered an opinion concerning the completeness and accuracy of information supplied by others. No warranty or guarantee, whether express or implied, is made with respect to the data reported or to the findings, observations and conclusions expressed in this report. Further, such data, findings and conclusions are based solely upon site conditions, information and drawings supplied by the Client *etc*. in existence at the time of the investigation.

This report has been prepared on behalf of and for the exclusive use of the Client, and is subject to and issued in connection with the provisions of the agreement between Martens & Associates Pty Ltd and the Client. Martens & Associates Pty Ltd accepts no liability or responsibility whatsoever for or in respect of any use of or reliance upon this report by any third party.

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Document and Distribution Status									
Author(s)			**Reviewer(s)**		**Project Manager**		**Signature**		
Mr Ben Rose Dr Daniel Martens			Dr Daniel Martens		Dr Daniel Martens		[signature]		
Revision No.	**Status**	**Release Date**	**Document Location**						
			File Copy	MA Library	Crighton Properties	Worley Parsons	Void	Void	
1	Draft	05.04.2011	1P, 1H	-	1P	1P			
1	Final	06.04.2011	1P, 1H, 1E	-	1P	1P			

Distribution Types: F = Fax, H = hard copy, P = PDF document, E = Other electronic format. Digits indicate number of document copies.

All enquiries regarding this project are to be directed to the Project Manager.

Contents

1 Introduction

1.1 Background

Martens and Associates Pty Ltd have previously prepared a preliminary groundwater investigation and documented a Concept Groundwater Management Plan (CGMP) for land known as the Myall River Downs (MRD) site at Tea Gardens, NSW. The report was prepared as part of a general information package to support rezoning of the site. Findings are documented in Martens & Associates Pty Ltd report no. P0902346JR02V03 dated August, 2010.

Further to the report being prepared, the groundwater and stormwater (prepared by Worley Parsons) investigations were reviewed by Council's consultant WBM. A primary question that came out of the review process was that there remained some doubt as to the level of stormwater discharge from the developed site and how this compared to existing conditions. This supplementary report provides further quantification of this issue.

1.2 Scope

We note that the previous groundwater investigations and modelling were preliminary in nature and not specifically tailored to provide a more detailed estimate of surface water discharge from the developed site (ie. the central stormwater drainage system).

The following scope of supplementary works have been undertaken in order to quantify stormwater discharge conditions from the developed site.

1. Extend the MODFLOW groundwater models developed previously as part of the initial investigations so that a more realistic representation of distributed aerial recharge, evapotranspiration (ET) and water balances were included.

2. Re-run the extended MODFLOW groundwater model for 'developed conditions' (model M2) to determine stormwater discharge rates from the principal drain which discharges at the sites southern boundary within the proposed revegetation area.

2 Method

2.1 Modifications Made to Model M1 (Existing Conditions)

MODFLOW model M1 for existing conditions was modified (model M1a) in the following way:

1. Previously, for the site the adopted aerially uniform recharge rate of 125 mm/year provided a good fit between observed and predicted bore levels. However, this did not account for recharge variations between different vegetation and land-use types.

   To refine this, model M1 was modified to include four distinct recharge zones which are summarised in Table 1 and shown in Figure 1. Given high evapotranspiration potential of the wetlands, 0 mm/year recharge was considered appropriate and realistic.

2. Following inclusion of the spatially variable recharge rates, the adopted aquifer permeability coefficients (K) for the study area required minor adjustments in order that a good fit between observed and predicted bore levels was retained. Bulk aquifer permeability was increased to 7 m/day and the lower permeability K zone around bore no. MW4 was increased to 4 m/d. Both of these remain within the site testing ranges.

3. Calibration charts for the original M1 and updated M1a models are provided in Figure 2 which indicates that the updated M1a model improves the original calibration.

Table 1: Adopted recharge rates for individual recharge zones.

Zone	Adopted Recharge (mm/yr)	Comment
Wetland Zone	0	ET and recharge assumed to balance.
Undeveloped Zone	175	Arrived at through model iteration.
Developed Zone	87.5	Assumed to be 50% of undeveloped zone.
Industrial Zone	52.5	Assumed to be 30% of undeveloped zone.

2.2 Modifications Made to Model M2 (Developed Conditions)

MODFLOW model M2 for developed conditions was modified (model M2a) in the following way:

1. Permeability coefficient (K) and recharge zones derived for model M1a were applied to model M2a.

2. A net aerial water balance assessment was conducted for the development area in order to determine runoff volumes to the treatment wetlands and bioretention basins. Methodology adopted included the following:

    a. Net aerial crop factors were determined based on proposed land-uses. These are summarised, together with individual aerial coverages in Table 2. This yielded a net aerial crop factor of 0.42 for the development area. This is 0.24 lower than the net aerial crop factor of 0.66 estimated for existing site conditions and provides an estimate of the net change in site water balance (due to loss of potential ET).

    b. Net aerial ET losses for the development area were determined by multiplication of the net aerial crop factor of 0.42 by Class A Pan Evaporation of 1720 mm/year. This yielded a net ET loss of 722.6 mm/year for the development area.

    c. Net aerial recharge within the development footprint was taken as 50 % of the calibrated 175 mm/year determined for undeveloped areas in model M1a.

    d. A net water surplus of 515.9 mm/year was estimated for the site. However, given that there is ample opportunity for water to reinfiltrate into the sandy groundwater system prior to being discharged in the wetlands, 40 % of this surplus water was assumed to recharge groundwater en-route to the wetlands. This resulted in an estimate of net recharge over the developed area of 293.9 mm/year.

    e. Net surface water discharge to the wetlands was estimated by deducting ET and recharge losses from incident rainfall, yielding a net aerial surface runoff depth of 309.5 mm/year to the wetlands.

3. Recharge depths to each of the individual linear wetlands was determined as follows:

    a. Net aerial runoff (determined above) was converted to a volumetric basis by multiplying through with the total development area of 177.91 ha. This resulted in a net volume of 551 ML/year.

b. The net runoff volume was reduced to account for ET losses at the proposed bio-infiltration systems. 45 ML/year losses were estimated from the site based on preliminary bio-infiltration systems design widths of 2 m adjacent all wetland boundaries and crop factors 1.2. A total bio-filtration area of 2.16 ha yielded an annual ET loss of 45 ML/year. Net water available for recharge within wetlands was therefore 506 ML/year.

c. Total runoff volume was apportioned to each wetland system on the basis of proportional contributing catchment areas (which were supplied by Worley Parsons).

d. Recharge depths at each wetland were determined by dividing the contributing annual flow volumes by the receiving area.

4. In addition to the above, water runoff from the industrial area at the sites north east was added to the total sites water budget. Contributions from the industrial area runoff were accommodated within the groundwater models as follows:

   a. A net aerial water balance assessment was conducted for the industrial area in order to determine runoff volumes to treatment wetlands near to the industrial area.

   b. Adopted crop factors are summarised in Table 3.

   c. The same methodology as outlined above (for the development site) was used to estimate a total site runoff volume of 191.7 ML/yr. We note that this estimate was derived on the basis that no stormwater was assumed to recharge en-route.

   d. This additional volume was added to recharge at wetlands near to the industrial area.

