Appendices

Appendix A – Summary table of submissions and AGL responses

Appendix B – Water Balance Modelling Report (Worley Parsons)

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Appendix A – Summary table of submissions and AGL responses

Extracted Water Management Strategy - September 2014 Agency Submissions on the Consultation Draft

Issue No.	Submission By	Date Received	Issue/Comment	AGL Response	Amendment to Report (Yes/No)	Relevant Section
A001	NSW Office of Water (now DPI Water)	17/09/2014	***Provision of Reverse Osmosis Water to third parties (section 5.8)*** . NOW notes the lack of security of water supply, and recommends that the finite nature of the water supply be made clear to those parties lodging an expression of interest. NOW considers that new industries should understand the risks and limitation of investing based on limited water supply	AGL agrees - text updated	Yes	Updated in Section 5.4.3
A002	NOW	17/09/2014	***Discharge of Water to Dog Trap Creek/Avon River*** . Although the EWMS indicates that discharge water will be treated to ANZECC standards, it does not address the potential ecological or geomorphic impacts of the proposal. The following studies should be completed: * Identification of proposed discharge point and alternatives; * Geomorphic Assessment, including assessment of impacts of discharge * Detailed design of outlet devices and scour protection; * Ecological assessment to determine the impacts of discharge on ecosystem conditions and assets, and the impacts on biota and the downstream environment; * Consideration of temperature of discharge water and the risk of thermal pollution and associated impacts on the aquatic ecosystem	Geomorphological and ecological study completed for potential discharge locations along the Avon River/Dog Trap Creek	Yes	Section 11.6.2 and Appendix C
A003	NOW	17/09/2014	***Discharge of Water to Dog Trap Creek/Avon River*** . NOW requests: * Confirmation of volumes likely to be discharged to Dog Trap Creek. * Modelling being the estimated water use and discharge rates to also be provided. Present both 'likely' and 'worst case scenario	Dog Trap Creek now discounted as a discharge location. Volume to the Avon River expected to be zero for P50 water production case and less than 20ML for P90 water production case .	Yes	Section 5.1.5, Section 5.5, Section 11.6.2 and Appendix B
A004	NOW	17/09/2014	***Monitoring Bores in the vicinity of the Tiedmans Storages.*** NOW recommends that as a control measure, monitoring bores also be installed up gradient of the Tiedmans storages to facilitate comparative analysis. These should include construction in both the shallow and weathered rock zones, acting as a control of the down gradient bores to ascertain if any water quality fluctuations are naturally occurring, or as a consequence of seepage. Additionally these bores should be installed prior to commencement of Stage 1 to allow for attainment of baseline levels	Additional monitoring has been included north of the Tiedman storages prior to commissioning of Stage 1 (upgradient not possible as storages are at the top of the ridgeline)	Yes	Appendix E
A005	NOW	17/09/2014	***Monitoring Frequency (ref Pg 106)*** . NOW does not support any decrease in monitoring frequency based solely on the period of time elapsed since project commencement. Any proposed reduction in monitoring frequency should be subject to assessment of monitoring data.	Noted - any PWMP and GMMP will be written accordingly. Monitoring program to be reviewed annually.	Minor	Appendix E
A006	NOW	17/09/2014	***Definition of 'Flowback' Water, and Adequacy of Water Balance*** . Confirmation is requested as to whether the definition of 'flowback' water includes water injected for fracture stimulation purposes. If injected water is not included in the water balance, the predicted volume of extracted water may be under-estimated. Subsequently, calculated storage volumes may be inadequate, resulting in a higher reliance on surface water discharge. To further assess this issue, it is requested that the modelling behind the estimated water use and discharge rates be provided	Flowback water is included in the water balance modelling. Full Water Balance Modelling Report included as Appendix. Extracted water volumes are lower than originally predicted. Storage will be more than adequate.	Yes	Appendix B

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A007	NOW	17/09/2014	***Adequacy of Contingency Planning (surface water discharge).*** The EWMS relies on surface water discharge as the contingency for management of excess extracted water. It is requested that additional contingency measures be investigated in the event that surface water discharge is deemed inadequate.	Water production profiles are now 25% lower than originally proposed in 2014. The strategy relies on storage then surface water discharge Storage volumes (both extracted water and treated water) will be maximised before any discharge occurs	Yes	Section 5.5, Section 11.6.2 and Appendix B
A008	NOW	17/09/2014	***Aquifer Storage Feasibility Study*** . Condition 21 of EPBC Act Approval 2008/4432 required AGL to undertake a feasibility study into aquifer storage. NOW endorses AGL's conclusion that aquifer recharge is not a feasible water and brine management strategy for this project.	Noted	No	Text is provided in Section 9.7
A009	Environment Protection Authority (EPA)	19/09/2014	**Water Treatment Plant**. System details will need to be specified for treatment processes, pre-treatment processes, treatment chemicals and water discharge/delivery configuration and methods (including quality and timing) as part of a final EWMS or other appropriate document to confirm the suitability of the RO system for the proposed water management options, i.e. whether the produced water quality is fit-for-purpose	Final engineering design and WTP system details are not available at this time. System details are beyond the requirements of this EWMS	No	NA
A010	EPA	19/09/2014	**Water Treatment Plant**. All system inputs and outputs (waste streams) must be identified, including quantities to be stored on-site and storage specifications	Streams identified in the Water Balance Modelling Report, however actual quantities are dependent on the actual water production profile and the fine sediment loads transported to the WTP which are unknown at this time.	Minor	Appendix B
A011	EPA	19/09/2014	**Water Treatment Plant**. Technological limitations of RO to reduce levels of some indicators need to be considered (e.g.. Boron) and any treatment or cleaning/maintenance chemicals that may be introduced into the RO treatment process will need to be assessed for each end use or discharge option.	WTP will meet the proposed water quality targets	Yes	Section 12
A012	EPA	19/09/2014	**Trigger values for water reuse and discharge (ref: EWMS Exec Summ - Preferred Strategy)**. Trigger values expressed as TDS do not relate to ANZECC guidelines for salinity which are generally expressed in micro Siemens per centimetre (µS/cm EC). If TDS is to be used an appropriate conversion factor should be determined based on adequate data for both TDS and EC that provide a robust correlation	Target water quality has been reassessed as part of the FEED studies and latest Basis of Design. Both TDS and EC limits are proposed for treated water	Yes	Section 12
A013	EPA	19/09/2014	**Trigger values for water reuse and discharge (ref: EWMS Exec Summ - Preferred Strategy)**. A salinity trigger value for surface water discharge of < 500 mg/L TDS (upper range) is not consistent with ANZECC (2000) guidelines for salinity (see Table 2.6 in EWMS). 500 mg/L TDS is approximately 730 µS/Cm which exceeds the upper end of the ANZECC default trigger level range for upland rivers (350 µS/cm) and exceeds trigger values for NSW coastal lowland rivers of 200-300 µS/cm (see Table 3.3.3 of ANZECC 2000). This is potentially significant during any low flow discharges when there may be inadequate dilution to achieve the ANZECC or site specific triggers at the edge of an initial (near-field) mixing zone. The overall load of salts discharged to the catchment should be a further consideration in appropriate trigger values for the discharge volumes and timing that may be proposed in the final EWMS.	Table 2.6 are the proposed water quality thresholds (water quality criteria that will never be exceeded). The target water quality values for the treated water (Table 12.1) are much lower and based on the expected design performance of the RO plant and associated conditioning of the treated water. The ANZECC guidelines does specify an EC salinity range of 125 to 2200 uS/cm for some lowland streams in SE Australia (Table 3.3.3). The Avon River fits into this category	Yes	Section 2.4.2 and Section 12

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A014	EPA	19/09/2014	**Trigger values for water reuse and discharge**. Following RO, treated water can be extremely pure. Treated water could potentially be used in an environmentally detrimental manner if it is too pure (e.g. inadequate salt levels) for the receiving waters or reuse application. Water in the natural environment contains levels of dissolved solids/salts, nutrients and organise matter. If not undertaken properly, releasing highly pure water into a natural water body could potentially cause harm to the receiving waterbody, therefore additives to the pure water may be needed prior to end use or disposal. The expected lower range target for treated water of 150 mg/L TDS specified in the EWMS is likely to be adequate to prevent environmental impacts due to low salinity. Initially mixing in a near-field zone could also be taken into account in assessing surface water discharge risk of low salinity.	Pure water from the RO plant will not be directly released into the environment. The treated water will be conditioned at the WTP to add back in essential salts and to adjust pH (if necessary) prior to reuse and any stream disposal. High flow discharges are only proposed so the dilution factor is expected to be greater than 5 times.	Yes	Section 11.3.3. and Section 12
A015	EPA	19/09/2014	**Trigger values for water reuse and discharge**. The EPA recommends that Table 10.5: "Stream Discharge Water Quality Targets" should include a lower limit (in addition to an appropriate upper limit) taking into account the relevant ANZECC (2000) range for salinity for upland rivers or lowland rivers (whichever is relevant where upland streams are defined as those above 150m altitude).	A single water quality type will be prepared for all reuse water and any water that has to be discharged to streams. Table 12.1 proposes lower and upper limits for salinity.	Yes	Section 12
A016	EPA	19/09/2014	**Trigger values for water reuse and discharge (ref: EWMS 2.4.2)**. The default ANZECC trigger values should apply to receiving waters associated with GGP (these are mostly the 95% species protection trigger values). The 80% species protection trigger values are not appropriate for the GGP. Existing poor condition is not an appropriate basis for establishing water quality objectives. It is not appropriate to allow poor environmental performance or water pollution simply because a waterway is degraded. The goal is to restore highly modified systems to slightly to moderately disturbed systems. The community have selected a goal for slightly to moderately disturbed conditions which relates to the default trigger values (i.e. 95% species protection but in some cases the 99% species protection values are the default value for chemicals that may bio accumulate).	Agree that the 95% species protection criteria should apply. Reference to 80% criteria deleted	Yes	Section 2.4.2
A017	EPA	19/09/2014	**Trigger values for water reuse and discharge (ref: EWMS 2.4.2)**. Prior to collecting data, AGL should justify an appropriate reference site based on a good quality site that represents slightly to moderately disturbed conditions in the catchment. Reference sites should be agreed with the EPA prior to data collection. Data requirements specified in ANZECC should be adopted.	Details are to be included in any PWMP prepared for the project and/or the GMMP that needs to be prepared for water management purposes Reference site maybe the upgradient site from the recommended stream discharge location AV2. Requires further liaison with EPA at PWMP/GMMP/EPL stage	No	Section 14 and Appendix E is relevant
A018	EPA	19/09/2014	**Trigger values for water reuse and discharge (ref: EWMS 5.1.5)**. The expected target treatment water quality (subject to refinement based on the other comments provided) should be adopted as the irrigation, river discharge and other end use thresholds as they reflect treatment performance of the system when it is working in a proper and efficient manner. Environment protection licence limits will be set to reflect a proper and efficient treatment process taking into account end use discharge requirements.	A single treated water type is proposed as the output from the WTP	Yes	Section 12

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A019	EPA	19/09/2014	**Assessment of the current irrigation program in the EWMS (ref: EWMS 2.4.1 & 3.1)**. ANZECC thresholds alone are not adequate to assess irrigation sustainability. ANZECC (2000) volume 3 sets out a risk based approach that takes into account the whole landscape, irrigation water quality, soils, site and application rates. The EWMS should refer to Section 9.2 of ANZECC (2000) Volume 3, including Table 9.2.1 and figure 9.2.1. Data and assessment from the current irrigation scheme has not provided adequate information to assess long term sustainability of the irrigation scheme using blended water. Based on the proposal and initial results the EPA assessed that the irrigation of blended water is likely to be unsustainable. Treatment is therefore required to remove salt loads and therefore the target water quality related to treatment performance should be adopted as initial threshold values for treated water irrigation.	Blended water is not under consideration for the Stage 1 development. The reuse of exploration phase produced water should not be confused with the reuse of (treated) extracted water from the Stage 1 development. Revised target water quality criteria proposed in Section 12	Yes	Section 12
A020	EPA	19/09/2014	**River flow objectives (ref: EWMS 5.6)**. The EPA recommends that opportunities to time flows with natural flow patterns/regimes should be incorporated into the EWMS.	Agreed - stream discharges will be minimised and only occur during periods of higher stream flow.	Yes	Sections 9.2 and 9.3
A021	EPA	19/09/2014	**Brine tank**. The EWMS notes that the WTP will include a brine tank. There are no details in the report regarding the design of the tank (open top / enclosed, indoors / outdoors), and system design contingencies (alarms, bunding). This needs to be addressed in the EWMS.	Brine tank will be enclosed and indoors Design element for inclusion in any PWMP - not an EWMS item	Minor	Section 11.2.4
A022	EPA	19/09/2014	**Salt and disposal options**. Salt produced from the thermal brine treatment system is to be stored in 1 tonne bulkabags. The EWMS does not identify the maximum on-site storage capacity that will be dedicated for the storage of salt, or details of the storage area (location, surface / floor, containment).	Design element for inclusion in any PWMP - not an EWMS item	No	NA
A023	EPA	19/09/2014	**Salt and disposal options**. The disposal of brine generated by reverse osmosis remains a key area of concern due to its high concentration of salts and other chemicals and the fate of these salts in landfill has not been assessed at this stage. Several licenced waste facilities have been identified but none were specifically nominated as the final destination of the produced mixed salts. AGL must ensure that suitable licensed sites are identified in the EWMS, and that these premises have sufficient capacity to accept the quantity of mixed salts to be generated from the activity. The EWMS should also identify contingency measures should the volume of salts generated from the activity exceed available landfill capacity for either short or extended periods. Details of the landfilling methods and long term fate of the salt in each landfill should be specified and assessed in the EWMS. Containment methods during landfilling should prevent off-site migration to ensure that the salt does not contaminate or harm the environment.	Not a matter for inclusion in the EWMS as defined by the Part 3A condition. With lower extracted water volumes, salt volumes will also be reduced. Containment is the responsibility of the licensed facility that receives the waste stream (testing to confirm that the salt is GSW- non-putrescible).	No	NA
A024	EPA	19/09/2014	**Salt and disposal options**. The EWMS should take into account future opportunities for reuse of the salt after landfilling.	Containment (and any landfill recovery) is the responsibility of the licensed facility that receives the waste stream.	No	NA

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A025	EPA	19/09/2014	**Other waste streams**. The EWMS should clearly identify all waste streams (solid and liquid), quantities, on-site storage capacity and handling of each waste stream, waste classification and the fate of all waste products generated from the water treatment process, including the pre-treatment system. The EPA regulates waste through the Protection of the Environment Operations Act 1997 (POEO Act), together with the Waste Avoidance and Resource Recovery Act 2001 and the Protection of the Environmental Operations (Waste) Regulation 2005. All waste should be classified according to the NSW Waste Classification Guidelines (DECCW 2008). These key statutes and guidelines contain the requirements for classifying, managing, storing, transporting, processing, recovering and disposing of waste; and need to be considered in the assessment of waste products generated by the proposed treatment of extracted water.	Noted. Assays for the sediment/grit from the WTP and the mixed salt are not available at this time. For inclusion in any PWMP. Also noted that new (2014) waste regulation and guidelines now apply	Minor	Section 2.2 and Section 13.5
A026	EPA	19/09/2014	**Quality of treated working water**. Working water, used for well workovers, drilling and fracture stimulation, post-treatment is defined as having a salinity <7000 µS/cm (pg 82). Prior to utilising treated extracted water for working water, it is specified as sourced from freshwater sources (i.e. Pontilands dam and Avon River). Working water must continue to be of similar quality and no harm to the receiving environment. There are likely to be instances when electrical conductivities of 6999 µS/cm for drilling water would be harmful to shallow beneficial groundwater.	Working water will now be low salinity treated water from the WTP	Yes	Section 12
A027	EPA	19/09/2014	**Recommended Guidelines**. Volumes 1 -3 of the ANZECC (2000) guidelines should be referred to in the EWMS, e.g. Lower-reliability trigger values specified in Volume 2 under the detailed description for each chemical can be used as a basis for determining discharge risks when "ID - insufficient data to determine guideline" is indicated in Volume 1. Volume 3 provides detailed guidance in relation to reuse option. ***(Refer to Attachment B - Recommended Guidelines, which summarise the relevant guidelines)***	Noted.	No	
A028	Gloucester Shire Council (GSC)	19/09/2014	***Waste Management Preference*** . Council advocates for reuse or recycling of salt by-products from desalination where appropriate, and encourages AGL to consider investing in treatment technologies that will allow for a potential waste stream to be beneficially reused and avoid landfill.	Salt volumes and tonneages are low. Mixed dry salt characteristics may vary over time. No economic value at present given its variable quantity and quality.	Minor	Sections 13.4 and 13.5

Issue No.	Submission By	Date Received	Issue/Comment	AGL Response	Amendment to Report (Yes/No)	Relevant Section
A029	GSC	19/09/2014	***Development of a Produced Water Management Plan*** . At the workshop held on 13 August, it was identified that further detailed information on produced water management such as treatment technologies, expected produced water quality and river disposal location are expected to be provided in a subsequent Produced Water Management Plan, that AGL will have a requirement to prepare under a Petroleum Production Lease (PPL) (***ref: EWMS 7.3***). It is unclear however at this stage as to: a) whether the PPL will require the development of a Produced Water Management Plan b) what the conditions of a Produced Water Management Plan would be were it to be included as a condition of approval for a PPL c) how a Produced Water Management Plan would interact with an Extracted Water Management Strategy for the same project i.e. production during stage 1, in contracts to the existing PEL Produced Water Management Plan requirements that cover exploration activities. d) whether community consultation would be undertaken for a Produced Water Management Plan were it to be developed	DRE have advised that a PWMP is unlikely to be included in the PPL/s. This matter requires further consideration by Government - its not a matter for AGL to resolve in the EWMS	Yes	Mostly Sections 1.1, 1.4, 2.2 and 7.2.1
A030	GSC	19/09/2014	***Development of a Produced Water Management Plan*** . It needs to be made clear that if a Produced Water Management Plan is not a condition of the PPL, whether AGL will still commit to the preparation of a Produced Water Management Plan, or will operate within the provisions of the EPL, the consent conditions and the EWMS, all of which been approved, granted or prepared.	AGL will operate the project under all relevant planning consents, plan approvals and licences, and is committed to a PWMP.	Yes	Section 2.3.1 and Section 14
A031	GSC	19/09/2014	***Development of a Produced Water Management Plan*** . Until the above details are confirmed and provided, it is considered appropriate that the EWMS be considered the primary document for the water management for Stage 1 of the GGP, and the Strategy be updated to provide additional details as requested by relevant Council's and State Government agencies and the Part 3A consent conditions, particularly in relation to: * further characterisation of extracted water, including provision of existing produced water quality data and statistics showing upper and lower limits that will be used as part of the treatment process design * further description of process analysis and selection for proposed treatment processes, as well as the physical unit operations that will be incorporated into the treatment plant design and further detail of waste management from pre and post treatment processes * provision of results from detailed monitoring that describes receiving environment water quality and flow condition for treated water discharges * analysis of risk to groundwater users and or surface waters and groundwater dependent ecosystems as part of a contingency strategy for volumetric extraction greater than 2 ML per day * assessment of the potential impacts to water quality due to wildlife access	The detail provided in the EWMS is considered appropriate for this strategy document	Minor	Some extra detail provided in: Section 6 (water quality characteristics) Section 10 (existing infrastructure) Section 11 (proposed infrastructure)

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A032	GSC	19/09/2014	***Development of a Produced Water Management Plan*** . It is not expected that the PPL for the GGP will specifically require AGL to prepare the Plan in consultation with Council's or undertake community consultation on the Plan. Therefore it is unclear to Council as to whether further consultation opportunities will be provided once the EWMS be approved. As such, while the EWMS provides a framework for produced water management as part of Stage 1 of the GGP, there is additional detail that is yet to be provided in subsequent documentation in which Council would expect to have the opportunity to provide input. Alternatively, the EWMS should be modified to be the primary management plan for produced water management and be modified to feature additional details as requested during the consultation process.	This matter requires further consideration by Government - its not a matter for AGL to resolve in the EWMS No plan to modify the EWMS. The EWMS is a strategy document that needs to be endorsed by all stakeholders to provide certainty for developing the extracted water/treated water management infrastructure for the Stage 1 GFDA	Minor	
A033	GSC	19/09/2014	***Development of site specific water quality criteria*** . The EWMS should provide additional detailed information on the development of site specific water quality criteria in accordance with the ANZECC guidelines, including: * proposed locations for monitoring to develop site specific water quality criteria * parameters to be incorporated into a monitoring program * frequency of monitoring	Not being progressed at this time. Likely location is TSW01.	No	NA
A034	GSC	19/09/2014	***Development of site specific water quality criteria*** . Evidence of consultation with the NSW Office of Water/NSW Office of Environment should also be included in the Strategy, as per the conditions of approval	Not being progressed at this time. Likely location is TSW01.	No	NA
A035	GSC	19/09/2014	***Development of site specific water quality criteria*** . Although no required as part of the conditions of approval, it is considered appropriate that for process water reuse as described in the Strategy that a human health assessment framework also be taken into consideration. Numerous examples of dual reticulation of non-potable water and industrial water reuse exist, with a focus on microbiological contaminant and upper limits for these as indicators of water quality. As the process water reuse as described in the Strategy such as toilet flushing, fire water systems and service water have high potential for human contact, it is considered appropriate that a bacteriological water quality target be incorporated into the Strategy, and that the upper limit or range for this parameter (potentially E. coli, as an indicator organism) be suitable for direct contact and ingestion.	There is no source or possibility of bacterial contamination for or from the treated water processing and distribution. Process water will however be chlorinated prior to reuse at the CPF.	Yes	Section 12
A036	GSC	19/09/2014	***Surface Water discharge*** . As the stream gauge 208028 is located downstream of the Waukivory Creek confluence with contributes approximately 31% of flow to the Avon River, it would be preferable for a stream gauge site to be used that is more representative of flows near the proposed river discharge location. Alternatively, flows of a higher magnitude should be considered to be measured at the 208028 site that would be an estimate of flows of > 5ML/day at the proposed river discharge location. A rainfall trigger instead of a flow trigger could also be considered.	GS 208028 is for comparison purposes only TSW01 is the likely gauging location. Flow is a better criteria than rainfall - can get high rainfall locally and limited runoff and conversely higher catchment runoff can occur with small local rainfall events.	Yes	Section 9.3
A037	GSC	19/09/2014	***Further Approvals*** . While it is acknowledged by Council that the Part 3A approval incorporates the Central Processing Facility and associated infrastructure, there is likely to be additional approvals required for components of the project associated with the CPF under the Local Government Act 1993 that may require Council approval	Noted no extracted water management infrastructure approvals are likely to involve Council.	No	NA

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A038	GSC	19/09/2014	***Comment on EWMS - Glossary; pg1.*** Total dissolved solids is referred to in the report, but is not included in the glossary, EC is.	Included in Glossary	Yes	Glossary
A039	GSC	19/09/2014	***Comment on EWMS - Exec Summary - preferred strategy; pg11.*** Add 'workovers' to glossary	Included in Glossary	Yes	Glossary
A040	GSC	19/09/2014	***Comment on EWMS - Exec Summary - preferred strategy; pg11.*** "more areas may be developed initially to cater for production peaks ..." If these are AGL properties in the first instance, this should be mentioned, otherwise I would expect further information about securing buyers of the water in accordance with the conditions.	Irrigation and stock reuse will involve a mixture of AGL and privately owned properties - 60ha is expected maximum. New water balance modelling confirms that 60Ha is sufficient for peak water production.	Yes	Section 9.6.1 and Appendix B
A041	GSC	19/09/2014	***Comment on EWMS - Exec Summary - preferred strategy; pg11.*** "... between 500mg/L TDS" convert to EC or add TDS to glossary	Included in Glossary	Yes	Glossary
A042	GSC	19/09/2014	***Comment on EWMS - 1.2; pg14.*** include the right month which the Concept Plan Approval and Project Approval were modified	Done	Yes	Section 1.2
A043	GSC	19/09/2014	***Comment on EWMS - Table 2.1; pg19.*** change responsible authority from 'OCSG within *DoTI* ' to OCSG within *DTIRIS* '	EWMS updated with new agency arrangements	Yes	Section 7
A044	GSC	19/09/2014	***Comment on EWMS - Table 2.3 - condition 3.12 i); pg25.*** There is more detail on this in Section 2.4 than Section 10, so this should also be referenced in the table. Alternatively the report could be restructured so that information pertaining to this condition is not in two disjunct sections of the report.	Agencies need to recognise difference between thresholds and target water quality criteria. Basic structure left as is	Minor	Table 2.3
A045	GSC	19/09/2014	***Comment on EWMS - Table 2.6; pg29.*** If you are not familiar with the ANZECC guidelines, then it appears based on the previous paragraph that the ranges for pH, EC, DO and turbidity are the 80 to 95% trigger values e.g. 125 is the 95% trigger value, and 2200 is the 8-% trigger value for EC. This was interpreted to be the case by a community member who asked me about it, so the table might need to be adjusted to make the source of these values clearer, as the superscript (2) appears to have been overlooked.	Reviewed Table 2.6 and content appears OK	No	Table 2.6
A046	GSC	19/09/2014	***Comment on EWMS - 3.5; pg33.*** Title should read "Gloucester Shire Council Baseline Water Survey"	Done	Yes	Section 3.5
A047	GSC	19/09/2014	***Comment on EWMS - 3.5; pg33.*** They weren't all farming properties, some were lifestyle properties in Forbesdale Estate.	Done	Yes	Section 3.5
A048	GSC	19/09/2014	***Comment on EWMS - 3.5; pg34.*** If these are going to be identified as groundwater sources formally in AGL documentation, then follow up sampling should be undertaken to confirm this, as discussed previously.	??	No	NA
A049	GSC	19/09/2014	***Comment on EWMS - 6.4; pg53.*** A summary of produced water quality was included in the Gloucester Shire Council produced water evaluation study. This could be referenced in the EWMS	Done	Yes	Section 6.4
A050	GSC	19/09/2014	***Comment on EWMS - Table 10.2; pg83.*** Bacteria have been removed from first to second draft?	Now only one water quality table for all reuses - singular water quality table. Bacteria criteria not warranted (see A035 above)	No	Refer new Table 12.1
A051	Midcoast Water	19/09/2014	***Reliance on river discharge*** . MCW preference is to avoid river discharges and increase irrigation volumes.	Done - revised water balance modelling clearly demonstrates reliance on river discharges	Yes	Appendix B

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A052	Midcoast Water	19/09/2014	***Reliance on river discharge*** . MCW strongly recommend that the irrigation area be extended beyond proposed 60 ha or the storage capacity increased to reduce discharges to the Avon River and maximise reuse. Having extensive reticulated water system covering entire Stage 1 of the project provides opportunity to deliver water to additional area of land for irrigation. Small expansion of storage capacity at Tiedmans property beyond what is proposed would also reduce river discharges. There is no modelling data presented in the strategy to justify that proposed irrigation area and storage capacity are at optimum level.	Water balance modelling has confirmed no benefit in expanding irrigation area beyond 60ha. With lower extracted water volumes there are now no Avon River discharges likely with P50 water production profile - only P90 and during wet seasons to Year 3	Yes	Appendix B
A053	Midcoast Water	19/09/2014	***Reliance on river discharge*** . In addition the adopted irrigation water application rate of 4 ML/ha/year may be overestimated as it was obtained from the irrigation project at Tiedman property. MCW recommend that some contingency, apart from increase in river discharges, has to be provided to the management of water design to accommodate for differences between adopted and actual values.	Different irrigation modelling approach adopted in latest Water Balance modelling approach Application rates likely to be between 2 and 6 ML/ha/yr Storages will provide additional buffer given the expected lower produced water volumes	Yes	Various
A054	Midcoast Water	19/09/2014	***Consultation process*** . MCW welcomes the opportunity to provide input into the EWMS. However the presented strategy is a high level document, lacking necessary technical details for proper assessment of expected risks and effectiveness of proposed control measures. More details are expected to be included in the subsequent management plans such as the Produced Water Management Strategy. These documents will be developed based on the presented strategy. As we have a substantial stake in catchment protection we would like to see MCW's involvement in the consultation process to continue beyond the strategy level. Our expertise in water treatment/reuse may also add value to the further planning process.	Noted - will keep MidCoast Water in the loop. Discharges of treated water to the Avon River will be <20ML and are not expected to extend beyond Year 3. Catchment implications are negligible.	No	NA
A055	Midcoast Water	19/09/2014	***Discharges to river under low flow conditions*** . A statement that "AGL is not discounting the opportunity to discharge water during lower flow periods to provide stock water supplies to downstream users" is included in chapter 5.6 addressing the surplus water discharge to surface waters. We do not agree with the statement that such discharge would improve water quality in the river and maintain environmental flows. We strongly oppose the idea of using waterways as transportation routes for recycled water. Such water has to be transported by pipelines.	Low flow discharges have been removed from there use and stream discharge strategy	Yes	Taken out of EWMS
A056	Midcoast Water	19/09/2014	***Operational risk*** . MCW would like to underline that the proposed extracted water management scheme will be very complex with a number of risks associated with its operation. A comprehensive risk assessment has to be undertaken and contingency measures developed during the planning process.	Numerous risk assessment studies completed. Detail for the PWMP	No	NA

Issue No.	Submission By	Date Received	Issue/Comment	AGL Response	Amendment to Report (Yes/No)	Relevant Section
A057	Midcoast Water	19/09/2014	***Discharge point location and dilution factor*** . It is proposed that up to 1.5 ML/day of treated water from the WTP will be discharged to Dog Trap Creek and the discharge would only occur when there was at least a 5-fold mixing factor. Flows are to be greater than 5 ML/d for the discharge to occur. Apart from the fact that the above figures are inconsistent, the dilution factor with the stream flow is to be assessed using flows at the gauging station located on the Avon River d/s of confluence with Waukivory Creek. The chapter is poorly worded as it confuses dilution of the discharge in the Avon River with dilutions in the Dog Trap Creek. It is not acceptable to use Avon River flows to claim that dilutions are appropriate for Dog Trap Creek. It is highly unlikely that such small tributary can accept 1.5 ML of discharge without adverse impact on the creek. A discharge point location has to be moved or dilution factor for Dog Trap Creek estimated and found acceptable.	Specialist consultants report prepared. Preferred discharge location is now located on the Avon River south of the confluence with Dog Trap Creek (AV2). A rating curve will be established for TSW01 gauge site and discharges aligned to flows at this location (a factor of 5 is still proposed)	Yes	Various but mainly Section 9
A058	Midcoast Water	19/09/2014	***Deficiencies in monitoring plan*** . The Monitoring Plan contained in chapter 14 contains only general information regarding proposed monitoring. Water quality monitoring is proposed on quarterly basis, which is in our opinion highly inadequate. Especially the discharge water pond has to be sampled more frequently (monthly or fortnightly).	Principles outlined in Chapter 14. Outline of monitoring program provided in Appendix E - pond monitoring has been increased to monthly. More details to be provided in subsequent plans	Yes	Appendix E
A059	Midcoast Water	19/09/2014	***Deficiencies in monitoring plan*** . MCW are particularly concerned with the lack of a sampling point to monitor the performance of the RO treatment. Continuous salinity loggers are proposed in the receiving water pond and the discharge water pond, but not in the treated water pond or water flowing out of the RO treatment. Salinity in the discharge water pond will be higher than in the treated water pond or out of RO as it is proposed to dose chemicals to achieve balanced water for irrigation. Only the measurements of salinity upstream of chemical dosing can give an indication of the RO effectiveness. The most effective monitoring point to assess the performance of the RO system would be a continuous measurement of salinity/conductivity in the pipe flowing out of RO system.	Monthly sampling of the TW is proposed. AGL considers this to be adequate given the testing at the DWP. Further clarification would be provided in any PWMP/GMMP.	Yes	Appendix E
A060	Office of Coal Seam Gas (OCSG)	25/09/2014	The Petroleum Production Lease(s) (PPL) that will be required for the Stage 1 GGP may contain conditions requiring AGL to undertake operations in accordance with relevant OCSG Codes of Practice (CoPs). These CoPs may include Well Integrity (Drilling) CoP and Fracture Stimulation CoP. Other CoPs or guidelines may be in place that will be included as conditions of PPLs (e.g.. regarding rehabilitation standards and security).	Noted. AGL will operate the project under all relevant planning consents, codes, plan approvals and licences.	Yes	Section 1.4 and 2.2
A061	OCSG	25/09/2014	At present a Produced Water Management Plan may not be required as a condition of a PPL, CoP or guideline for production activities. The regulation of extracted water as part of the Stage 1 GGP should be via the EWMP required as a condition of consent. I note section 7.3 of the draft EWMP states that it is expected that a similar condition to the PEL285 condition requiring a Produced Water Management Plan will be included in PPLs for the Stage 1 GGP. I would be happy to discuss this section with you.	DRE/OCSG have indicated that a PWMP will not be part of any PPL that is issued. The detail required for a PWMP is not appropriate for this EWMS --- its up to Government to decide whether and when an approved PWMP is required and what approval process is appropriate	Yes	Various but mainly Sections 1.6, 7.2.1 and 14
A062	OCSG	25/09/2014	I note that the Environment Protection Authority and Office of Water have made specific comments relating to monitoring requirements and operational matters that will require licensing under the Protection of the Environment Operations Act 1997 and Water Management Act 2000 respectively.	Noted and recognised in the EWMS report	Yes	Section 2

Issue No.	Submission By	Date Received	Issue/Comment	AGL Response	Amendment to Report (Yes/No)	Relevant Section

Extracted Water Management Strategy - September 2014 Public Submissions on the Consultation Draft

Issue No.	Submission By	Date Received	Issue/Comment	AGL Response	Amendment to Report (Yes/No)	Relevant Section
P001	Local Community Member	19/09/2014	AGL is to be commended for adopting a RO approach rather than the environmentally flawed concept of diluting the produced water and using it for irrigation as practiced at Tiedmans	Noted - RO was always the preferred water treatment approach for the Stage 1 development	No	Sections 5 and 11
P002	Local Community Member	19/09/2014	It is a serious mistake to use the term "extracted water" in the EWMS as the combination of flowback water and produced water as this will aggravate community opposition. The two types of water need to be kept separate.	This is the terminology used by the Department of Planning and Environment in the Part 3A conditions. AGL plans and responses must be consistent with the consent conditions.	No	NA
P003	Local Community Member	19/09/2014	I imagine that the RO facility will require an EIS because of its potentially significant impacts in relation to: a. Disposal of salt. b. Disposal of heavy metal brine – resin extracted metals. c. Use and allocation of the 'pure water' product. d. Concept of disposing of excess water into the Avon River and ecosystem changes. e. Impact of the use of additional irrigation water in the valley.	The RO facility for treating wastewater and irrigation/stock reuse was outlined in the original (exhibited) EA and is covered under the Part 3A approval. No further planning approvals are required. AGL has provided the community with the further opportunity to comment on the extracted water proposals with the exhibition of this EWMS.	No	NA
P004	Local Community Member	19/09/2014	It is only by preparing an EIS and related DA that the community will have any confidence in this development of a RO plant. Without such a level of scrutiny there will be considerable community opposition and a further issue against AGL's "social licence" to operate in the area.	Noted. The EWMS has been exhibited twice (AGL only received two community submissions on the Consultation Draft)	No	NA
P005	Local Community Member	19/09/2014	The irrigation water should be made available to irrigators that decide to initiate a new industry such as growing (and Processing) industrial hemp. This water should be at below market rates to enable an industry to start and then purchase commercial water as the RO volume decreases. By doing this AGL would indicate a real commitment to supporting the Gloucester area. The processing plant would also be a potential market for energy and an employment source in the area. Further information on this will be available in the Agricultural Strategy that Gloucester Shire will release in October 2014.	The expected treated water volumes are very small (now < 0.9 ML/d) and will diminish as the field matures. There is insufficient water for any substantial new industry - start up water maybe available together with supplementary water to existing irrigators. AGL is committed to an Expression of Interest process to gauge interest in beneficially reusing all available water.	Yes	Section 5
P006	Local Community Member	19/09/2014	The concept of using the "clean water" environmental dam storage at Stratford mine should be considered as a way of storing water when not being used by irrigators in the winter. This would also expand the volume of irrigation water available for a new irrigation crop industry	Not commercially viable for very small volumes of treated water. Would require a modification to the EA and the current project approval for the Stage 1 development	No	NA
P007	Manning Valley Community Member	17/09/2014	Likely discharge of CSG (produced) water into the Manning River catchment	There will be no discharge of untreated extracted water to the Avon River (or anywhere within the Manning catchment). All extracted water will be treated to meet a target water quality that is suitable for local irrigation, stock and stream discharge.	Yes	Sections 5.5, 9.2 and 11.6.2
P008	Manning Valley Community Member	17/09/2014	Size and cost of a desalination plant	The FEED for the Stage 1 gas development and the basis of design for the WTP have been prepared, however tenders will not be called for until an investment decision is made on the project. The RO desalination plant is likely to comprise 2 x 0.6 ML/d modular units given the lower produced water volumes that are likely. No costs are currently available.	No	NA

Issue No.	Submission By	Date Received	Issue/Comment	AGL Response	Amendment to Report (Yes/No)	Relevant Section
P009	Manning Valley Community Member	17/09/2014	Desalination is a public relations exercise, not a serious proposal from AGL	The desalination plant is a confirmed component of the WTP infrastructure and the industrial development at the CPF. The project cannot proceed without a desalination plant and an approved extracted water management strategy.	Yes	Section 5 and Section 11
P010	Manning Valley Community Member	17/09/2014	No development consent for a desalination plant	The RO facility for treating wastewater and irrigation/stock reuse was outlined in the original (exhibited) EA and is covered under the Part 3A approval. No further planning approvals are required AGL has provided the community with the further opportunity to comment on the extracted water proposals with the exhibition of this EWMS	No	NA
P011	Manning Valley Community Member	17/09/2014	CSG water contains contaminated salts while seawater contains non-toxic sea salt	This is not the case. The CSG produced water is formation water from sedimentary rocks that were mostly deposited in estuarine and shallow marine environments. The salts in the deep groundwater are exactly the same salts that you find in seawater today.	No	Section 6. Community is also referred to the September 2014 Fact Sheet on Heavy Metals and the environment where different water sources and water quality across the catchment were tested (including produced water and seawater)
P012	Manning Valley Community Member	17/09/2014	There is no landfill or licensed facility for the disposal of salt	There are no assays currently available for the salt likely to be derived from the extracted water. It is premature to talk to licensed facilities about the potential for landfilling this general solid waste until there is an approved EWMS, there is an investment decision to proceed, and salt assays are available.	No	NA
P013	Manning Valley Community Member	17/09/2014	Removal of boron from extracted water	The desalination plant will be designed with membranes to deal with boron concentrations in the range 0.08 to 22.4 mg/L	Yes	Section 6.5 and Appendix D
P014	Manning Valley Community Member	17/09/2014	Will Stages 2 and 3 overlap with Stage 1	There is no approval to construct any subsequent stages beyond the Stage 1 GFDA at this time. The CPF compressor plant and pipeline capacity will be limited so an expansion beyond the expected production rates of the Stage 1 development are unlikely. New wells will come on line after the first wells decline in production within the Stage 1 area however the total number of operational wells is unlikely to ever exceed 110 wells.	No	NA

Appendix B – Water Balance Modelling Report (Worley Parsons)

WorleyParsons
resources & energy

EcoNomics™

AGL ENERGY LTD

AGL Gloucester Gas Project

Water Balance Modelling Report

401015-00130 – GL4-RPT-H-0003

21-Jul-2015

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SYNOPSIS

A water balance model has been developed to simulate the transfer, storage and management of water extracted from the planned 110 CSG wells in AGL's Gloucester Gas Project. The model was used to assist in the development of the Extracted Water Management Strategy and the sizing of the associated water handling and treatment infrastructure. The model reports results for key system outcomes, such as pond levels, transfers between unit processes and irrigation loads etc. It also calculates volumes and timings of discharges to local waterways, if any.

The model was used to simulate a range of loading, equipment and infrastructure sizing and control philosophy cases to explore the likely response of the system to stochastic influences, such as rainfall and equipment failure. The study found that:

- RWP and DWP volumes of 13 ML (to the overflow level) are expected to be adequate;
- An irrigation area of 60 Ha is expected to be adequate;
- Frost and irrigation area soil type are not expected to be key system determinants;
- Approximately 11 ML of initial storage is required to meet the working water demands;
- The nominated 1.2 ML/d capacity of the WTP, with a 95% availability appears adequate;
- For the system as modelled, for the 90th percentile extracted water production profile and the worst case climatic conditions, it is expected that about 1% of the (treated) total extracted water flow will need to be released to the environment via the Avon River Release Point. The remaining water may be reused for irrigation and stock watering etc.
- No environmental release is expected for the 50th or 10th percentile extracted water production profiles under any climatic conditions; and
- Untreated water was fully contained in the Receiving Water Pond and the Tiedman's East Dam for all scenarios modelled under all climatic conditions.

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PROJECT 401015-00130 - AGL GLOUCESTER GAS PROJECT

REV	DESCRIPTION	ORIG	REVIEW	WORLEY-PARSONS APPROVAL	DATE	CLIENT APPROVAL	DATE
B	Issued for Review	G Gloag	R de Vos		17-Jun-15	N/A	
C	Issued for Review	G Gloag	R de Vos		2-Jul-15		N/A
D	Issued for Review	G Gloag	J Ross		17-Jul-15		N/A
0	Issued for Use	G Gloag	R de Vos	J Ross	21-Jul-15		

CONTENTS

Appendices

ABBREVIATIONS

Term	Definition
BoM	Bureau of Meteorology
CPF	Central Processing Facility
CSG	Coal Seam Gas
DWP	Discharge Water Pond
EC	Electrical conductivity
ET/ET_o	Evapotranspiration
EWMS	Extracted Water Management Strategy
FAP	United Nations Food and agricultural Organisation
FEED	Front End Engineering Design
GFDA	Gas Field Development Area
GGP	Gloucester Gas Project
IX-regen	Ion exchange regeneration waste water
PontD	Pontiland's Dam
RO	Reverse osmosis
RWP	Receiving Water Pond
TDS	Total Dissolved Solids
TED	Tiedeman's East Dam
TN&SD	Tiedeman's North & South Dams (combined)
TND	Tiedeman's North Dam
TSD	Tiedeman's South Dam
TWL	Top water level
TWS	Treated Water Storage/Tank
WTP	Water Treatment Plant

1 INTRODUCTION AND OVERVIEW

1.1 Overview

AGL's *Extracted Water Management Strategy* (EWMS) (AGL, 2014) details how AGL will manage water extracted from coal seam gas (CSG) wells associated with the Gloucester Gas Project (GGP). A water balance model was developed to inform the development of the EWMS. The water balance model was prepared to simulate the transfer, storage, management and beneficial reuse of water extracted from the CSG wells and treated in the Water Treatment Plant (WTP). The water balance model identifies inflows and outflows to the water handling and management infrastructure and assists in the development and timing of the required treatment and management infrastructure.

In this report (and in the EWMS), extracted water is the term used to describe both flowback and produced water from the CSG wells.

1.2 Scope

This Water Balance Modelling Report has been prepared as an appendix to the EWMS. This document presents the methodology adopted to develop the water balance model, the model outputs for various scenarios as well as the key inputs and assumptions on which the modelling is based. Summary details regarding the results of the water balance modelling and discussion regarding project water handling infrastructure are provided in the EWMS.

The scope of the water balance modelling covers the following:

- Receival and storage of the extracted water from the 110 CSG wells forming Stage 1 of the GGP; and
- Transfer of water between the various elements that make up the system, including the storage ponds/dams, the water treatment plant, the irrigation area and environmental releases.

1.3 Changes to the water balance model

A spreadsheet based water balance model was developed during the FEED stage of the project to provide a preliminary, basic understanding of the system. However it had several limitations which reduced its usefulness, including:

- It was based on a weekly balance and consequently was relatively coarse;
- The balance did not allow the impacts of infrequent, large rainfall events to be assessed; and
- A very simple irrigation model was used.

Consequently, when a new water production profile was developed, a new water balance model was developed to address these issues and to provide sound basis for the water balance, using a more refined daily time step. The basis and assumptions of the new model are set out in this report.

1.4 Objectives

The objectives of the water balance modelling are to:

- Assess the proposed water handling and treatment infrastructure against expected extracted water inflows;
- Provide a basis to optimise the sizing of the new water handling and treatment infrastructure;
- Assist the development of appropriate water management options, which maximise beneficial reuse;
- Report flows of the key streams in the water handling and treatment process;
- Develop projections for key project performance indicators, including:
    - Irrigation application rates; and
    - Timing and rates of disposal to local waterways.
- Report performance under a range of scenarios representing various operating conditions, such as:
    - High rates of CSG water extraction;
    - High rainfall; and
    - Changes in the WTP performance.
- Investigate potential risks.