Table 2: Crop coverage and net crop factor analysis summary for development area.

Crop	Adopted Crop Factor	Adopted Crop Coverage (%)
Grass	0.6	50
Trees	1.2	10
Hardstand	0.0	40
Net Aerial Crop Factor		0.42 [1]

Notes: [1]. Coverage estimated based on a proposed site landscaping plan.

Table 3: Crop coverage and net crop factor analysis summary for industrial areas.

Crop	Adopted Crop Factor	Adopted Crop Coverage (%)
Grass	0.6	20
Trees	1.2	10
Hardstand	0.0	70
Net Aerial Crop Factor		0.24 [1]

Notes: [1] Coverage estimated based on aerial photograph.

3 Results and Conclusions

3.1 Existing Conditions (model M1a)

Groundwater head for existing groundwater conditions (model M1a) is provided in Figure 3. This is very similar to that provided in our original report although levels within the fringing wetland areas are slightly depressed due to reduced assumed recharge rates within the wetlands.Developed Conditions (model M2a)

3.2 Developed Conditions (model M2a)

3.2.1 Groundwater Head

Modelled groundwater head for developed conditions (model M2a) is provided in Figure 4. This demonstrates that groundwater flow directions remain broadly unchanged from those modelled for existing conditions.

3.2.2 Changes to Groundwater Level

Figure 5 provides a groundwater 'drawdown' plot for differences between existing and developed groundwater conditions (ie. model M1a – model M2a). This shows that the internal drainage system results in some localised groundwater lowering within the development footprint. However, results indicate that there will be no significant drawdown (ie. groundwater level change) at the sites boundary or within the fringing SEPP 14 wetland areas.

3.2.3 Drain Flow

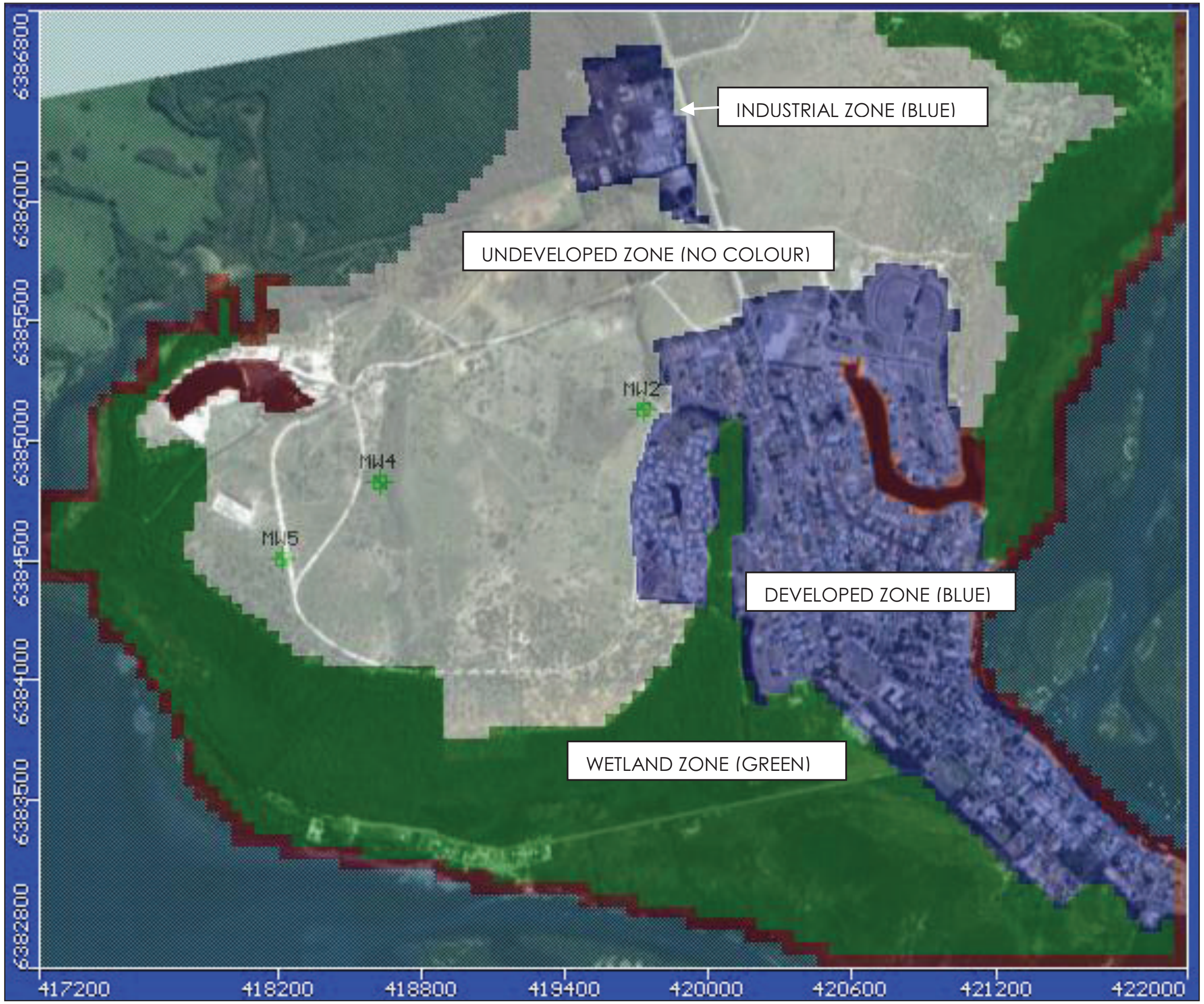
The sites discharge location is the drain which releases excess surface flows and re-surfaced groundwater at the sites southern boundary (marked on Figure 4). Discharge at this location was determined to be 1,079 ML/yr under developed conditions.

We note that land to the east and west of the discharge location is to be allowed to regenerate. This will increase aerial ET in these areas and assist with excess water uptake.

3.3 Conclusions

The supplementary modelling presented in this report has determined that mean annual stormwater discharge from the site is in the order of 1,079 ML/year. The supplementary modelling does not alter the conclusions provided in our original assessment.

4 Attachment A – Figures



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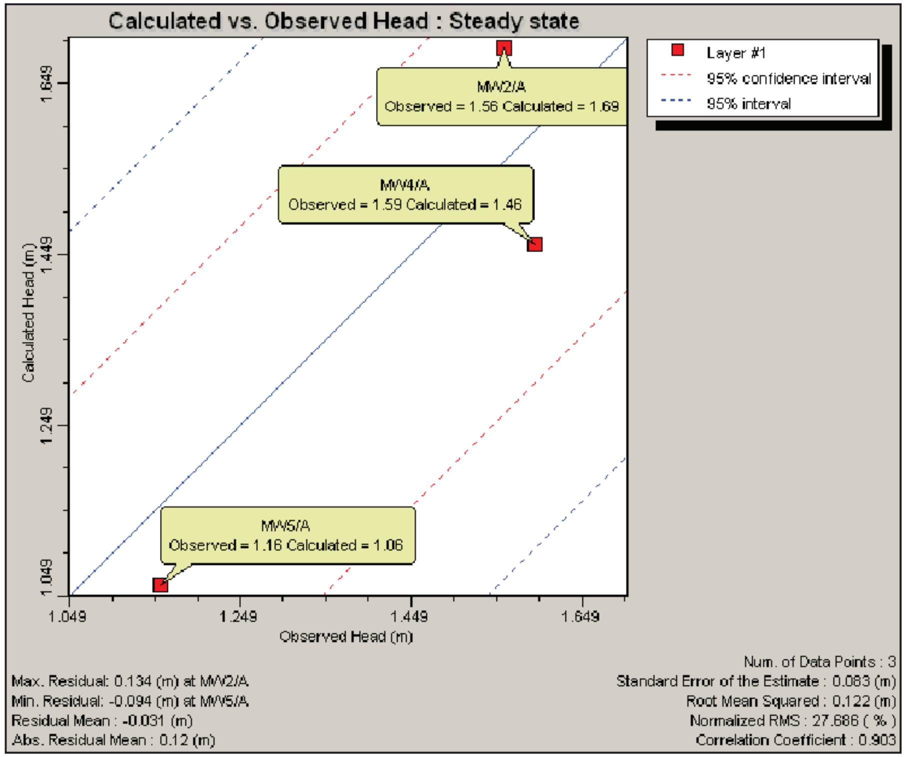
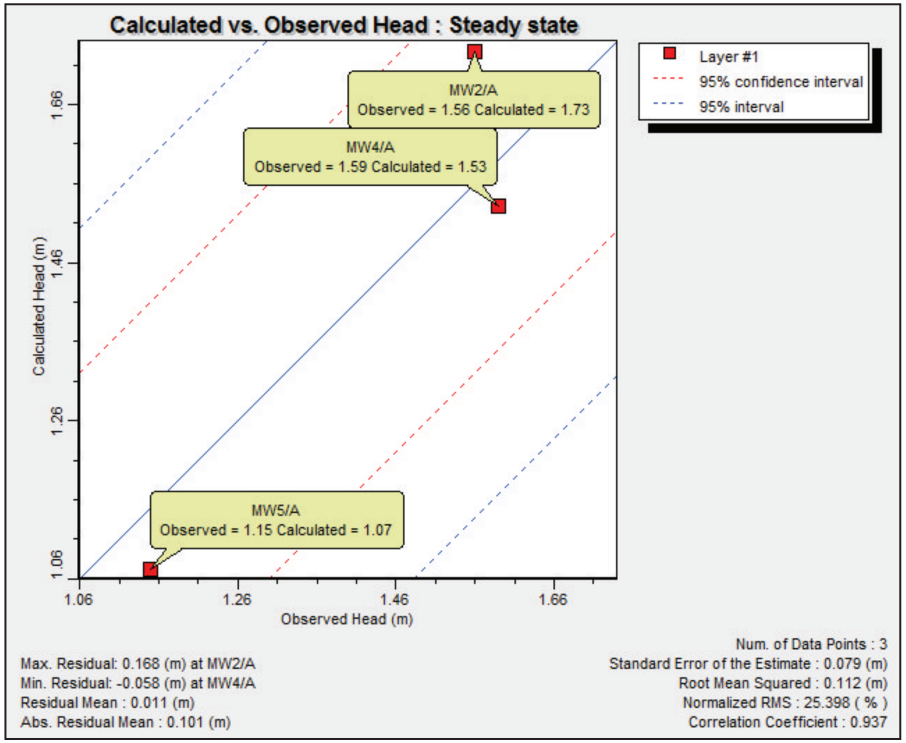
Martens & Associates Pty Ltd ABN 85 070 240 890		Environment | Water | Wastewater | Geotechnical | Civil | Management	
Drawn:	BR	**AMENDED RECHARGE ZONES FOR GROUNDWATER MODEL M1a**	Drawing No: **FIGURE 1**
Approved:	DM		
Date:	18.03.2011		
Scale:	APPROX 1: 28,450		Job No: P0902346