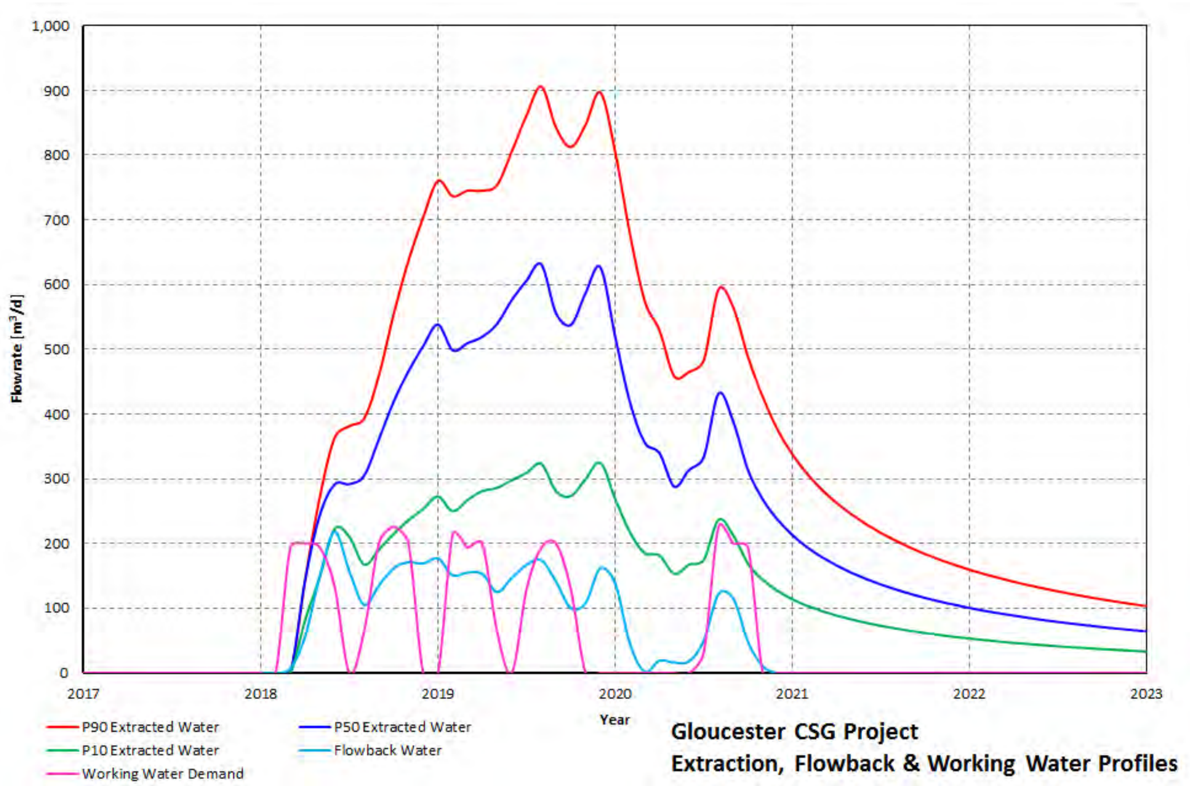
1.5 Key modelling assumptions

The key assumptions and other basis information for the modelling are summarised below:

- The extracted and flowback water production rates as well as the working water demand are summarised in Figure 1-1 for the P90, P50 and P10 cases. The working water demand leads the production and flowback water profiles slightly, while the flowback water peaks match those of the extracted water profiles. The flowback water profile is shown for completeness only as these flows are included in the extracted water profiles. The time period shown in this figure has been limited to 2017 - 2023 to highlight the peak flow and well development programme. The actual profile extents out until 2050;
- 110 wells in total. 13 wells are understood to already exist as part of the pilot programme and consequently 97 wells will be drilled and fracture stimulated as part of the Stage 1 development;
- The well drilling programme will occur over a 24 month period, commencing in April 2017 (water for drilling is not included in the water balance model). Fracture stimulation is scheduled to commence in March 2018 and will be complete by October 2020 (31 months) and water for (and from) the stimulation programme is included in the model. Since the drilling and fracking programmes overlap, the combined construction period is 42 months;
- The WTP's supply specification calls for a plant with a capacity of 1,200 m^3/d, and an availability of 95%. As this is unlikely to be achievable in a single train, for model simulation purposes, it is assumed that the WTP will consist of 2 independent trains configured in a lead-follow arrangement, with each train having a 600 m^3/d capacity. Each train will have an availability of 90%, to match the specification requirements;
- Nominal pond sizes (to the design top water level) are:

  - Receiving water pond: 10,500 m^3 (subject to change);
  - Treated water storage: 1,000 m^3 (subject to change);
  - Discharge water pond: 10,500 m^3 (subject to change);
  - Tiedeman's North Dam: 18,200 m^3
  - Tiedeman's South Dam: 18,200 m^3
  - Tiedeman's East Dam: 20,200 m^3
  - Pontiland's Dam: 50,000 m^3 (approximate)
- A nominal irrigation area of 60 Ha.

Figure 1-1: Water production and demand profiles



1.6 Hold points

Some information is outstanding or has not yet been fully investigated. This includes:

- The final locations and consequently the sizes of the WTP ponds and tanks have yet to be decided;
- The influence of salinity has not been directly investigated, either as a result of changes in the salinity of the extracted water or the impact of rainfall. An order of magnitude impact of water chemistry is investigated however as a reduction in the WTP's capacity.

2 WATER HANDLING INFRASTRUCTURE

The key water handling and treatment process are:

- Water gathering and storage;
- Water treatment (including brine management); and
- Water management.

2.1 Water gathering

The water received at the Water Treatment Plant (WTP) comprises two components, each with a distinct flow profile over time:

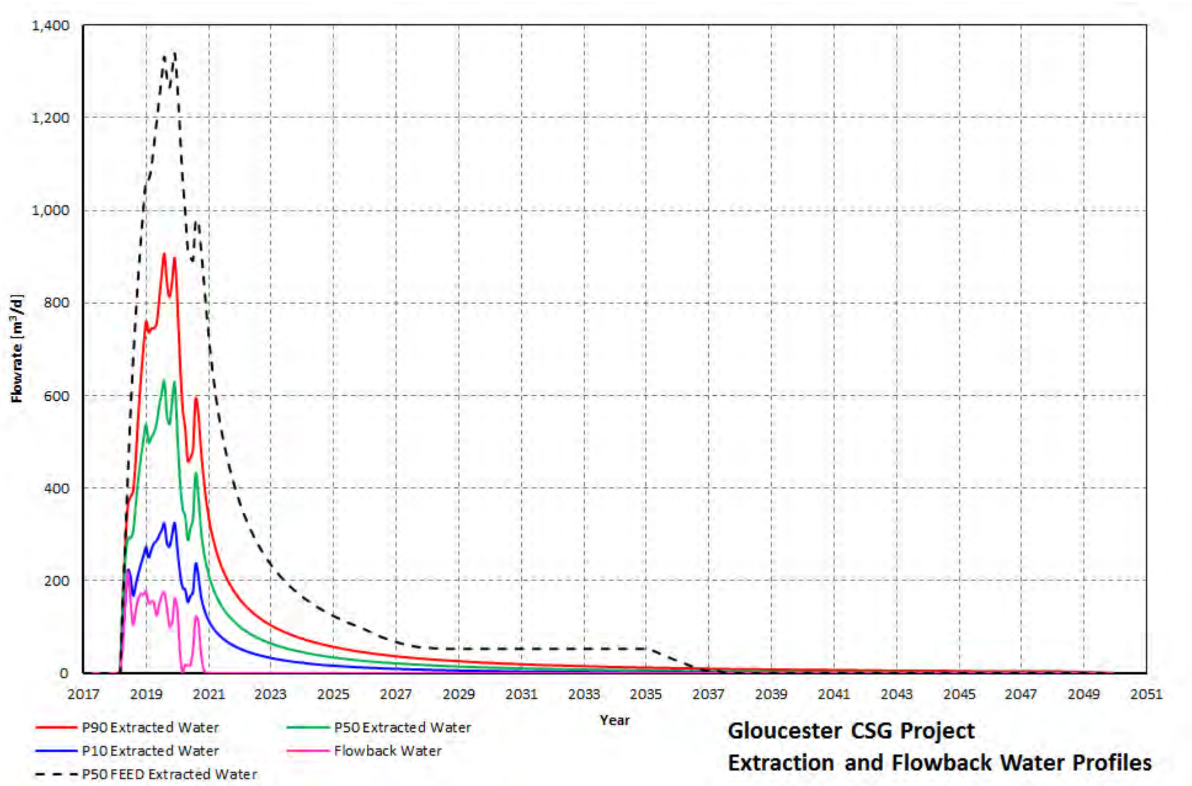
- *Extracted water:* The rate of extracted water production from each CSG well varies with time and the location and nature of the target coal seam. Typical CSG extracted water profiles peak soon after dewatering begins and then exponentially decline over time. AGL have provided expected P10, P50 and P90 water extracted profiles for the 110 wells in the Gloucester Gas Project (GGP) area. These profiles represent the probability that the actual extracted water profile does not exceed the forecast profile. That is, the P90 extracted water profile denotes the profile which is expected to exceed 90% of the forecast extracted water profiles. The P50 profile gives the median or best estimate of the expected profile, with the actual profile having a 50% chance of being greater or less than the forecast. The P90 case is often used for infrastructure sizing purposes.
- *Flowback water (a component of extracted water):* Flowback water is generated primarily as a consequence of the hydraulic fracking procedures used to fracture the coal seam and prepare it for gas production. The water and fracking fluid pumped into the well is recovered over time, with the following typical profile assumed:
    - 20% of the fracking water is recovered in the first 3 days; and
    - The remaining water is recovered over the next 3 months.

Extracted water profiles for the GGP were developed by applying the P10, P50 and P90 type curves to each well in the gas field. Flows from each well are accumulated based on the drilling schedule to produce the daily flowrates. Similarly, the expected flowback water profile was developed from the fracking programme for each well in the project. This data is shown graphically in Figure 2-1. Also shown in the figure is the P50 profile developed for the FEED study, which is given for completeness only.

The extracted water profiles (as given in Figure 2-1) include the impacts of flowback water.

The profiles show production beginning in April 2018 (after the commencement of the fracture stimulation programme), with water production rising rapidly and peaking in mid to late 2019, at about 900 m^3/d (for the P90 case) before tapering down. The flowrate is expected to reduce to approximately 10% of the peak flow by 2023 – just over 5 years after production commences.

Figure 2-1: Expected extracted and flowback water profiles



2.2 Oily water and condensate from the CPF

Water and condensate water arriving at the Central Processing Facility (CPF) with the gas stream is separated and after preliminary treatment is directed to the Receiving Water Pond pending further treatment and disposal. The quantity of water received in this way is assumed to be 5% (adjustable) of the extracted water flowrate.

2.3 Water storages

Several storages will be either constructed or re-purposed to receive and contain water prior to treatment and reuse. The storage volumes and dimensions are given in Table 3-6. The principal storages are:

- Receiving Water Pond (RWP): A new, double lined pond, receiving extracted water from the gathering system and storing it pending treatment in the WTP. The inflow to this pond is diverted to the Tiedeman's East Dam when it is full;
- Treated Water Storage Tank (TWS): New covered and lined storage tank(s) receiving treated water from the WTP and providing a storage for water conditioning to occur. The outflow from the TWS is directed to the Discharge Water Pond;

- Discharge Water Pond (DWP): A new double lined pond receiving flow from the TWS, and holding conditioned water, pending it being transferred to the Tiedeman's North and South dams for reuse;
- Tiedeman's North and South Dams (TN&SD): Existing lined dams used to store the conditioned water pending irrigation and reuse. For modelling purposes, these dams are assumed to be a single unit;
- Tiedeman's East Dam (TED): An existing double lined dam. Extracted water will be diverted to the TED if insufficient capacity is available in the RWP. In the modelling scenarios it is assumed that the TED is full of extracted water from the pilot testing programmes. This water will be pumped through the WTP and stored in the DWP prior to the gas wells being fracture stimulated. This stored water will then be used to meet the initial working water demand;
- Pontiland's Dam (PontD): An existing unlined farm dam, used for the storage of rainwater runoff. Water from this dam may be used to assist in meeting the working water requirements, primarily for drilling.

2.4 Water treatment

The water treatment plant (WTP) itself is only modelled to the extent that it impacts on the overall water balance, which includes:

- The WTP's overall recovery (i.e. the fraction of the water directed to the plant and passes through it as treated water). The recovery is a function several factors, including the feed water salinity, the pre-treatment requirements, temperature, membrane selection and the ions present etc.;
- The WTP's availability. Given the plant is likely to be relatively complex, with multiple, dependent process units, 100% availability of each train is unlikely to occur.

Water received at the WTP will pass through various treatment processes to produce a high quality water, suitable for reuse or release to the environment. Treatment processes, may include coagulation and settlement (or flotation) for the removal of sediment, ultrafiltration for the removal of particulate material, ion exchange for the removal of di-valent compounds and silica, reverse osmosis for the removal of salts and conditioning to produce a stable, balanced water. With the exception of conditioning, each step of the process will produce a product and one or more waste streams, which require further treatment or disposal. Currently it is assumed that all waste streams will be recycled internally to the WTP, with the exception of the dewatered solids (i.e. sediment etc. removed in the clarification stage). These waste streams, along with the dewatered mixed salt product will be directed to offsite disposal. Consequently, the model assumes no recycling from the WTP RWP.

2.4.1 Treated water management

It is intended that treated water will primarily be reused for irrigation of crops and pastures on local properties adjacent to the existing Tiedeman's irrigation area. Secondary uses include water for industrial and stock water uses. Surplus treated water generated during high rainfall periods will be discharged to the Avon River.

2.4.2 Brine management

The water treatment process will generate a brine stream containing salts from the extracted water, with a salt concentration of approximately 10 times the extracted water concentration. This brine stream will be further concentrated using brine concentration and crystallisation to produce a mixed salt product which can be disposed of to an appropriate solid waste landfill.

3 MODEL CONFIGURATION

3.1 Structure

A bespoke water balance model was developed using Intel Fortran-95, using a daily time step. At each time interval, the model accounts for all inflows and outflows from each storage node. The storages modelled are:

- Receiving Water Pond (RWP);
- Treated Water Storage Tank (TWS);
- Discharge Water Pond (DWP);
- Tiedeman's North and South Dams (TN&SD) (modelled as a single unit);
- Tiedeman's East Dam (TED); and
- Pontiland'sDam (PontD). Since this dam receives only rainfall runoff, and is used only intermittently to meet working water demand (in particular on startup), Pontiland's is not an integral part of the water balance model.

The physical and modelling arrangements are given in model's structure is given in Figure 3-1 and Figure 3-2. Figure 3-1 shows how the water infrastructure is physically connected, which differs slightly from the model configuration, with the principal differences being:

- Water is stored is Pontiland's Dam, which may be used to meet the working water demands, in particular at startup (i.e. when the working water demand exceeds the extracted water supply, See Figure 1-1). Pontiland's dam is an existing unlined farm dam with a runoff catchment of approximately 250 Ha and consequently naturally overflows during large wet weather events. The captured water is used for stock watering as well as irrigation. Since:
    - The dam receives no flow from AGL's CSG water gathering or treatment systems;
    - The inflows and outflows cannot be determined accurately;
    - The dam is unlined and overflows naturally in normal operation.

  the Pontiland's dam is not modelled and is not part of the water balance. However, the volume is tracked, assuming it is lined and that the only inflows and outflows are rain falling directly on the dam and evaporation from the water surface. The model assumes that all working water demands can be met from the DWP and the TN&SD.

- The actual arrangement of the Tiedeman's North and South Dams is more complex than is modelled. In reality, although inflow can be directed to both dams, irrigation water is drawn from TSD only. Bi-directional flow is allowed into and out of TND. For modelling purposes, TND and TSD are assumed to be a single dam. This is not expected to significantly impact the results;
- The model includes overflows from each dam or pond to allow a mass balance to be developed. This does not necessary imply that an overflow from a given pond/dam actually exists, or that an overflow will be allowed to occur in practice.

Figure 3-2 shows the interconnectivity between the process units as modelled and the capacities of major infrastructure units (note that the storage volumes given in the figure refer to the overflow volumes rather than the design top water levels). All connections with a stream number are calculated on a daily basis. The model only considers those storages shown in Figure 3-2. Any local storages (if any) located in the gathering system or elsewhere are excluded.

The passage of water through the system is described as follows. All extracted and flowback water is directed to either:

- The RWP, in normal circumstances;
- The Tiedeman's East Dam, when the RWP is full. The TED provides additional containment, in the event of a potential overflow of the RWP. TED is not expected to be used in normal circumstances, as it provides a storage of last resort, and is only expected to be used in the event of prolonged wet weather or a prolonged shutdown of the WTP. Flow directed to the TED is returned to the RWP at a low rate (when volume is available).

Return streams from the WTP are either recycled internally or directed to the RWP. From the RWP, the water is pumped to the WTP, where it receives treatment for salt removal.

The water recovery in the WTP is modelled as simple factors of the feed stream, with a portion of the rejected water returned to the RWP for re-processing. The low TDS, treated water from the WTP is directed to the Treated Water Storage Tank (TWS) from where it is pumped or overflows to the Discharge Water Pond (DWP). Conditioning chemicals are added to the TWS to ensure the water has the right salt balance and pH value for reuse.

Water in the DWP is pumped to individual gas wells (or groups) to satisfy the working water requirements. This water that is delivered via these working water lines is primarily used for fracking and for stock watering, with the majority of the fracking water returned to the water treatment system 'flow-back' water). Water surplus to the working water requirements is pumped to the Tiedeman's North and South Dams for storage pending irrigation or being directed to the environment (i.e. pumped to the Avon River Release Point) when the system's storage capacity is exceeded and irrigation is not possible.

For modelling purposes, the RWP, DWP, TN&SD, TED and the PontD are allowed to overflow to the environment (i.e. to the nominated stream discharge locations) when the storages are full. However, it is understood that in practice the RWP and the TED will not be allowed to overflow and that the gas production wells will be shutdown to prevent an overflow.

Figure 3-1: Water treatment infrastructure physical arrangement

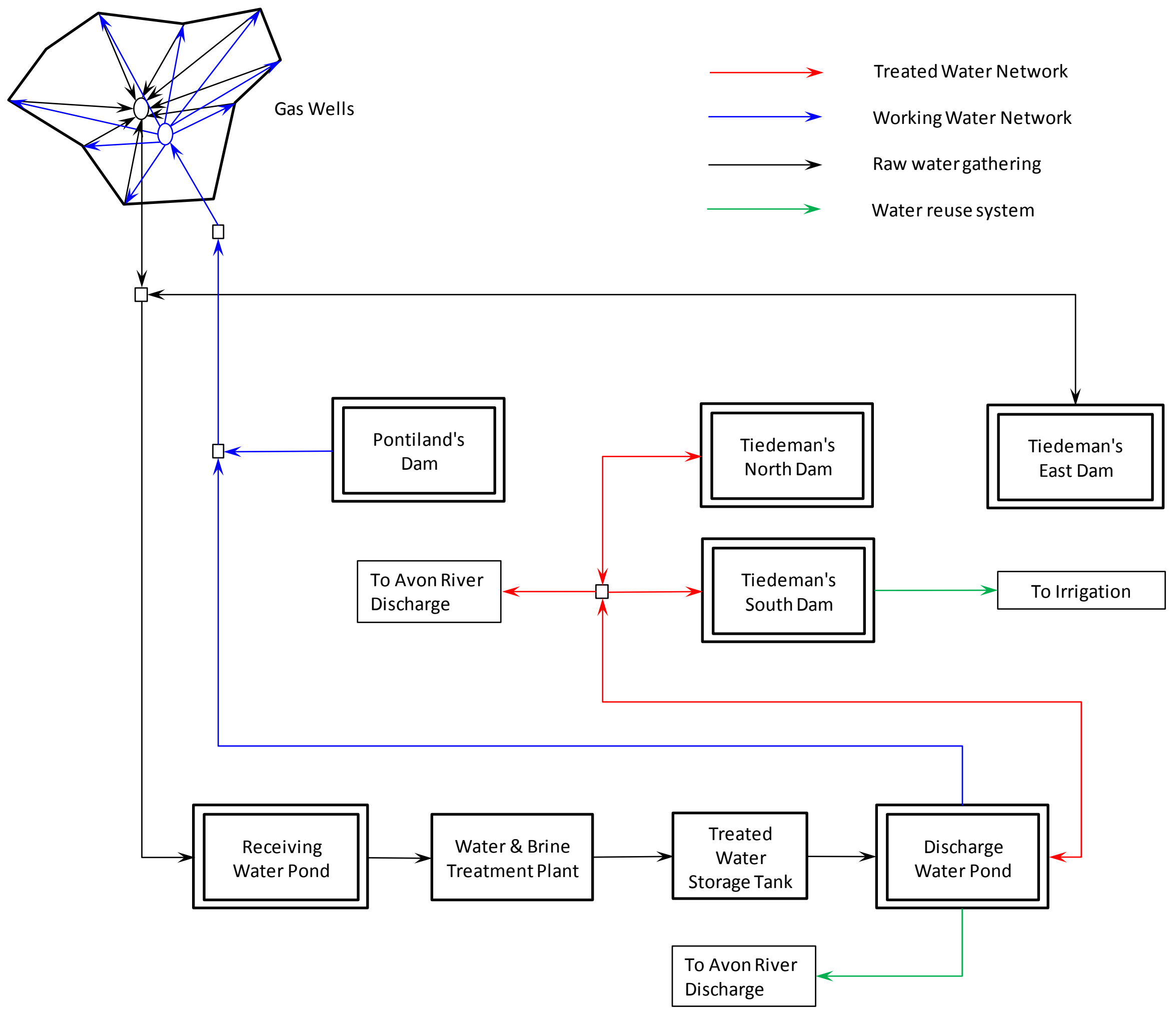
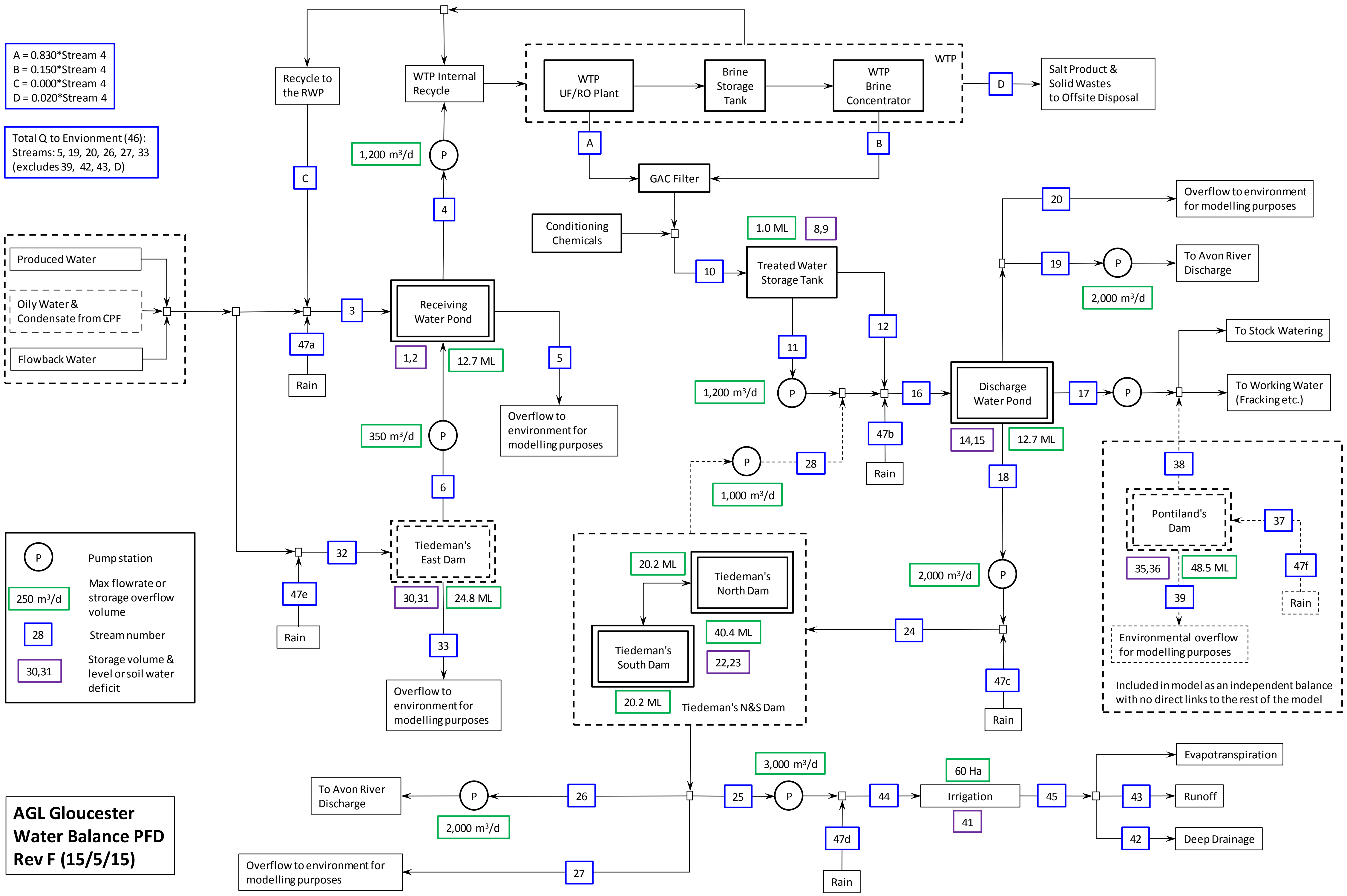


Figure 3-2: Water balance model configuration



All storages are assumed to be fully lined and leak proof. All ponds and dams are assumed to be open to the atmosphere and subject to the impacts of rainfall and evaporation, however the TWS and the Brine Storage Tank (BST) are assumed to be covered tanks (and therefore immune to weather impacts).

The model only considers flow into the system from the gathering system, rainfall and returns from the WTP. It is assumed that the ponds and dams are constructed such that they receive no overland inflows, or inflows from other (external) sources. Similarly, the only outflows from the system are evaporation, irrigation, working and stock water and flows to the environment via overflows or pumped discharges. No other water demands are allowed.

3.2 Modelling approach

The modelling approach adopted produces a 'hydrograph' of the system's performance for a given climate data set. Approximately 130 years of daily climate data is available (see below), giving a similar number of hydrograph profiles. This data set is then assessed to select the profiles of interest, which are then reported.

Thus assuming the first climate data set available begins in 1889, a daily water balance is undertaken using the expected water production schedule (starting on the 1st January 2017), with the climate data shifted to match the production schedule. This gives a single hydrograph, defining all the parameters given in Figure 3-2. The water balance is then repeated using the climate data set starting in 1890, to give a second hydrograph. A third hydrograph is obtained using climate data beginning in 1891 and so forth for all the available climate data set start years (until 2015).

Since the production schedule is several years long, insufficient data is available for the later climate years (e.g. for 2015, climate data is only available for the period January to March). Consequently, the additional data is filled in using data from the start of the period (in this case climate data from 1889 and so forth).

Once all the profiles are available, they are searched to select profiles of interest. In this case, the objective is to minimise the volume of water directed to the environment from pond overflows etc. Consequently, the model searches the profiles for those giving the nominated percentile flows to the environment (for example the profiles giving the minimum, 10th, 50th, 90th and maximum (or other percentiles as appropriate) flows to the environment). This data is then presented in an excel readable format for additional processing such as graphing and tabulation etc.

Inspection of Figure 2-1 indicates that the extracted water profile has a very long, slowly diminishing tail. Consequently, for modelling purposes, production or extracted water is assumed to cease on the 1st January 2038 – a total production run of 21 years. This reduces the amount of data to be managed, and has little impact on the validity of the results.

The model gives a realistic interpretation of how the system would behave, in any of the preceding 130 years. Since the model is based on historical data, which in general will not encompass the complete climate variability, it cannot be said with absolute certainty that a future year will not generate a greater environmental discharge than any of the past years. However as the climate set is reasonably large, and the critical water production period (i.e. the 5 year period incorporating the peak flows) is relatively short, the risk of significantly under predicting the system's performance is small.

Plant availability is incorporated using a pseudo-random number generator. On each day of the simulation, a uniformly distributed random number is generated which represents the probability that the equipment will be available on that day. This allows the model outputs to be adjusted to reflect the expected planned and unplanned equipment maintenance schedules, in a relatively simply way.

3.3 Water balance

The water balance assumes that the ponds/dams are commissioned and filled to their initial starting volumes on a nominated day. From this point forward, until the WTP is commissioned they will be subject to inflows from the gathering system (if any) and rainfall, while outflows are limited to transfers between the ponds/dams (either controlled with pumps or via overflows etc.), evaporation and working water demands. Irrigation from Tiedeman's North and South dams is suppressed until the irrigation system commissioning date is reached. Once the WTP and the irrigation systems are commissioned, the system will function as described in Section 3.1.

Each pond/dam acts as a node, with the volume at the end of the day determined from the initial volume and the difference between the daily inflows and outflows. Evaporation from the ponds/dams is determined using the surface area at the start of the day, using the pan evaporation rate for the day in question. The pan rates were adjusted to estimate evaporation from dams using a factor of 0.75, as determined from data presented by Luke *et al*. 2003. Rainfall entering each pond is calculated from the climate data, using the top of bank pond dimensions.

3.3.1 Pond/Dam control strategy

On each day the flows into and out each pond/dam are calculated, using the following control structure (the actual control values used are given in Table 3-1):

Receiving Water Pond (RWP)

- The flow into the RWP is largely unrestricted, but with the following limits:
  - Extracted water from the gathering system is diverted to the TED when the level in the RWP is high; and
  - Return flows from the TED are suppressed when the level in the RWP is high;
- The flow out of the RWP is determined based on the volume in the pond:
  - When the pond is above a high volume cut off, both the lead and follow WTP trains will operate at their maximum capacities;
  - When the pond is above a mid-volume cut off, the lead WTP train will operate at its maximum capacity;
  - When the pond is above a low-volume cut off, the lead WTP train will operate at its minimum capacity;
  - When the pond is below the low volume cut off all WTP trains will be stopped;

- When the level in the TWS is above a high volume cut off, the WTP will stop if the level in the TED is below a cutoff value. If the level in the TED is above the cutoff value, the WTP will operate at the rate determined above (i.e. based on the level in the RWP), subject to availability limitations. This allows the storage potential of the TED to be utilised, while managing the risk of an overflow occurring.

The control strategy is intended to pump the maximum volume of water to the WTP, without allowing the pond to drain completely or generating long periods between operations. When the TWS is full, water will accumulate in the RWP, and potentially the TED. When the RWP & TED levels are high, the system attempts to pump raw water to the WTP irrespective of the levels in the TWS, DWP or TN&SD, thus preferentially directing treated water to the environment.

Treated Water Storage (TWS)

- Flows into the TWS are determined by the operation of the WTP;
- Flows out of the TWS are determined by the level in the storage:
  - Transfer to the DWP: The transfer pump will only operate if the level is above a high level cutoff and will stop if the level falls below a minimum value. The volume of water that can be pumped per day is limited to a maximum value;
  - The transfer to the DWP will be suppressed when the DWP is above the high volume cut off.

Essentially the control system emulates a simple level control system. When the DWP is full, water will accumulate in the TWS.

Discharge Water Pond (DWP)

- Flow into the DWP is as described above (and in the TN&SD section below for the augmentation of the working water supply), however water can overflow from the TWS in an uncontrolled manner as necessary;
- Flow out of the DWP is controlled as follows:
  - The working water pump's operation has preference and it will operate on demand according to the programme schedule, with the pump starting if the volume is above a mid-volume cut off. The working water pump will lower the pond to an adjustable minimum level in an attempt to meet the working water demands;
  - Flow is pumped at a fixed rate to the TN&SD when the DWP volume is above a high-volume cut off value;
  - Flow is pumped at a fixed rate to the Avon River Release Point when the DWP volume is above a high-high volume cut off value and the TN&SD is full;
  - Flow to the TN&SD is suppressed when the volume in the dam is above a high level cut off.

The control system maintains a reserve volume of water in the pond to meet the working water requirements but otherwise attempts to minimise the volume in the DWP, transferring water to the TN&SD when volume is available. Water will accumulate in the DWP when the TN&SD is full, and will eventually be pumped to the Avon River. In principle, the excess water could be pumped to the TN&SD and discharged to the Avon River from there if desired.

Tiedeman's North & South Dams ((TN&SD) These dams are modelled as a single entity)

- Flow into the dam is as described above;
- Flow out of the dam is controlled as follows:
    - Working water demands (i.e. those demands that cannot be drawn from the DWP) are met first, by pumping water from the dam to the DWP (there is no direct connection between the TN&SD and the working water network). Pumping allowed if the dam volume is above a low level cut off;
    - Flow is pumped to irrigation, as described in Section 3.4, when the volume is above a mid-volume cut off value;
    - Flow is pumped at a fixed rate to the Avon River Release Point when the dam volume is above a high volume cut off value.

The control system attempts to direct water to reuse (either for working water, stock watering or irrigation), until the level in the dam reaches a high level value, after which a fixed amount per day is pumped to the Avon River Release Point.

Tiedeman's East Dam (TED)

- Flow into the dam from the gathering system only occurs when the RWP is full and the flow is diverted to the TED. For modelling purposes is unrestricted, however in reality it is understood that the gas wells will be shutdown to prevent further water inflow into the TED when this dam is nearly full;
- Flow is pumped to the RWP when the level in the dam is above a cut off value and the volume in the RWP is below a cut off value;
- Evaporation from the dam is stopped when the level falls below a minimum value.

The control system attempts to minimise the volume in Tiedeman's East dam, by pumping the water back to the RWP as soon as possible – but without unduly overloading the RWP.

Pontiland's Dam (PontD)

Currently, no control system is imposed on the Pontiland's Dam, with the exception that evaporation from the dam is stopped when the level falls below a minimum value.

3.3.2 Pond/Dam level control values

As described above, the model attempts to maintain the pond and dam volumes within certain limits. These limits are summarised in Table 3-1. For each pond/dam, the volume fraction is compared to the overflow level. The associated water depths at each control volume are also given.

Table 3-1: Pond/Dam level control limits

No.	Limit Description	Stream No. (Fig 3.2)	Volume[1] [%]	Volume[1] [m³]	Level [m]
Receiving Water Pond (RWP)				12,718	4.50
1	Level above which the lead and follow WTP trains operate at their maximum capacities	4	55	6,995	3.05
2	Level above which the lead WTP train operates at its maximum capacity	4	40	5,087	2.44
3	Level above which the lead WTP train operates at its minimum capacity	4	20	2,544	1.45
4	Level above which extracted water is diverted to TED		83	10,556	4.00
5	Level below which the WTP feed pump is suppressed when the TWS tank is full	4	70	8,903	3.58
6	Level above which the TED to RWP (return) pump is suppressed	6	75	9,539	3.75
Treated Water Storage Tank (TWS)				1,000	3.50
1	Level above which the WTP feed pump is suppressed	4	90	900	3.15
2	Level above which the TWS to DWP pump will start	11	25	250	0.88
3	Level below which the TWS to DWP pump will stop	11	5	50	0.18
Discharge Water Pond (DWP)				12,718	4.50
1	Level above which the TWS to DWP pump is suppressed	11	85	10,810	4.06
2	Level below which the working water pump is suppressed	17	4	509	0.36
3	Level below which the DWP to TN&SD pump is suppressed	18	25	3,180	1.72
4	Level above which the Avon River discharge pump will start	19	95	12,082	4.36
Tiedeman's North and South Dam (TN&SD)				40,418	4.00
1	Level above which the DWP to TN&SD pump is suppressed	18	90	36,376	3.69
2	Level above which the TN&SD to DWP (working water flow return) pump is suppressed	28	4	1,617	0.23
3	Level above which the irrigation feed pump can start	25	12	4,850	0.66
3a	Level below which the irrigation feed pump will stop	25	8	3,233	0.45
4	Level above which the Avon River discharge pump will start	26	95	38,397	3.85
Tiedeman's East Dam (TED)				24,800	4.88
1	Level below which the TED to RWP (return) pump is suppressed	6	8	1,984	0.64
2	Level below which evaporation is suppressed in the TED		2	496	0.17
Pontiland's Dam (PontD)				50,360	4.50
1	Level below which evaporation is suppressed in the PontD		2	1,007	0.12

1. Volume fraction is to the overflow level

3.4 Irrigation model

The irrigation system is modelled using the method presented in Allen *et al.* (1998). This model was developed by the United Nations Food and Agriculture Organisation (FAO), and presents a step by step procedure for estimating crop evapotranspiration rates. The procedure involves calculating the base evapotranspiration rate (ET_0), which would be expected for a reference crop growing under ideal conditions. This rate varies based on the climatic conditions, site location and solar radiation etc. The FAO report presents several correlations for the calculation of ET_0, with the model using the Penman-Monteith method, which is reported to be the most accurate. A 10% safety factor (adjustable) is applied to the calculated ET_0, value to ensure some degree of conservatism.

Once the ET_0 value is known, it is corrected for the type of crop expected to be grown in the AGL irrigation area. In this case, a permanent pasture grass is assumed, over sown with a suitable winter crop to ensure that evapotranspiration does not fall to very low values over winter.

The method selects several factors which define how the soil will behave with respect to its moisture holding capacity. These factors are used to correct (reduce) the ET_0 value to reflect the non-ideal conditions in the actual soil:

- *Field capacity* of the soil, which represents the amount of water the soil can hold under freely draining conditions – i.e. this gives the maximum soil moisture content that can be maintained against gravity. It differs from soil saturation, in that the spaces between the soil particles are filled with both water and air, whereas under saturated conditions, the spaces contain only water. Saturated soils will typically drain to the field capacity within 1 to 2 days. This is a soil based parameter that is independent of the crop. The field capacity varies between about 7% for sand and 44% for heavy clay
- *Wilting point,* which is the value at which the soil moisture content is too low for the plant to draw water from the soil. Typically about half of the water in the soil at field capacity is held too tightly to be accessible to plants. This value is primarily dependent on the soil structure, but also to some degree on the type of crop. Typical wilting points vary from about 2% for sand to 26% for heavy clays;
- *Total available moisture content,* is the difference between the field capacity and the wilting point;
- *Readily available soil moisture content*, which is the point at which the crop growth is reduced as a result of the water in the soil becoming harder to access. Currently, a value of 55% of the difference between the field capacity and the wilting point is assumed; and
- *Root zone depth,* which is the depth to which the roots penetrate. Currently the root zone is set at 300 mm, which is suitable for a pasture type crop.

Soil texture data was obtained from the NSW Soil and Land Information Database for several locations adjacent the Tiedeman's Dams. Four of the sites were collected for the AGL-Tiedeman's survey undertaken in July 2011 and are for locations near the dam and trial irrigation area. The remaining 2 sites were from pits approximately 1.5 km to the north (Waukivory Cr.) and south (Wenham's Cox Rd.) of the dams, and were collected in 1996. Some laboratory measured field capacity and wilting point data was also available for the remote sites (however this data should be interpreted with caution as the soil structure and compaction etc. is altered during sample collection).

The data is summarised in Table 3-2, and indicates that the top soil horizon, which appears to extend from the surface to about 0.2 m, has a silty loam or silty clay loam texture. The next horizon, which extends to between 0.3 and 0.5 m deep has a predominantly silty loam texture, with some silty-clay-loam and some light clay. The deeper layers are predominantly light to light-medium clays.

Typical field capacity and permanent wilting point values were obtained from the UNSW TerraGIS website and are given in Table 3-3 for a range of soil textures. These values are not too dissimilar to the measured values, at least for the field capacity, given in Table 3-2. Based on these values, the model uses a field capacity of 30%, and a permanent wilting point of 18%, which are consistent with the soil textures in the top 2 horizons (down to about 0.4-0.5 m). This gives a total available moisture content of 12%, which is well within the normal range for most soils given in Table 3-3. Based on this data, the soil type would not be expected to be a critical determinant of the system's performance.

Table 3-2: Soil texture data

Parameter	Site					
	2	4	5	10	Wenham's Cox Rd	Waukivory Cr
Location	Near dams	Near dams	Near dams	Near dams	2.0 km south	1.3 km north
Map Reference	Dungog 9233	Dungog 9233	Dungog 9233	Dungog 9233	Dungog 9233	Dungog 9233
Easting	402697	402150	402178	402750	402205	402905
Northing	6448725	6449230	6449128	6448821	6447089	6450389
Layer 1						
- Depth [m]	0.00 - 0.15	0.00 - 0.20	0.00 - 0.15	0.00 - 0.20	0.00 - 0.10	0.00 - 0.10
- Texture	Silty clay loam	Silty loam	Silty loam	Silty clay loam	Silty clay loam	Clay loam sandy
- Field Capacity [%]					35	51.9
- Wilting Point [%]					13.8	13
Layer 2						
- Depth [m]	0.15 - 0.30	0.20 - 0.30	0.15 - 0.60	0.20 - 0.40	0.10 - 0.30	0.10 - 0.50
- Texture	Silty clay loam	Silty loam	Light clay	Silty loam	Silty clay loam	Silty clay loam
- Field Capacity [%]					30	43.1
- Wilting Point [%]					11.3	11
Layer 3						
- Depth [m]	0.25 - 0.95	0.30 - 0.50	0.60 - 1.50	0.40 - 1.00	0.30 - 0.60	
- Texture	Light clay	Light clay	Light medium clay	Light clay	Light medium clay	
- Field Capacity [%]					42.8	
- Wilting Point [%]					20.9	
Layer 4						
- Depth [m]	0.95 - 1.50	0.50 - 1.00		1.00 - 1.30		
- Texture	Light clay	Sandy clay		Light clay		
- Field Capacity [%]						
- Wilting Point [%]						

Although the irrigation model limits water application such that the field capacity is not exceeded, rainfall may cause the moisture content to rise above the field capacity. This 'excess' water (i.e. water applied above the field capacity) is assumed to flow to deep drainage (i.e. to drain below the crop root zone) or to run off the site. The model does not deterministically distinguish between runoff and deep drainage but instead uses an adjustable constant to separate the values. Currently the model assumes that 80% of the water applied above the field capacity will runoff the site.

Starting from an initial soil moisture content the model tracks daily variations in the moisture content owing to evapotranspiration and rainfall, and applies irrigation water (if available) when the soil moisture content falls below a nominated value. The model tries to ensure that the soil moisture content remains in the 'readily available moisture' range, such that the crop is never water starved.

Currently, irrigation is applied (when water is available) whenever the soil moisture content falls below 20% of the readily available moisture content.

Table 3-3: Field capacity and wilting point

Soil Texture	Field Capacity[1] [% by Vol]	Wilting Point [% by Vol]	Available Water [% by Vol]
Sand	7 - 17, 10	2 - 7, 5	5 - 10, 7
Loamy sand	11 - 19, 14	3 - 10, 5	8 - 9, 8.5
Sandy loam	18 - 28, 22	6 - 16, 11	12 - 14, 13
Sandy clay loam	24 - 32, 26	16 - 20, 18	8 - 12, 10
Loam	20 - 30, 25	7 - 17, 14	12 - 15, 13
Sandy clay	24 - 32, 26	16 - 26, 22	8 - 12, 10
Silty loam	22 - 36, 28	9 - 21, 15	11 - 15, 13
Silt	28 - 36, 32	12 - 22, 15	12-16, 14
Clay loam	22 - 32, 27	16 - 24, 20	6 - 12, 9
Silty clay loam	30 - 37, 33	17 - 24, 20	12 - 14, 13
Silty clay	30 - 42, 36	17 - 29, 25	12 - 14, 13
Light clay	25 - 32, 28	20 - 24, 22	5 - 8, 6
Medium clay	30 - 40, 35	22 - 26, 24	8 - 14, 12
Heavy clay	36 - 44, 40	24 - 28, 26	12 - 16, 14

Source: www.terragis.bees.unsw.edu.au/terraGIS_soil/sp_water-soil_moisture_classification.html

1. Range and typical (adopted) value

The model also considers rain and irrigation water lost to evaporation before impacting the soil moisture content. Currently rainfall events of less than 2 mm are assumed to have no soil impact, while the equivalent of 1 mm of irrigation water is lost to evaporation in each irrigation event.

Since a daily water balance is being used, the timing of the irrigation is important – i.e. irrigation can occur either early or late in the day. Early irrigation is assumed to occur before any rainfall, which may otherwise mean that irrigation is not required. This means that water reuse is maximised, however a greater portion is wasted to runoff and deep drainage. If irrigation occurs late in the day (i.e. after rainfall) or co-currently with rainfall, the runoff and deep drainage are reduced, but the volume of water that can be disposed of is also reduced. Currently, the model assumes that irrigation occurs early in the day.

Several factors limit the amount of irrigation water that is applied on a given day:

- Water availability: A minimum volume of water is retained in the irrigation dam (irrigation is suppressed when the level falls below 8% of the dam's volume), irrespective of the irrigation demand. Thus the irrigation amount is limited to the difference between the dam's current and minimum volumes;

- Irrigation demand: Irrigation will only occur if the soil moisture content falls below the nominated value. The amount is limited to the quantity required to raise the moisture content from its current value to the field capacity. This ensures that no irrigation water flows directly to deep drainage or to runoff – however runoff and deep drainage will occur if rain falls after irrigation and the field capacity is exceeded; and
- Irrigation system capacity: The flow of water to the irrigation system is limited to the pump and system capacity.

The actual amount irrigated is the minimum of the limits listed above.

3.5 Meteorological data

3.5.1 Data source

Daily climate data was obtained from the Queensland Government's 'SILO' database for the town of Gloucester, located at a latitude of 32 00'S and a longitude of 151 57'E and an elevation of 155 m (The proposed irrigation areas are located at elevations of between 100 and 130 m AHD). SILO (Scientific Information for Land Owners) is an enhanced climate database hosted by the Science Delivery Division of the Department of Science, Information Technology and Innovation (DSITI) containing daily historical climate records for Australia from 1889 onwards. The database is founded on BoM data, with missing data filled in by interpolation from nearby stations or by correlating the data from available measurements or long term averages, to give a complete data set for the period. The following daily average data was obtained from the SILO database for the period 1889 onwards:

- Maximum and minimum temperatures [^{o}C]. Where required, the daily temperature was assumed to be the average of these values;
- Daily rainfall [mm];
- Class A pan evaporation rate [mm];
- Solar radiation [MJ/m^2];
- Vapour pressure [hPa]; and
- Relative humidity [%] at the maximum and minimum temperatures.

The climate data is summarised in Table 3-4 and indicates median maximum and minimum temperatures of 24 and 11.5 ^{o}C, with a range of -4 to 44 ^{o}C. The median annual rainfall is about 960 mm/yr, which is somewhat below the median pan evaporation rate of 1,410 mm/yr.

Table 3-4: Climate Data Summary (Years 1889 - 2015)

Parameter	Units	Min	Percentile			Maximum
			10th	50th	90th	
Maximum temperature	°C	10.5	17.5	24.0	31.0	44.0
Minimum temperature	°C	-4.0	4.5	11.5	18.0	24.5
Annual rainfall	mm/yr	425	651	959	1,268	1,864
Annual evaporation	mm/yr	1,147	1,308	1,408	1,431	1,664
Solar radiation	MJ/m2	2.0	9.0	17	26	34
Vapour pressure	hPa	4.0	9.0	15	22	35
Relative humidity ast Tmax	%	11.0	35.6	48.5	64.5	100
Relative humidity ast Tmin	%	36.9	87.1	100	100	100

3.5.2 Frost frequency expectations

Frost is a potential concern for the irrigation area, owing to its impact on evapotranspiration rates, which can fall to effectively zero for frost sensitive plant species. Frost occurs when the ground temperature falls below zero °C for sufficiently long to either freeze dew or to precipitate ice on the plant surfaces, however other weather conditions are also typically required, such as sufficient humidity and low wind speeds.

Since all the required data to predict frost events was not available, for this assessment, the propensity for frost to occur was investigated simply by determining the frequency of sub zero temperatures thereby giving the maximum likelihood of frost occurring. This data is summarised in Table 3-5, which gives the minimum temperatures during the winter months (May to October). Generally the minimum temperatures remain above 0 °C, with June, July and August being the critical months. For the 127 year record period, sub zero temperatures were obtained in about 25% of years in July, with lower values obtained in June and August. Consequently, on average, frost may be expected in 1 year in every 4, however micro-climate effects may cause more frequent events in some areas.

Table 3-5: Frost propensity (1889 – 2014)

Parameter	Units	May	June	July	August	September	October
Minimum Temperatures							
- Lowest	[°C]	-2.0	-1.5	-4.0	-1.5	0.0	1.0
- 5th Percentile	[°C]	1.5	-0.5	-1.4	-0.5	1.1	3.0
- 10th Percentile	[°C]	2.0	0.0	-1.0	-0.5	2.0	4.0
- 25th Percentile	[°C]	2.5	1.0	0.0	0.5	2.5	5.0
- Highest	[°C]	8.0	5.5	4.5	4.0	7.5	10.5
Years with Sub-zero Temperatures							
- Number	[#]	1	9	30	14	0	0
- Percentage	[#]	0.8	7.1	23.8	11.1	0.0	0.0

3.6 Frost impacts

As discussed in Section 3.5.2, frost has the potential to impact the irrigation system by reducing the evapotranspiration rate for some period after the event. However frost events and their impacts on plant growth are difficult to estimate (Snyder *et al.* 2005), with the impacts dependent on a variety of factors, including:

- Plant species and variety;
- The growth phase (e.g. seedlings, flowering, mature etc.);
- Recent historical temperatures, which can 'harden' the plant against the impact of frost;
- Micro-climate, which can vary quite considerably over relatively short distances (< 200 m); and
- Severity of the frost event (e.g. temperature, duration, humidity soil moisture and wind etc.).

Given the complexity of the frost response, it was assumed that:

- Frost impacts will be managed through the selection of a range of pasture grasses, at least some of which will be frost tolerant, or that the irrigation area will be annually over sown with an appropriate frost resistance species (it is likely that this would only be required for the first 4 – 5 years of the project i.e. until the peak production period has passed); and.
- Frost impacts can be indicatively assessed by reducing the evapotranspiration rate by an adjustable amount for an adjustable period following a sub-zero minimum temperature.

3.7 Pond volumes and areas

The pond/dam volumes and dimensions have been approximated as regular truncated rectangular prisms, with flat floors. The dimensions and volumes of the storages are given in Table 3-6. There is a slight difference between the pond volumes as designed and modelled, as described below:

- The original (FEED) 'as-designed' ponds incorporated a dead volume, with a depth of approximately 0.5 m above the floor of the pond. This volume is generally unusable owing to the difficulty of extracting water from a pond at a depth of less than about 0.5 m. This is not formally modelled however. Although minimum cut offs are used in all ponds, these relate only roughly to the dead volume. The modelled low volume cut offs are generally set to ensure that the discharge pumps will not start if insufficient volume is available for a typical day's pumping;
- The 'as-designed' ponds have target and reportable top water levels, whereas the modelled ponds only consider the overflow volumes. This is because the water model is focused on how much water will overtop the ponds, and not so much on a nominal top water level (TWL).

There remains some uncertainty with respect to the pond volumes. The final locations and capacities of the WTP ponds (RWP and the DWP) are yet to be decided. For the base modelling case, it is assumed that the ponds will be located to the north of Parkers Road and will have the top of wall dimensions given in Table 3-6. The ponds are assumed to have a bottom to top of wall depth of 5.0 m. This gives a capacity to the TWL of about 10.5 ML, which is somewhat smaller than the nominal 20 ML values used during the FEED design. If the ponds are located to the south of Parkers Road, where the area is less restricted, larger ponds more akin to the FEED design can be used.

The dimensions of the Tiedeman's East Dam were obtained from the Manufacturer's Data Report (2012/13), which also provided information on the dam's depth and wall slopes. This information has been transcribed into Table 3-6. The dimensions, depths and walls slopes of the Tiedeman North and South Dams were obtained from the Surveyor's Drawings (Calco, 2007).

For modelling purposes, the Tiedeman's North and South dams are assumed to be a single unit. Consequently a Pseudo North & South dam is shown in the table, which has the same surface area and volume (at the overflow level) as the combined north and south dams, with the dimensions adjusted to compensate.

Based on the Surveyor's Drawings (Calco, 2014) for 'Farley Property', Pontiland's is an irregularly shaped dam, with a nominal capacity of 50 ML at the weir level, and a surface area of 4.0 Ha. The dam is about 330 m long, with a maximum width of about 130 m. The dam's maximum depth of 4.5 m is located near the spillway, however owing to the dam's shape, the average depth is considerably less. For consistency with the other dams, the Pontiland's Dam 'equivalent' dimensions are given in Table 3-6, assuming it has a regular shape and a flat floor.

The assumed initial volumes (i.e. the volume held in each pond on the pond commissioning day (See Section 3.8.1)) held in each pond are also given in Table 3-6. For the most part, these values are relatively arbitrary, being set to ensure that the pond/dam does not completely empty prior to water being received from the gathering/treatment systems. TED however is likely to contain about 15 ML of extracted water from the pilot programmes, while the TN&SD is likely to hold greater than 7.5 ML of fresh water. A nominal initial volume of 15 ML was assumed for the PontD.

Table 3-6: Pond/dam dimensions

Parameter	Units	WTP Storages/Ponds			Tiedeman's Ponds				Pontiland's
		RWP	TWS	DWP	North	South	Pseudo N&S	East	Dam
Base of Pond									
- Length	m	82.0	16.9	82.0	65.0	65.0	233.7	110.7	315.4
- Width	m	16.0	16.9	16.0	53.0	53.0	29.3	25.7	112.4
- Area	m^2	1,312	286	1,312	3,445	3,445	6,858	2,847	35,434
Wall slope: Length	V:H (1:X)	3.0	0.0	3.0	3.0	3.0	3.0	3.0	4.0
Wall slope: Width	V:H (1:X)	3.0	0.0	3.0	3.0	3.0	3.0	3.0	4.0
Dead Storage Above Floor									
- Depth	m	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.1
- Area	m^2	1,615	286	1,615	3,808	3,808	7,656	3,265	35,777
- Volume	m^3	730	143	730	1,812	1,812	3,626	1,527	3,561
- Fraction of overflow volume	%	5.7	14.3	5.7	9.0	9.0	9.0	6.2	7.1
Top Water Level (Design)									
- Depth	m	4.0	3.0	4.0	3.7	3.7	3.7	4.2	1.3
- Area	m^2	4,240	286	4,240	6,557	6,557	13,190	6,971	40,098
- Volume	m^3	10,547	857	10,547	18,198	18,198	36,455	20,200	50,197
- Usable storage volume	m^3	9,817	714	9,817	16,386	16,386	32,829	18,673	46,636
Overflow Water Level (Model TWL)									
- Depth	m	4.5	3.5	4.5	4.0	4.0	4.0	4.9	1.3
- Area	m^2	4,687	286	4,687	6,853	6,853	13,747	7,703	40,098
- Volume	m^3	12,718	1,000	12,718	20,209	20,209	40,418	24,800	50,197
- Usable storage volume	m^3	11,988	857	11,988	18,397	18,397	36,792	23,273	46,636
Top of Wall									
- Depth	m	5.0		5.0	4.3	4.3	4.3	5.4	1.8
- Area	m^2	5,152		5,152	7,155	7,155	14,310	8,294	41,910
- Length	m	112.0		112.0	90.8	90.8	259.5	143.0	330.0
- Width	m	46.0		46.0	78.8	78.8	55.1	58.0	127.0
- Volume (apparent)	m^3	15,106		15,106	22,310	22,310	44,539	28,700	70,687
Initial volumes in the ponds	m^3	1,000	500	1,500			7,500	15,000	15,000

3.8 Other input parameters

The model requires certain data to control how the simulation proceeds. The key input parameters and assumptions are detailed in the following subsections.

3.8.1 Starting dates

The model simulation always begins on the 1st January in the selected starting year (currently 2017). Three dates are then selected, with the following current values:

- The pond commissioning and water volume initialisation: 1st September 2017
- WTP commissioning date: 1st March 2018
- Irrigation start date: 15th May 2018

Currently the pond commissioning date (i.e. the date from which volume changes in the ponds are tracked) is relatively arbitrary. The WTP commissioning date has been selected such that the plant begins operation 1 month prior to the start of the extracted water flows (as given in the production water schedule (Figure 1-1)). This offset gives the system and WTP time to transfer and process extracted water held in the TED and make it available for use to meet the initial working water demands. The irrigation start date is delayed slightly to ensure that the initial working water demands are met prior to the water held in the DWP and TN&SD Dam being irrigated. The actual irrigation start date will need to be reviewed when the flows begin to ensure that water is:

- Available to meet the working water demands; and
- Irrigated prior to the dams becoming too full.

3.8.2 Working water requirements

The model is set up to draw working water from the DWP only. However, in the event of the DWP level being low, water can be transferred to the DWP from the TN&SD (which is allowed in the model). It is understood that working water can also be drawn from the Pontiland's Dam, however this is not included in the model.

A monthly working water demand schedule was provided, giving the number of wells to be drilled, fracked and worked, in the month in question. For modelling purposes, the monthly programme was converted to a daily programme with each demand type distributed over the month as evenly as possible, with no regard given to normal working days.

Working water is required for 3 uses:

- *Drilling water*, which is understood to require about 500 m^3 per well drilled. It is understood that this water will not be sourced from the WTP/Tiedeman's Dam system, with the most likely source being the Pontiland's dam. Similarly, spent drilling water will not be returned to WTP system and will be dealt with independently. Consequently, for modelling purposes the drilling water demand was set to zero;
- *Fracture stimulation water.* It is understood that each fracking event requires between 500 and 1,500 m^3 with a nominal value of 1,000 m^3 adopted. Further, it is understood that fracking occurs over a 2 day period and consequently the model assumes a daily demand of half the nominated fracking water flow per event, on each of two consecutive days.
- *Work-over water* relates to the water used to periodically re-habilitate and enhance the gas well's productivity after it has been in operation for some time, with a water demand of about 50 m^3/well worked. The schedule provided currently does not nominate any work-over events and consequently, for modelling purposes the work-over water demand was set to zero.

It is understood that some irrigation water will be used for stock watering. Currently no estimate of the stock watering demand is available and it has not been included in the model, on the assumption that it will be small (insignificant).

The cumulative working water demands are shown in Figure 3-3 for the drilling, fracture stimulation and work-over programme as supplied. The demand is expected to cease in about 2021, with a total draw of just over 100,000 m^3 which is equivalent to about 17.5% of the total P50 extracted water flow.

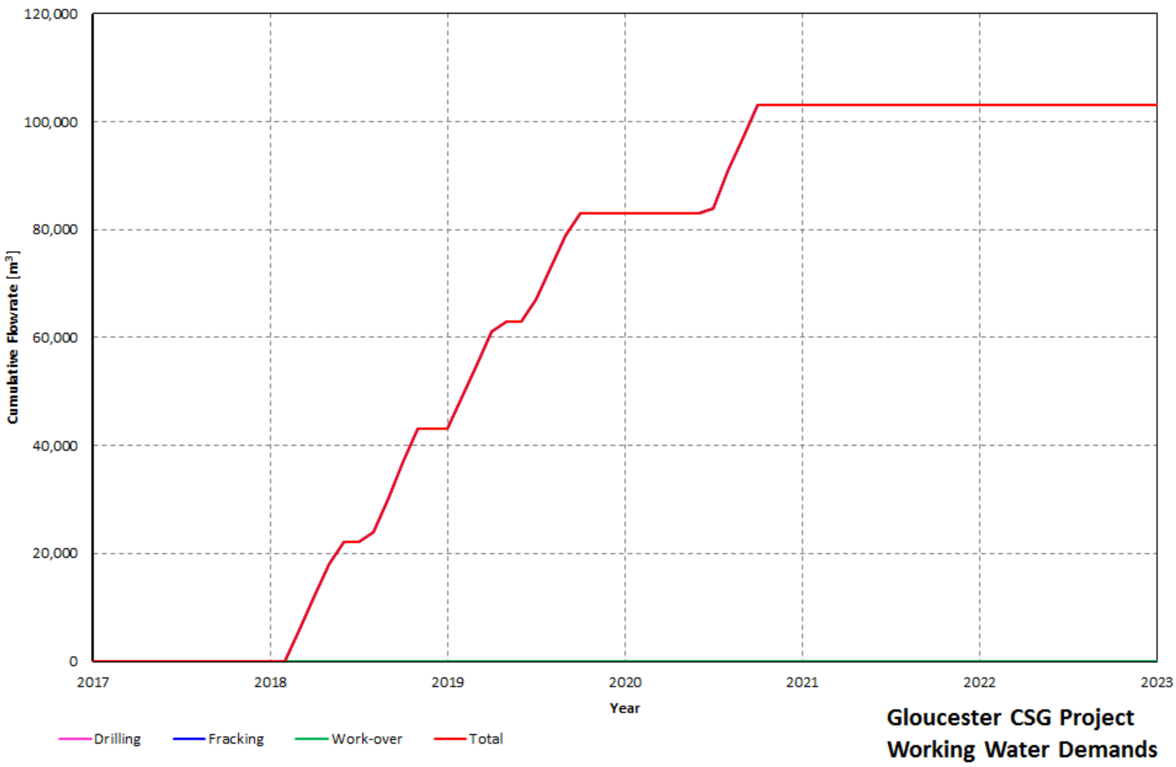
3.8.3 Extracted and flowback water

The model currently allows any of 4 extracted water production profiles to be simulated, including the:

- 50th percentile FEED profile (used for comparative purposes only);
- Expected 10th percentile profile;
- Expected 50th percentile profile; and
- Expected 90th percentile profile.

The model is set up to allow flowback water to be either included in the profiles given above or added in separately. The extracted water profiles given in Figure 2-1 include the flowback water.

Figure 3-3: Working water demands



3.8.4 WTP recovery

The WTP recovery is dependent on several factors, including the total dissolved salts (TDS) concentration in the extracted water, the water temperature, pre-treatment method(s), membrane type, operating pressure and the salts present etc. The recoveries listed below are based on a nominal TDS value of 4,300 mg/L (the expected TDS range is 3,000 – 9,000 mg/L), however the TDS is not a model input. An adjustable water recovery is set at run time, with the following values extracted from the WTP water balance given in Appendix 1 (all the values are fractions of the flow directed to the WTP (i.e. factions of Stream 4 in Figure 3-2):

- Fraction of water returned to the RWP from pre-treatment: 0.000
- Fraction of water recovered in the treatment system: 0.830
- Fraction of water recovered in the brine concentration system: 0.150
- Total: 0.980

The remaining water (about 2%) passes out of the system with the salt product, and other solid wastes generated in the WTP.

3.8.5 Pump and transfer rates

The capacity of pumps directing flow around the system is limited. The current capacities are given in Table 3-7. The model uses daily flowrates, however the instantaneous rate is also given in the table, assuming the pump runs 24 hours per day.

Table 3-7: Pump capacities

Pump	Stream No. (Figure 3.2) [#]	Capacity Daily [m^3/d]	Capacity Instantaneous[1] [L/s]
Water Treatment Plant Feed Pump			
- 2 Pumps running, full speed	4	1,200	13.9
- 1 pump running at full speed	4	600	6.9
- 1 pump running at minimum speed	4	300	3.5
Treated Water Storage to the Discharge Water Pond	11	1,200	13.9
Discharge Water Pond to working water	17	Unlimited[2]	-
Discharge Water Pond to the Avon River	19	2,000	23.1
Discharge Water Pond to Tiedeman's North & South Dam	18	2,000	23.1
Tiedeman's North & South Dam to Discharge Water Pond	28	1,000	11.6
Tiedeman's North & South Dam to the Avon River	26	2,000	23.1
Tiedeman's North & South Dam to irrigation	25	3,000	34.7
Tiedeman's East to the Receiving Water Pond	6	350	4.1

1. Assumes 24 hour/d operation, 2. Set by demand

3.9 Other assumptions

It is further assumed that:

- The salinity of the extracted water (and hence the treatment/brine concentrator recovery efficiencies) will be constant over the project life;
- An irrigation area of 60 Ha is available;
- Stock water requirements are included in the water volume available for irrigation;
- Drilling water, both the source of and the treatment/disposal of spent drilling water is not included in the model; and
- Inflows from any development beyond Stage 1 are not included in the model.

3.10 Verification

It is not possible to 'prove' the model is correct. It can only be shown to be incorrect. However the model has been developed with all due care and attention, and is believed to correctly simulate the process described.

3.10.1 Mass balance check

The model automatically calculates and reports a mass balance check, incorporating all streams over each of the following components:

- Each pond (i.e. RWP, TWS, DWP, Tiedeman's North & South and Tiedeman's East);
- The combined TWS & DWP system;
- The irrigation area; and
- The entire system.

The balances are summed over the entire production period and report deviations of less than 0.1 m^3. It is acknowledged that this does not mean the simulation is correct – just that it is 'not wrong'.

3.10.2 Stress testing

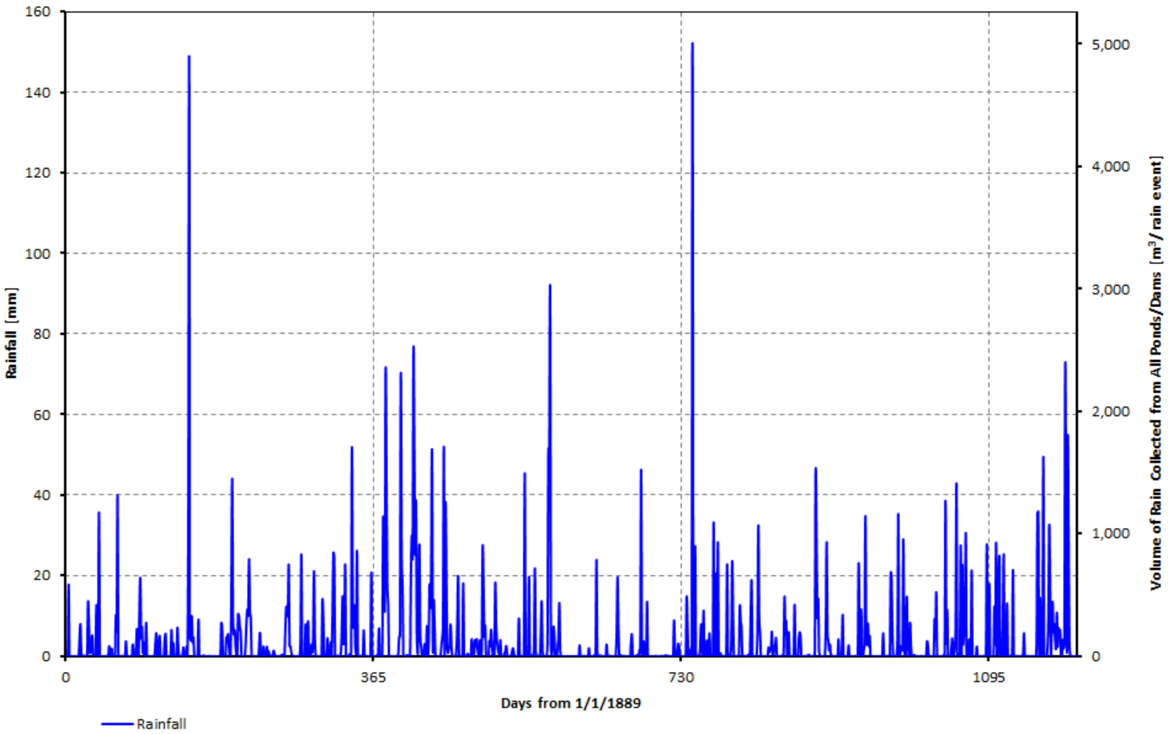
The model has been stress tested by varying the key parameters and observing that the model behaves as expected. Key streams have been analysed in detail, to assess potential errors.

3.10.3 Rainfall

Gloucester is located in a high rainfall area (~ 980 mm/yr on average) and consequently the ponds are impacted by large rainfall events. Figure 3-4 shows the rainfall pattern for the 1st 3 years of the climate data set, starting in the Year 1889. The figure shows several large rainfall events in the order of, or greater than 100 mm. Also shown in the figure is the impact of rainfall on all ponds and dams (excluding Pontilands). Rain events increasing the total stored volume by 1 ML or more are common, with events generating increases of greater than 5 ML occurring every few years.

The RWP has a nominal top of wall surface area of about 5,200 m^2 and consequently 100 and 150 mm rain events will generate flows of about 520 and 780 m^3 respectively on the day. These values are of a similar order of magnitude as the peak daily extracted water production rates.

Figure 3-4: Gloucester rainfall pattern for the period beginning 1st Jan 1889



4 SIMULATION CASES

Several scenarios have been modelled, to investigate the system sensitivities. The key areas that have been examined are:

- Changing the WTP pond sizes;
- Changing the irrigation parameters;
- Changing the WTP recovery and availability;
- Investigating the impact of frost; and
- Investigating the working water availability and initial pond storage requirements.

The scenarios assessed are summarised in Table 4-1. More information on the scenarios modelled is given in the text in the following sections. Graphical outputs for some of the results are presented in Appendices 2 to 13.

Table 4-1: Scenario summary

No.	Scenario	Extracted Water Profile	Climate Profile[1]	Specification
	WTP Pond Sizes			
1	P50 Base case	P50	Min, 10th, 50th, 90th and maximum	Model parameters as detailed in the report
2	P90 Base case	P90	Min, 10th, 50th, 90th and maximum	Model parameters as detailed in the report
3	Large WTP ponds	P90	Min, 10th, 50th, 90th and maximum	Base case plus: RWP = 14.4 & DWP = 23.5 ML[2]
4	Small WTP ponds	P90	Min, 10th, 50th, 90th and maximum	Base case plus: RWP & DWP = 9.5 ML
	Irrigation Parameters			
5	Higher clay content soil	P90	Min, 10th, 50th, 90th and maximum	Base case plus: light clay soil structure
6	Large irrigation area	P90	Min, 10th, 50th, 90th and maximum	Base case plus: 75 Ha irrigation area
7	Small irrigation area	P90	Min, 10th, 50th, 90th and maximum	Base case plus: 45 Ha irrigation area
	WTP Recovery/Performance			
8	WTP capacity reduced by 5%	P90	Min, 10th, 50th, 90th and maximum	Base case plus: 1,140 m^3/d WTP feed flowrate
9	WTP capacity reduced by 10%	P90	Min, 10th, 50th, 90th and maximum	Base case plus: 1,080 m^3/d WTP feed flowrate
10	WTP availability reduced	P90	Min, 10th, 50th, 90th and maximum	Base case plus: 90% availability
11	WTP capacity & avail. reduced	P90	Min, 10th, 50th, 90th and maximum	Base case plus: 90% avail & 1,080 m^3/d cap
	Frost Impact			
12	Light frost impact	P90	Min, 10th, 50th, 90th and maximum	Base case plus: 40% initial ET reduction
13	Heavy frost impact	P90	Min, 10th, 50th, 90th and maximum	Base case plus: 80% initial ET reduction
	Working Water Availability/Storage Requirements			
14	Base case	P10	Min, 10th, 50th, 90th and maximum	Model parameters as detailed in the report
15	Lower initial pond storage	P10	Min, 10th, 50th, 90th and maximum	As described in the text
16	Lower initial pond storage	P50	Min, 10th, 50th, 90th and maximum	As described in the text

1. The climate profile, is that profile which gives the nominated percentile flow to the environment (e.g. 10th or 90th %ile etc.)
2. Volumes at the overflow level

In all cases the pond and dams were operated such that no overflow of the RWP or the TED occurs – to avoid the discharge of untreated water.

4.1 WTP pond sizes

The intent of this modelling was to determine the impact of changing the RWP and DWP sizes. The cases modelled are summarised in Table 4-2. Scenarios 1 and 2 present the 'Base case' 50th and 90th percentile extracted water flows, and how these are impacted by a range of climatic conditions. Graphical representations of selected model outputs are given in Appendices 2 to 5, including:

- The extracted water flow and rainfall (to the RWP);
- The daily volumes of the ponds and dams;
- The working water demands drawn from the DWP and TN&SD;
- The instantaneous and cumulative flow to river discharges (combined total from the DWP, TN&SD and TED);
- Irrigation rates; and
- Cumulative rainfall to the ponds and dams.

As described in Section 3, the balance was undertaken for 127 climate data sets, with each data set starting in a year between 1889 and 2015. The 127 resulting water balances were then searched to extract those profiles giving the nominated percentile flow to the environment (i.e. the summation of all overflows and discharges to the Avon River, taken over the approximately 20 year production period modelled). The model findings are summarised in Table 4-2, which gives the expected flow to the environment for the nominated climate percentiles, as well as the climate data set starting year (which allows the appropriate profile to be selected for reporting purposes). The size of the environmental release is also compared to the total extracted water flow as a percentage for comparison purposes. In cases where the environmental discharge is zero, the profiles are selected based on a secondary measure – i.e. sum of the peak volumes in the DWP, TED and TN&SD (i.e. those storages which can discharge to the environment), which provides an indicative measure of the potential to overflow.

The 'Base Cases', use the input data as described in the preceding sections of this report and provide a point of comparison for input data modifications. For the P50 extracted water profile, no environmental release would be expected – essentially implying that 100% reuse of the treated water may be expected. For the P90 extracted water profile, about 10 ML of water is expected to be released to the Avon River Release Point over the 20 year modelling period for the worst case climatic conditions – equivalent to just over 1% of the total extracted water volume. The rest of the water will be irrigated. As indicated in the graphs in Appendix 3, several release events would be expected at times roughly corresponding to the peak of the extracted water profile. For the 95 percentile climatic conditions, the flow to the Avon River Release Pt falls to about 2 ML (or about 0.15% of the extracted water flow over the 20 year modelling period). As before this release is expected to occur during the peak extracted water production period. No releases would be expected for the lower climate data percentiles for which data is presented. This implies that there is risk of somewhat less than 1 in 100 of an environmental release being required for the system, as modelled.

The graphical output for the TED given in Appendix 2 indicates that a significant degree of storage occurs in the peak period when the extracted water flow is diverted from the RWP. To a large extent, the degree of reliance on the TED is dependent on the control system (in particular the maximum level allowed in the TED before water is pumped to the WTP (from the RWP) irrespective of level in the downstream storages – See Section 3.3.1). This control level was set to ensure no overflow from the TED in the worst climate conditions recorded to date, including a reasonable safety margin. Currently, as indicated in Table 3-1, the control value is set at 70% of the TED capacity. If a greater degree of security against an overflow of the TED/RWP is required, this value can be lowered – at the expense of a greater release of treated water to the Avon River (i.e. from the DWP and the TN&SD).

Table 4-2: Impact of WTP pond sizes

Percentile (of flow directed to the environment)	Scenario 1 P50, Base Case			Scenario 2 P90, Base Case			Scenario 3 P90, Base + Large WTP Ponds			Scenario 4 P90, Base + Small WTP Ponds		
	Start Yr[1] [#]	Discharge to Env [m^3]	Discharge to Env [%]	Start Yr [#]	Discharge to Env [m^3]	Discharge to Env [%]	Start Yr [#]	Discharge to Env [m^3]	Discharge to Env [%]	Start Yr [#]	Discharge to Env [m^3]	Discharge to Env [%]
Minimum	1980	0	0.00	1980	0	0.00	2002	0	0.00	1980	0	0
25th Percentile	1931	0	0.00	1916	0	0.00	1936	0	0.00	1940	0	0
50th Percentile	1933	0	0.00	1963	0	0.00	1989	0	0.00	1925	0	0
75th Percentile	1921	0	0.00	1954	0	0.00	1960	0	0.00	1926	0	0
90th Percentile	1955	0	0.00	1972	0	0.00	1928	0	0.00	1928	0	0
95th Percentile	1890	0	0.00	1891	2,000	0.21	1987	0	0.00	1929	3,300	0.21
Maximum	1948	0	0.00	1948	10,000	1.05	1948	6,000	0.63	1948	14,000	1.47

1. The start year refers to the starting year of the climate data set used for the simulation

Scenarios 3 and 4 explore the impact of changing the RWP and DWP volumes for the P90 water extracted water profile. Scenario 3 shows the impact of increasing the RWP and DWP sizes to 14.4 and 23.5 ML (to the overflow level) respectively, however this has relatively small impact on the environmental release. Similarly, reducing the pond volumes by ~ 25% (to 9.5 ML each) has a relatively minor impact, increasing the magnitude but not the frequency, relative to the base case.

The reason for this appears to be the very sharp peak in 2019/2020. Any restriction to the transfer of water from Tiedeman's to irrigation, causes a backup in the DWP, which in turn restricts the flow through the WTP and causes an overflow of the RWP to TED. Consequently to avoid an overflow of the TED, treated water must be directed to the Avon River Release Pt from the TN&SD. The limiting feature appears to be the ability to move the water though the system rather than the size of the WTP storages *per se*. Clearly however, a larger storage provides more scope, but a relatively small increase does not fundamentally alter the outcome.

4.2 Irrigation parameters

Three scenarios were modelled, with the outcomes presented in Table 4-3, for a soil structure with a higher clay content and poorer total available moisture content than was used for the base case. This entailed changing the soil texture from a silty loam - silty clay loam texture to light clay. The soil's lower total available moisture content (falling from 12 to 6%) resulted in a small improvement to both the magnitude and frequency of the environmental release, as compared to the P90 Base Case. This somewhat unexpected result is attributed to the soil drying out faster, requiring more frequent, smaller water applications to the irrigation area. This has a minor impact on the pond/dam levels and consequently could impact the magnitude of an overflow in either direction (in this casing making it slightly smaller). Consequently, it is believed that the soil texture is unlikely to be a key system determinant. Graphical output data is given in Appendix 6 for the clay rich soil scenario (Scenario 5).

Table 4-3 : Impact of changing the irrigation parameters

Percentile (of flow directed to the environment)	Scenario 2 P90, Base Case			Scenario 5 P90, Base + Light Clay Soil			Scenario 6 P90, Base + 75 Ha Irrigation			Scenario 7 P90, Base + 45 Ha Irrigation		
	Start Yr	Discharge to Env		Start Yr	Discharge to Env		Start Yr	Discharge to Env		Start Yr	Discharge to Env	
	[#]	[m^3]	[%]	[#]	[m^3]	[%]	[#]	[m^3]	[%]	[#]	[m^3]	[%]
Minimum	1980	0	0.00	1980	0	0.00	1900	0	0.00	2002	0	0.00
25th Percentile	1916	0	0.00	1964	0	0.00	1937	0	0.00	1939	0	0.00
50th Percentile	1963	0	0.00	1935	0	0.00	1999	0	0.00	1922	0	0.00
75th Percentile	1954	0	0.00	1974	0	0.00	2011	0	0.00	2007	0	0.01
90th Percentile	1972	0	0.00	1929	0	0.00	1929	0	0.00	1889	4,600	0.42
95th Percentile	1891	2,000	0.21	1954	0	0.00	1892	0	0.00	1901	10,000	1.05
Maximum	1948	10,000	1.05	1948	4,000	0.42	1948	4,000	0.42	1948	26,000	2.73

Increasing the size of the irrigation area from 60 to 75 Ha had only a minor impact, suggesting that a large increase in area would be required to make a substantial difference. In contrast, reducing the irrigation area to 45 Ha, has a more significant impact, increasing both the magnitude and expected frequency of an environmental release (in this case increasing the risk of an environmental release to between 1:40 and 1:100). Under these conditions around 3% of the extracted water flow must be directed to an environmental release rather than irrigated. Selected graphical output for Scenarios 6 and 7 is given in Appendices 7 and 8.

In part, the results obtained reflect an overloaded irrigation condition during the peak production period (where the system relies on storage) and an under-loaded condition at all other times – i.e. there is insufficient water to effective irrigate the entire area. Consequently a small increase in irrigation area does little to relieve the peak period overloading, while a reduction in area increases the storage stress.

The average (i.e. the irrigation rate calculated over the entire 20 year simulation period) and the peak period (i.e. the period from 1st July 2018 to 1st December 2020, when the P90 extracted water flowrate is greater than 400 m^3/d) irrigation rates are given in Table 4-4. The long term average values are quite low – in the order of 77 – 120 mm/yr, however this is somewhat misleading as insufficient water is available to meet the irrigation demand for extended periods. The peak period irrigation rate (where water limitations are less prevalent) varies between ~300 and 500 mm/yr, with the base case giving a value of about 370 mm/yr (~ 1.0 mm/d). These values are similar to typical guidelines values of ~ 0.8 to 1.5 mm/d. Data extracted from the original FEED water balance suggests an irrigation rate of ~ 280 mm/yr, which is somewhat less than that found in this study, but in a similar order of magnitude.

Overall, this assessment suggests that the proposed 60 Ha irrigation area is probably about right and that there is little to be gained from increasing its size. A reduction in size however would not be recommended.

Table 4-4: Nominal irrigation rates

Parameter	Units	Scenario 2 P90 Base Case	Scenario 5 Light Clay Soil	Scenario 6 Large Irrig Area	Scenario 7 Small Irrig Area
Average irrigation rate	mm/yr	88	90	77	117
Peak period irrigation rate	mm/yr	370	367	299	496

4.3 WTP recovery and performance

Although the extracted water salinity is not part of this model, it is recognised that salinity changes, amongst other things such as equipment faults, maintenance work, water chemistry and temperature etc. will impact the WTP's performance. Two issues are of primary concern:

Plant performance: Salinity, water chemistry changes and membrane aging, amongst other reasons, may cause the WTP to operate at less than its design flowrate. The RO system's recovery is believed unlikely to change significantly in response to these changes – rather the throughput will be reduced to protect the brine concentrator system. Consequently Scenarios 8 and 9 consider throughput reductions of 5 and 10% to 1,140 and 1,080 m^3/d respectively.

Equipment availability: The WTP supply specification calls for a total plant with a capacity of 1.2 ML/d and a 95% availability. Given the likely complexity of the plant it is unlikely that this will be achievable in a single train. Consequently, for modelling purposes it was assumed that the plant would consist of two trains, connected in a lead-follow arrangement, each with an availability of 90%. To investigate the impact of a poorer than specified availability being achieved, Scenario 10 considers an overall availability of 90% (i.e. each train has an 80% availability).

Given that availability and plant performance are often related, Scenario 11 considers the impact of a 10% reduction in plant capacity (i.e. to 1,080 m^3/d) and a 90% overall plant availability. The data for these scenarios is summarised in Table 4-5 and Table 4-6. Graphical representation of selected output data is given in Appendix 9 for Scenario 11.

Reducing the WTP capacity by 5% has a small impact on the total volume directed to the environment, however incongruously, a 10% reduction in capacity results is a smaller environmental release. The reason for this result is that the limiting factors for the base case are the DWP, TN&SD and irrigation system, rather than the treatment plant itself, which means that not all the available volume in the RWP and TED is used. If the WTP capacity is restricted however, then some of this excess storage capacity is used up – effectively increasing the risk of an overflow of untreated water but reducing the environmental release of treated water.

Similar outcomes were obtained with the reduced WTP availability (Scenario 10) and combined reduced availability and capacity (Scenario 11). Overflows of the RWP or the TED were not predicted in either case. Nevertheless, graphical data presented in Appendices 3 and 9 for these scenarios show that even a relatively small reduction in capacity and/or availability results in appreciable storage in the TED – highlighting the need to carefully schedule planned maintenance to avoid shutting down the entire plant during critical times. Further, it emphasises that a rapid response will be required for unplanned shutdowns, and the need to ensure that critical spares are readily available. Adequate staff training will be essential to minimise the need for extended shut downs.

Table 4-5 : Impact of a reduction in the WTP's capacity

Percentile (of flow directed to the environment)	Scenario 2 P90, Base Case			Scenario 8 P90, Base + 5% Cap Reduct.			Scenario 9 P90, Base + 10% Cap Reduct.		
	Start Yr	Discharge to Env		Start Yr	Discharge to Env		Start Yr	Discharge to Env	
	[#]	[m^3]	[%]	[#]	[m^3]	[%]	[#]	[m^3]	[%]
Minimum	1980	0	0.00	2002	0	0.00	2002	0	0.00
25th Percentile	1916	0	0.00	1916	0	0.00	1916	0	0.00
50th Percentile	1963	0	0.00	1982	0	0.00	1970	0	0.00
75th Percentile	1954	0	0.00	1953	0	0.00	2011	0	0.00
90th Percentile	1972	0	0.00	1902	0	0.00	2013	0	0.00
95th Percentile	1891	2,000	0.21	1901	2,000	0.21	1929	1,300	0.14
Maximum	1948	10,000	1.05	1948	12,000	1.26	1948	8,000	0.84

Table 4-6: Impact of a reduction in the WTP's availability

Percentile (of flow directed to the environment)	Scenario 2 P90, Base Case			Scenario 10 P90, Base + 90% Availability			Scenario 11 P90, Base + 90% Avail & Cap		
	Start Yr	Discharge to Env		Start Yr	Discharge to Env		Start Yr	Discharge to Env	
	[#]	[m^3]	[%]	[#]	[m^3]	[%]	[#]	[m^3]	[%]
Minimum	1980	0	0.00	1980	0	0.00	2002	0	0.00
25th Percentile	1916	0	0.00	1981	0	0.00	1909	0	0.00
50th Percentile	1963	0	0.00	1925	0	0.00	1982	0	0.00
75th Percentile	1954	0	0.00	1923	0	0.00	1893	0	0.00
90th Percentile	1972	0	0.00	1961	0	0.00	1996	0	0.00
95th Percentile	1891	2,000	0.21	2015	2,000	0.21	1987	2,000	0.21
Maximum	1948	10,000	1.05	1948	8,000	0.84	1948	8,000	0.84

4.4 Frost impacts

As discussed in Section 3.6, frost has the potential to negatively impact the irrigation area. To simulate the impact, the model uses an adjustable factor to reduce the evapotranspiration rate for an adjustable period after the frost event. For simplicity, frost events were assumed to occur following a sub-zero minimum temperature. Two scenarios were considered, with the impact on the evapotranspiration rate detailed in Table 4-7, with selected graphical output given in Appendices 10 and 11. The results of these scenarios are summarized in Table 4-8. Scenario 12 suggests that a light frost is unlikely to significantly impact the systems performance, although the environmental release is expected to increase slightly. In contrast a heavy frost is likely to be more significant, - in the modelled case increasing the environmental discharge under the worst case climatic conditions to about 3% of the total extracted water flowrate.

Although the values presented under these scenarios are illustrative only, they do emphasise the importance of selecting an appropriate frost tolerate crop.

Table 4-7: Frost impact on evapotranspiration rate

Scenario 12 - Light Frost		Scenario 13 - Heavy Frost	
Reduction Period [d]	ET_0 Multiplier [#]	Reduction Period [d]	ET_0 Multiplier [#]
10	0.6	15	0.2
10	0.7	15	0.4
10	0.8	15	0.6
10	0.9	15	0.8

1. ET_0 - Evapotranspiration rate under ideal conditions

Table 4-8: Impact of frost

Percentile (of flow directed to the environment)	Scenario 2 P90 Base Case			Scenario 12 P90, Base +Light Frost			Scenario 13 P90, Base + Heavy Frost		
	Start Yr	Discharge to Env		Start Yr	Discharge to Env		Start Yr	Discharge to Env	
	[#]	[m^3]	[%]	[#]	[m^3]	[%]	[#]	[m^3]	[%]
Minimum	1980	0	0.00	2002	0	0.00	2002	0	0.00
25th Percentile	1916	0	0.00	1940	0	0.00	1977	0	0.00
50th Percentile	1963	0	0.00	1942	0	0.00	1975	0	0.00
75th Percentile	1954	0	0.00	1920	0	0.00	1906	0	0.00
90th Percentile	1972	0	0.00	1988	600	0.06	1891	2,000	0.21
95th Percentile	1891	2,000	0.21	1891	2,000	0.21	1941	4,000	0.42
Maximum	1948	10,000	1.05	1948	10,000	1.05	1898	26,000	2.74

4.5 Working water availability and initial storage requirements

The P10 extracted water Base Case (Scenario 14) is given in Table 4-9, along with P10 and P50 simulations with lower initial storage volumes in the DWP and TN&SD (Scenarios 15 and 16). Graphical output is given in Appendix 12 for the P10 Base Case.

Inspection of Figure 1-1, indicates that the working water requirement exceeds the P10 extracted water flow rate at the start of the production period (in the year 2018) and briefly in late 2020. Storage will be required to meet the working water requirements at these times. In principal it is possible to determine the storage requirements by determining the area enclosed between the working water demand and the P10 extracted water profile, which suggests a net volume of about 8,500 m^3. This is the minimum volume required, and does not consider changes in the pond levels or climate influences. Consequently, the model was run with different initial storage values until no working water deficits were recorded.

Scenario 14 shows the P10 Base Case, which indicates that no environmental discharge occurs (as would be expected) and that the initial storage requirements are adequate to meet the working water demands. Initially some problems were experienced later in the production schedule, with working water deficits occurring in late 2020, however this was easily remedied by increasing the minimum storage volumes in either the DWP (to ~ 30%) or TN&SD (to about 15%). Although this requires ‘foresight’, it is unlikely to be problematic in practice, since by this stage the extracted water production profile should be better understood, allowing the system management strategy to be amended appropriately.

Table 4-9: Working water requirements

Percentile (of flow directed to the environment)	Scenario 14 P10, Base Case			Scenario 15 P10, Base + WW Storage			Scenario 16 P50, Base + WW Storage		
	Start Yr	Discharge to Env		Start Yr	Discharge to Env		Start Yr	Discharge to Env	
	[#]	[m³]	[%]	[#]	[m³]	[%]	[#]	[m³]	[%]
Minimum	1901	0	0.00	1901	0	0.00	1980	0	0.00
25th Percentile	1897	0	0.00	2012	0	0.00	1986	0	0.00
50th Percentile	1951	0	0.00	1975	0	0.00	2008	0	0.00
75th Percentile	1947	0	0.00	1910	0	0.00	1917	0	0.00
90th Percentile	1963	0	0.00	1925	0	0.00	1889	0	0.00
95th Percentile	1948	0	0.00	1948	0	0.00	1893	0	0.00
Maximum	1892	0	0.00	1950	0	0.00	1948	0	0.00
Min TiedN&S storage[1]		4,500			2,500			2,500	
Min TiedE storage[1]		13,000			11,000			8,400	

1. Minimum initial storage volumes to ensure all working water requirements are met

Several adjustments were made to Scenario 14 to estimate the initial storage requirements. These included:

- Changing the pond commissioning date to 30th April 2018 – i.e. just prior to the commencement of the working water demand, to reduce the impact of rainfall and evaporation;
- Setting the initial stored water volumes in the RWP and DWP to the minimum values that did not completely empty the ponds owing to evaporation losses. This entailed reducing the initial storage volumes in these ponds to about 300 m^3 (in each pond).

Since the treatment of water likely to be held in the TED provides the bulk of the initial working water demand, attention was focused on determining the minimum pre-start storage requirements in this dam. The model output, given in Table 4-9, suggests that for the P10 extracted water profile, about 11 ML of water should be available. Slightly less initial storage water will be required for the P50 and P90 extracted water profiles. This value is somewhat greater than the 8,500 m^3 estimated above with the difference attributed to the minimum storage volume requirements in the various ponds.

Consequently, a minimum volume of at least 11,000 m^3 should be available at the start of the project to ensure the working water requirements can always be met. In practice this water may be located in any one (or more) of the DWP, TN&SD, TED and/or the Pontiland's Dam.

4.6 Water releases to the Avon river

For the 'Base Case' scenarios (i.e. the scenarios depicting the system as designed), flow to the environment (i.e. generated either from a pond/dam overflowing or from water being pumped to the

Avon River Release Pt.) only occurs for the 90th percentile extracted water flows and for wet years in excess of the 90th percentile. Even for these 'extreme' conditions, with estimated likelihood of less than 1 in 100, the quantity of water released to the environment is small – in the order of 1% of the total extracted water flowrate. This is shown in Figure 4-1, which shows the cumulative environmental flows for the 90th percentile extracted water profile (P90) over the 20 year modelling period. Three separate curves are shown – i.e. the maximum, 95th and 90th percentile environmental flows. For the worst case climate conditions (i.e. the climate conditions generating the maximum environmental discharge), pumping to the Avon River occurs on 5 occasions, all near to the peak of the extracted water production period. For the 95th percentile climate case, a single discharge is expected, as before near the peak production period. No overflow is expected for the 90th percentile climate case.

Note that the (for example) 90th percentile climate data does not necessarily refer to the 90th percentile rainfall year, but rather the climate year causing the 90th percentile environmental release. While it is likely that this will be a wetter than average year, serval other factors also influence the outcome, including the timing of major rainfall events, pan evaporation rates, the rainfall quantity and frequency as well as the historical climate data.

The curves given in Figure 4-1 all refer to the base case – i.e. allowing the TED to fill to 70% before the overriding the restrictions on pumping to the WTP when the DWP is full (See Section 3.3.1). If the WTP feed restrictions are lifted at a lower level in the TED, say at 40%, (which provides a safer outcome, since the risk of an overflow of untreated water is reduced) then a greater fraction of treated water must be pumped to the Avon River to maintain the balance. This is shown in Figure 4-2, and indicates that the environmental discharge is increased to about 18,000 m^3 over the production period for the worst case climate conditions. No changes are expected for the 95th and 90th percentile climate conditions. Although the environmental discharge increases under these conditions, it remains less than 2% of the total extracted water flowrate.