martens

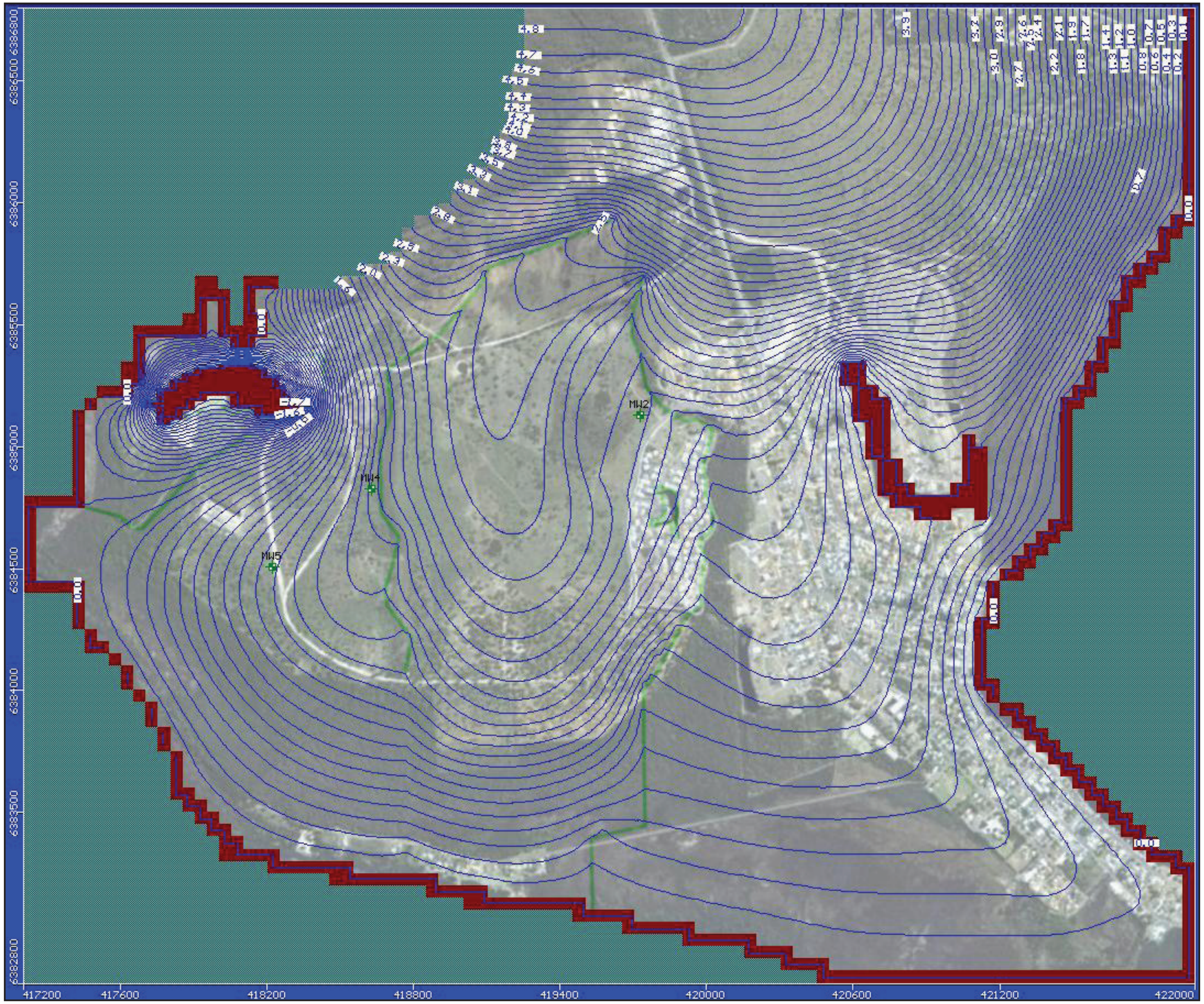


CALIBRATION DATA FOR ORIGINAL EXISTING CONDITIONS MODEL M1



CALIBRATION DATA FOR REVISED EXISTING CONDITIONS MODEL M1a

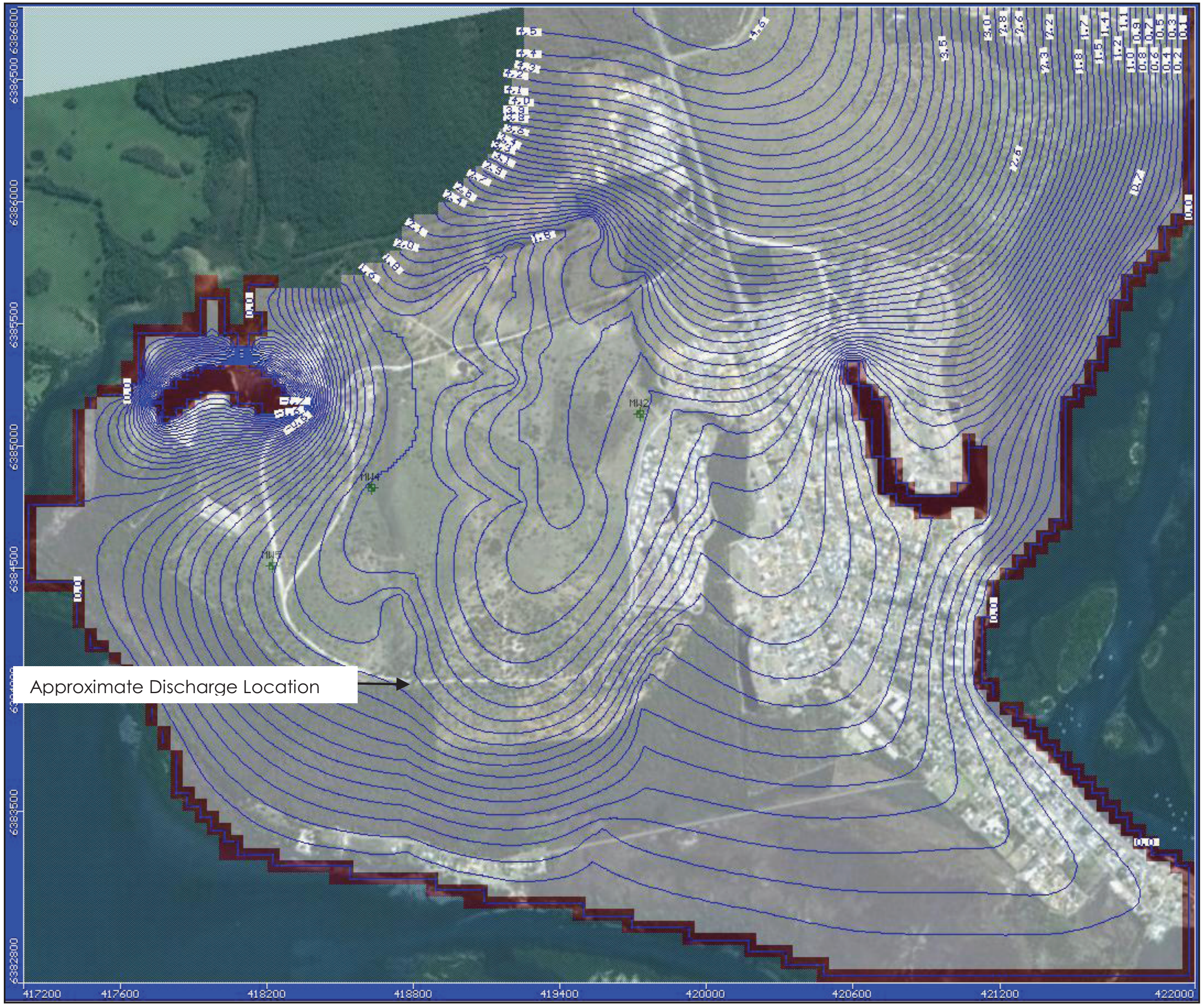
Martens & Associates Pty Ltd ABN 85 070 240 890		**Environment | Water | Wastewater | Geotechnical | Civil | Management**	
Drawn:	BR	**EXISTING CONDITION MODEL CALIBRATION CHARTS**	Drawing No: **FIGURE 2**
Approved:	DM		
Date:	18.03.2011		
Scale:	NA		Job No: P0902346



martens

Key:
Blue Lines – Groundwater Head Contour (0.1 m interval)

Martens & Associates Pty Ltd ABN 85 070 240 890		Environment | Water | Wastewater | Geotechnical | Civil | Management	
Drawn:	BR	M1a GROUNDWATER HEAD	Drawing No: FIGURE 3
Approved:	DM		
Date:	05.04.2011		
Scale:	APPROX 1: 26,060		Job No: P0902346



martens

Key:
Blue Lines – Groundwater Head Contour (0.1 m interval)

Martens & Associates Pty Ltd ABN 85 070 240 890		Environment | Water | Wastewater | Geotechnical | Civil | Management	
Drawn:	BR	M2a GROUNDWATER HEAD	Drawing No: FIGURE 4
Approved:	DM		
Date:	05.04.2011		
Scale:	APPROX 1: 26,060		Job No: P0902346

Key:

Brown Lines – Drawdown Contour (0.1 m)

Martens & Associates Pty Ltd ABN 85 070 240 890		Environment | Water | Wastewater | Geotechnical | Civil | Management	
Drawn:	BR	M2a DRAWDOWN TO M1a	Drawing No: FIGURE 5
Approved:	DM		
Date:	05.04.2011		
Scale:	APPROX 1: 26,060		Job No: P0902346

Appendix 7 - Martens Consulting Engineers, Response to WBM BMT Requests for Additional Groundwater Model Data (20th June 2011)

martens
consulting engineers since 1989

Posted		
Faxed		
Emailed	X	peter@crighton.com.au
Courier		
By Hand		
Contact:		Dr D. Martens
Our Ref:		P0902346JC09-V3
Pages:		6
cc.		-

20th June, 2011

Crighton Properties
Att: Peter Childs
PO Box 3369
Tuggerah, NSW 2259

Dear Peter,

RE: BMT WBM REQUESTS FOR ADDITIONAL GROUNDWATER MODEL DATA, MYALL RIVER DOWNS REZONING SITE, TEA GARDENS, NSW

OVERVIEW

This further advice has been prepared following various emails and discussions between Martens & Associates (MA) and BMT WBM subsequent to the provision of our previous supplementary groundwater advice (Report P0902346JR04V01 06.04.2011). Based on our most recent discussions with WBM BMT on 14th June, 2011, we have prepared summary water balance assessments in accordance with the parameters specified by BMT WBM's email dated 12th May, 2011.