Figure 4-1: Cumulative environmental flows (70% accumulation in the TED)

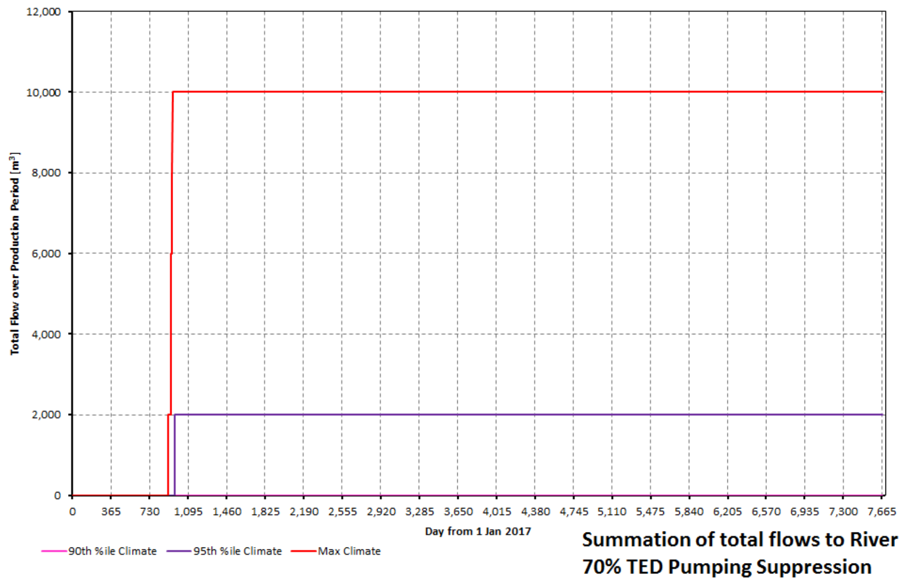
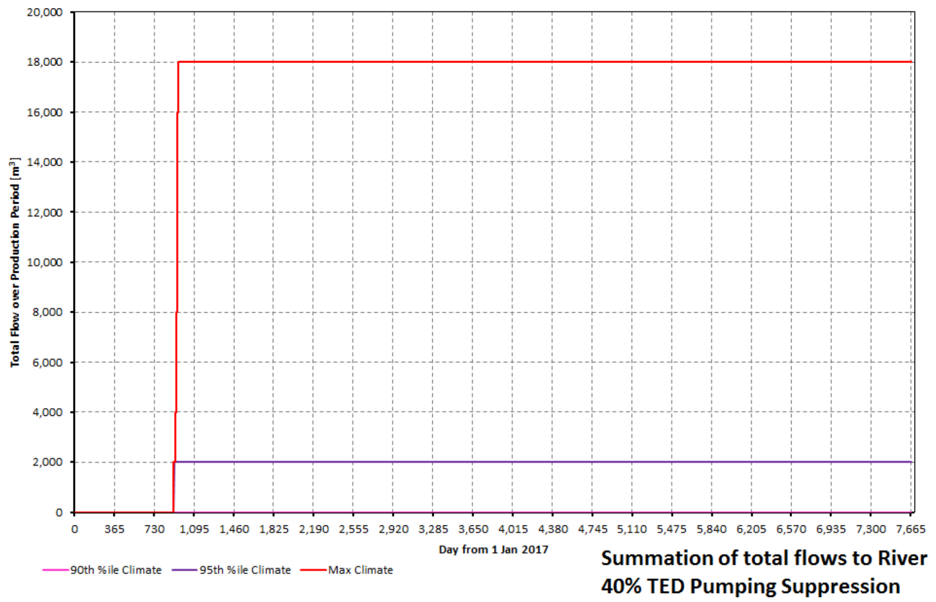


Figure 4-2: Cumulative environmental flows (45% accumulation in the TED)



5 CONCLUSIONS

A daily water balance model has been developed to simulate the transfer, storage and management of water extracted from CSG wells in AGL's GGP. The model was used to help develop the Extracted Water Management Strategy and to provide data for the sizing of the associated water handling and treatment infrastructure. In particular, the model may be used to:

- Estimate flows through key streams in the water handling and treatment process;
- Estimate the supply of treated water for beneficial reuse via irrigation; and
- Investigate potential risks, such as the accumulation of water and potential for uncontrolled discharges.

Key model parameters may be varied to simulate a variety of scenarios and generate the associated outputs. For modelling purposes, the WTP was assumed to consist of 2 trains in a lead-follow configuration, each with a capacity of 600 m^3/d and an availability of 90% to meet the WTP's design specification of 1,200 m^3/d at an availability of 95%.

In general, the results of the water balance modelling show that large rates of CSG water are produced during the early years of production and that these rates decline rapidly after about 3 to 4 years. Treated water can mostly be managed via irrigation and stock watering, with relatively small amounts (~ 1% of the extracted water flow for the 90th percentile extracted water production case) needing to be directed to the Avon River during the peak of the production period. The model indicates the water production is too high in the peak period to be completely irrigated and that the irrigation area is too large in the tailing period to be effectively irrigated. Surface water discharge is not expected to be required after the 4th year of production.

More specifically, the simulation cases undertaken found that for the expected extracted water production profiles:

- The proposed RWP and DWP capacities (i.e. with overflow volumes in the order of 13 ML each) are adequate for most scenarios. It is noted that operation between the design TWL and overflow levels may be expected, in particular during the peak extracted water production periods. Reducing the sizes of these ponds is not recommended
- For the base case or 'as designed' conditions, environmental releases only expected for the 90th percentile extracted water profile (P90) and for climate conditions exceeding the 90th percentile. The risk of a release of treated water to the environment (i.e. to the Avon River) is estimated to be less than 1:100;
- For the 90th percentile extracted water production profile (P90), the environmental release of treated water to the Avon River is expected to be less than 1% of the total extracted water flow;
- The soil type in the irrigation area is believed unlikely to significantly impact the environmental release risk;
- Frost may be expected once in every 4 years on average. Frost is not expected to have a significant impact on the system's performance, provided appropriate frost tolerant plant species are used – at least until the peak production period has passed;

- Several scenarios considered the impact of treatment plant capacity and availability. Although no scenarios modelled resulted in an overflow of the RWP or the TED, reduced WTP availability or capacity significantly increased the reliance on the TED (owing to limitations in the rate at which water can be passed through the treatment plant). This will has some implications regarding built in system redundancies, availability of spares, maintenance planning and staff training etc.;
- A minimum initial water storage requirement of about 11 ML is required at the start of the working water demand period to avoid working water deficits. This water can be distributed between the DWP, TN&SD, TED and the Pontiland's Dam. Deficits later in the production schedule can be managed through judicious operation of the ponds and dams.

6 REFERENCES

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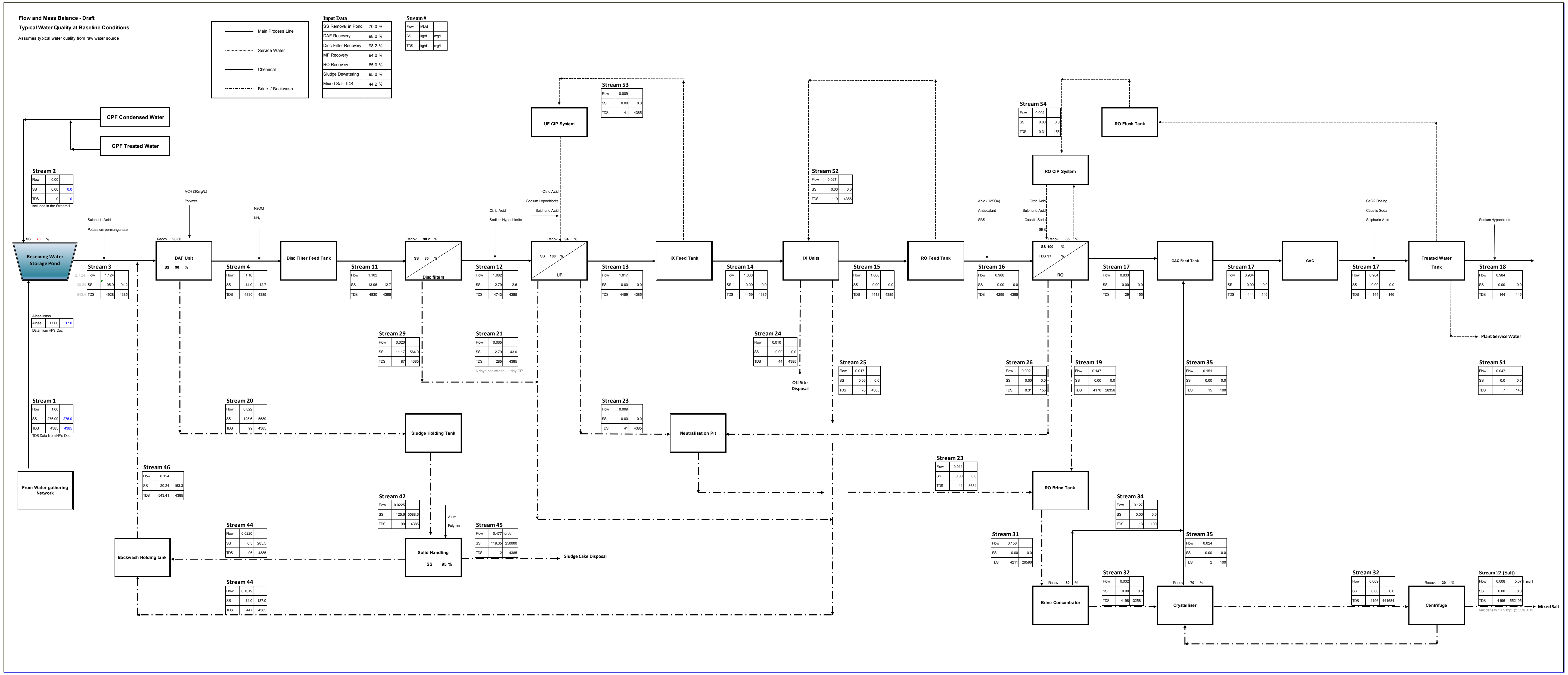
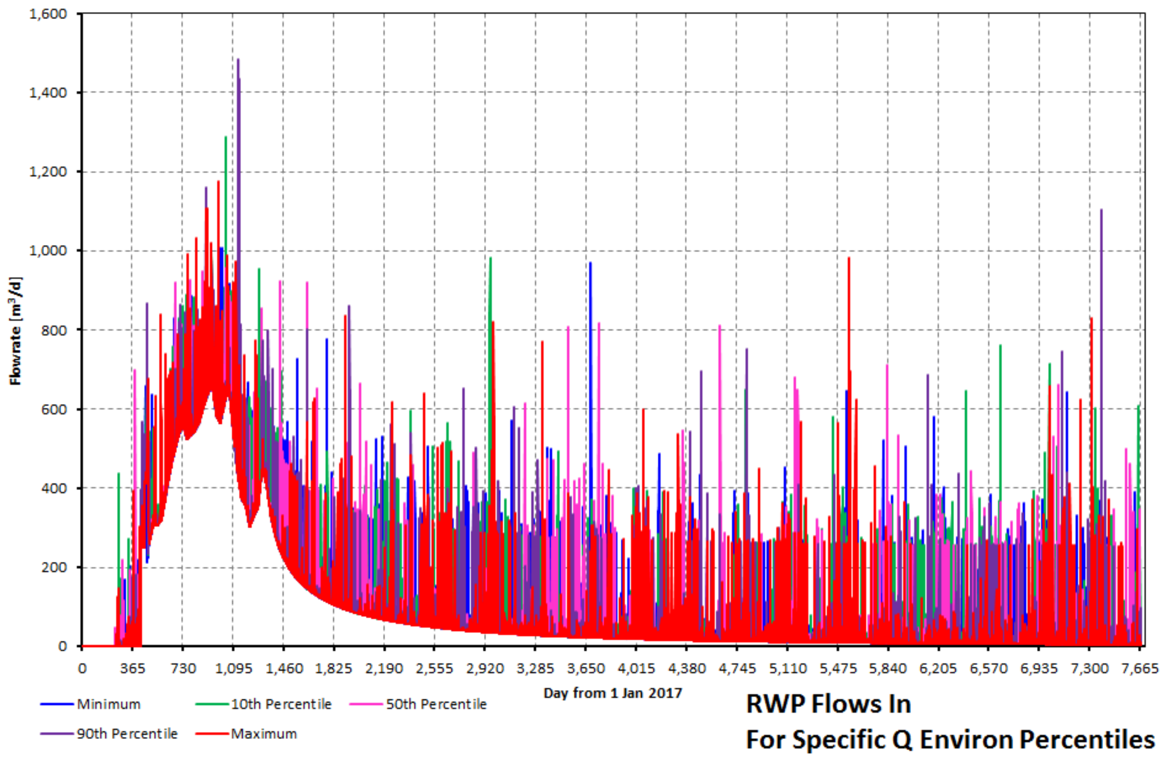
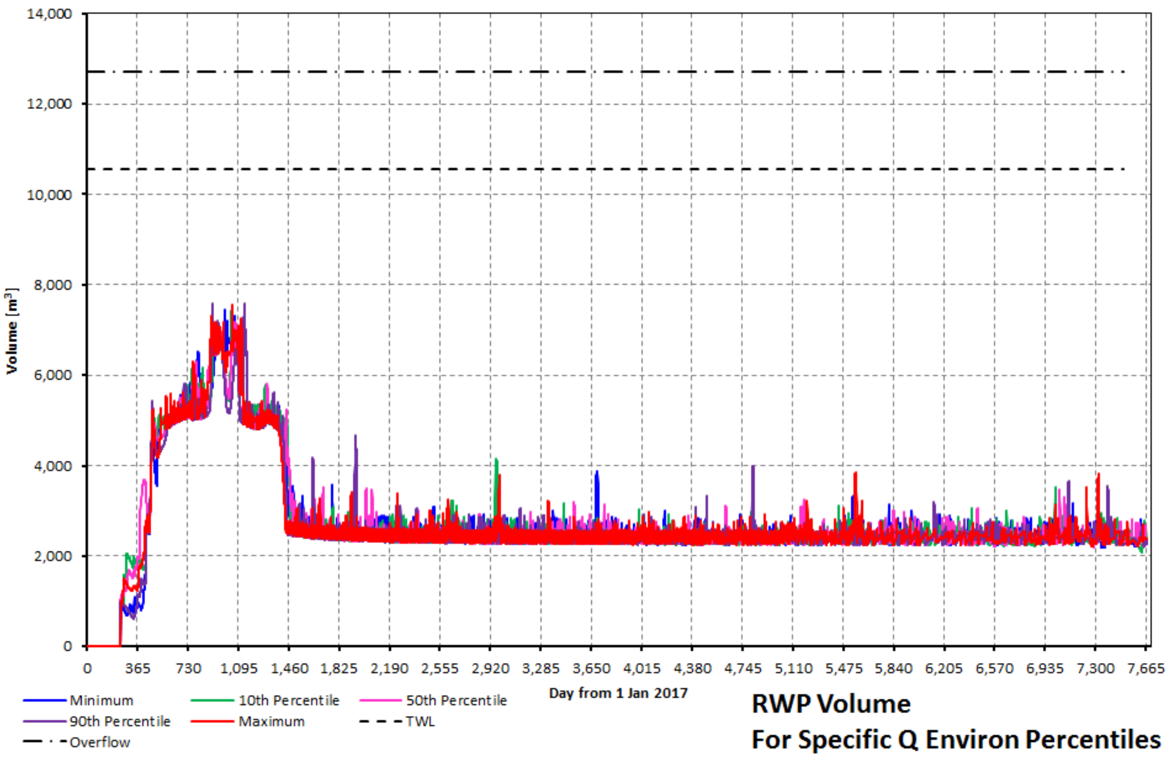
Appendix 1 WTP Water Balance


Flow and Mass Balance - Draft
Typical Water Quality at Baseline Conditions
Assumes typical water quality from raw water source
Main Process Line
Service Water
Chemical
Brine / Backwash
Input Data
SS Removal in Pond 70.0 %
DAF Recovery 98.0 %
Disc Filter Recovery 98.2 %
MF Recovery 94.0 %
RO Recovery 85.0 %
Sludge Dewatering 95.0 %
Mixed Salt TDS 44.2 %
CPF Condensed Water
CPF Treated Water
Receiving Water Storage Pond
DAF Unit
Disc Filter Feed Tank
Disc filters
UF
UF CIP System
IX Feed Tank
IX Units
RO Feed Tank
RO
RO CIP System
RO Flush Tank
GAC Feed Tank
GAC
Treated Water Tank
Plant Service Water
Sludge Holding Tank
Neutralisation Pit
RO Brine Tank
Solid Handling
Sludge Cake Disposal
Backwash Holding tank
From Water gathering Network
Brine Concentrator
Crystalliser
Centrifuge
Mixed Salt
Off Site Disposal

Appendix 2 Simulation Scenario 01: P50 Extracted Water Production: Base Case


Flowrate [m³/d]
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
RWP Flows In
For Specific Q Environ Percentiles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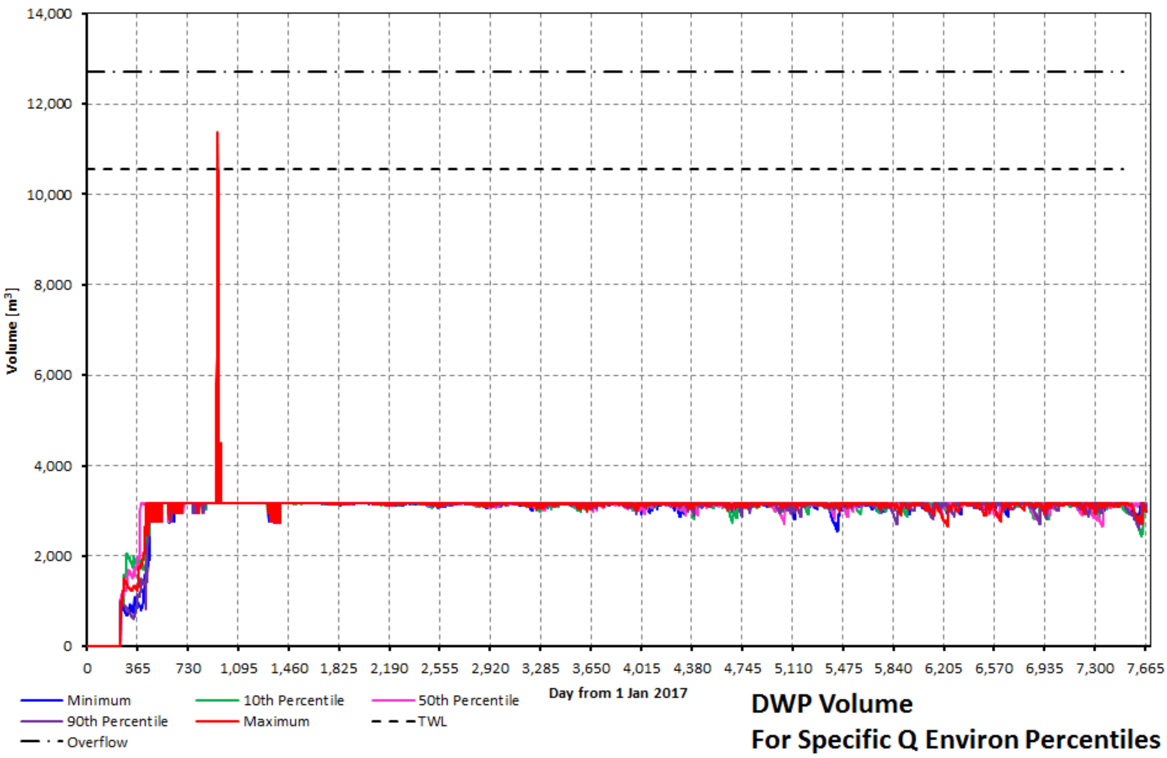
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
TWL
Overflow
RWP Volume
For Specific Q Environ Percentiles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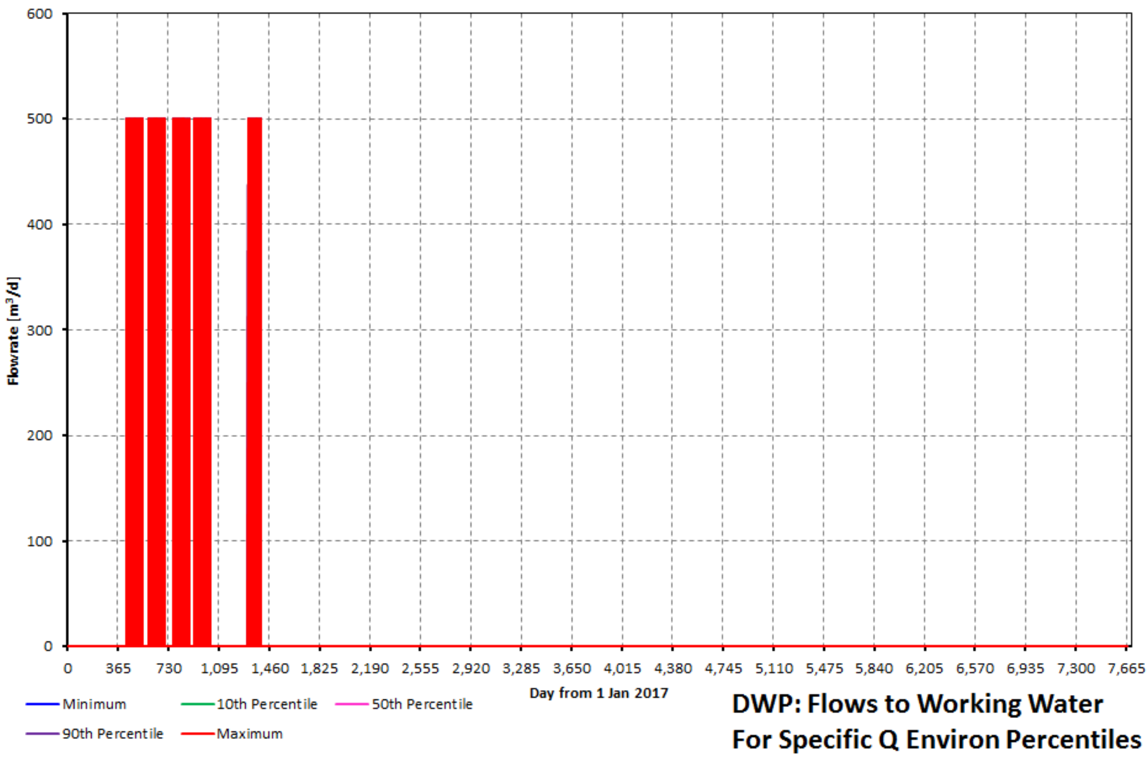
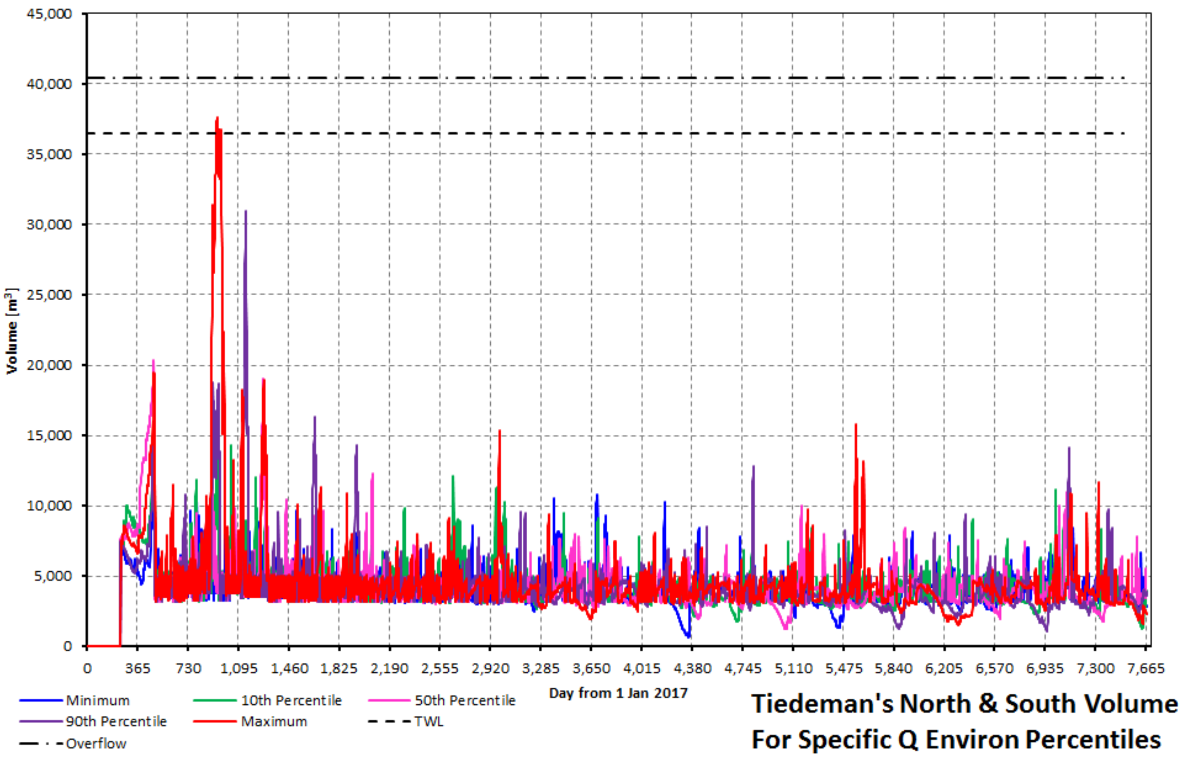
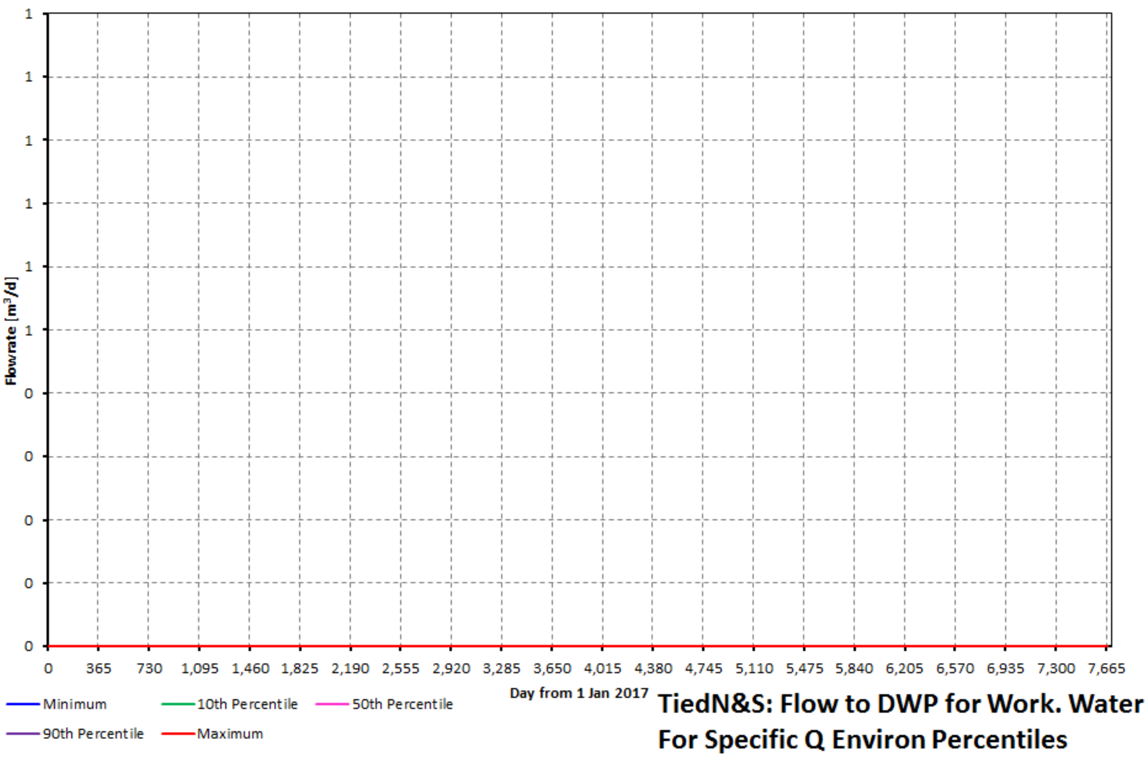
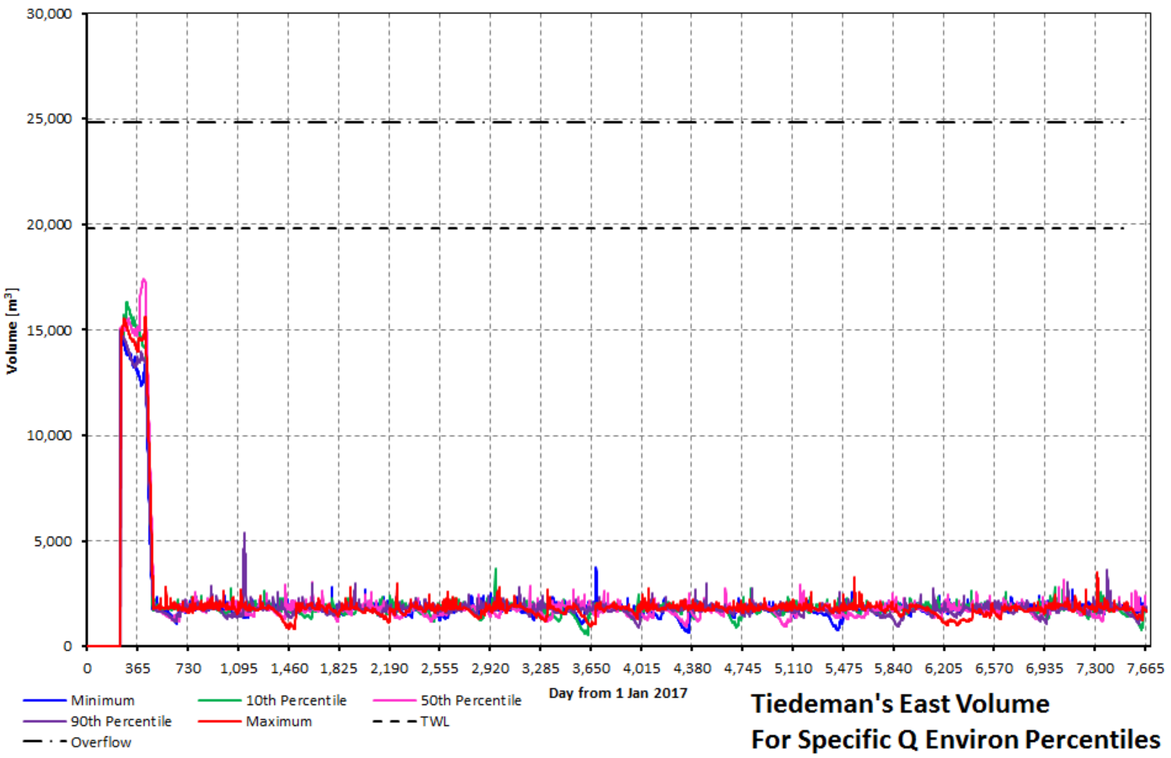
12,000
10,000
8,000
6,000
4,000
2,000
0
Volume [m³]
0
365
730
1,095
1,460
1,825
2,190
2,555
2,920
3,285
3,650
4,015
4,380
4,745
5,110
5,475
5,840
6,205
6,570
6,935
7,300
7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
TWL
Overflow
DWP Volume
For Specific Q Environ Percentiles


600
500
400
300
200
100
0
Flowrate [m³/d]
0
365
730
1,095
1,460
1,825
2,190
2,555
2,920
3,285
3,650
4,015
4,380
4,745
5,110
5,475
5,840
6,205
6,570
6,935
7,300
7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
DWP: Flows to Working Water
For Specific Q Environ Percentiles


Volume [m³]
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
TWL
Overflow
Tiedeman's North & South Volume
For Specific Q Environ Percentiles


Flowrate [m³/d]
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
TiedN&S: Flow to DWP for Work. Water
For Specific Q Environ Percentiles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25,000
20,000
15,000
10,000
5,000
0
Volume [m³]
0
365
730
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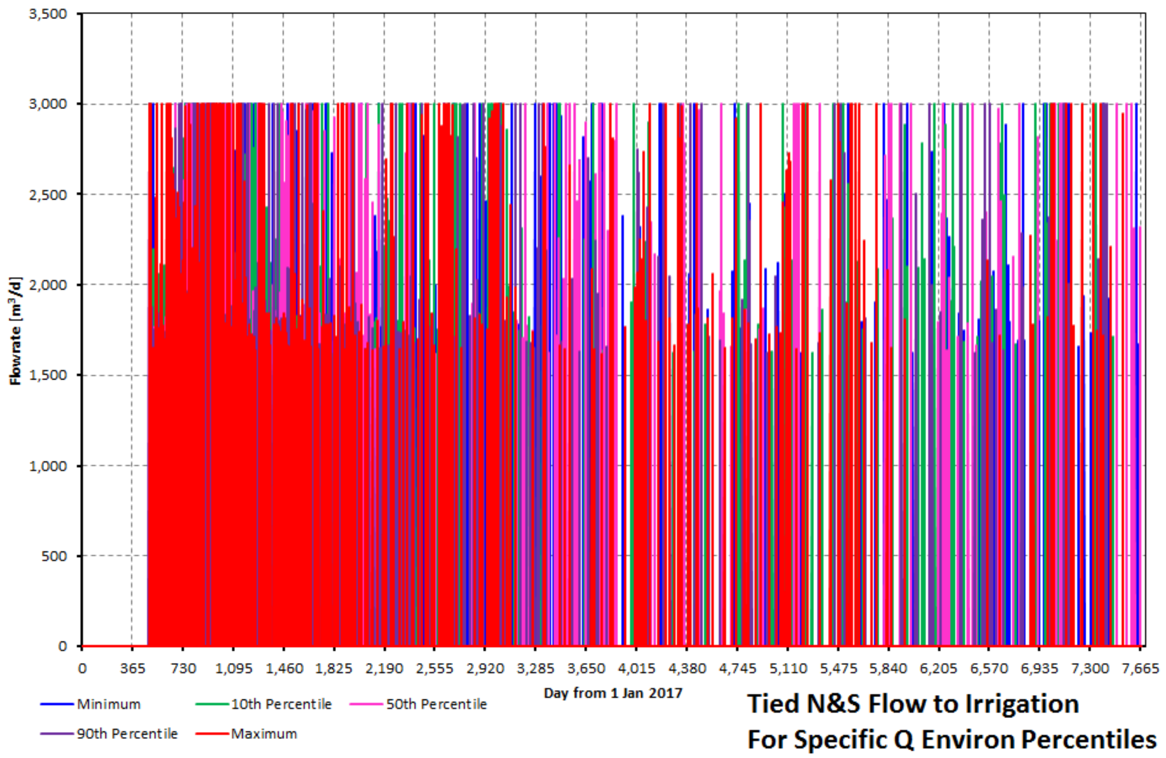
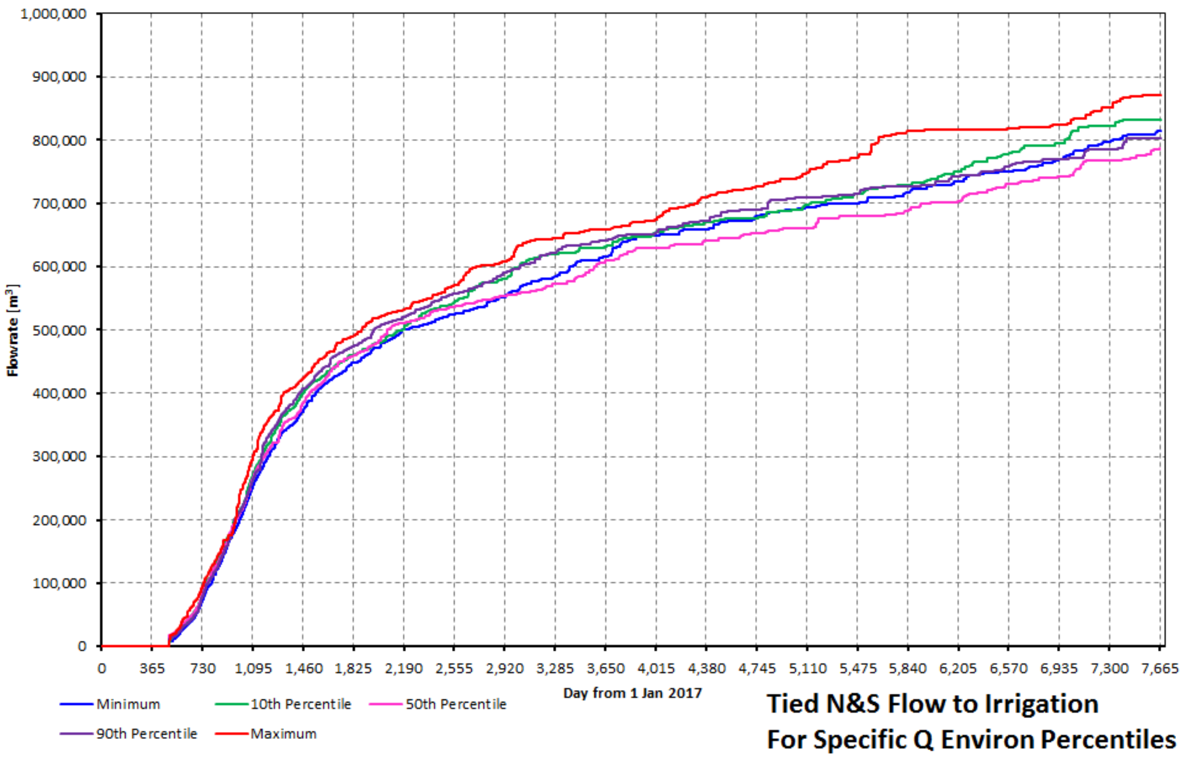
1,460
1,825
2,190
2,555
2,920
3,285
3,650
4,015
4,380
4,745
5,110
5,475
5,840
6,205
6,570
6,935
7,300
7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
TWL
Overflow
Tiedeman's East Volume
For Specific Q Environ Percentiles


3,500
3,000
2,500
2,000
1,500
1,000
500
0
Flowrate [m³/d]
0
365
730
1,095
1,460
1,825
2,190
2,555
2,920
3,285
3,650
4,015
4,380
4,745
5,110
5,475
5,840
6,205
6,570
6,935
7,300
7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
Tied N&S Flow to Irrigation
For Specific Q Environ Percentiles


Flowrate [m³]
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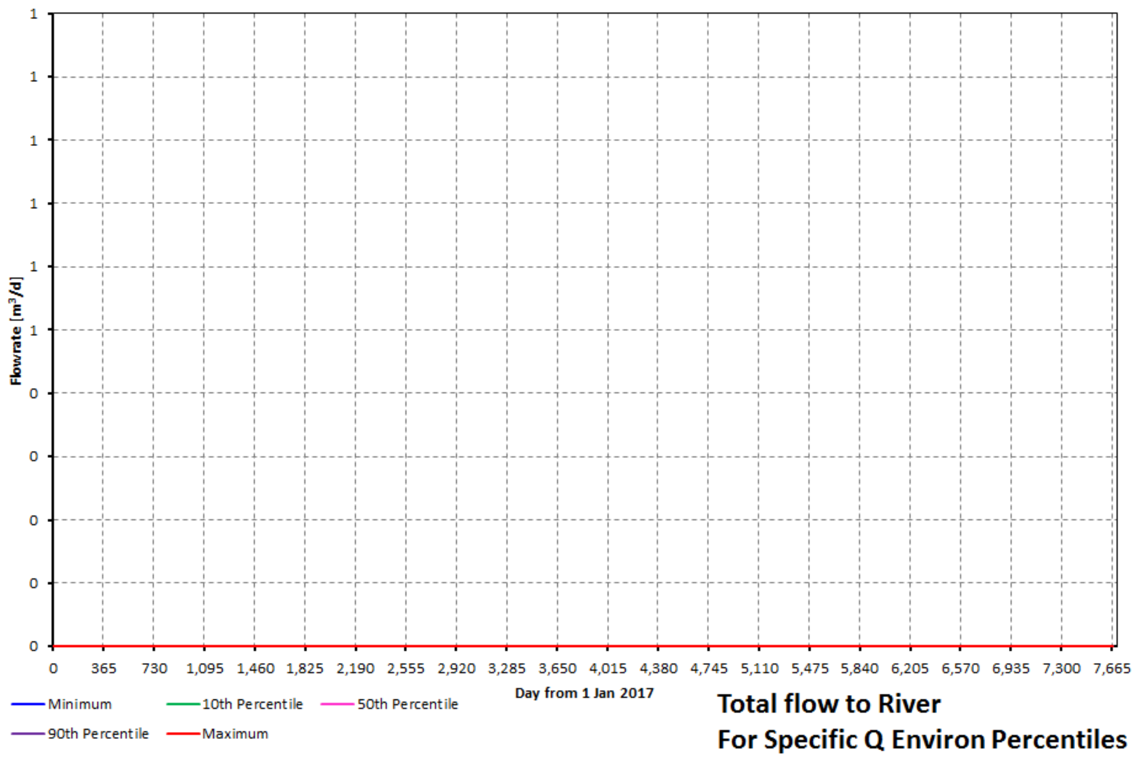
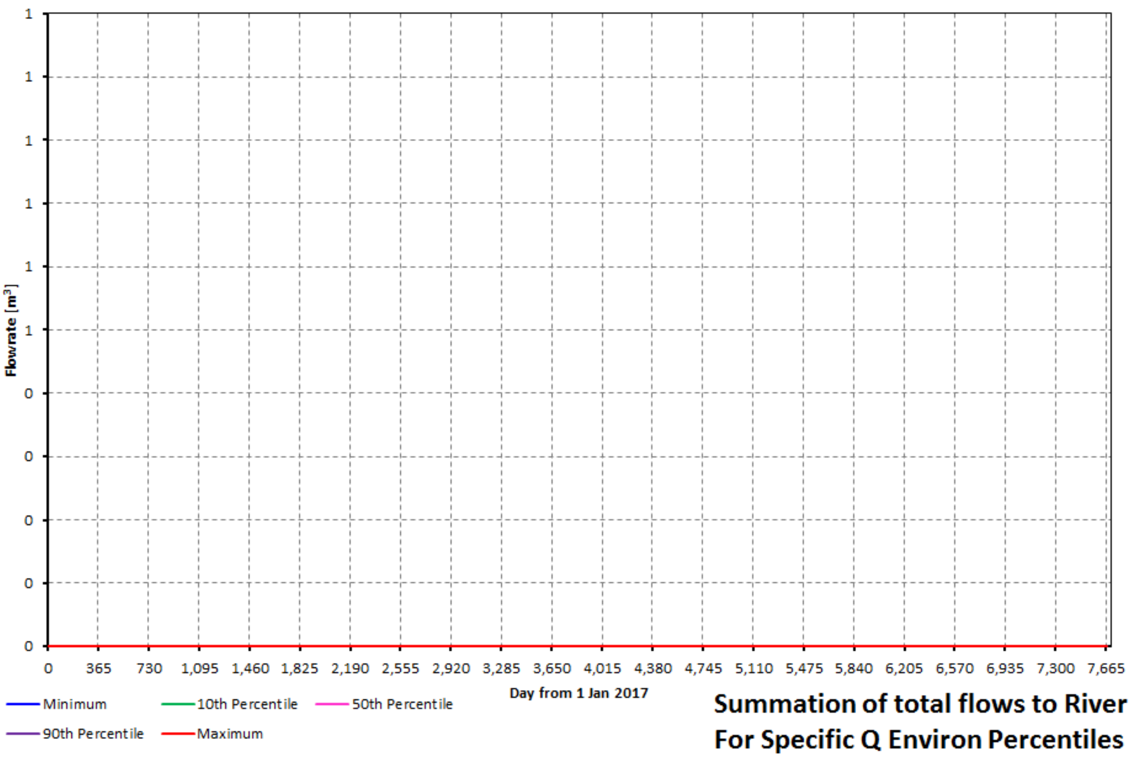
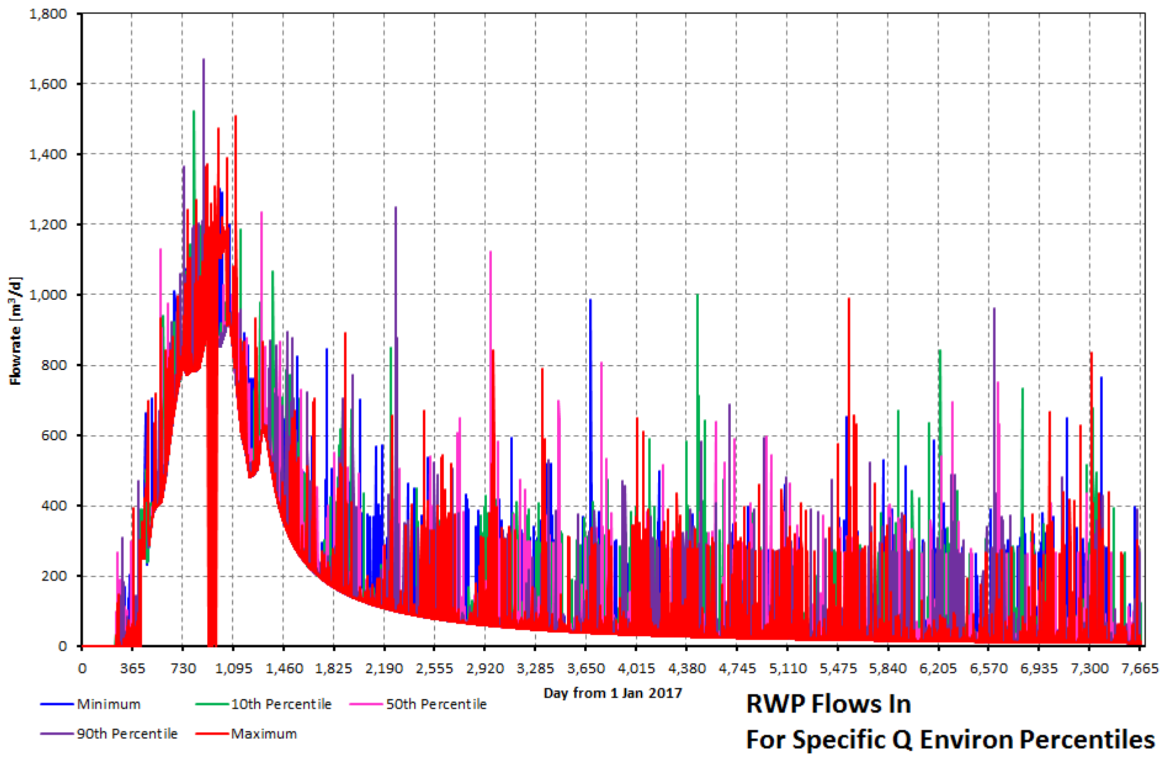
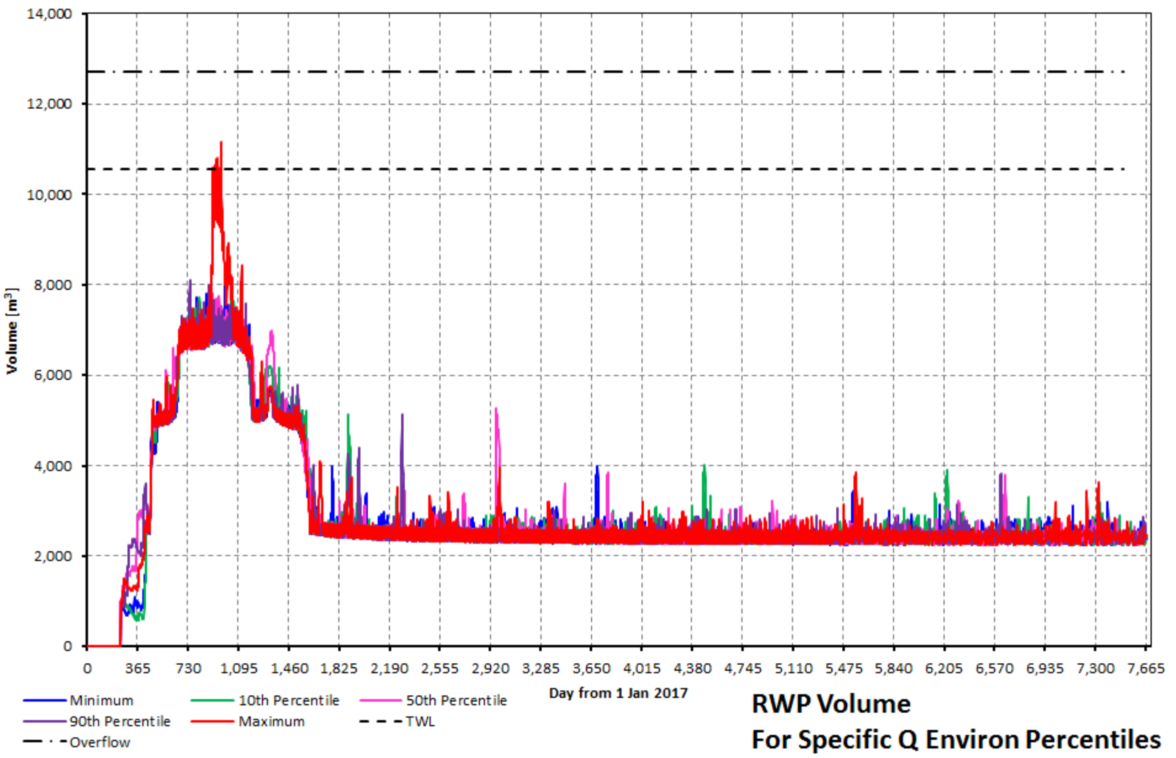
900,000
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
0 365 730 1,095 1,460 1,825 2,190 2,555 2,920 3,285 3,650 4,015 4,380 4,745 5,110 5,475 5,840 6,205 6,570 6,935 7,300 7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
Tied N&S Flow to Irrigation
For Specific Q Environ Percentiles

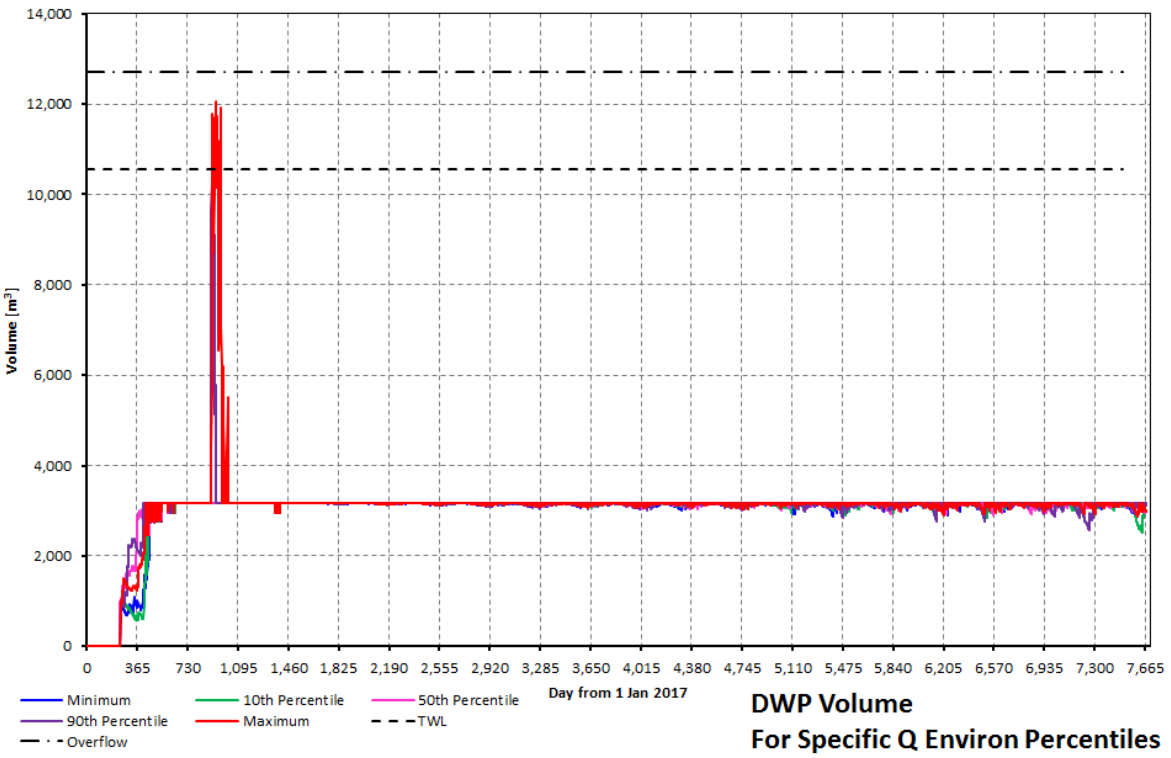

Flowrate [m³/d]
1
1
1
1
1
1
0
0
0
0
0
0 365 730 1,095 1,460 1,825 2,190 2,555 2,920 3,285 3,650 4,015 4,380 4,745 5,110 5,475 5,840 6,205 6,570 6,935 7,300 7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
Total flow to River
For Specific Q Environ Percentiles

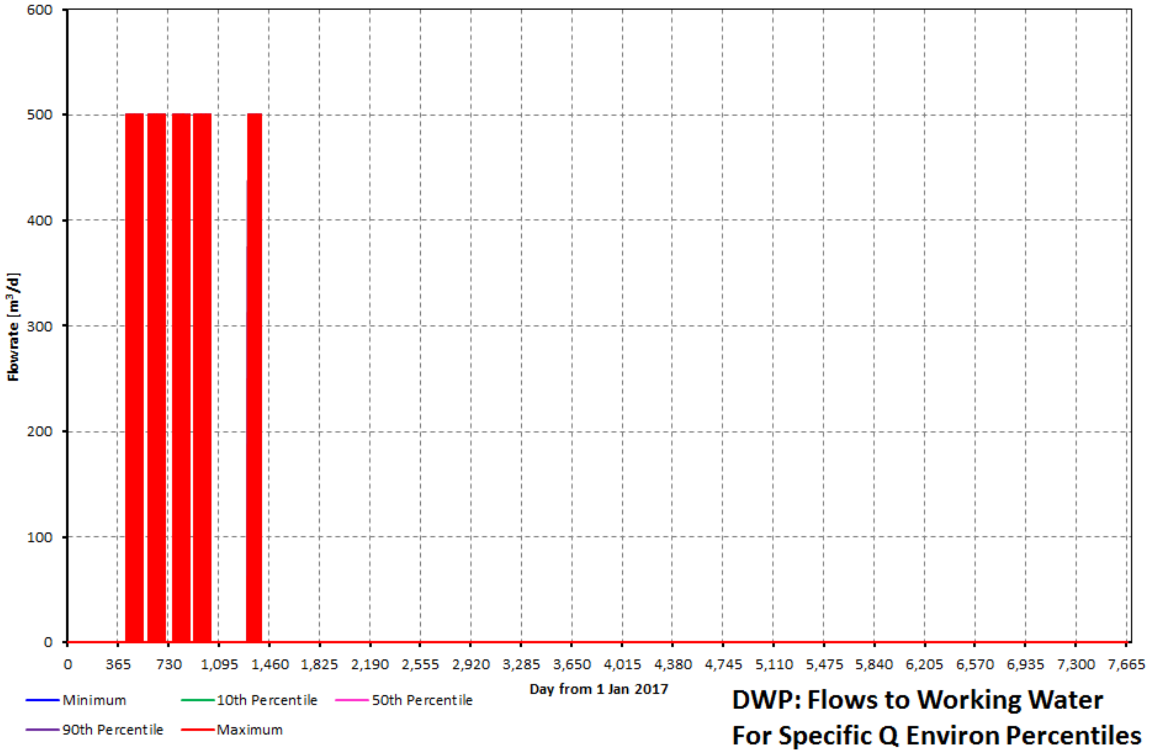

Flowrate [m3]
1
1
1
1
1
1
0
0
0
0
0
0
365
730
1,095
1,460
1,825
2,190
2,555
2,920
3,285
3,650
4,015
4,380
4,745
5,110
5,475
5,840
6,205
6,570
6,935
7,300
7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
Summation of total flows to River
For Specific Q Environ Percentiles

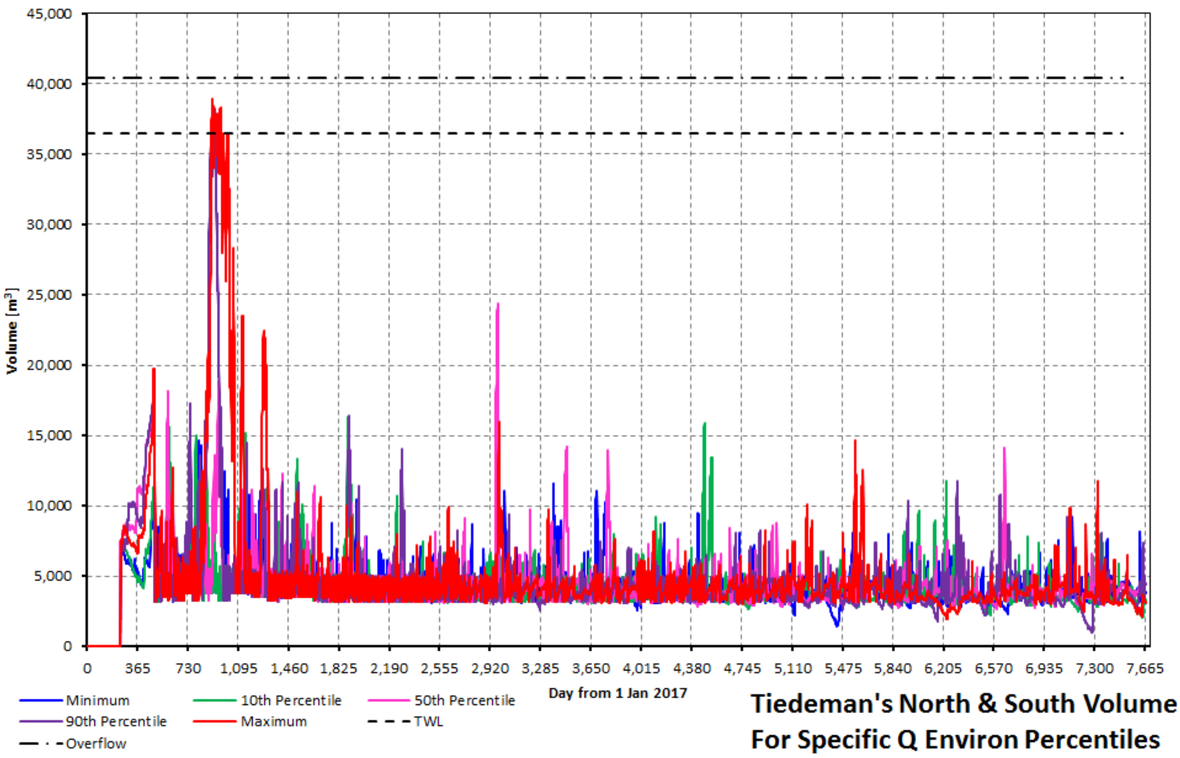
Appendix 3 Simulation Scenario 02: P90 Extracted Water Production, Base Case

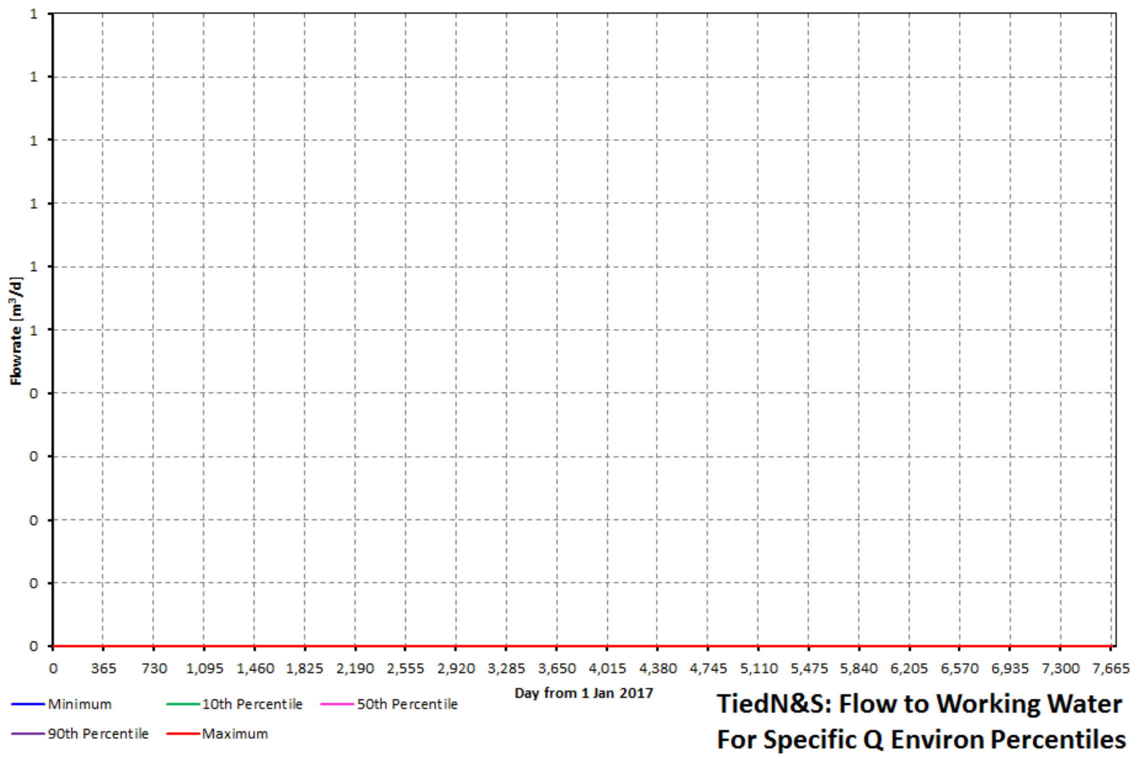

Flowrate [m³/d]
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
0 365 730 1,095 1,460 1,825 2,190 2,555 2,920 3,285 3,650 4,015 4,380 4,745 5,110 5,475 5,840 6,205 6,570 6,935 7,300 7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
RWP Flows In
For Specific Q Environ Percentiles

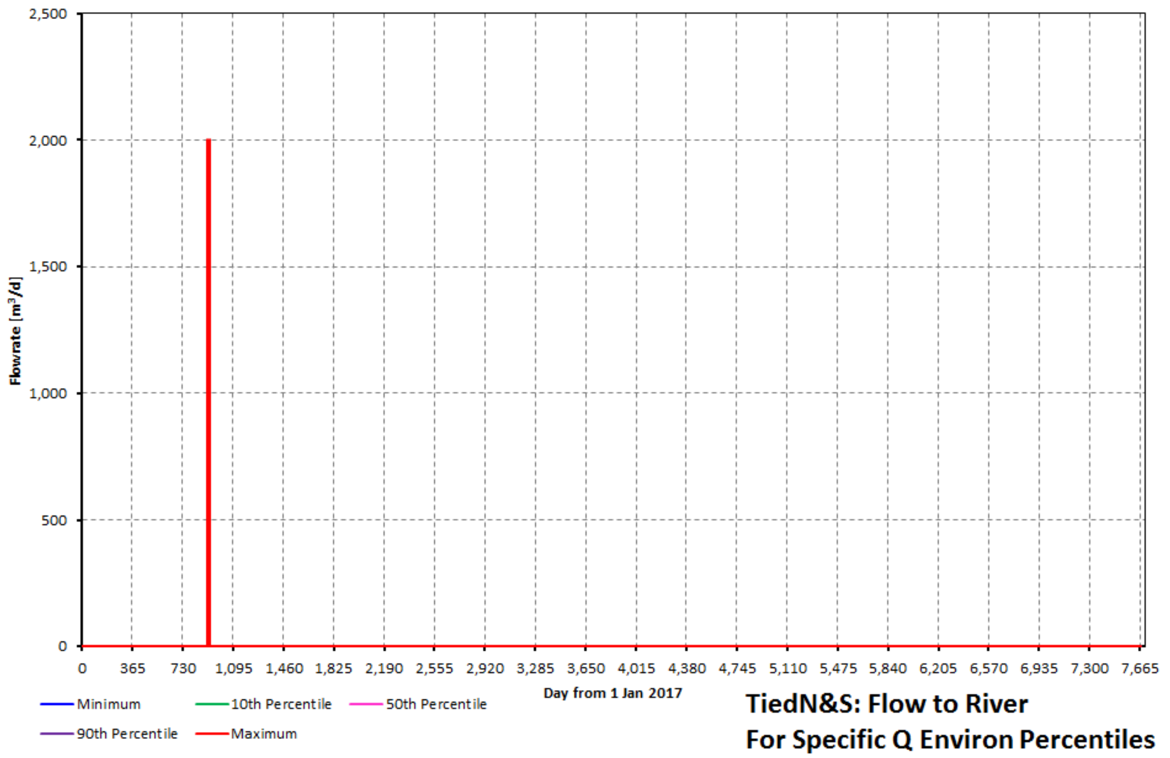

Volume [m³]
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
0 365 730 1,095 1,460 1,825 2,190 2,555 2,920 3,285 3,650 4,015 4,380 4,745 5,110 5,475 5,840 6,205 6,570 6,935 7,300 7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
TWL
Overflow
RWP Volume
For Specific Q Environ Percentiles

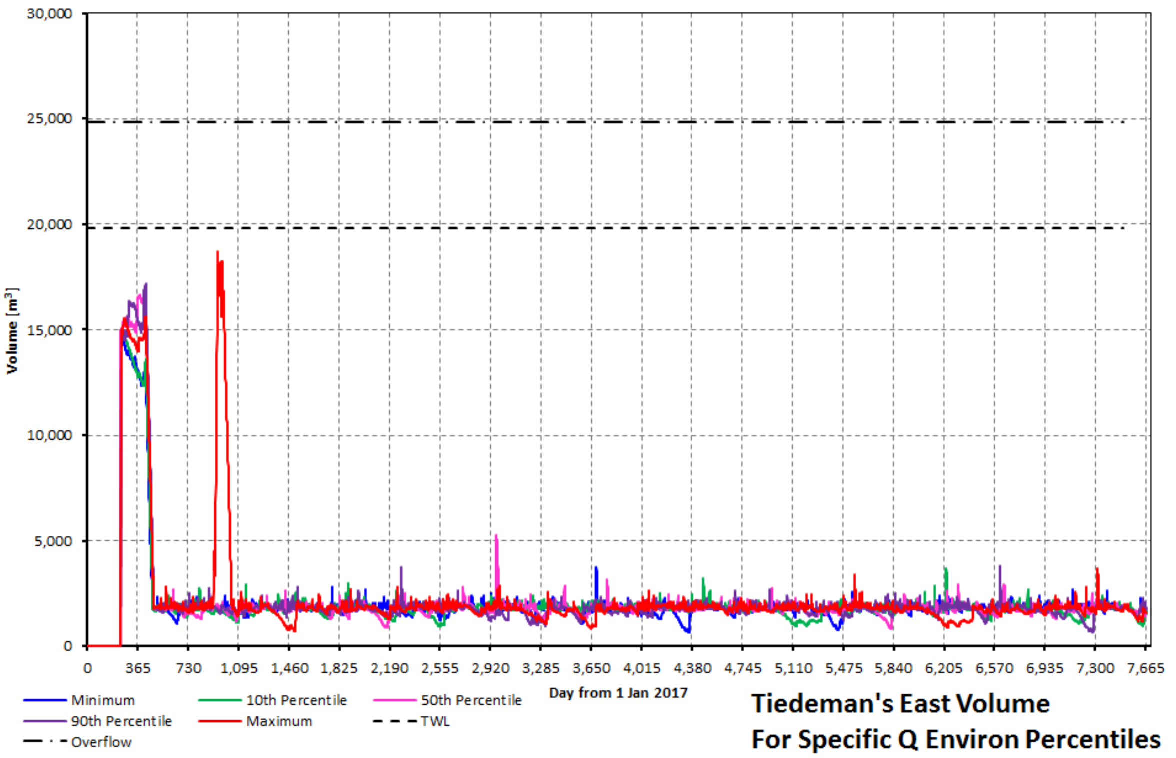

14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Volume [m3]
0 365 730 1,095 1,460 1,825 2,190 2,555 2,920 3,285 3,650 4,015 4,380 4,745 5,110 5,475 5,840 6,205 6,570 6,935 7,300 7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
TWL
Overflow
DWP Volume
For Specific Q Environ Percentiles

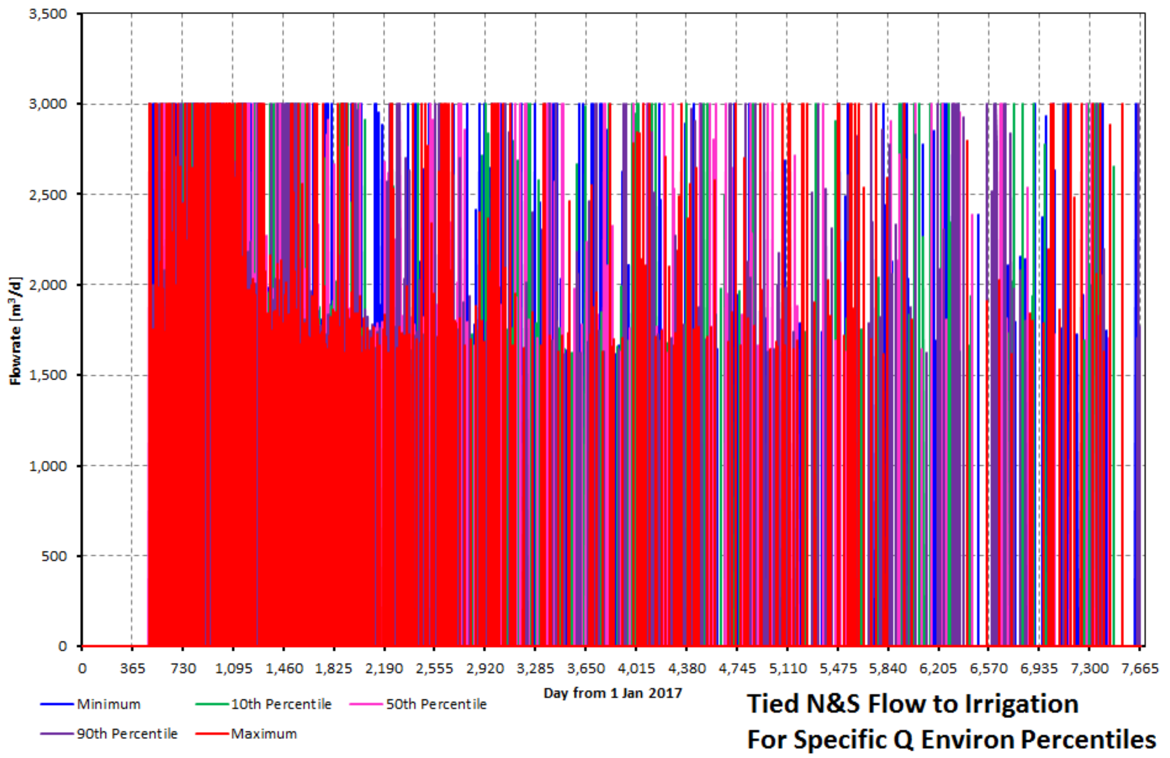

600
500
400
300
200
100
0
Flowrate [m3/d]
0 365 730 1,095 1,460 1,825 2,190 2,555 2,920 3,285 3,650 4,015 4,380 4,745 5,110 5,475 5,840 6,205 6,570 6,935 7,300 7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
DWP: Flows to Working Water
For Specific Q Environ Percentiles

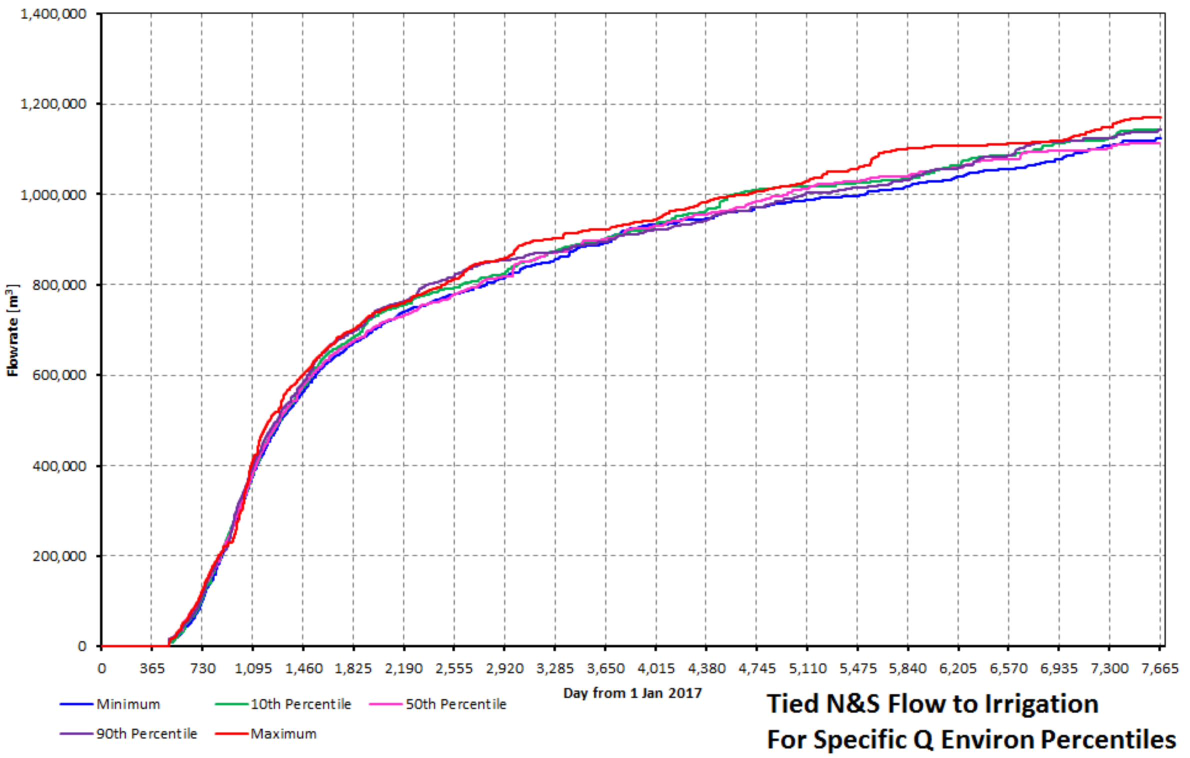

Tiedeman's North & South Volume
For Specific Q Environ Percentiles
Volume [m³]
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
TWL
Overflow

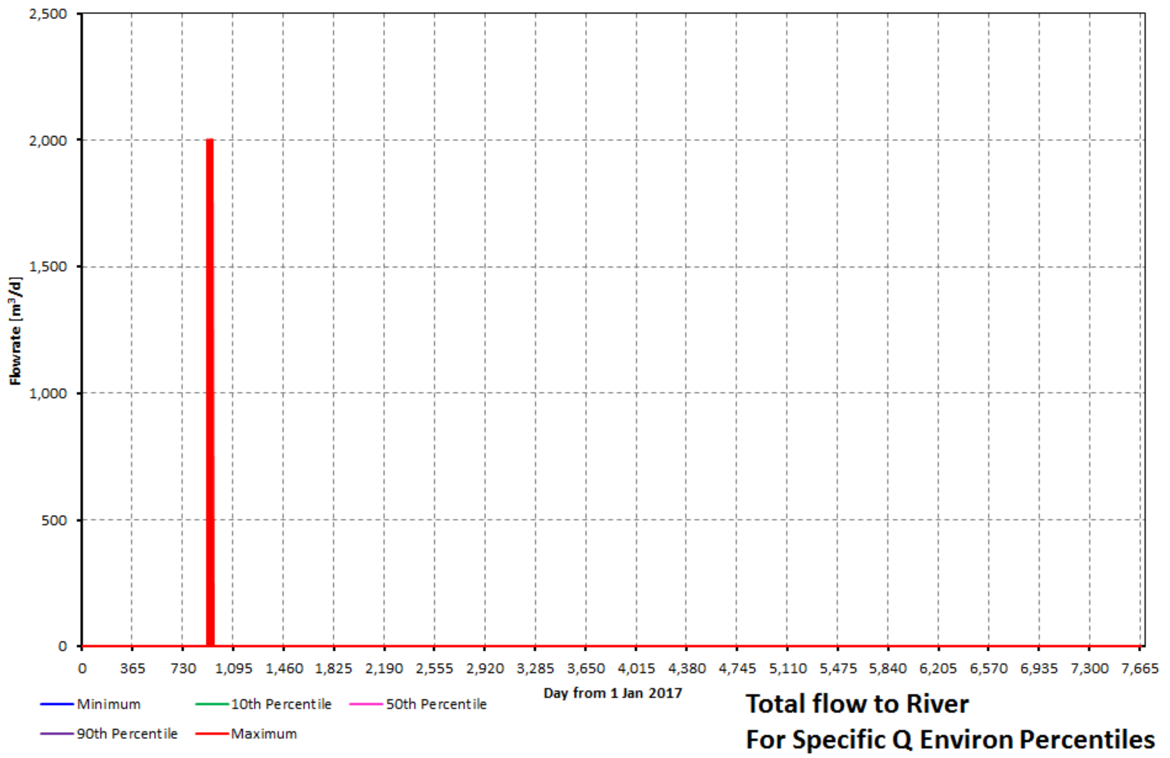

TiedN&S: Flow to Working Water
For Specific Q Environ Percentiles
Flowrate [m³/d]
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum

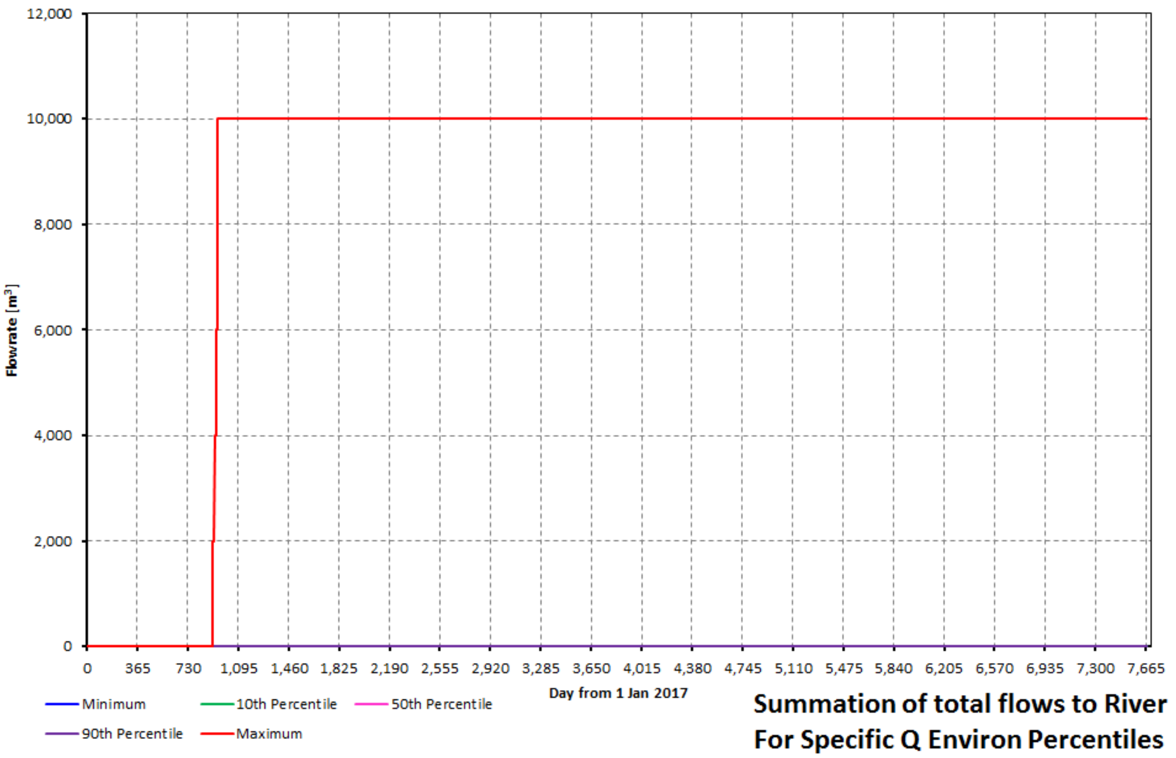

Flowrate [m³/d]
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
TiedN&S: Flow to River
For Specific Q Environ Percentiles

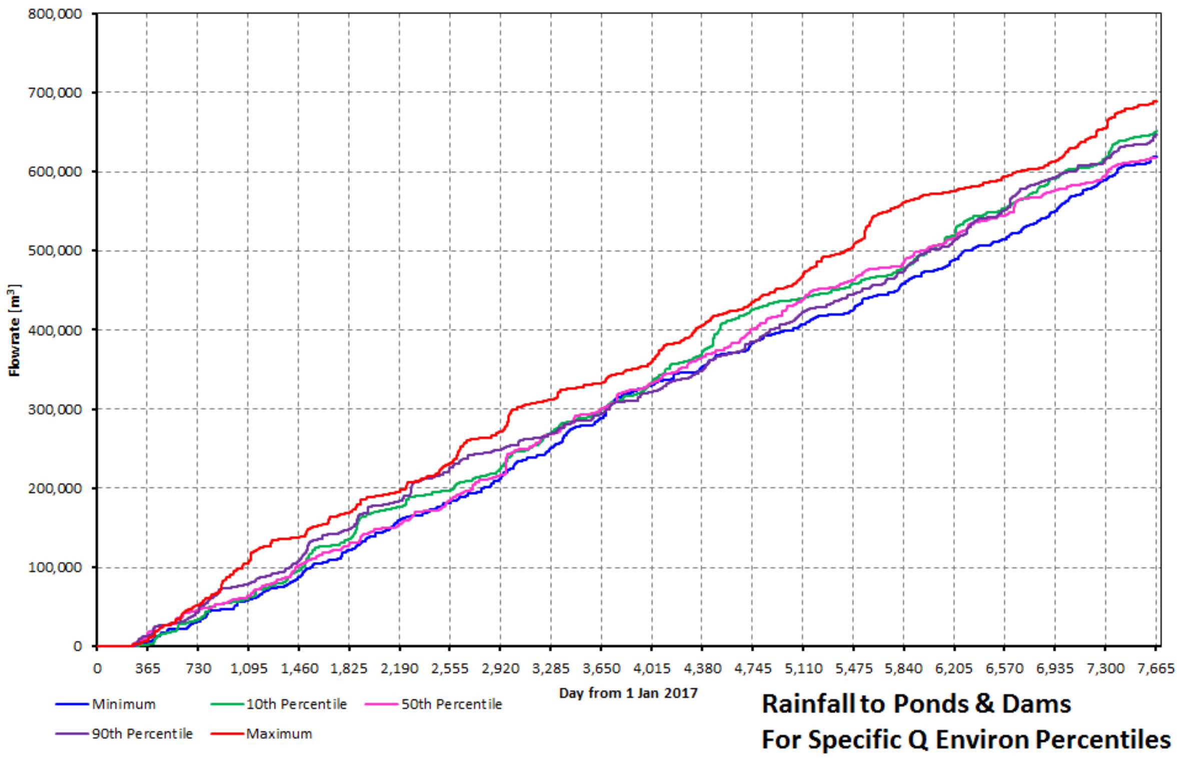

Volume [m³]
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
TWL
Overflow
Tiedeman's East Volume
For Specific Q Environ Percentiles


3,500
3,000
2,500
2,000
1,500
1,000
500
0
Flowrate [m³/d]
0 365 730 1,095 1,460 1,825 2,190 2,555 2,920 3,285 3,650 4,015 4,380 4,745 5,110 5,475 5,840 6,205 6,570 6,935 7,300 7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
Tied N&S Flow to Irrigation
For Specific Q Environ Percentiles

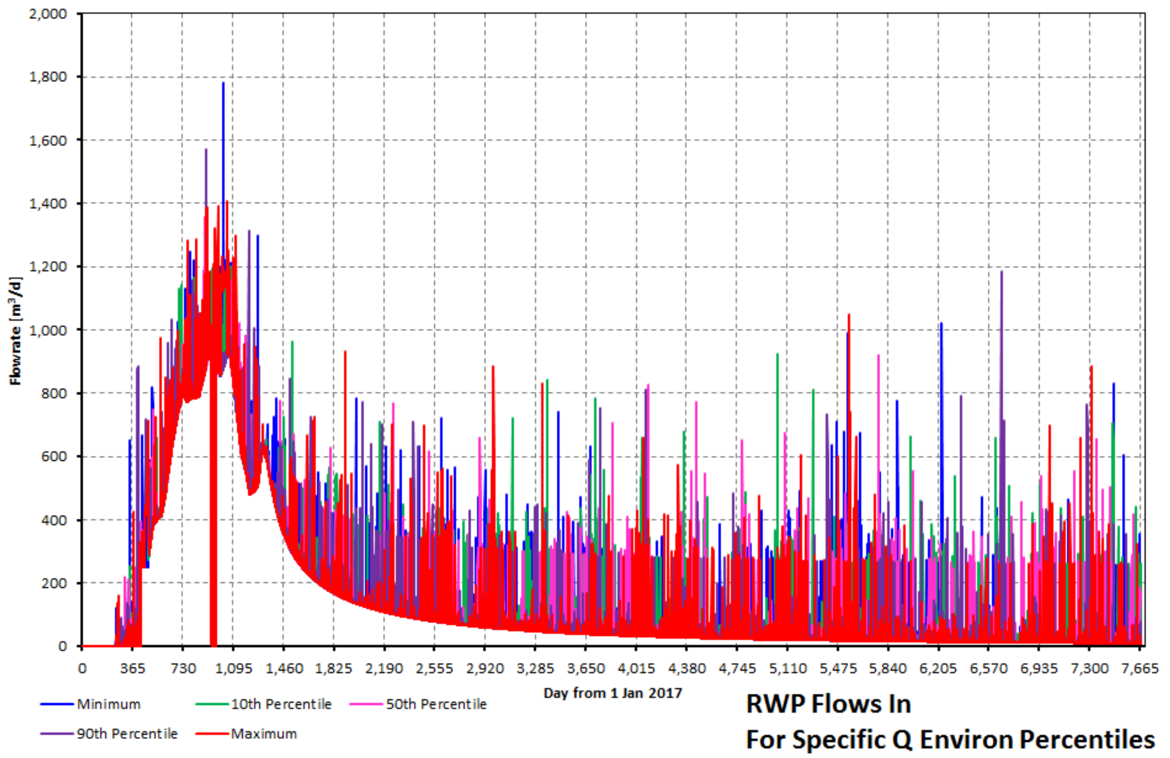

1,400,000
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
Flowrate [m³]
0 365 730 1,095 1,460 1,825 2,190 2,555 2,920 3,285 3,650 4,015 4,380 4,745 5,110 5,475 5,840 6,205 6,570 6,935 7,300 7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
Tied N&S Flow to Irrigation
For Specific Q Environ Percentiles

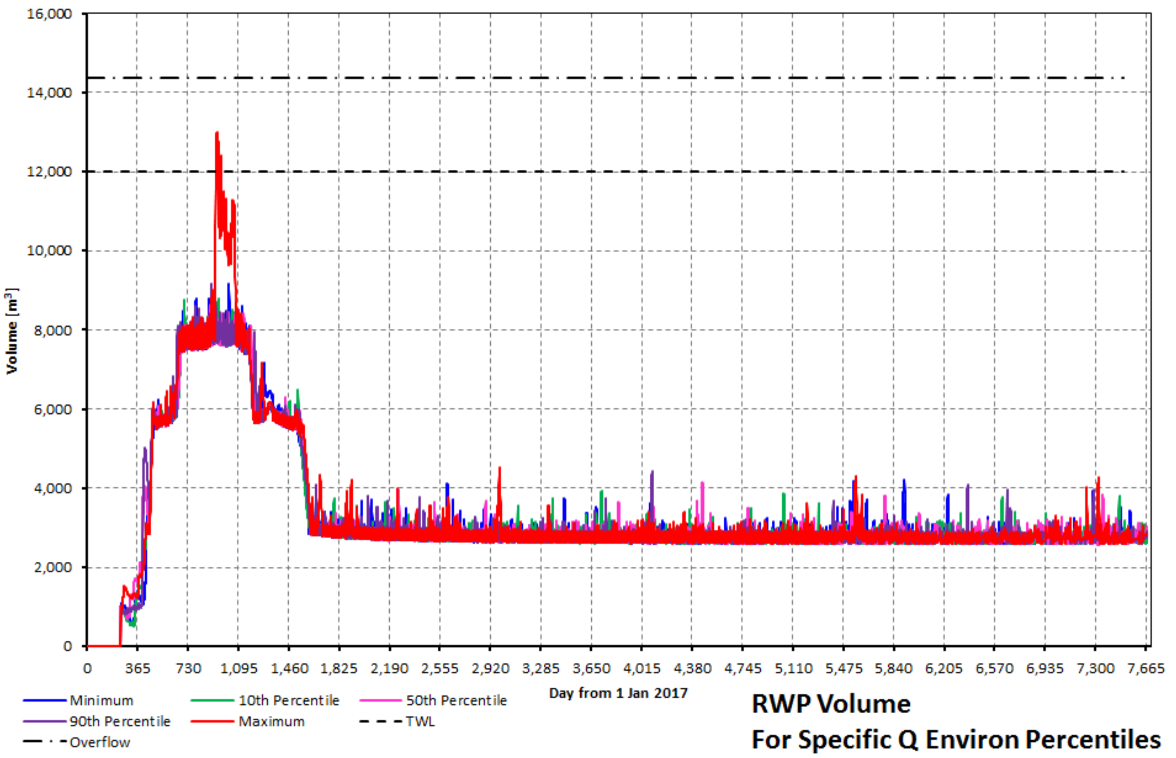

2,500
2,000
1,500
1,000
500
0
Flowrate [m³/d]
0 365 730 1,095 1,460 1,825 2,190 2,555 2,920 3,285 3,650 4,015 4,380 4,745 5,110 5,475 5,840 6,205 6,570 6,935 7,300 7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
Total flow to River
For Specific Q Environ Percentiles

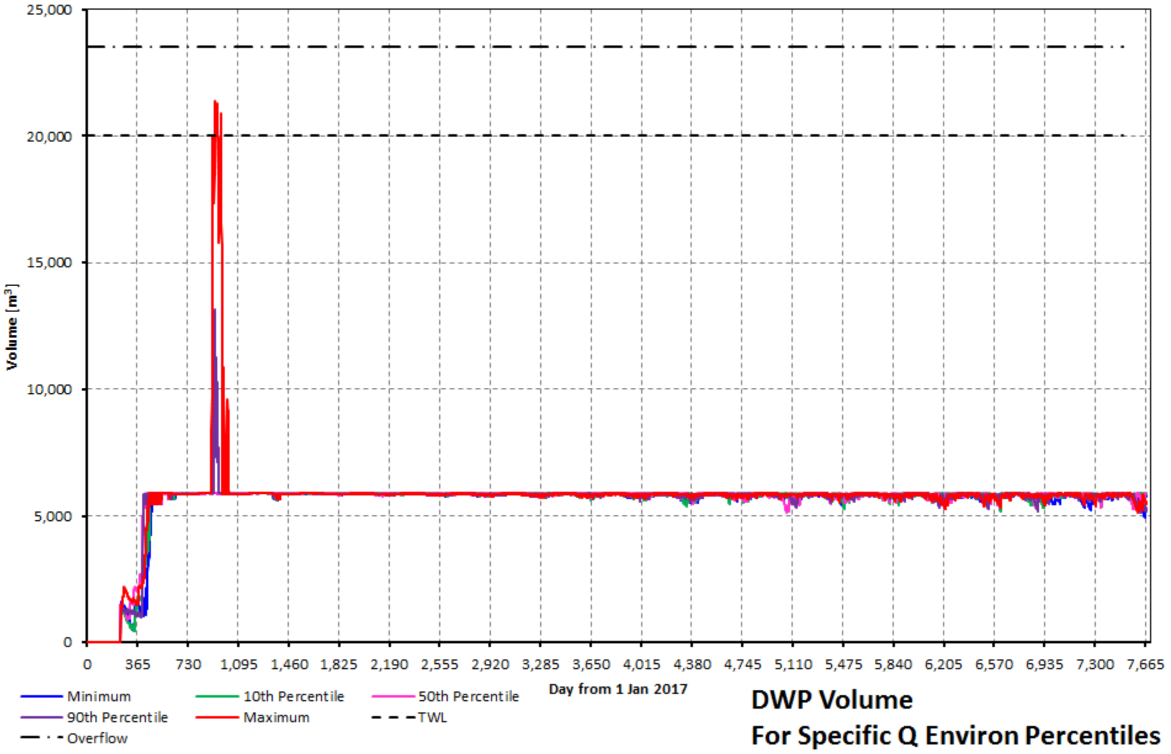

12,000
10,000
8,000
6,000
4,000
2,000
0
Flowrate [m³]
0 365 730 1,095 1,460 1,825 2,190 2,555 2,920 3,285 3,650 4,015 4,380 4,745 5,110 5,475 5,840 6,205 6,570 6,935 7,300 7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
Summation of total flows to River
For Specific Q Environ Percentiles