METHODOLOGY

In preparing this advice, previously created existing condition (model M1a) and developed condition (model M2a) MODFLOW groundwater models were used to prepare pre- and post-development water balance summaries. In the case of each model, explicit water budget zones were created including:

1. Zone 1 - Site and general surrounds (source zone).

2. Zone 2 – Wetland (receiving zone).

3. Zone 3 – Quarry (receiving zone).

The following methodology was used to complete the water balance assessment:

1. Location of each water budget zone is provided in Figure 1. Zone boundaries have been marginally modified from those adopted in our advice dated 6th April, 2011, in order that the aggregate of zonation would be hydraulically continuous.

2. Populating each of the water balance elements included undertaking the following:

    a. Rainfall was the total mean annual rainfall that fell on Zone 1.

    b. Groundwater discharge to wetland zone was determined by re-running models M1a and M2a.

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c. Surface drain discharges to the wetland zone was determined by re-running models M1a and M2a. Importantly, these represent groundwater flows which are intercepted by the drains.

d. Surface water discharges to the wetland zone in the existing conditions model (model M1a) which are not delivered by the drains are not specifically modelled in MODFLOW (which does not model overland flow). In the case of the existing conditions, an estimate of 5 % incident rainfall was used to determine this flux rate based on discussions with WBM dated 14th June, 2011. In the case of the development site, all site flows are directed to the drains and are therefore already accounted for in the modelled drain outputs.

e. Groundwater discharge to quarry zone was determined by re-running models M1a and M2a.

f. Two methods were used to estimate evapotranspiration (ET) within Zone 1 (see below):

    i. Method 1 – by back-calculation (ie. A-(C+D+E+F) see Table 1) to generate a complete water balance based on modelling.

    ii. Method 2 (Table 2) – by mean areal crop-factor (CF) determination for Zone 1 with CF decreasing from 0.61 (existing conditions) to 0.59 (untreated developed conditions). This approach was used as a broad acre check to substantiate Method 1.

WATER BALANCE RESULTS

Water balance modelling results are provided in Table 1 and indicate:

1. Based on differences between M2a and M1a water balances there is likely to be an annual increase in surface water flows to the wetland zone in the order of approximately 529 ML/year which includes redirected surface water flows and intercepted groundwater flows.

2. The increase in flows comes about primarily due to the reduced potential evapotranspiration within the development area.

3. The redirection of some existing condition overland flows to the site drainage infrastructure will cause surface flows to be more concentrated following site development.

Table 1: Water balance summary data.

Scenario	Rainfall (A)	Actual ET (method 1 / method 2 (B)	Groundwater Discharge to Wetland (C)	Drain Discharge to Wetland (D)	Non-drain Surface Water Flows to Wetland (E)	Flows to Quarry (F)
M1a	6844	5512/5415	128	491	342	371
M2a	6844	4997/5238	118	1362	0	367

Table 2: Method 2 Crop Factor analysis summary.

Type	Area (m²)	Area Proportion of Total Area (%)	Grass% (CF = 0.6)	Trees% (CF = 1.2)	Hardstand% (CF = 0)	Net Areal CF
Existing Conditions						
Industrial	663,270	13	25	5	70	0.21
Forested	468,310	9	370	70	0	1.02
Remaining cleared land	4,029,747	78	95	5	0	0.63
Net Areal CF						**0.61**
Developed Conditions (untreated)						
Industrial	663,270	13	25	5	70	0.21
Forested	468,310	9	370	70	0	1.02
Site Wetlands	21,600	0.4	0	1.2	0	1.2
Site (less wetlands)	777,526	14.6	50	10	40	0.42
Remaining cleared land	3,230,621	63	95	5	0	0.63
Net Areal CF						**0.59**

ASSESSMENT OF CONCEPT REMEDIATION OPTION

In order to mitigate against any potential impacts associated with the concentration and increase in overland flows to the wetland zone, a linear swale or constructed wetland could be built downslope of the site's perimeter road which would receive inflows from the site's primary drains. This would dissipate stormwater flows south of the development area within the western stormwater dissipation zone and eastern stormwater dissipation zone fire buffer area. The linear swale / constructed wetland would have the effect of:

1. Re-distributing concentrated stormwater flows from the site thereby substantially reducing any increases to surface flow rates per unit [wetland] length to the wetland zone.

2. Provide for opportunity for further groundwater recharge of site stormwater flows.

3. Provide for further surface water treatment prior to being released into the wetland zone (i.e secondary benefit).

In order to assess the value of the concept remediation option in terms of groundwater impact, the following methodology was utilised:

1. A new groundwater MODFLOW model (M4) was developed. This distributed the 529 ML/yr flow increase over the western and eastern stormwater dissipation zones (Figure 1) as additional recharge.

2. Change in net annual areal ET over the western and eastern stormwater dissipation zones (in M4) was based on existing and revegetated crop factors (Table 3) resulting in an ET increase of 568 mm/yr and 258 mm/yr respectively.

3. The 529 ML/year distribution swale inflow was apportioned such that 63% was directed west and 37% was directed east in order to account for varying ET rates. An appropriate flow distribution design would be required to achieve this.

Table 3: Adopted crop factors for western and eastern stormwater dissipation areas.

	Western Stormwater Dissipation Area		Eastern Stormwater Dissipation Area	
	Pre-development	Post-development [1]	Pre-development	Post-development [1]
Crop/Adopted Crop Factor	Adopted Crop Coverage (%)		Adopted Crop Coverage (%)	
Grass / 0.6	95	40	80	55
Trees / 1.2	5	60	20	45
Hardstand / 0.0	0	0	0	0
Net Aerial Crop Factor	0.63	0.96	0.72	0.87

Notes: 1. Assessment based on crop coverage estimate in 10 years' time from now.

A drawdown plot for M4 (using M1a as initial heads surface) indicates that there may be some minor increases to groundwater levels over the northern wetland interface with the stormwater dissipation zones. However, these increases are small and within the expected day to day groundwater fluctuation levels found within the wetland. The proposed remediation option therefore provides a suitable mechanism by which any potential impacts of point source surface water discharges to the wetlands can be mitigated against.