Flowrate [m³]
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
0
365
730
1,095
1,460
1,825
2,190
2,555
2,920
3,285
3,650
4,015
4,380
4,745
5,110
5,475
5,840
6,205
6,570
6,935
7,300
7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
Rainfall to Ponds & Dams
For Specific Q Environ Percentiles

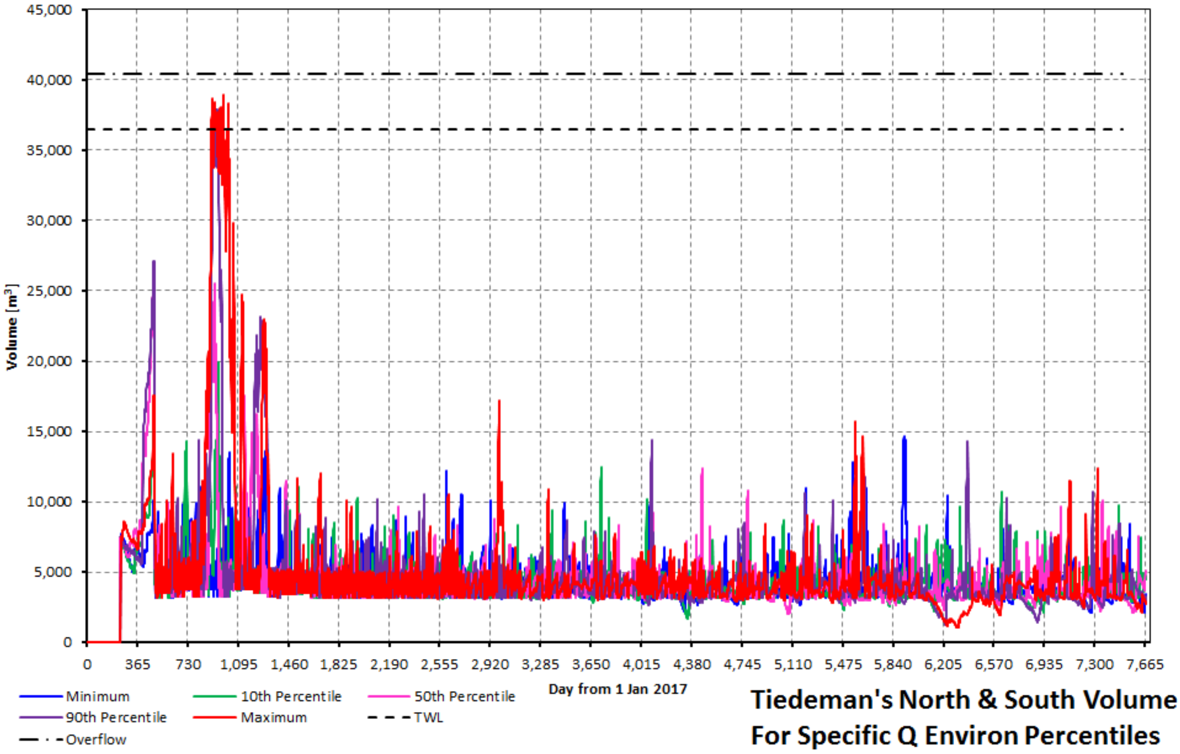
Appendix 4 Simulation Scenario 03: P90 Extracted Water Production, Large WTP Ponds


2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
Flowrate [m³/d]
0
365
730
1,095
1,460
1,825
2,190
2,555
2,920
3,285
3,650
4,015
4,380
4,745
5,110
5,475
5,840
6,205
6,570
6,935
7,300
7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
RWP Flows In
For Specific Q Environ Percentiles

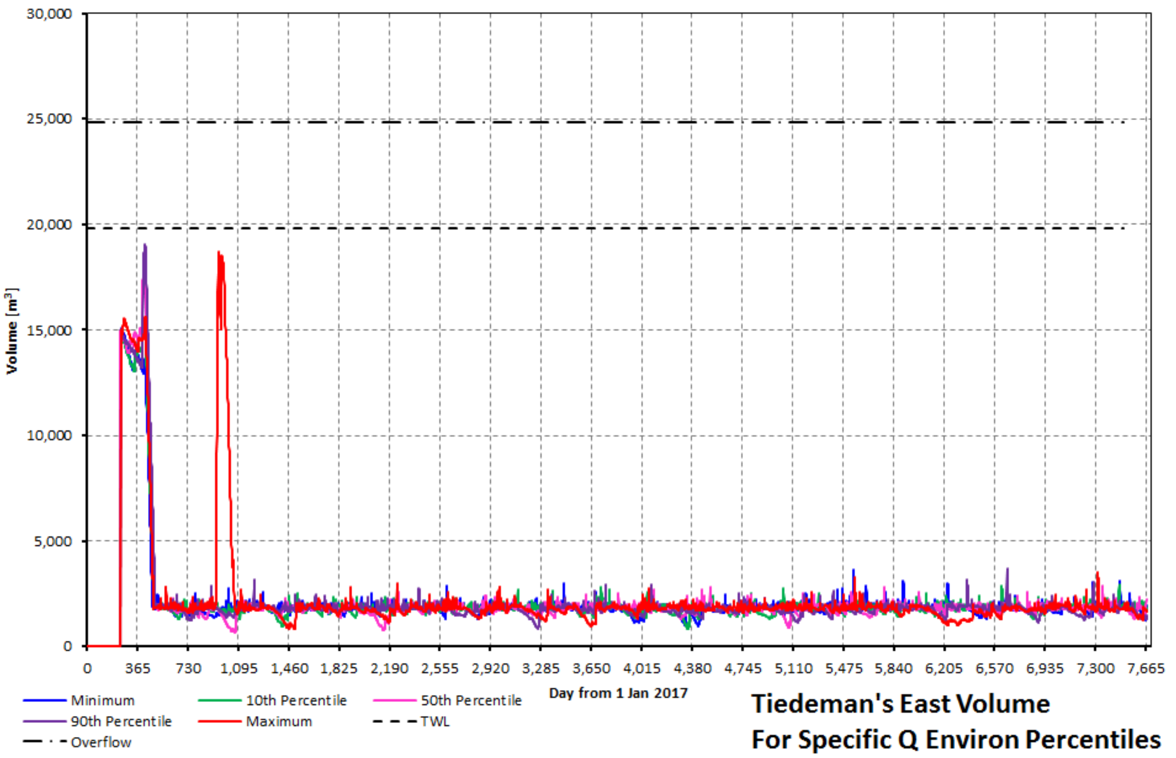

16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Volume [m³]
0
365
730
1,095
1,460
1,825
2,190
2,555
2,920
3,285
3,650
4,015
4,380
4,745
5,110
5,475
5,840
6,205
6,570
6,935
7,300
7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
TWL
Overflow
RWP Volume
For Specific Q Environ Percentiles

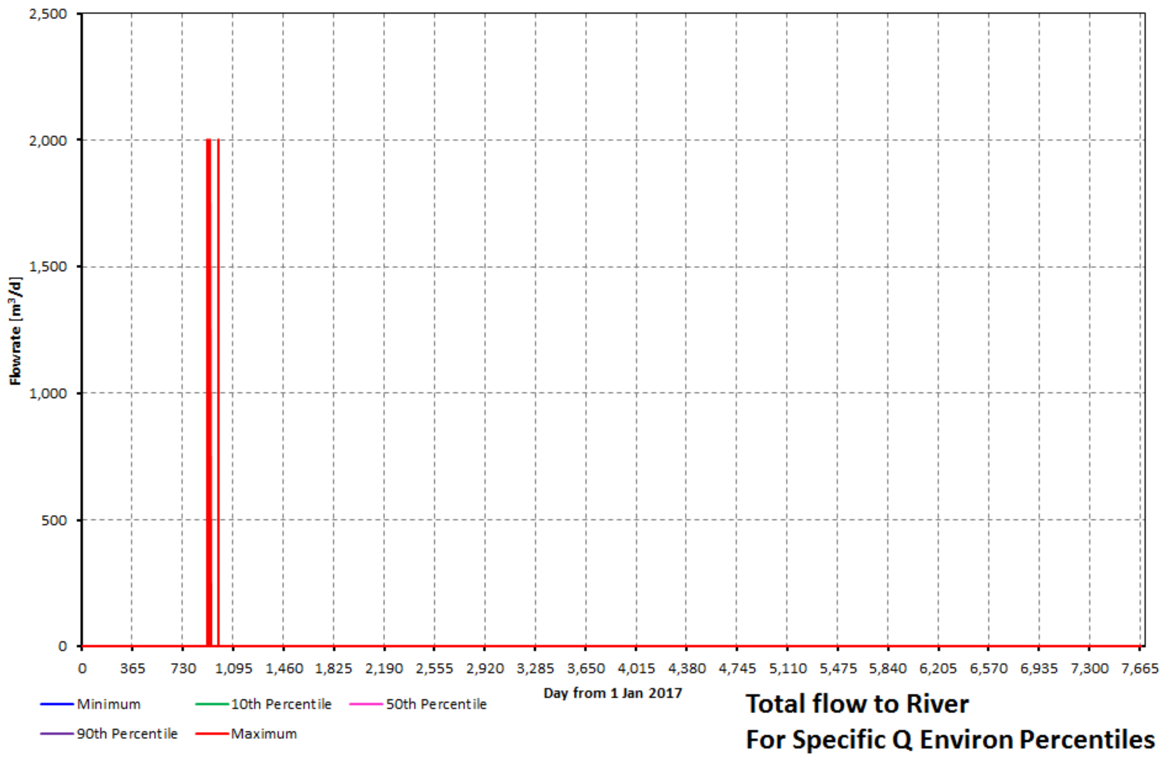


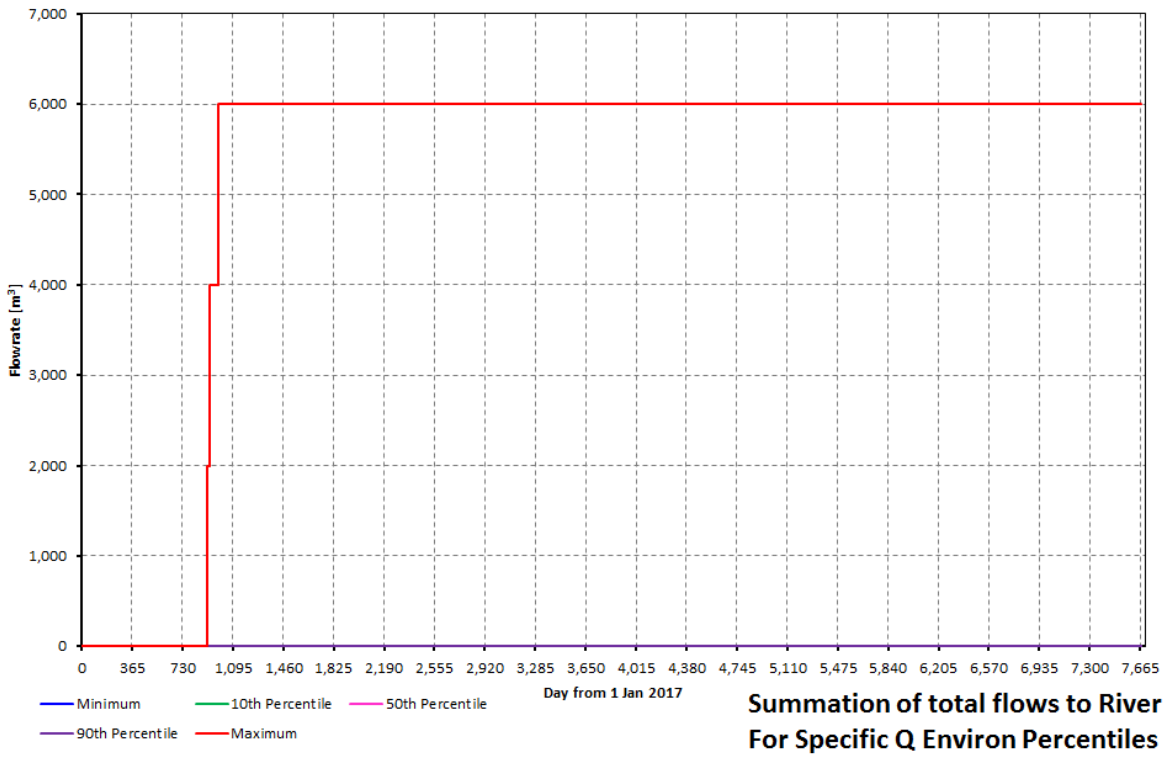
DWP Volume
For Specific Q Environ Percentiles



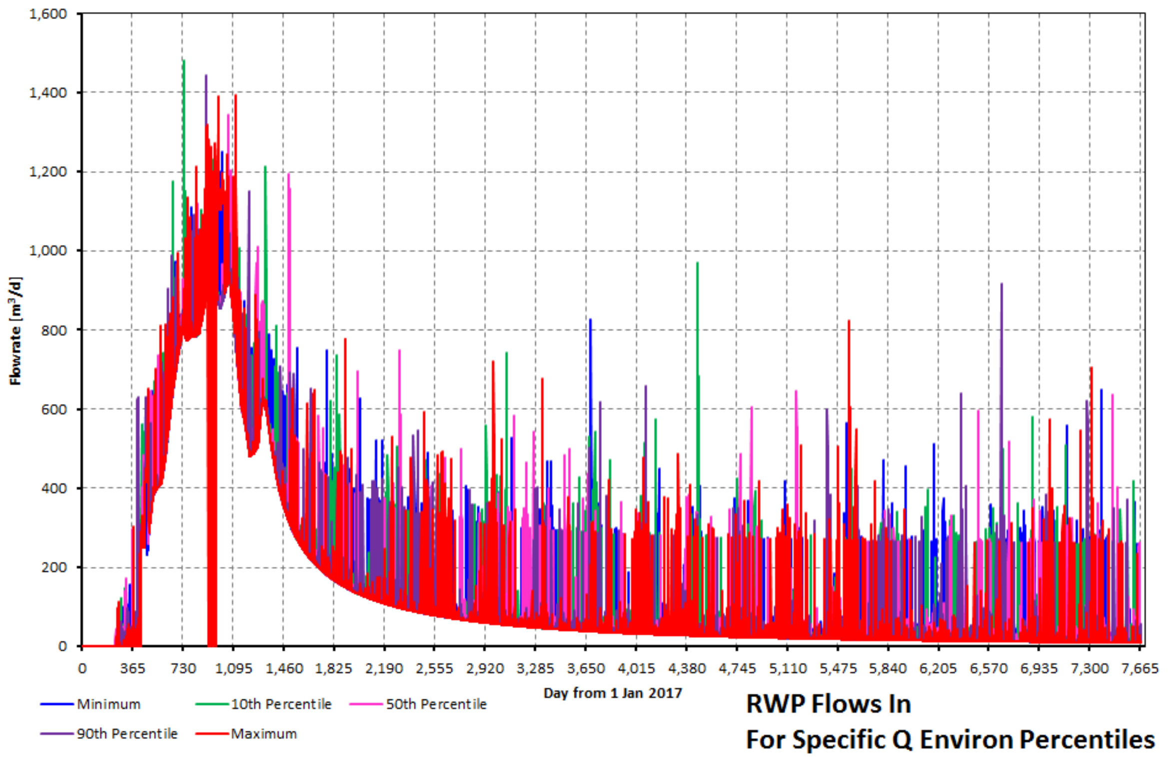
Tiedeman's North & South Volume
For Specific Q Environ Percentiles

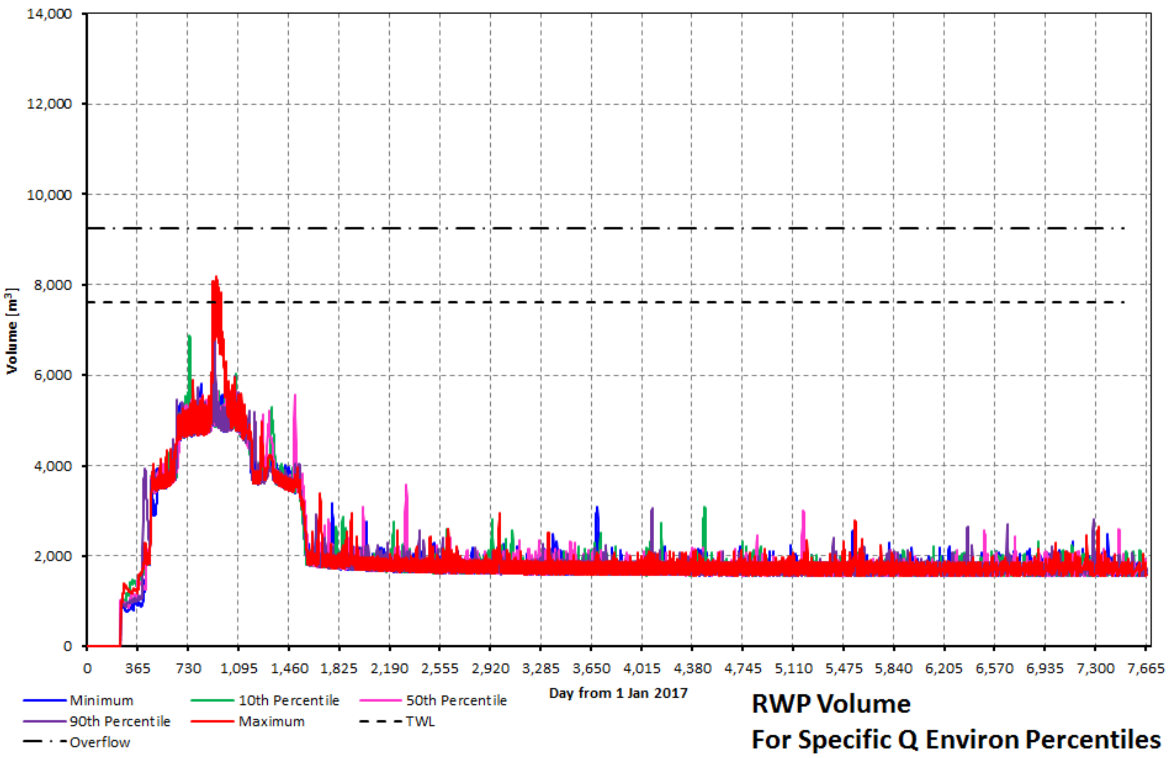

Volume [m³]
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
TWL
Overflow
Tiedeman's East Volume
For Specific Q Environ Percentiles

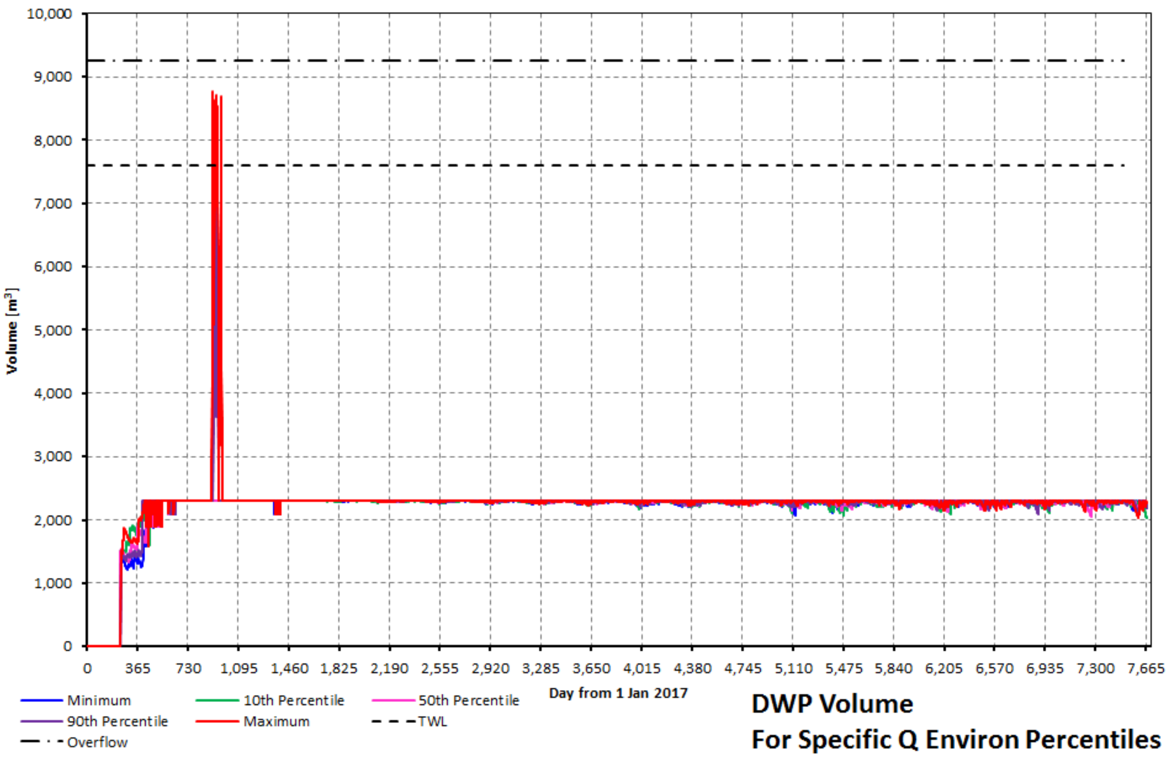

Flowrate [m³/d]
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
Total flow to River
For Specific Q Environ Percentiles

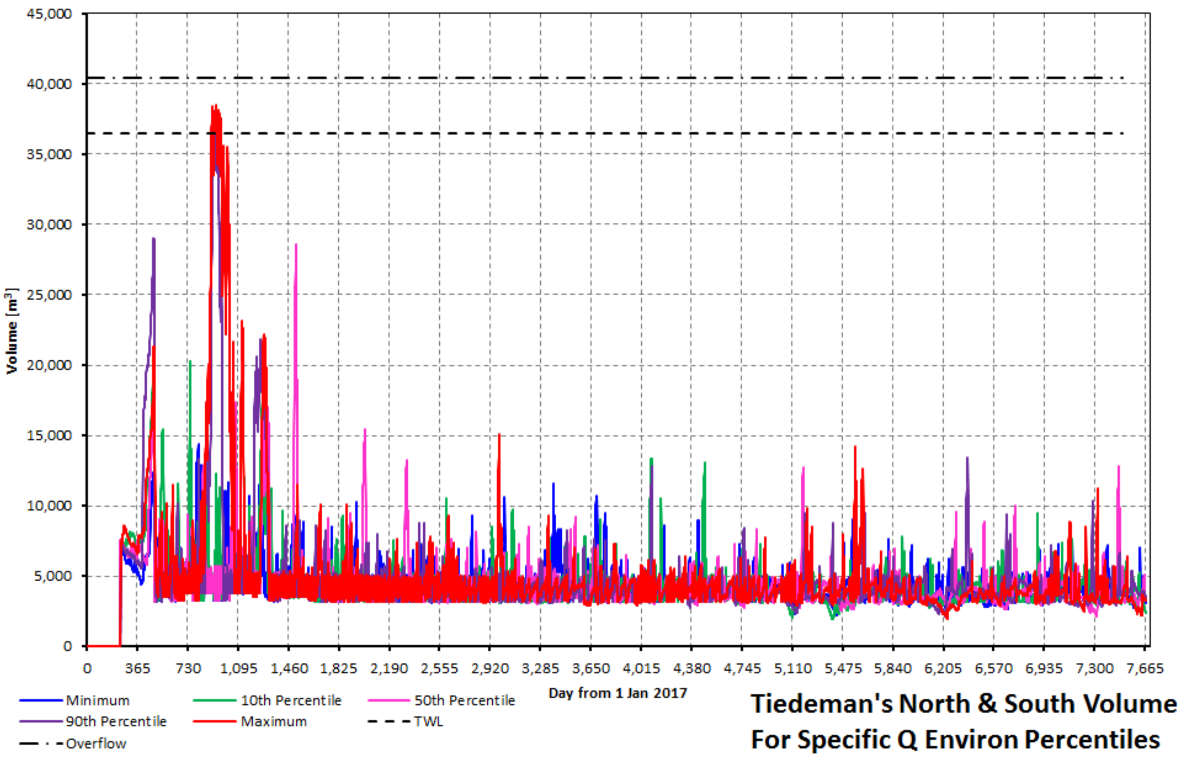

7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Flowrate [m³]
0
365
730
1,095
1,460
1,825
2,190
2,555
2,920
3,285
3,650
4,015
4,380
4,745
5,110
5,475
5,840
6,205
6,570
6,935
7,300
7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
Summation of total flows to River
For Specific Q Environ Percentiles

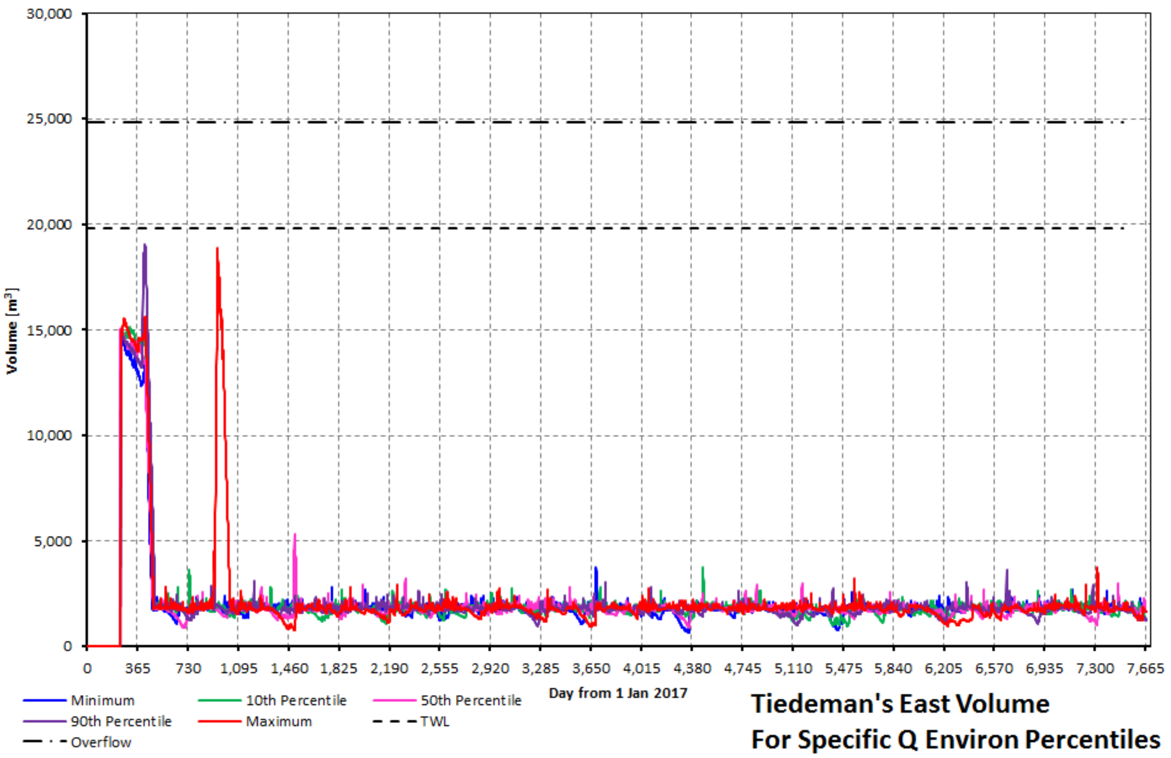
Appendix 5 Simulation Scenario 04: P90 Extracted Water Production, Small WTP Ponds

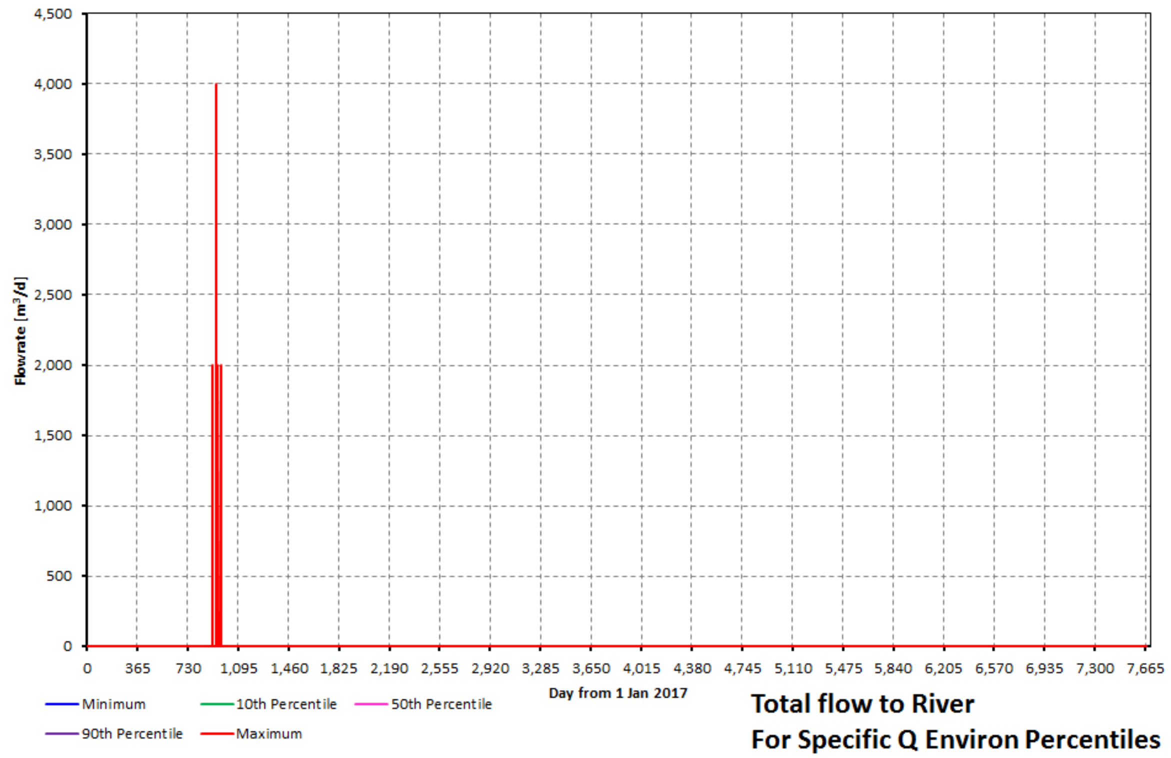

Flowrate [m³/d]
0
200
400
600
800
1,000
1,200
1,400
1,600
0 365 730 1,095 1,460 1,825 2,190 2,555 2,920 3,285 3,650 4,015 4,380 4,745 5,110 5,475 5,840 6,205 6,570 6,935 7,300 7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
RWP Flows In
For Specific Q Environ Percentiles

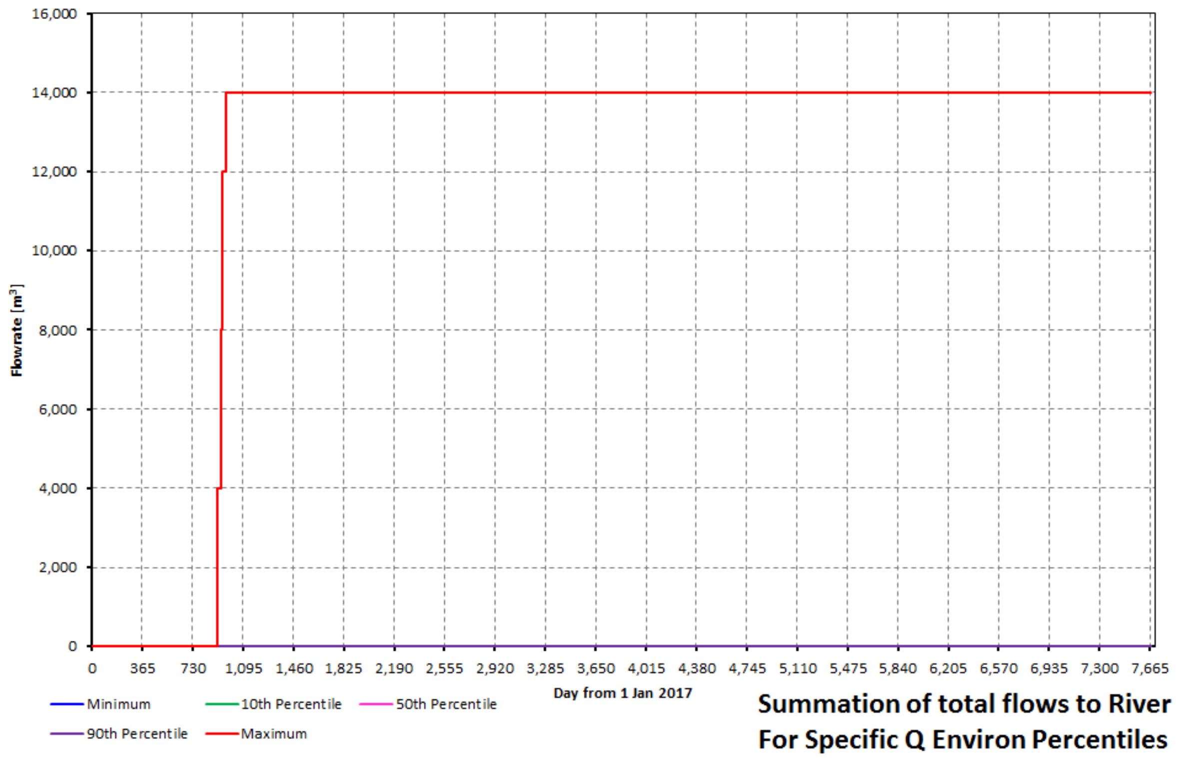

Volume [m³]
0
2,000
4,000
6,000
8,000
10,000
12,000
14,000
0 365 730 1,095 1,460 1,825 2,190 2,555 2,920 3,285 3,650 4,015 4,380 4,745 5,110 5,475 5,840 6,205 6,570 6,935 7,300 7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
TWL
Overflow
RWP Volume
For Specific Q Environ Percentiles


Volume [m³]
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0 365 730 1,095 1,460 1,825 2,190 2,555 2,920 3,285 3,650 4,015 4,380 4,745 5,110 5,475 5,840 6,205 6,570 6,935 7,300 7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
TWL
Overflow
DWP Volume
For Specific Q Environ Percentiles

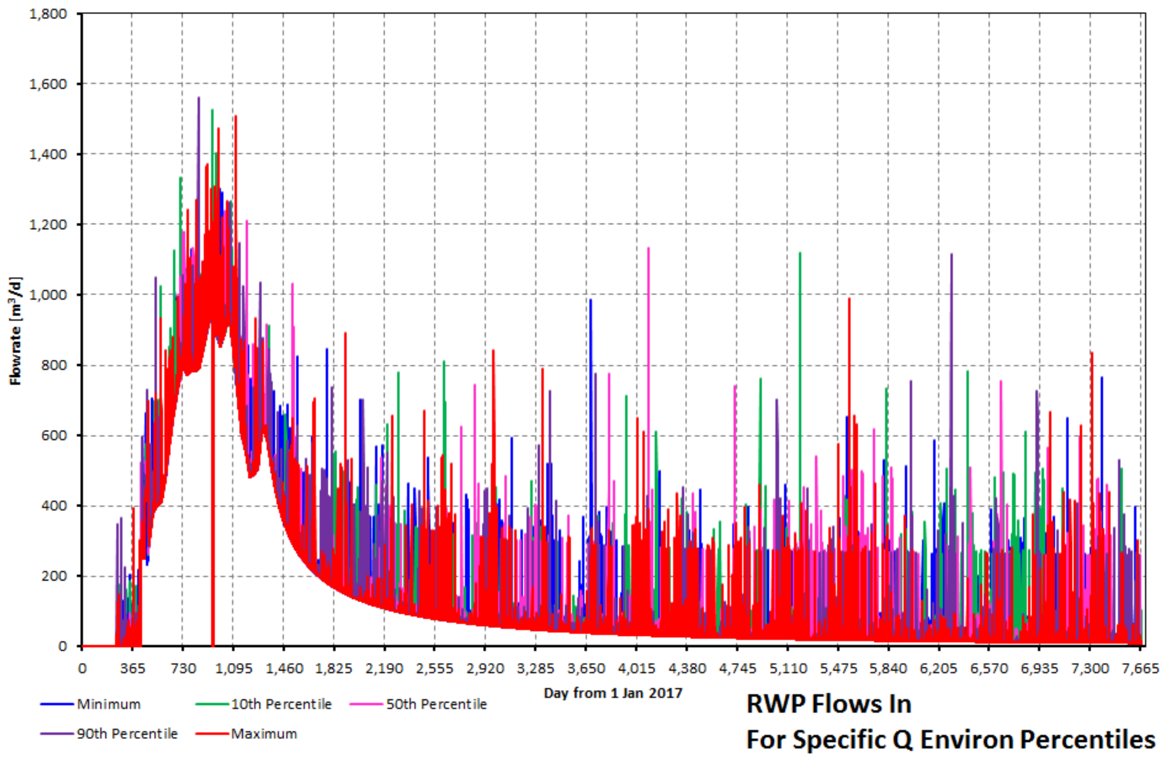

Volume [m³]
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
0 365 730 1,095 1,460 1,825 2,190 2,555 2,920 3,285 3,650 4,015 4,380 4,745 5,110 5,475 5,840 6,205 6,570 6,935 7,300 7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
TWL
Overflow
Tiedeman's North & South Volume
For Specific Q Environ Percentiles

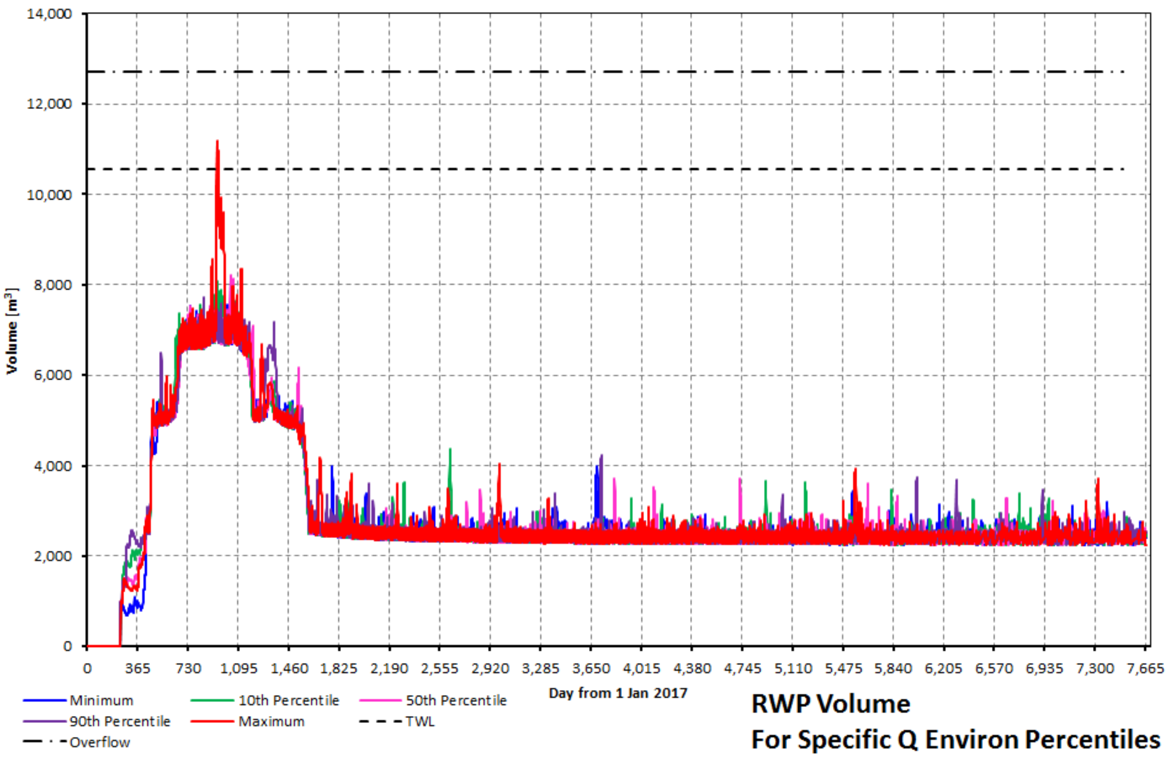

Volume [m3]
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
TWL
Overflow
Tiedeman's East Volume
For Specific Q Environ Percentiles

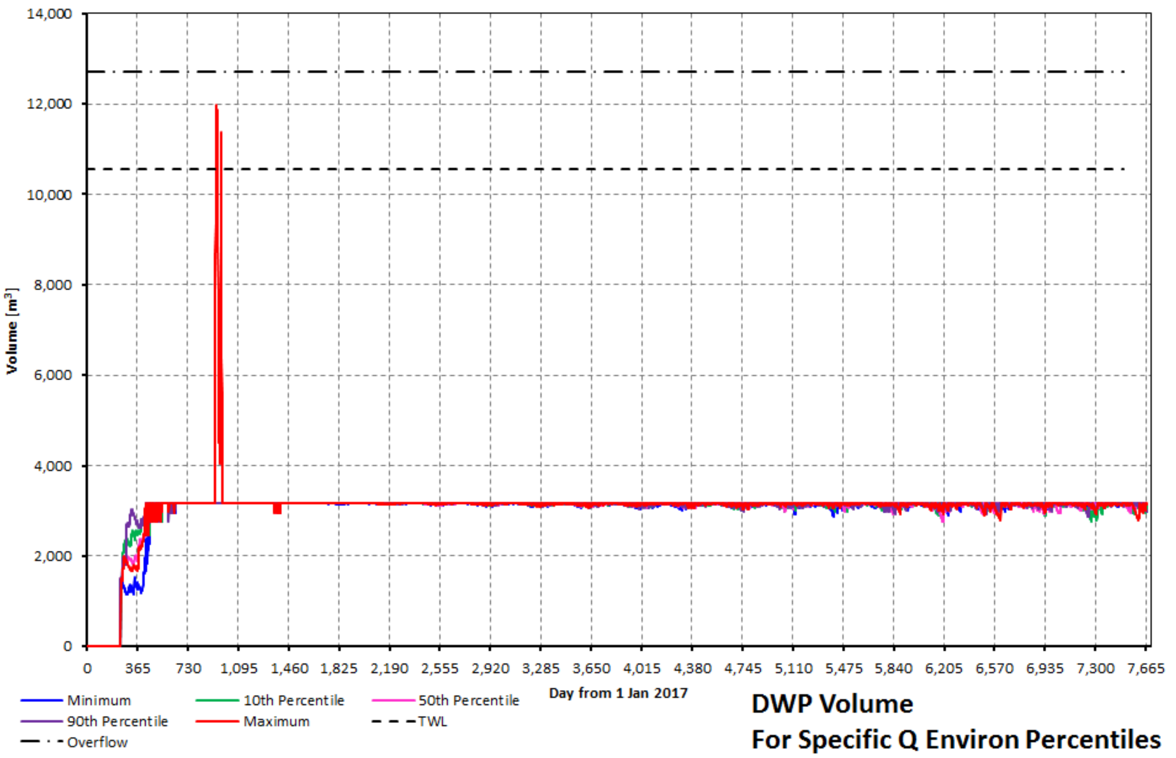

Flowrate [m3/d]
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
Total flow to River
For Specific Q Environ Percentiles

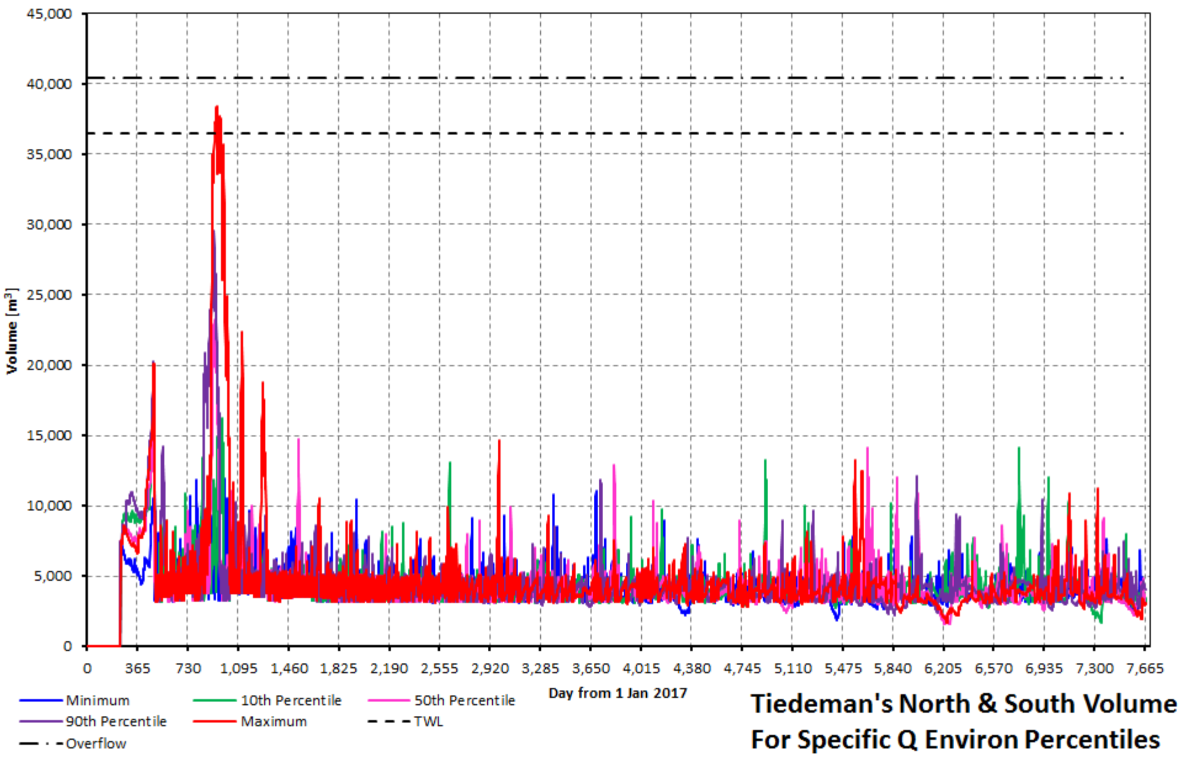

16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Flowrate [m3]
0
365
730
1,095
1,460
1,825
2,190
2,555
2,920
3,285
3,650
4,015
4,380
4,745
5,110
5,475
5,840
6,205
6,570
6,935
7,300
7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
Summation of total flows to River
For Specific Q Environ Percentiles

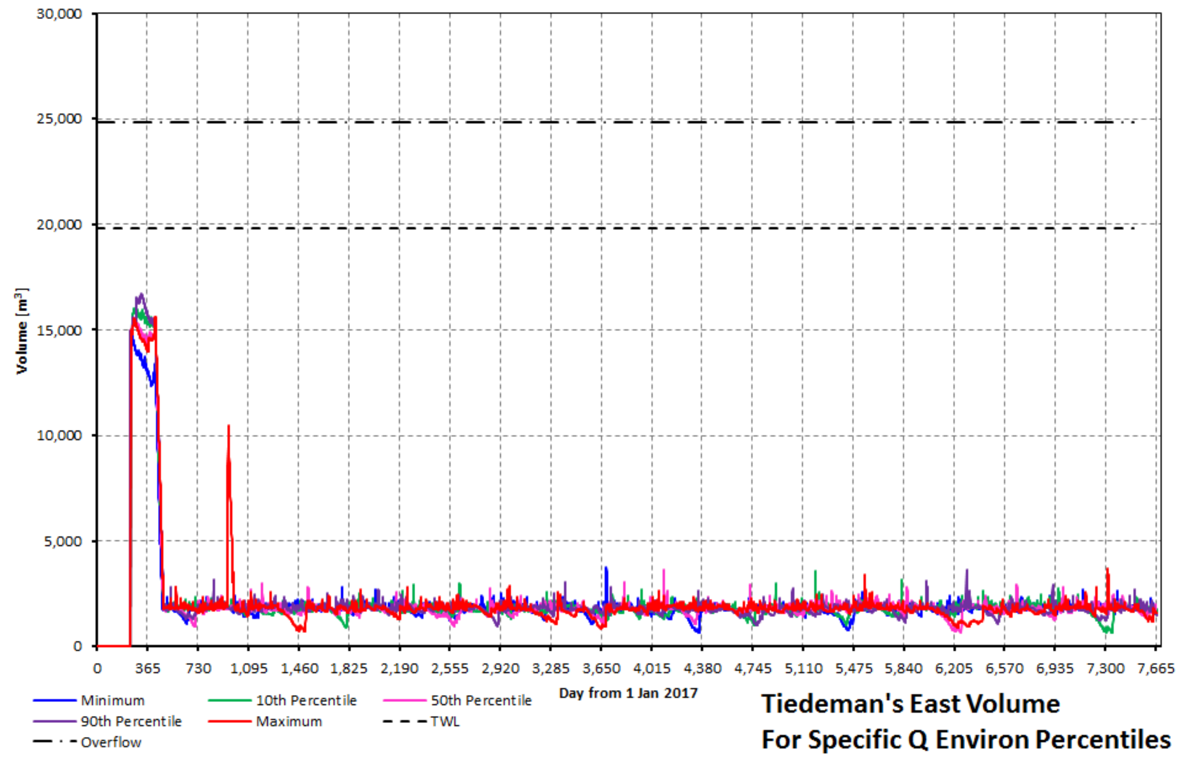
Appendix 6 Simulation Scenario 05: P90 Extracted Water Production, Light Clay Soil

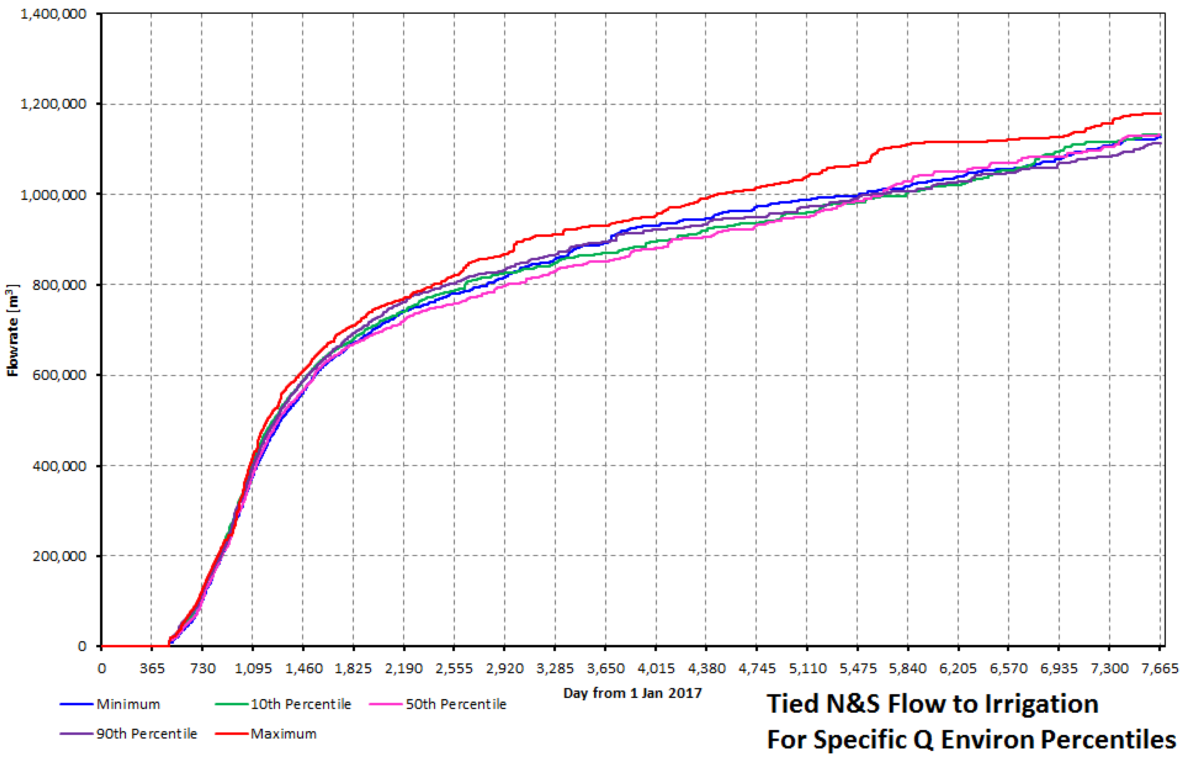

Flowrate [m³/d]
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
0 365 730 1,095 1,460 1,825 2,190 2,555 2,920 3,285 3,650 4,015 4,380 4,745 5,110 5,475 5,840 6,205 6,570 6,935 7,300 7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
RWP Flows In
For Specific Q Environ Percentiles

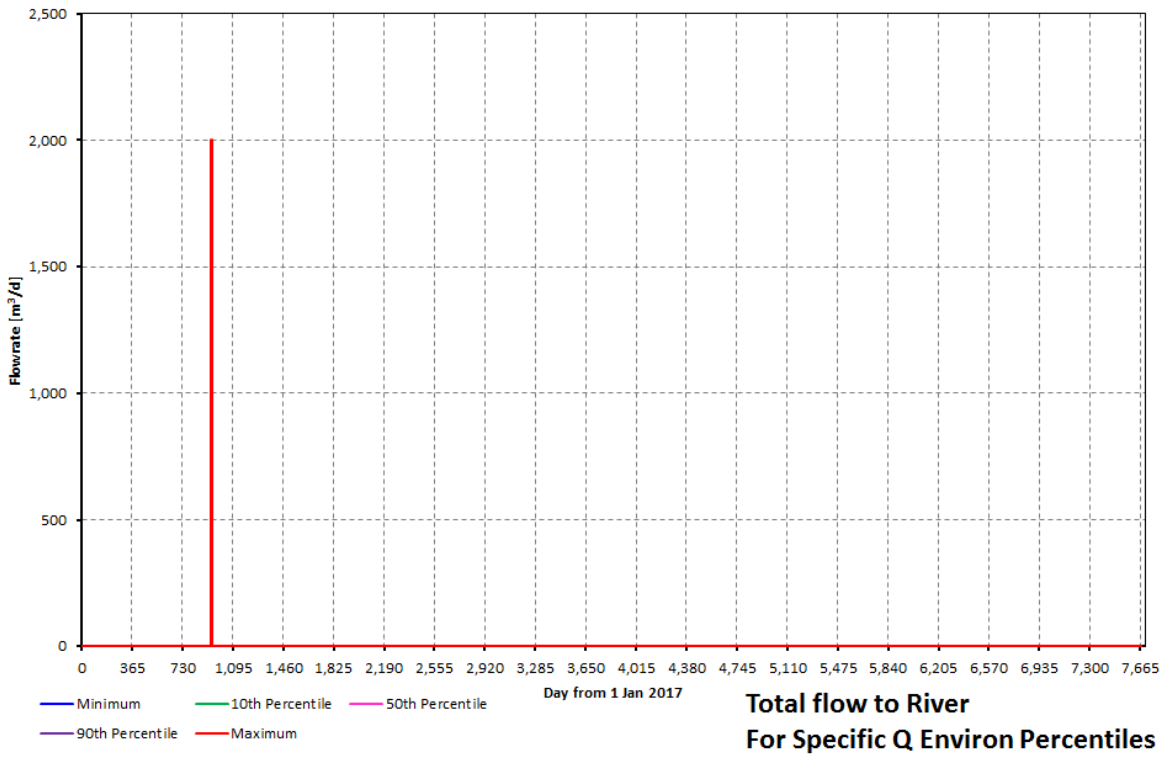

Volume [m³]
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
0 365 730 1,095 1,460 1,825 2,190 2,555 2,920 3,285 3,650 4,015 4,380 4,745 5,110 5,475 5,840 6,205 6,570 6,935 7,300 7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
TWL
Overflow
RWP Volume
For Specific Q Environ Percentiles

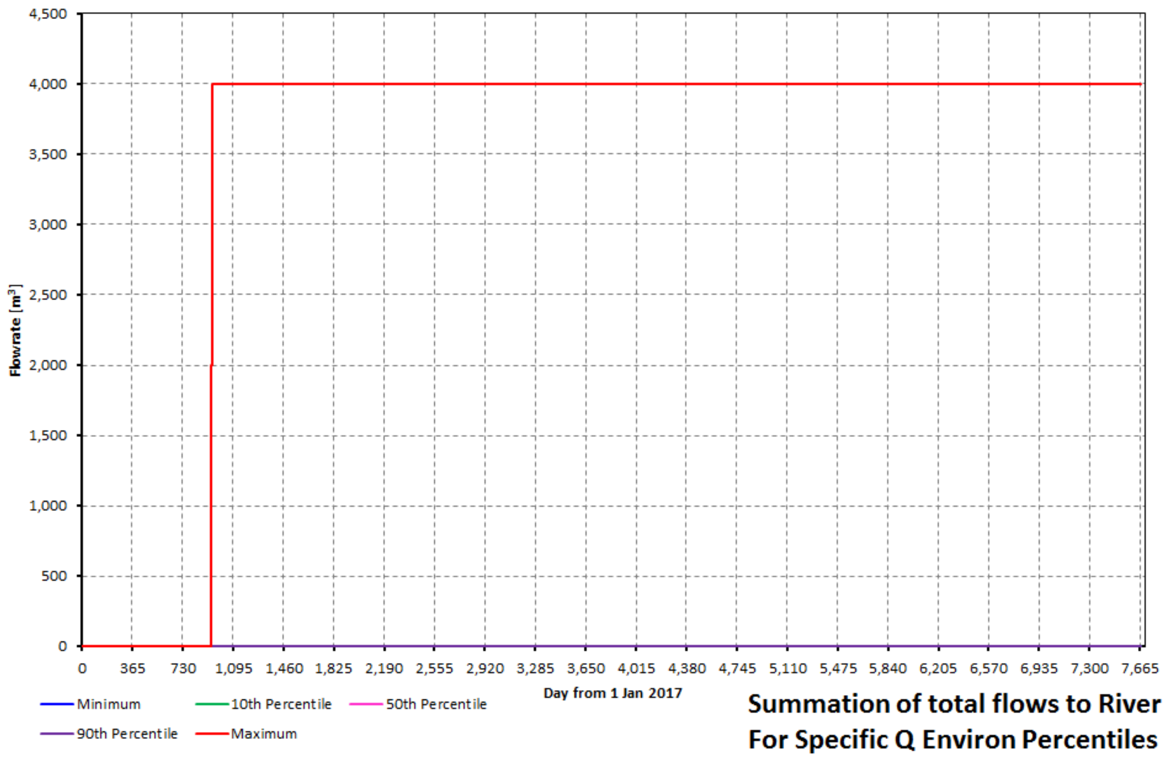

14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Volume [m³]
0
365
730
1,095
1,460
1,825
2,190
2,555
2,920
3,285
3,650
4,015
4,380
4,745
5,110
5,475
5,840
6,205
6,570
6,935
7,300
7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
TWL
Overflow
DWP Volume
For Specific Q Environ Percentiles

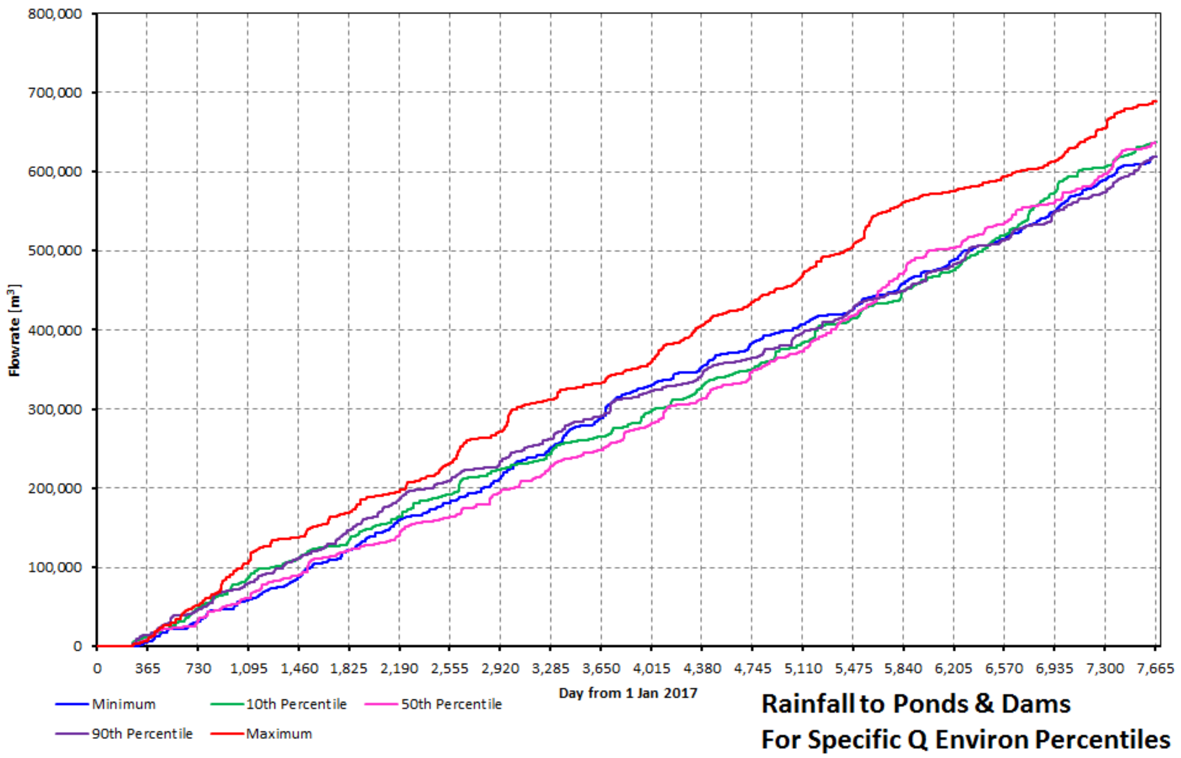

45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Volume [m³]
0
365
730
1,095
1,460
1,825
2,190
2,555
2,920
3,285
3,650
4,015
4,380
4,745
5,110
5,475
5,840
6,205
6,570
6,935
7,300
7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
TWL
Overflow
Tiedeman's North & South Volume
For Specific Q Environ Percentiles


30,000
25,000
20,000
15,000
10,000
5,000
0
Volume [m³]
0 365 730 1,095 1,460 1,825 2,190 2,555 2,920 3,285 3,650 4,015 4,380 4,745 5,110 5,475 5,840 6,205 6,570 6,935 7,300 7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
TWL
Overflow
Tiedeman's East Volume
For Specific Q Environ Percentiles

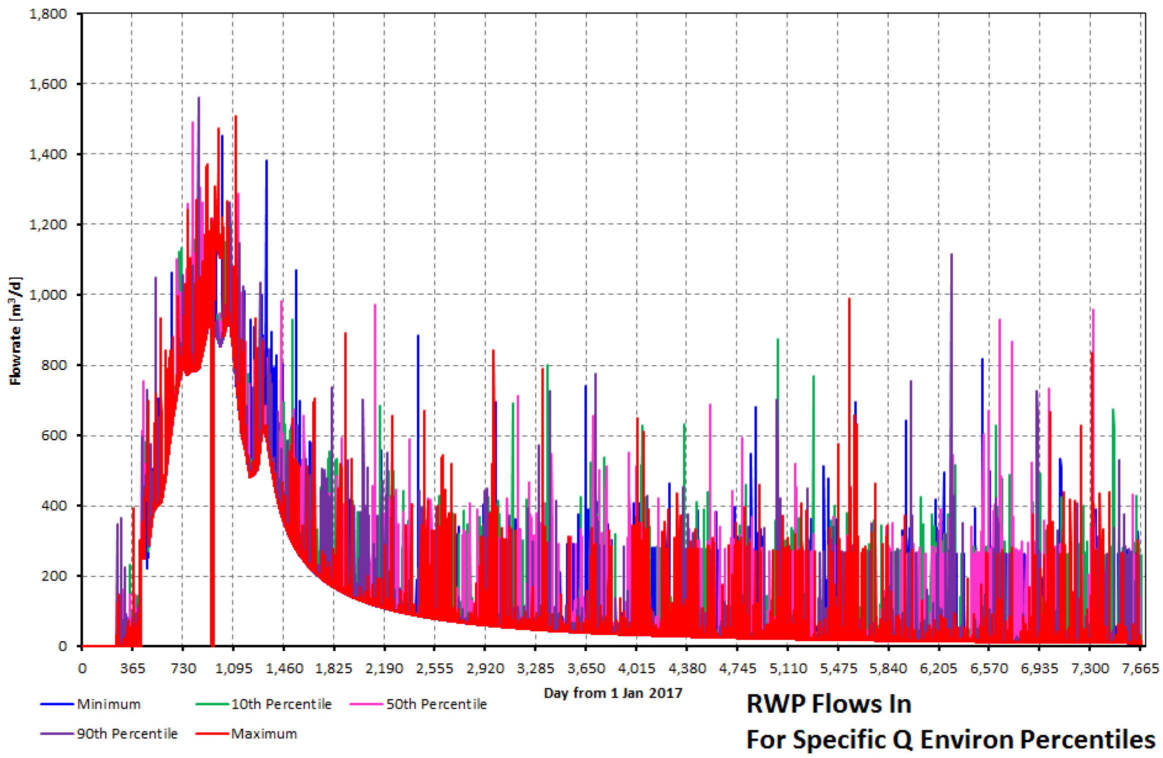

1,400,000
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
Flowrate [m³]
0 365 730 1,095 1,460 1,825 2,190 2,555 2,920 3,285 3,650 4,015 4,380 4,745 5,110 5,475 5,840 6,205 6,570 6,935 7,300 7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
Tied N&S Flow to Irrigation
For Specific Q Environ Percentiles

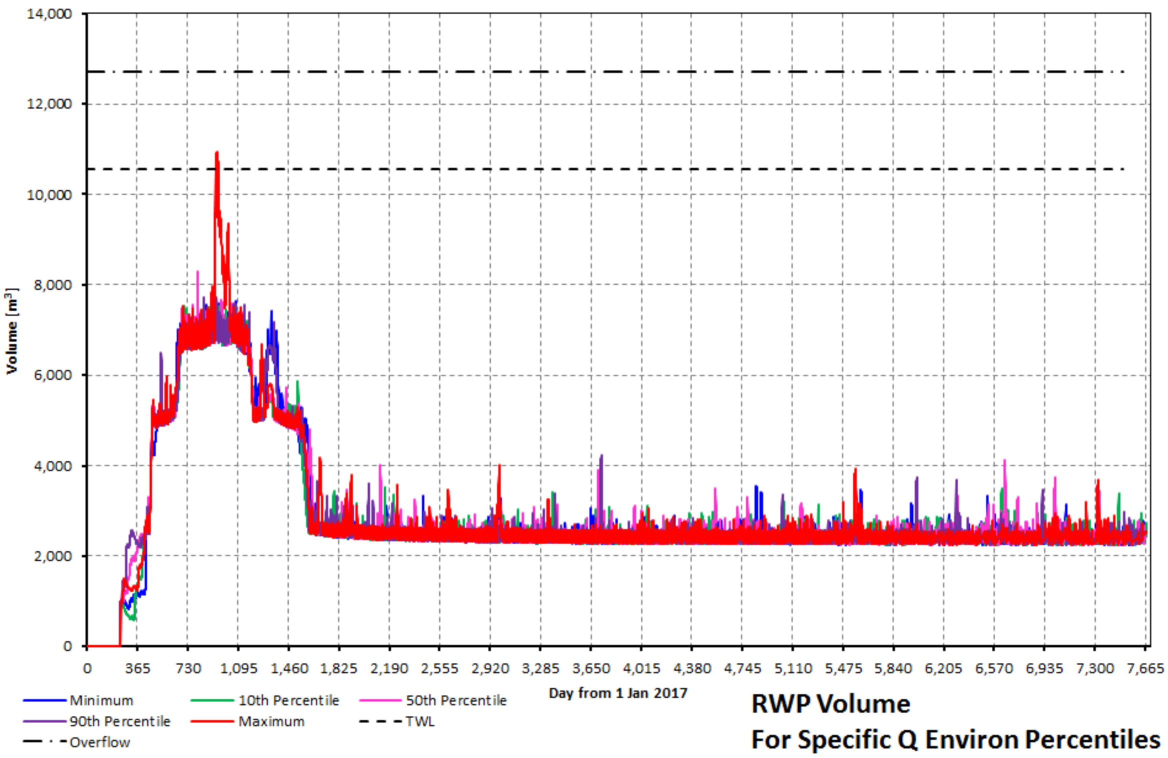

2,500
2,000
1,500
1,000
500
0
Flowrate [m³/d]
0
365
730
1,095
1,460
1,825
2,190
2,555
2,920
3,285
3,650
4,015
4,380
4,745
5,110
5,475
5,840
6,205
6,570
6,935
7,300
7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
Total flow to River
For Specific Q Environ Percentiles

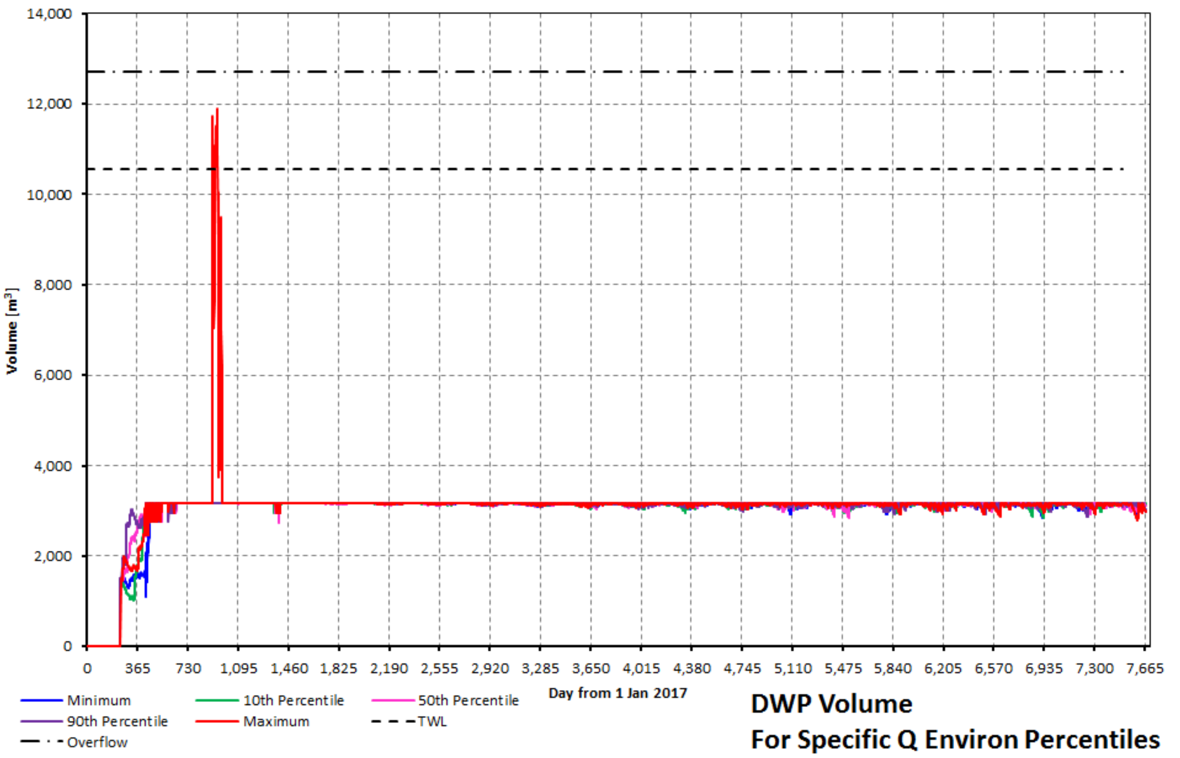

4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
Flowrate [m³]
0
365
730
1,095
1,460
1,825
2,190
2,555
2,920
3,285
3,650
4,015
4,380
4,745
5,110
5,475
5,840
6,205
6,570
6,935
7,300
7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
Summation of total flows to River
For Specific Q Environ Percentiles

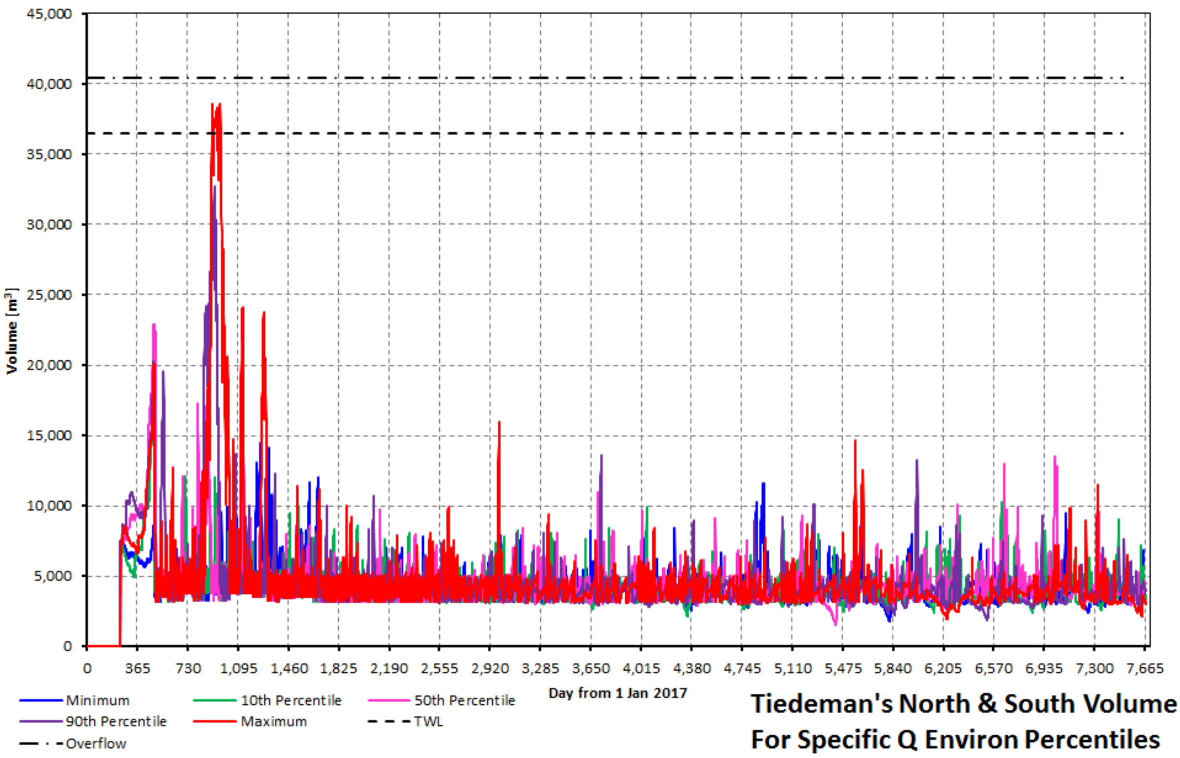

800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
Flowrate [m³]
0
365
730
1,095
1,460
1,825
2,190
2,555
2,920
3,285
3,650
4,015
4,380
4,745
5,110
5,475
5,840
6,205
6,570
6,935
7,300
7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
Rainfall to Ponds & Dams
For Specific Q Environ Percentiles

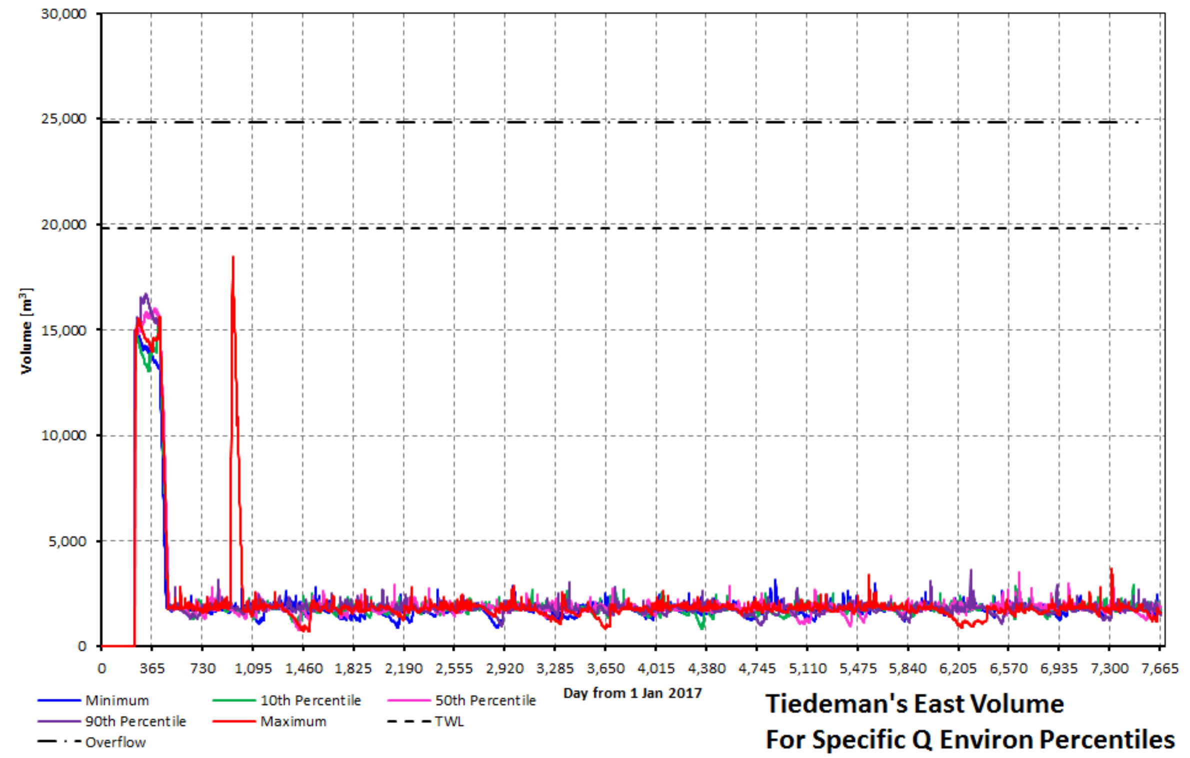
Appendix 7 Simulation Scenario 086 P90 Extracted Water Production: Large Irrigation Area

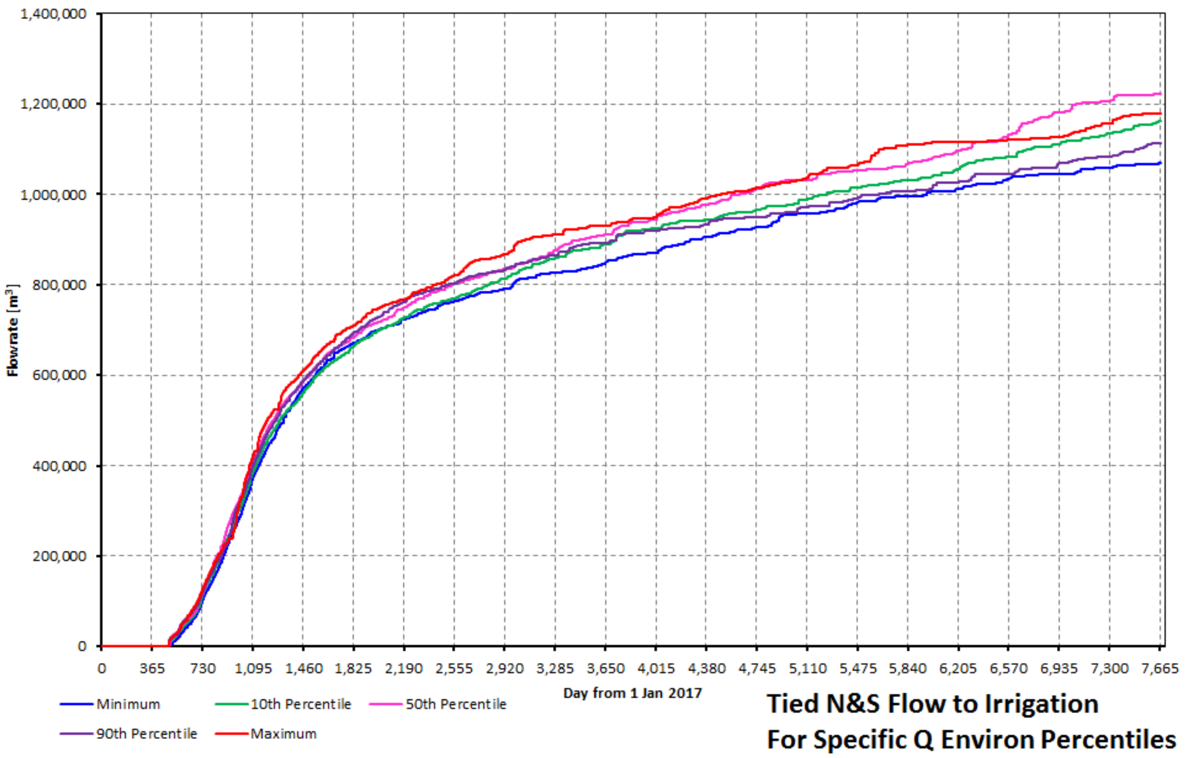

Flowrate [m³/d]
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
0 365 730 1,095 1,460 1,825 2,190 2,555 2,920 3,285 3,650 4,015 4,380 4,745 5,110 5,475 5,840 6,205 6,570 6,935 7,300 7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
RWP Flows In
For Specific Q Environ Percentiles

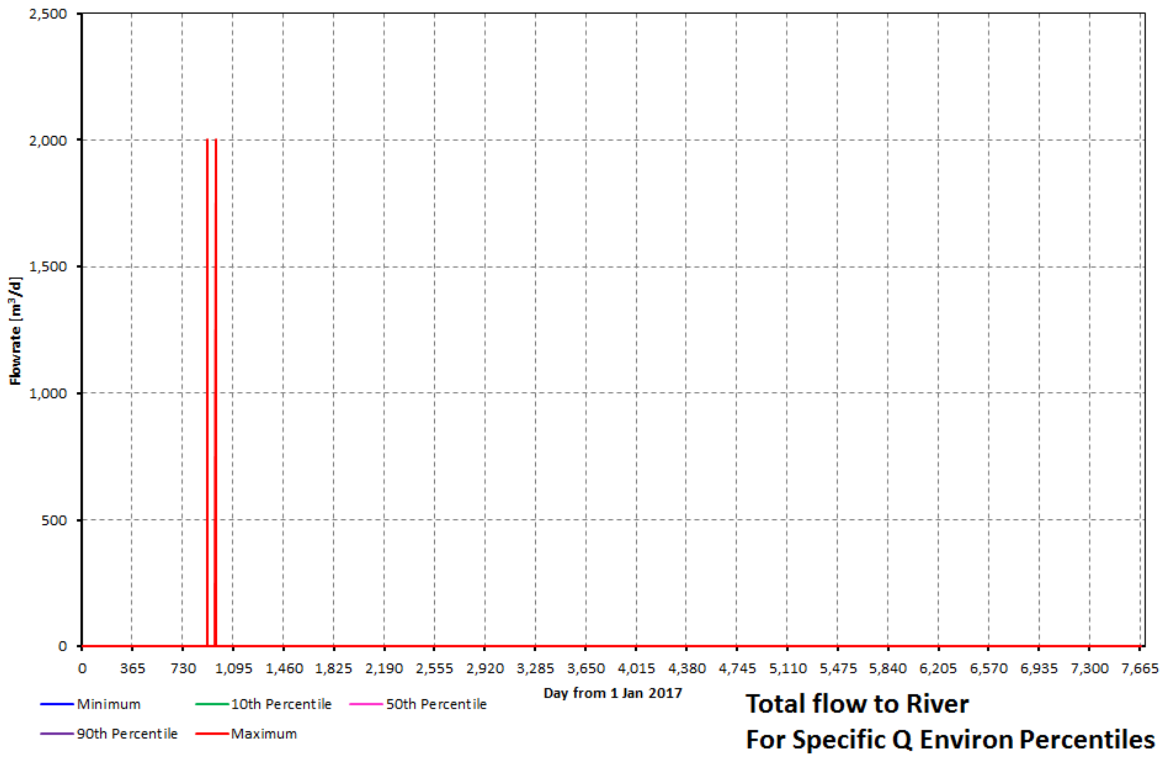

Volume [m³]
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
0 365 730 1,095 1,460 1,825 2,190 2,555 2,920 3,285 3,650 4,015 4,380 4,745 5,110 5,475 5,840 6,205 6,570 6,935 7,300 7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
TWL
Overflow
RWP Volume
For Specific Q Environ Percentiles

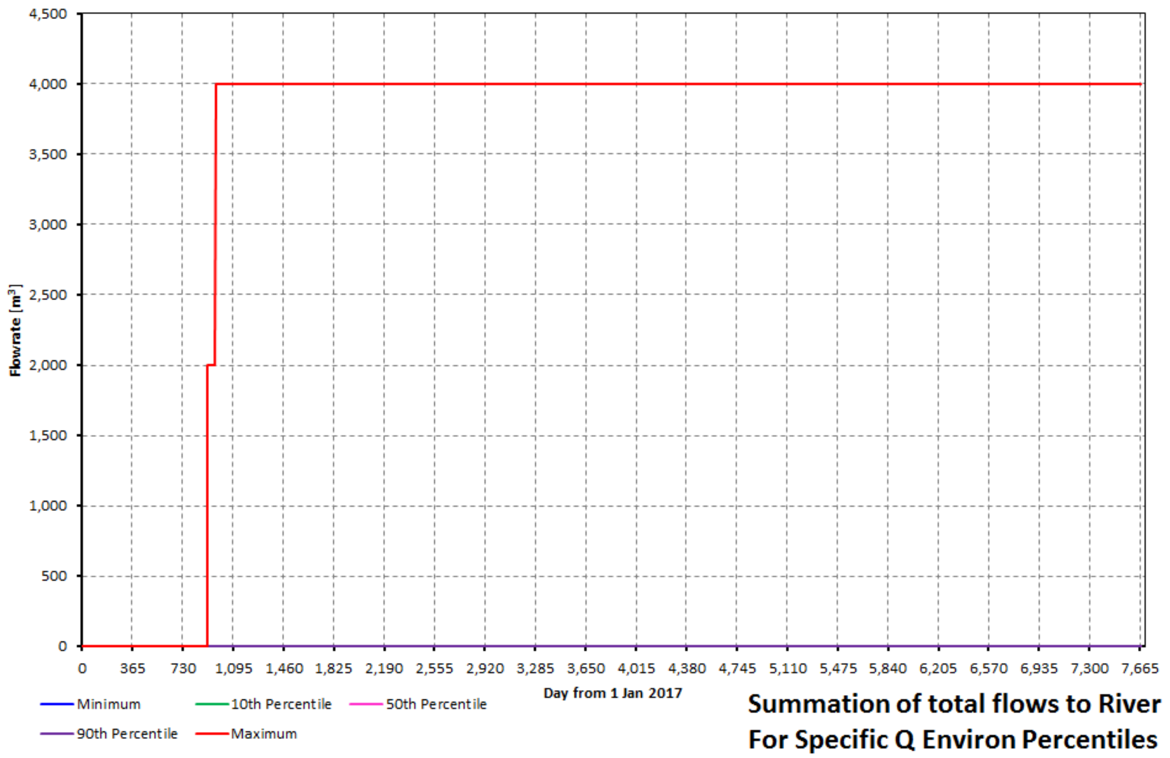

Volume [m³]
Day from 1 Jan 2017
Minimum
90th Percentile
Overflow
10th Percentile
Maximum
50th Percentile
TWL
DWP Volume
For Specific Q Environ Percentiles

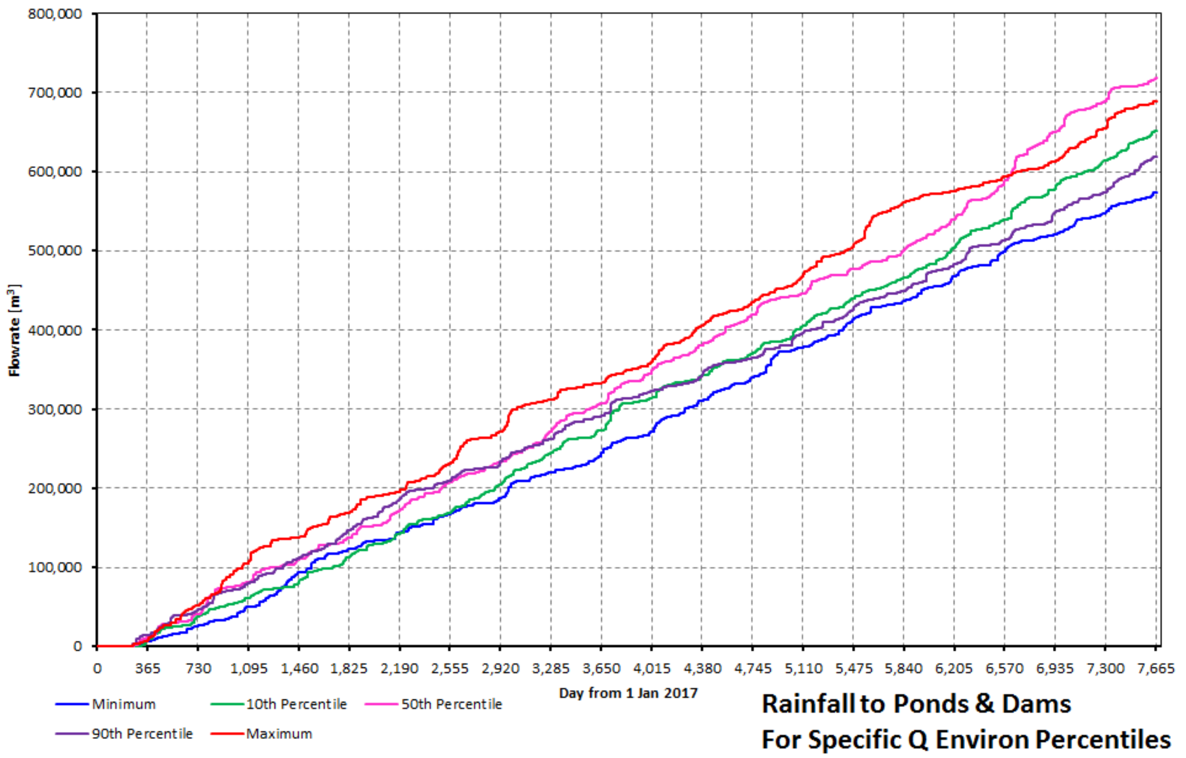

Volume [m³]
Day from 1 Jan 2017
Minimum
90th Percentile
Overflow
10th Percentile
Maximum
50th Percentile
TWL
Tiedeman's North & South Volume
For Specific Q Environ Percentiles


30,000
25,000
20,000
15,000
10,000
5,000
0
Volume [m³]
0
365
730
1,095
1,460
1,825
2,190
2,555
2,920
3,285
3,650
4,015
4,380
4,745
5,110
5,475
5,840
6,205
6,570
6,935
7,300
7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
TWL
Overflow
Tiedeman's East Volume
For Specific Q Environ Percentiles