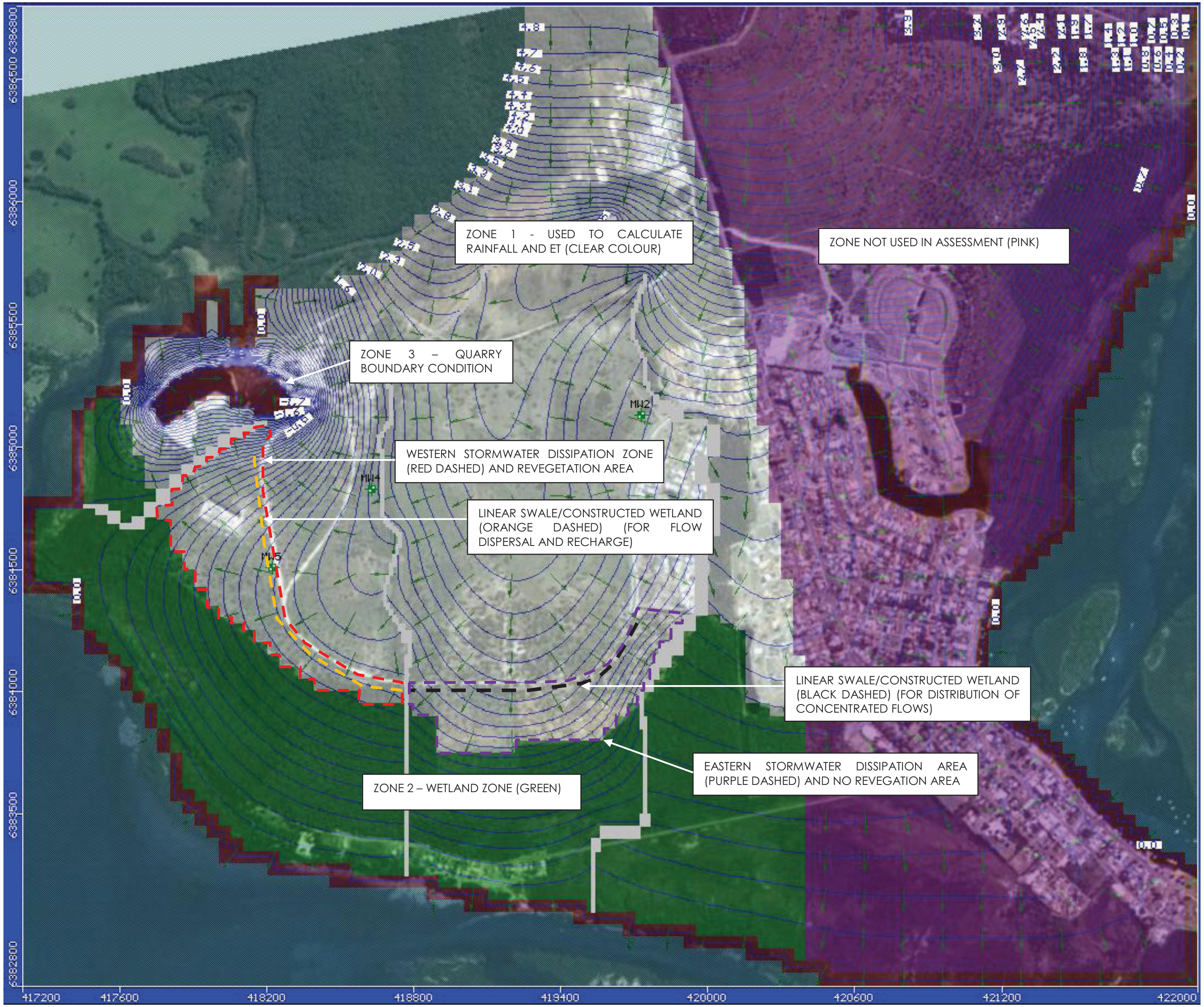
For and on behalf of

MARTENS & ASSOCIATES PTY LTD

BEN ROSE

BEnvMgt

Environmental Scientist



martens

Key:
Blue Contours – Groundwater Head Contour (0.1 m interval)

Green Arrows – Groundwater Flow Direction Vectors

Martens & Associates Pty Ltd ABN 85 070 240 890		**Environment | Water | Wastewater | Geotechnical | Civil | Management**	
Drawn:	BR	**MODEL M1a OUTPUT AND ZONE BOUNDARIES**	Drawing No: **FIGURE 1**
Approved:	DM		
Date:	20.06.2011		
Scale:	1:16,660 Approx		Job No: P0902346

martens

Key:

Brown Contours – Groundwater M4 to M1a Drawdown Contour (0.1 m interval)

Martens & Associates Pty Ltd ABN 85 070 240 890		Environment | Water | Wastewater | Geotechnical | Civil | Management	
Drawn:	BR	MODEL M4 DRAWDOWN FROM MODEL M1A GROUNDWATER HEAD	Drawing No: FIGURE 2
Approved:	DM		
Date:	20.06.2011		
Scale:	1:16,660 Approx		Job No: P0902346

Appendix 8 - BMT WBM, Review – Revised Water Management Reports (29th June 2011)

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www.wbmpl.com.au

Our Ref: BAA: L.N1514.007

29 June 2011

Great Lakes Council
PO Box 450
FORSTER NSW 2428

Attention: Roger Busby

Dear Roger

RE: MYALL RIVER DOWNS, TEA GARDENS REVIEW – REVISED WATER MANAGEMENT REPORTS

INTRODUCTION

This letter documents outcomes of BMT WBM's most recent review of the revised water management strategy for Myall River Downs (MRD). Following the meeting held by teleconference on 21 February 2011, three outstanding points remained unresolved from the original review by BMT WBM (dated 1 October 2008). Two of the three points (Point 22 and 27) were focused on the potential alteration of the site water balance and in particular, potential changes in water discharge via groundwater flow or surface discharge through the proposed wetland/channel.

In the February 21st meeting, Daniel Martens (DM) from Martens Consulting Engineers and Fiona Coe (FC) from Worley Parsons agreed to prepare additional material to support the proposed water management strategy for Myall River Downs, Tea Gardens. DM and FC advised that additional annual water balance calculations would be completed for the existing and future site to estimate the additional volume of water expected to discharge from the site as surface flow into the wetland. BMT WBM agreed that this information should enable a satisfactory level of hydrologic assessment for the rezoning stage.

REVIEW PROCESS SINCE FEBRUARY 2011

April 2011

A revised Water Management Report was submitted to Council on behalf of Crighton Properties along with a covering letter and supporting email (from Peter Childs to Roger Busby entitled "Summary of Outstanding Issues") dated 8th April 2011. This revised report included a report from Martens Consulting Engineers *Supplementary Groundwater Assessment Comments*. This information was reviewed by BMT WBM in late April and a number of issues were identified that required clarification to complete the assessment.

Of particular importance was the continued discrepancy between the water balance presented by Worley Parsons (derived from MUSIC modelling) and the MODFLOW models revised by Martens in their April supplementary report. Based on the information provided, BMT WBM were unable to reconcile the water balance presented by Worley Parsons (Table 3-11 of the revised April report) and the estimated water balance of the MODFLOW groundwater model (no explicit pre- or post-development water balance was provided for the groundwater model). While the volumetric discharge from the proposed wetland/channel generated by the MODFLOW model was comparable to the existing discharge presented in the MUSIC water balance, BMT WBM could not confirm that the existing condition MODFLOW model (M1) matched the existing condition

MUSIC model. It was also not clear how the MUSIC model water balance (Table 3-11) represented the surface water / groundwater connectivity of the site.

The Supplementary Groundwater Report (April 2011) submitted to Council involved the following key tasks.

- Increasing from a single recharge zone to 4 zones and an improved calibration of the existing case M1 model (M1a).
- Hydraulic conductivity values and recharge zones brought forward into a revised developed scenario model (M2a).
- Areal water balance used to develop recharge values, estimate surface runoff volumes and subsequent recharge (infiltration) of stormwater at WSUD measures.
- Existing industrial area included to improve water balance assessment.

BMT WBM support the approach taken in the April 2011 report (documented in Section 2.1 and 2.2) where models M1(a) and M2(a) were adjusted to ensure they provided a good representation of overall site water balance and the volumes of runoff discharging to the treatment wetlands and bioretention basins. The crop factors and crop coverage values utilised in the April 2011 report are considered logical and justified. We understand that recharge depths and surface runoff volumes directed to measures were estimated based on effective areal crop factors (pan evaporation) of 0.66 (M1a) and 0.42 (M2a) for the ~180 ha development area. This 36% reduction in Potential Evapo-transpiration (PET) equates to a total increase in water discharge off-site of ~735 ML/year (0.24 x 1720 mm x 1,779,100 m^2 converted to ML). This value is roughly consistent with the previous estimate made by BMT WBM.

Given the nature of the water management strategy and this estimate of increase site discharge, BMT WBM identified some concerns regarding the modelled zero increase in off-site discharge documented in the Water Management Report. It would not be possible for all of this ~700 ML/year additional runoff to leave the site as Evapo-transpiration (ET) alone.

May 2011

Following a preliminary review of the April 2011 supplementary report BMT WBM requested extraction of key water balance volumes in an email dated 12th May 2011. A phone meeting was held between Ben Asquith (BA), Mark Wainwright (MW) and Daniel Martens (DM) on 12 May 2011 to discuss these outstanding issues. We received this information in draft letter report dated 27th May 2011 and reviewed this in conjunction with the April 2011 Supplementary Report. This report estimated the average annual increase in surface discharge through the channel/wetland system to be 177 ML/year which was significantly different to the previous estimate of 735 ML/year submitted in the April 2011 Supplementary Report. This discrepancy largely related to the assumed volume of existing condition surface runoff not included in the MODFLOW model (10%).

Another phone meeting was held between BA, DM and Ben Rose (BR) of Martens Consulting Engineers on 14th June 2011 to discuss the approach taken in the 27th May letter report. A number of key issues were clarified and it was agreed that the letter needed to be revised to reflect the agreed conclusions between BMT WBM and Martens Consulting Engineers. DM and BR agreed to revise the report accordingly and re-submit it to BMT WBM for final review.

June 2011

The revised letter report was submitted to BMT WBM on 20th June 2011 and contains two key elements.

- A final water balance assessment for the existing and post development scenarios (Table 1): and
- Evaluation of a concept remediation option to mitigate potential impacts associated with increase channel/wetland discharge.

The final water balance presented in Table 1 of the 20th June report assumed existing surface runoff (not discharging via the existing drain) is approximately 5% of incident rainfall. Martens Consulting Engineers estimated the change in water discharge from the developed area (~180 ha) to be 529 ML/year which includes redirected surface water flows and intercepted groundwater flows. This includes a slight reduction in groundwater and quarry discharge and a ~870 ML/year increase in discharge from the southern channel/wetland (the major discharge point from the development).

In order to mitigate against any potential impacts associated with the increase in volume and concentration of flows from the site, Martens Consulting Engineers propose construction of a linear constructed wetland and recharge zone downslope of the sites perimeter road which would receive inflows from the site's major drains.

Reference should be made to Figure 1 of the 20th June letter report for further illustration of this proposed concept. The concept has been proposed to;

- re-distribute concentrated stormwater flows from the site;
- provide further opportunity for groundwater recharge of surface flows; and
- provide further opportunity for further treatment.

The 529 ML/year net change in average annual surface discharge to the wetland was applied to a new (M4) MODFLOW model as concentrated recharge along the proposed linear constructed wetland location to assess the potential impact on groundwater levels and drain discharge volumes. The resulting drawdown plot of steady state groundwater levels is shown in Figure 2 of this 20th June letter report.

BMT WBM has now reviewed the proposed Water Management Strategy in light of this final 20th June 2011 advice. The outcomes of our review are documented in blue italics below each point as follows.

ASSESSMENT OF JUNE 2011 ADVICE

Diversion of low flows near quarry (Point 18)

FC confirmed that the intention is to maintain low flows to the wetlands located west of the proposed development. Figure E2 will be revised to show continuation of the existing low flow channel along the southern side of the existing quarry to the wetlands.

Resolved.

Increased discharge to the receiving wetlands (Point 22)

DM, FC and MW agreed that runoff generated within the site will increase following development. DM, FC and MW agreed that a high proportion of the increased runoff would be directed via surface runoff, groundwater flow and minor channels to the main channel draining south into the existing wetlands. DM indicated that discharge from the site along this channel would be limited until the water level in the channel rises to RL 1.4m AHD. DM indicated that the steady state water table level in the drainage channel would typically be RL 0.9m AHD. DM and FC indicated they considered that the 0.5m depth between the typical steady state water table level in the channel and the control level of 1.4m AHD downstream of the site would be sufficient to retain a high proportion of the additional runoff volume prior to discharge into the downstream wetlands. DM and FC indicated that the processes involved in reducing the water level in the channel following storm events would include evapotranspiration and re-distribution to groundwater adjacent to the channel. DM indicated that surface flow would discharge from this channel when RL 1.4m AHD is exceeded, but advised that the frequency at which this would occur and the total flow volume discharging into the wetland from the channel have not been confirmed.

The estimate discharge volumes from the site reported from the MODFLOW model already account for these levels. A review of the channel (drain) boundary condition inputs used in the modelling confirms that RL 1.4m AHD was the adopted control level at the end of the drain. The suggestion that this arrangement could increase evapo-transpiration through temporary "redistribution" of stormwater is unlikely in our opinion. We would suggest that the final MODFLOW models have been re-calibrated adopting assumed ET rates at the upper end of PET ranges. The influence of this issue on the frequency and volume of surface water discharge to the wetland should be assessed further at the DA stage.

MW indicated he believed that previous discussions between DM and BA had resulted in an agreement that surface discharges along the channel would increase following development. MW indicated it was his understanding from discussions with BA that DM had concluded that groundwater discharges to the wetland would not change significantly following development and that additional runoff from the development would discharge from the site as surface flow along the channel. DM indicated that BA may have misinterpreted their conversation, and whilst flow to the channel may increase, in his opinion this would not necessarily result in significant additional discharge from the site along the channel (due to the previously discussed retention, evapotranspiration and redistribution within groundwater).

MW indicated that he believed the potential for a significant reduction in stored runoff in the channel and groundwater due to evapotranspiration would be significantly limited by the average annual potential evapotranspiration being similar to the average annual rainfall at this site. DM agreed.

MW indicated that he was not familar enough with the groundwater characteristics and modelling completed for the site to provide comment on the potential for the additional runoff to be stored and re-distributed within the groundwater adjacent to the channel without draining from the site. Further comment would need to be provided by BA.

The suggestion that increased flows would not necessarily result in significant additional discharge from the site (due to the previously discussed retention, evapotranspiration and redistribution within groundwater) has since been discounted by the additional water balance assessment undertaken by Martens Consulting Engineers. In our opinion, it would take localised ET rates (not accounted for in the MODFLOW model) well in excess of PET (maximum ET) and in fact pan evaporation to achieve no net increase in channel discharge from the site. DM agreed with this fundamental limitation during the February 2011 meeting.

DM indicated that additional analysis would be completed to estimate the existing and developed average annual flow discharging into the wetland. DM indicated that the analysis would be completed considering annual inputs of rainfall/recharge/ET. MW indicated that this annual analysis would tend to smooth out the flows, and therefore not account for pulses of stormwater during large events which would be important for estimating how regularly the channel storage may overflow into the wetlands and what flow volume would be involved. DM agreed that this more continuous analysis would provide a better estimate, but considers that this more detailed assessment would only be warranted at a later stage.

DM and FC advised that additional annual water balance calculations would be completed for the existing and future site to estimate the additional volume of water expected to discharge from the site as surface flow into the wetland.

BMT WBM consider the estimated increase in surface water discharge from the site (average of 529 ML/year) provided in the 20th June advice to be within a reasonable range. The rationale and back calculations undertaken to derive the estimate are considered reasonable and further refinement at this stage is not warranted. Notwithstanding, Method 2 for estimation of ET within Zone 1 (areal crop factor approach) documented in Table 2 of the 20th June advice is not considered representative and does not correlate with previous work submitted in April. It is unclear where the 180 ha development area fits into Table 2 of the June advice. In our opinion, the April 2011 areal crop factor assessment of the development site is the most robust. Regardless, the 529 ML/year estimated increase in surface water discharge is based on Method 1 (back calculation assuming existing surface runoff is 5% of incident rainfall).

It is important to note that while total surface discharge to the wetlands is estimated to increase by 529 ML/year, concentrated surface water discharge at the channel/wetland outlet is estimated to increase by 870 ML/year.

BMT WBM consider the proposed linear constructed wetland (Figure 2 of the June advice) to be a favourable strategy for mitigation of the impacts of this increase in concentrated surface water discharge. It is a strategy that attempts to mimic the natural hydrology of the site and utilise the flow and pollutant buffering capacity of the Climate Change Transition Zone. The potential benefits of this measure have been estimated through steady stage modelling of the impacts on groundwater levels however a more refined assessment will be necessary at a later stage that includes continuous, dynamic modelling of measure performance for critical design events in addition to long-term implications.

The potential impact of this measure on the ecosystem health of the wetland has not been assessed by BMT WBM and may require further consideration by Council. Notwithstanding, the proposed linear constructed wetland will reduce concentrated surface water discharge from the development without having a significant impact on steady state (average annual) groundwater levels based on the outcomes of the June advice.

Rainfall-runoff parameters / runoff volumes (Point 27)

MW confirmed with FC that the flow volume reported in MUSIC is the total of the surface runoff and baseflow volume (not surface runoff only). MW advised that further interrogation of the model is required to ascertain what proportion of the flow volume is surface runoff or baseflow.

DM and FC confirmed that the recharge volumes for the developed groundwater model may have been overestimated. DM, FC and MW agreed that this would result in conservative estimates of flow and therefore would represent an acceptable approach.

The Site Water Balance presented in Table 3-11 of the Worley Parsons Water Management Report does not consistently correlate with the groundwater assessments conducted by Martens Consulting Engineers. There appears to be some confusion over the interaction between baseflow (as modelled in MUSIC) and groundwater recharge on a site such as MRD. The reason for adopting deep seepage and baseflow as two independent outputs from the site is not clear.

BMT WBM see limited value in attempting to reconcile this MUSIC based water balance with the MODFLOW based water balance calculations. For a site such as MRD, MODFLOW is a more appropriate tool for assessing long-term water balance where MUSIC (or similar) is used to provide a reasonable estimate of overland flow volumes not accounted for in MODFLOW.

Given that the water quality aspects of the MUSIC model are considered acceptable, BMT WBM recommend adoption of the site water balance presented in Table 1 of the June letter report submitted by Martens and Table 3-11 of the Worley Parsons report be disregarded.

Need for in-line constructed wetlands (Point 41)

MW advised that he considered that biofiltration measures without instream constructed wetlands would be appropriate for achieving Council's water quality objectives. FC indicated that the constructed wetlands were included to achieve the TSS objectives. MW indicated that in his opinion if biofiltration measures could achieve acceptable treatment for TP and TN (as the strategy indicates), acceptable treatment for TSS should also be achieved.

FC advised that wetlands were also included to reduce poorly drained areas in the base of channel to assist maintenance and to reduce mosquito breeding habitat. MW indicated that provision of the constructed wetlands should be discussed further with Council (also refer comments on Points 52 and 56 below).

BMT WBM have not considered this issue further.

Existing groundwater quality (Points 52 and 56)

MW and DM agreed that the available data is insufficient to reach a conclusion on the background groundwater quality conditions across the site. It was agreed that further groundwater quality data should be collected prior to DA stage to confirm groundwater conditions. Notwithstanding this, it was agreed that the proposed treatment series including biofiltration should provide treated stormwater to an acceptable quality.

Resolved

SUMMARY OF OUTCOMES

BMT WBM consider the final Water Management Report (consisting of the report dated 7th April 2011 and letter report dated 20th June 2011) to adequately address the points raised in our original and subsequent reviews with respect to rezoning of the MRD site. Water quantity and quality issues have been broadly characterised and the predicted impacts of the MRD development are considered reasonable. However, it should be acknowledged that the level of detail in surface and groundwater modelling is limited. As such, there are some remaining issues we recommend be resolved at the DA stage. There are also two remaining issues that have not been addressed by this rezoning review process.

Issues for consideration prior to rezoning

1. The ability of the proposed linear constructed wetland within the Climate Change Transition Zone to manage the impacts of increased site discharge on the natural wetland / ecosystem health has not been assessed in this review.
2. The need for or appropriateness of the proposal to form unlined constructed wetlands in the base of the main channel needs to be considered by Council.

Issues for consideration at the DA stage

3. Given the fragmented nature of the current water management aspects of this rezoning application, it may be prudent to compile all of the elements to be carried through to the DA stage into a final, consistent Water Management Report that excludes elements discounted or superseded through the review process.
4. Collect more groundwater level and quality data to better characterise existing conditions and allow improved calibration / creation of a dynamic, continuous MODFLOW model.
5. Resolve discrepancies between surface and groundwater assessments in order to present a consistent approach.

6. Build a dynamic continuous groundwater flow model for the MRD site that enables more detailed assessment of the impacts of the central channel/wetland on surface water discharge volumes and frequencies (i.e. pulses).
7. Adopt the areal evapo-transpiration rationale documented in Sections 2.1 and 2.2 of Marten's April 2011 Supplementary Groundwater Assessment to develop and refine pre and post development water balances.
8. Design the proposed linear constructed wetland in a manner that ensures potential impacts of concentrated stormwater flows from the central channel to the natural wetland are mitigated.

Please do not hesitate to contact the undersigned if you have any questions or require clarification of any issue.

Yours Faithfully

BMT WBM Pty Ltd

Mark Wainwright, Associate