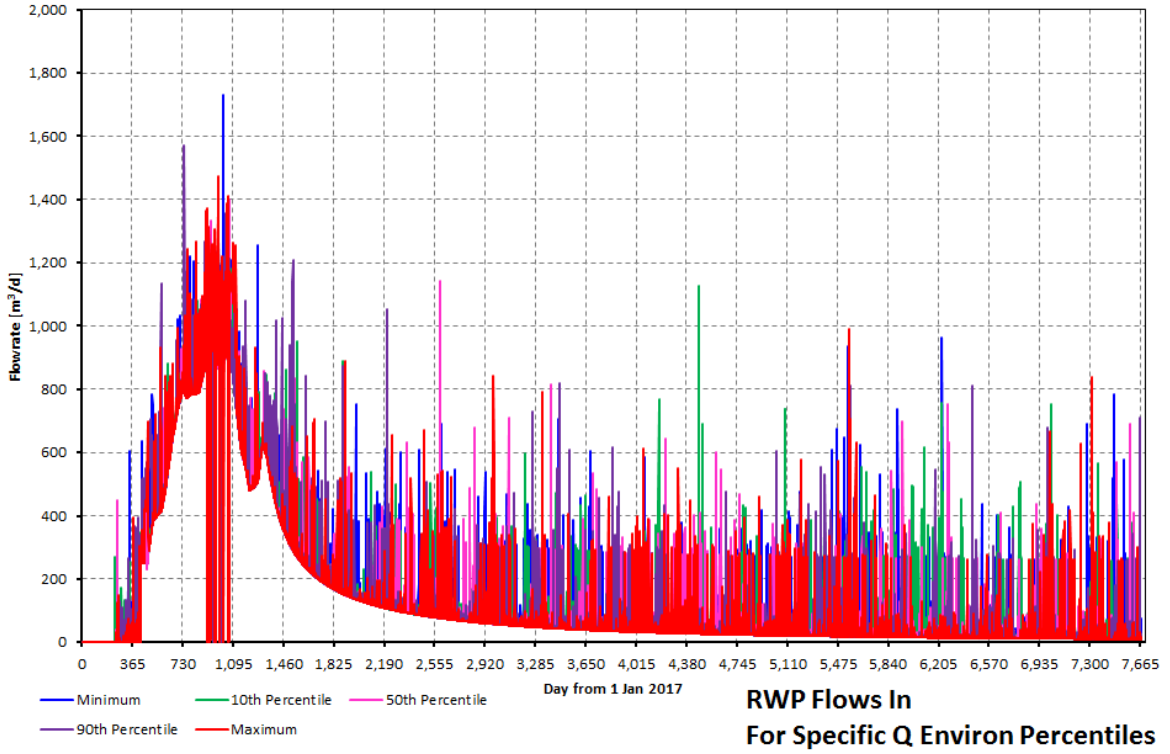

1,400,000
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
Flowrate [m³]
0
365
730
1,095
1,460
1,825
2,190
2,555
2,920
3,285
3,650
4,015
4,380
4,745
5,110
5,475
5,840
6,205
6,570
6,935
7,300
7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
Tied N&S Flow to Irrigation
For Specific Q Environ Percentiles

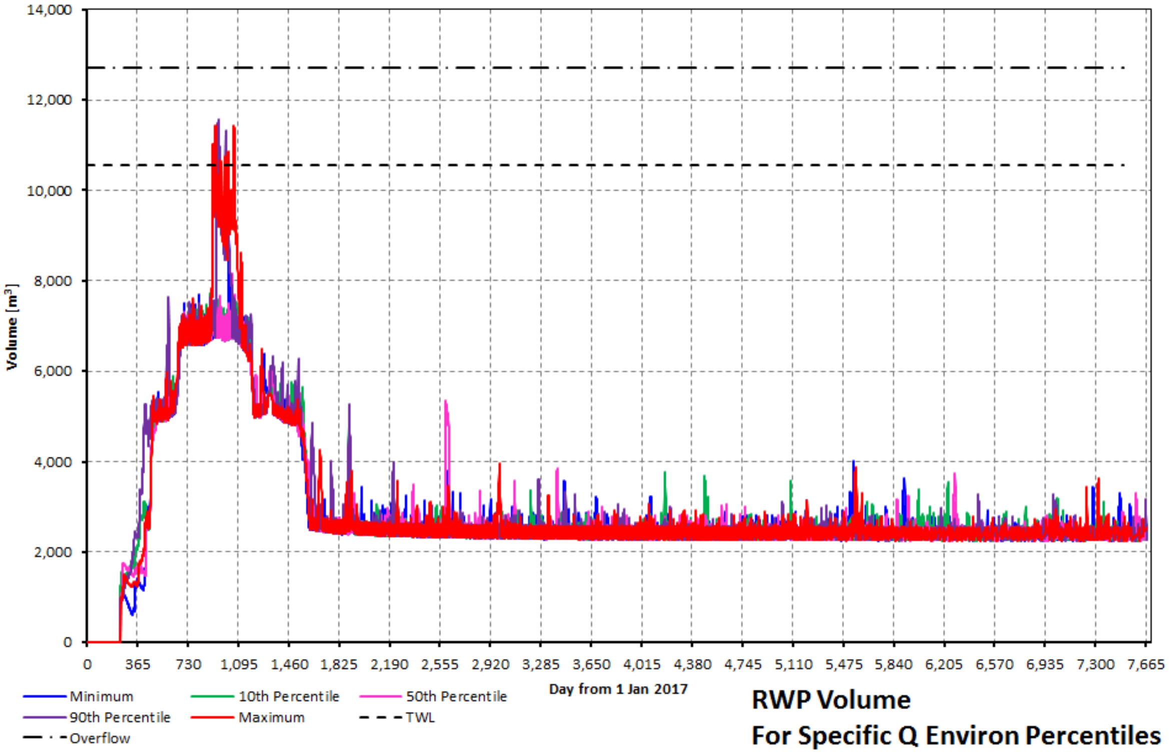

Flowrate [m³/d]
2,500
2,000
1,500
1,000
500
0
0 365 730 1,095 1,460 1,825 2,190 2,555 2,920 3,285 3,650 4,015 4,380 4,745 5,110 5,475 5,840 6,205 6,570 6,935 7,300 7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
Total flow to River
For Specific Q Environ Percentiles

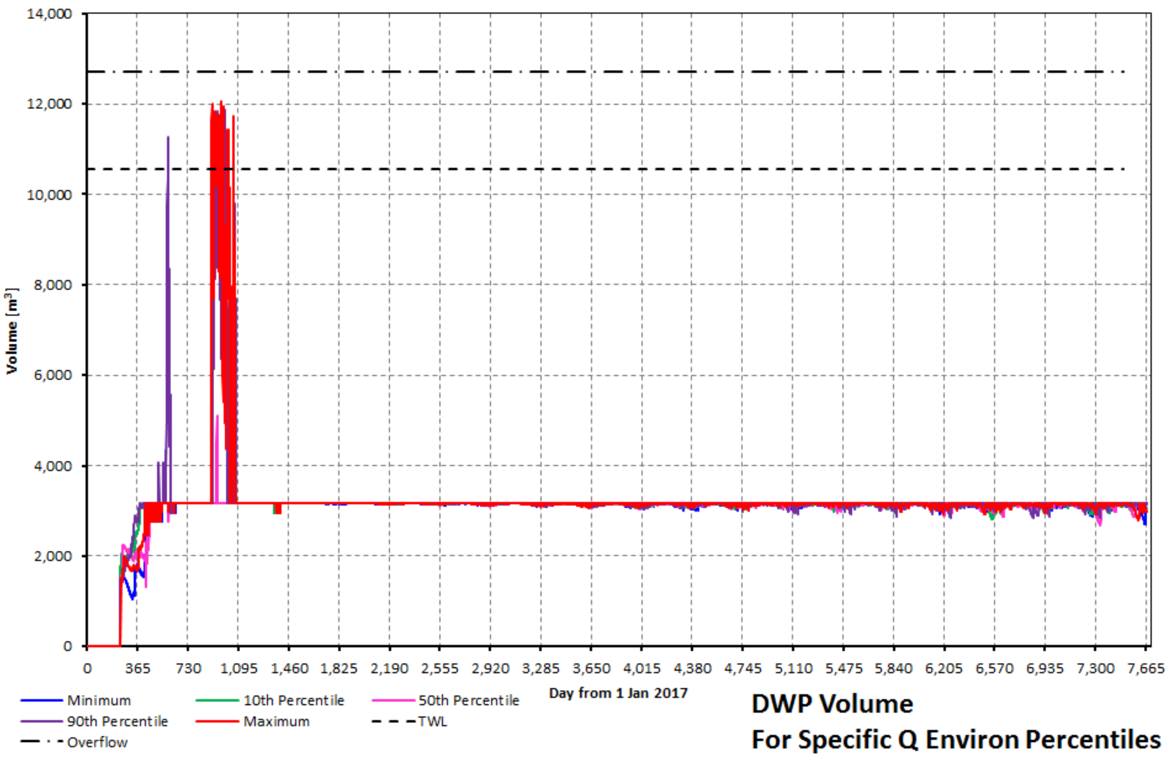

Flowrate [m³]
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
0 365 730 1,095 1,460 1,825 2,190 2,555 2,920 3,285 3,650 4,015 4,380 4,745 5,110 5,475 5,840 6,205 6,570 6,935 7,300 7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
Summation of total flows to River
For Specific Q Environ Percentiles

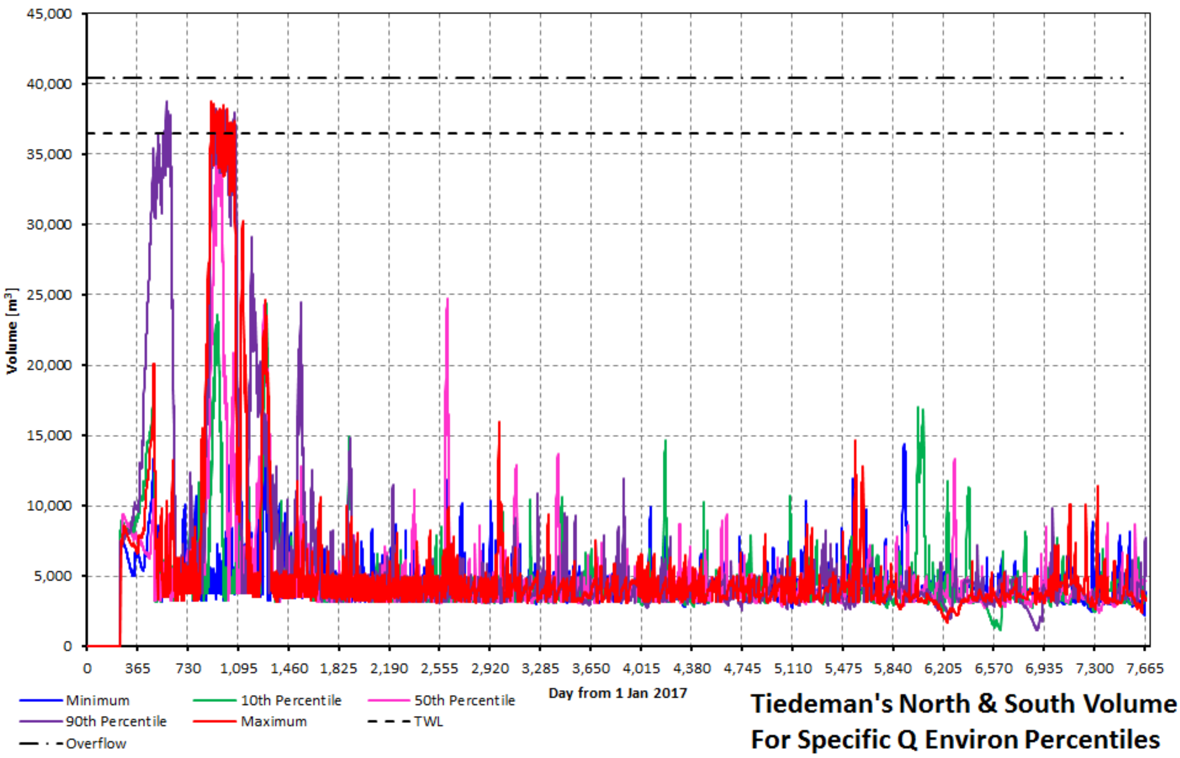

800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
Flowrate [m³]
0
365
730
1,095
1,460
1,825
2,190
2,555
2,920
3,285
3,650
4,015
4,380
4,745
5,110
5,475
5,840
6,205
6,570
6,935
7,300
7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
Rainfall to Ponds & Dams
For Specific Q Environ Percentiles

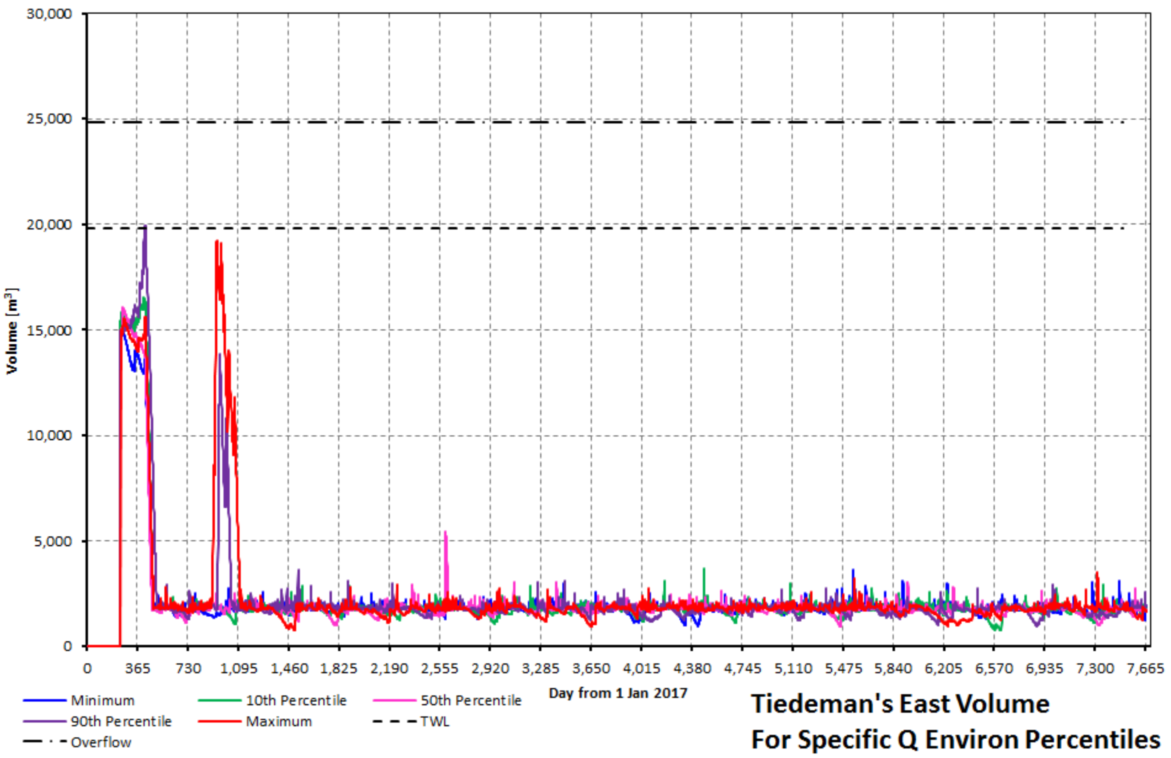
Appendix 8 Simulation Scenario 07: P90 Extracted Water Production: Small Irrigation Area

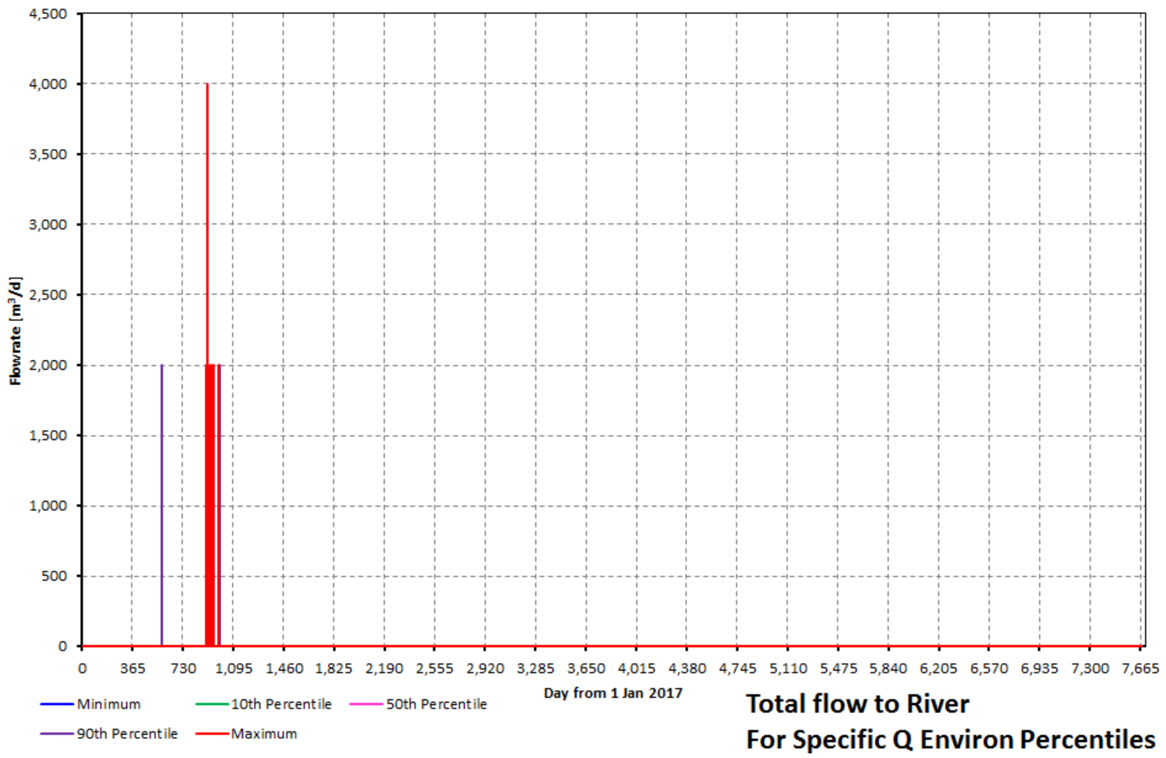

Flowrate [m³/d]
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
RWP Flows In
For Specific Q Environ Percentiles

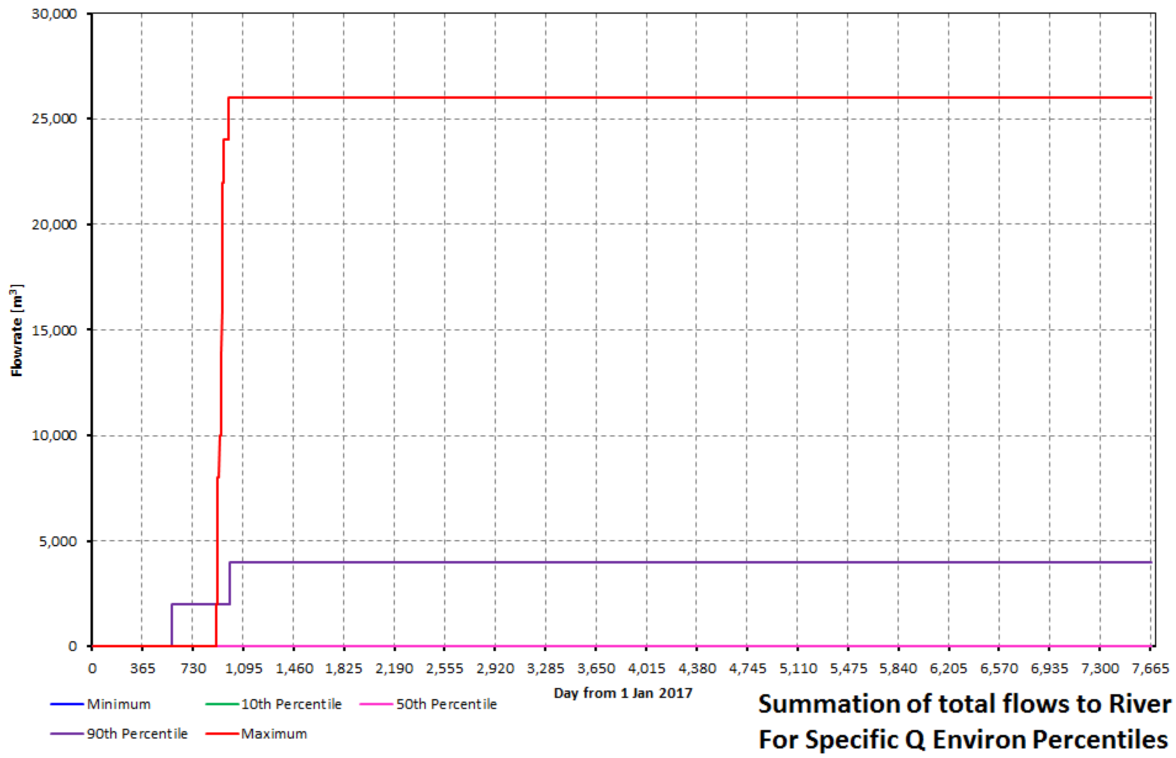

Volume [m³]
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
TWL
Overflow
RWP Volume
For Specific Q Environ Percentiles


14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Volume [m³]
0
365
730
1,095
1,460
1,825
2,190
2,555
2,920
3,285
3,650
4,015
4,380
4,745
5,110
5,475
5,840
6,205
6,570
6,935
7,300
7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
TWL
Overflow
DWP Volume
For Specific Q Environ Percentiles

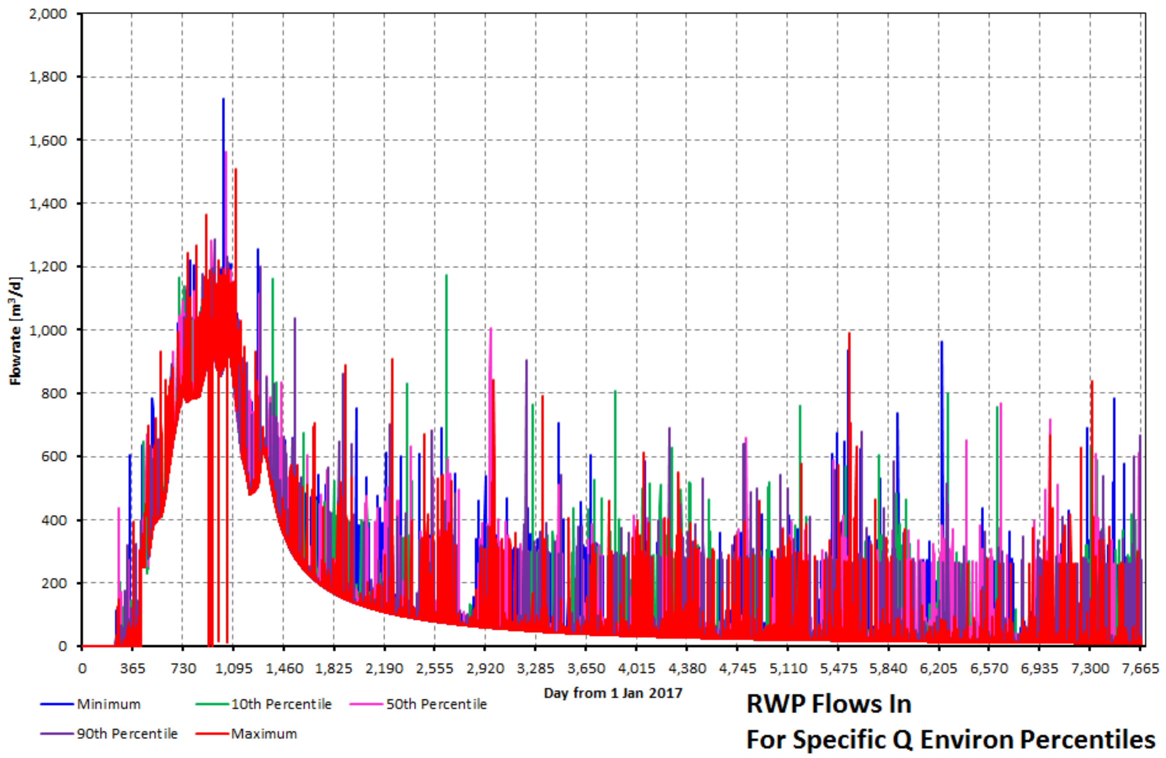

45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Volume [m³]
0
365
730
1,095
1,460
1,825
2,190
2,555
2,920
3,285
3,650
4,015
4,380
4,745
5,110
5,475
5,840
6,205
6,570
6,935
7,300
7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
TWL
Overflow
Tiedeman's North & South Volume
For Specific Q Environ Percentiles

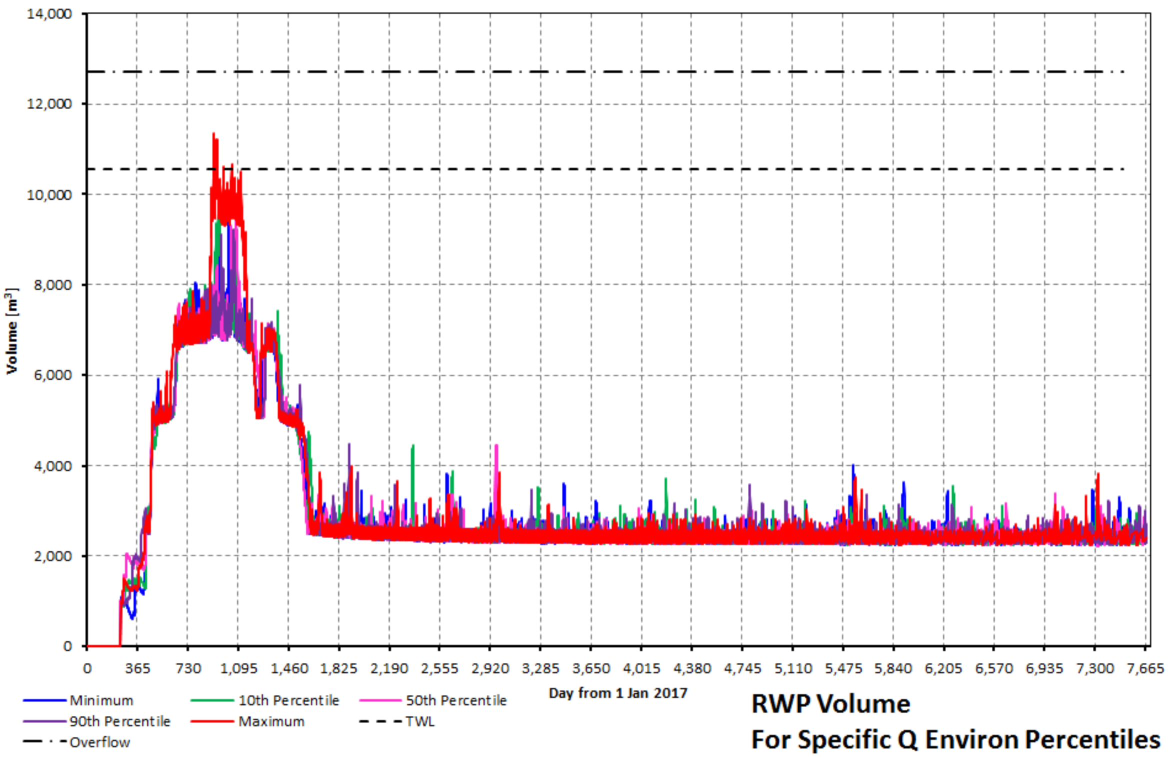

Volume [m³]
30,000
25,000
20,000
15,000
10,000
5,000
0
0 365 730 1,095 1,460 1,825 2,190 2,555 2,920 3,285 3,650 4,015 4,380 4,745 5,110 5,475 5,840 6,205 6,570 6,935 7,300 7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
TWL
Overflow
Tiedeman's East Volume
For Specific Q Environ Percentiles

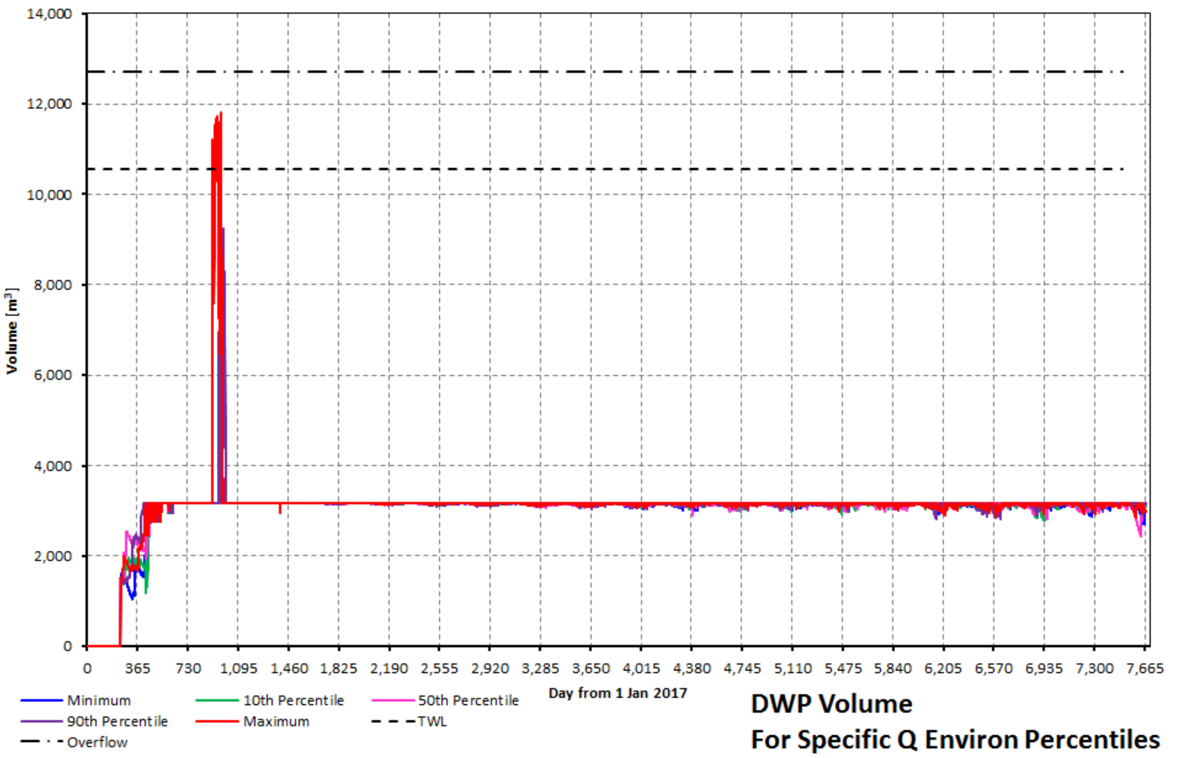

Flowrate [m³/d]
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
0 365 730 1,095 1,460 1,825 2,190 2,555 2,920 3,285 3,650 4,015 4,380 4,745 5,110 5,475 5,840 6,205 6,570 6,935 7,300 7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
Total flow to River
For Specific Q Environ Percentiles

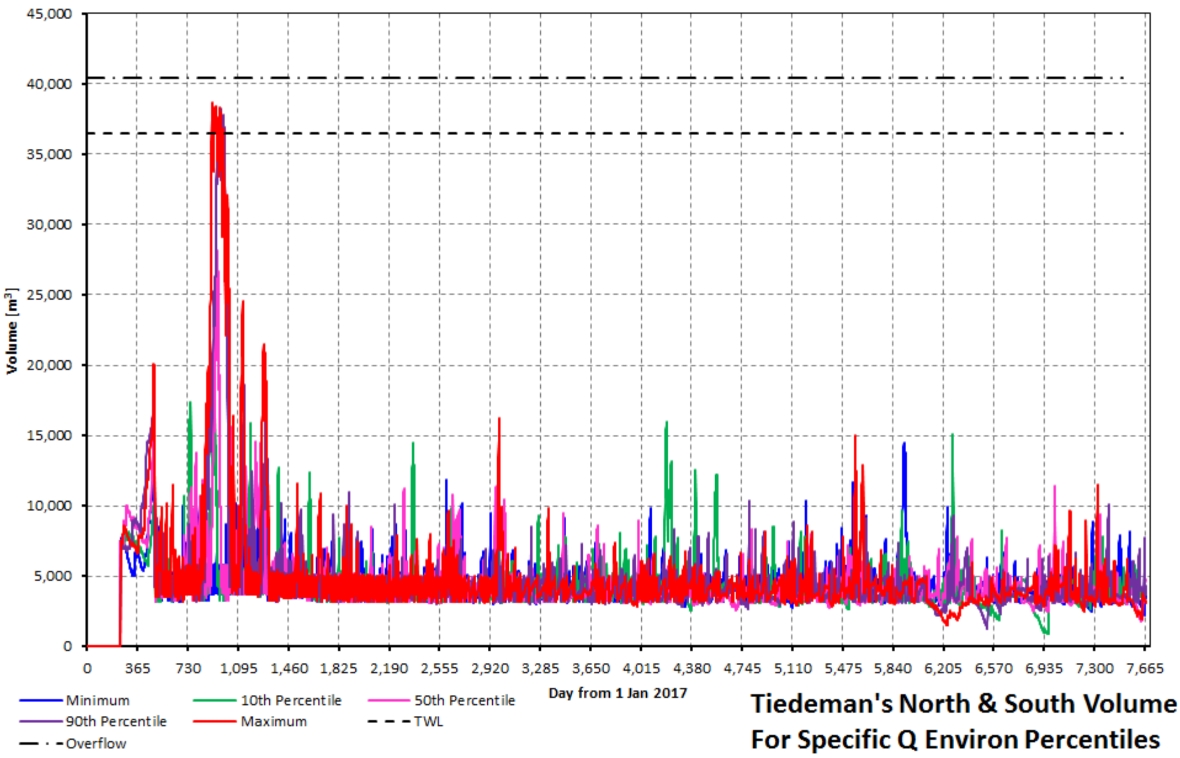

30,000
25,000
20,000
15,000
10,000
5,000
0
Flowrate [m3]
0
365
730
1,095
1,460
1,825
2,190
2,555
2,920
3,285
3,650
4,015
4,380
4,745
5,110
5,475
5,840
6,205
6,570
6,935
7,300
7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
Summation of total flows to River
For Specific Q Environ Percentiles

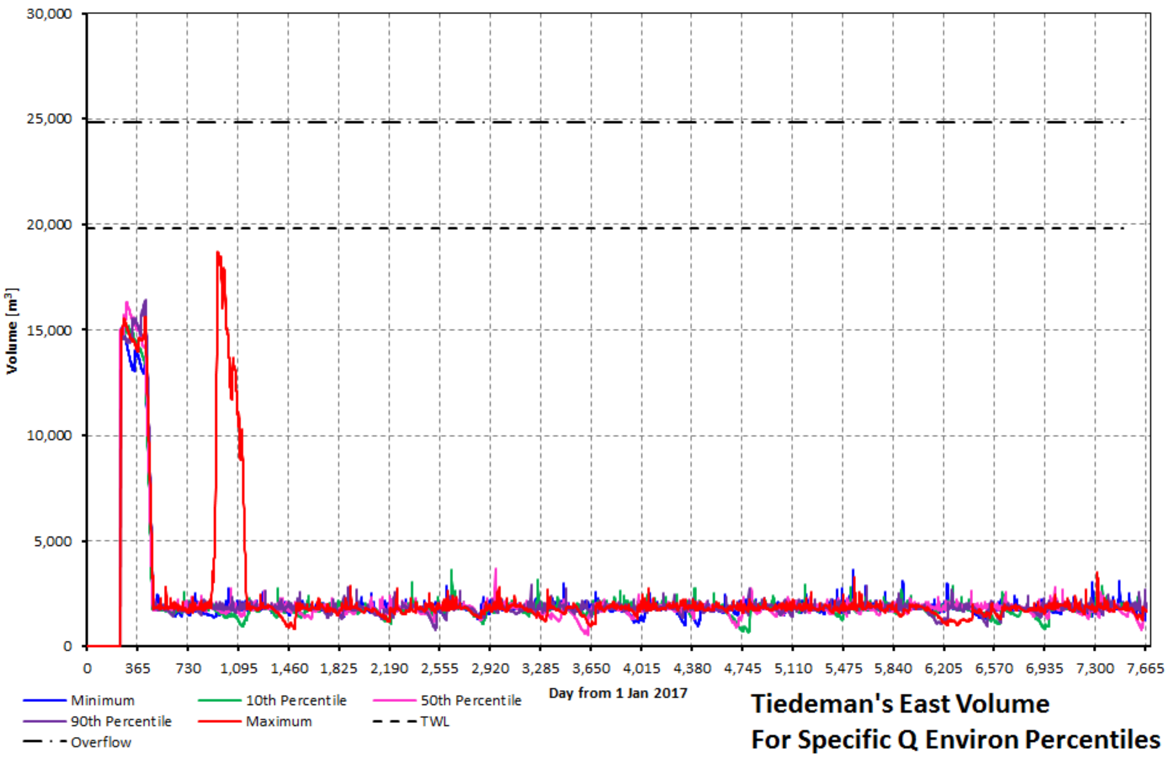
Appendix 9 Simulation Scenario 11: P90 Extracted Water Production: 10% Capacity Reduction & 90% Availability


2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
Flowrate [m³/d]
0 365 730 1,095 1,460 1,825 2,190 2,555 2,920 3,285 3,650 4,015 4,380 4,745 5,110 5,475 5,840 6,205 6,570 6,935 7,300 7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
RWP Flows In
For Specific Q Environ Percentiles

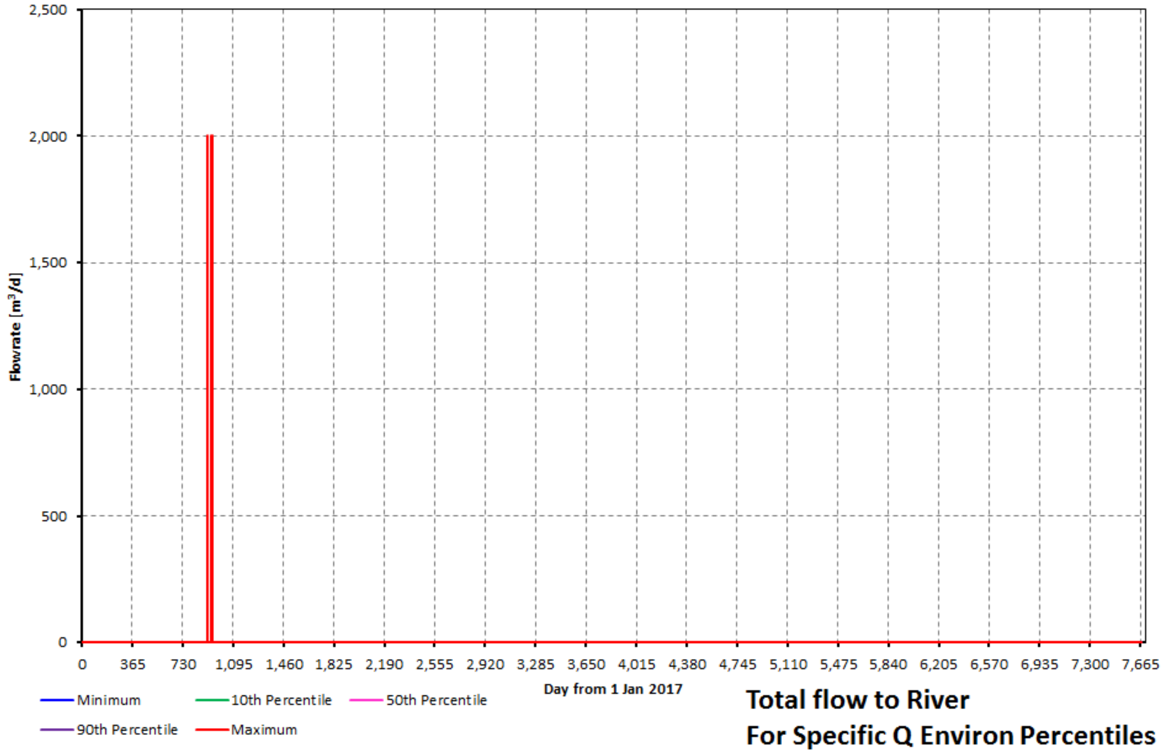

14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Volume [m³]
0 365 730 1,095 1,460 1,825 2,190 2,555 2,920 3,285 3,650 4,015 4,380 4,745 5,110 5,475 5,840 6,205 6,570 6,935 7,300 7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
TWL
Overflow
RWP Volume
For Specific Q Environ Percentiles


14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Volume [m³]
0
365
730
1,095
1,460
1,825
2,190
2,555
2,920
3,285
3,650
4,015
4,380
4,745
5,110
5,475
5,840
6,205
6,570
6,935
7,300
7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
TWL
Overflow
DWP Volume
For Specific Q Environ Percentiles

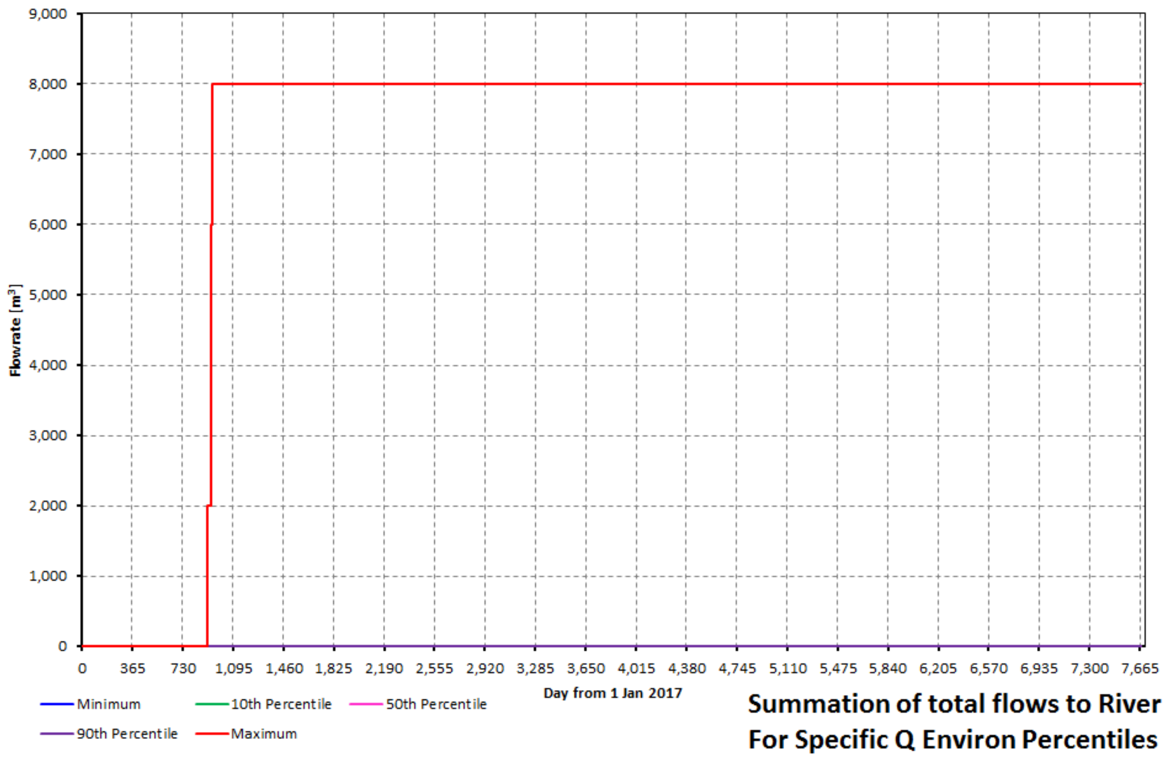

45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Volume [m³]
0
365
730
1,095
1,460
1,825
2,190
2,555
2,920
3,285
3,650
4,015
4,380
4,745
5,110
5,475
5,840
6,205
6,570
6,935
7,300
7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
TWL
Overflow
Tiedeman's North & South Volume
For Specific Q Environ Percentiles



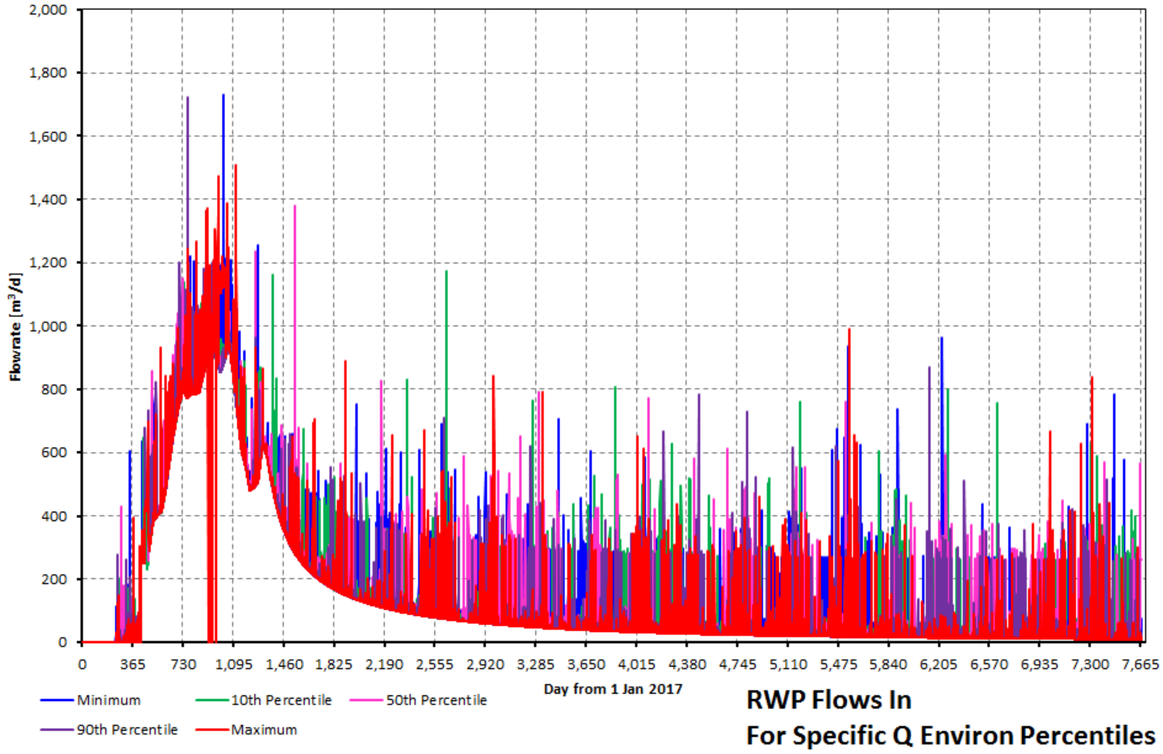
Tiedeman's East Volume
For Specific Q Environ Percentiles

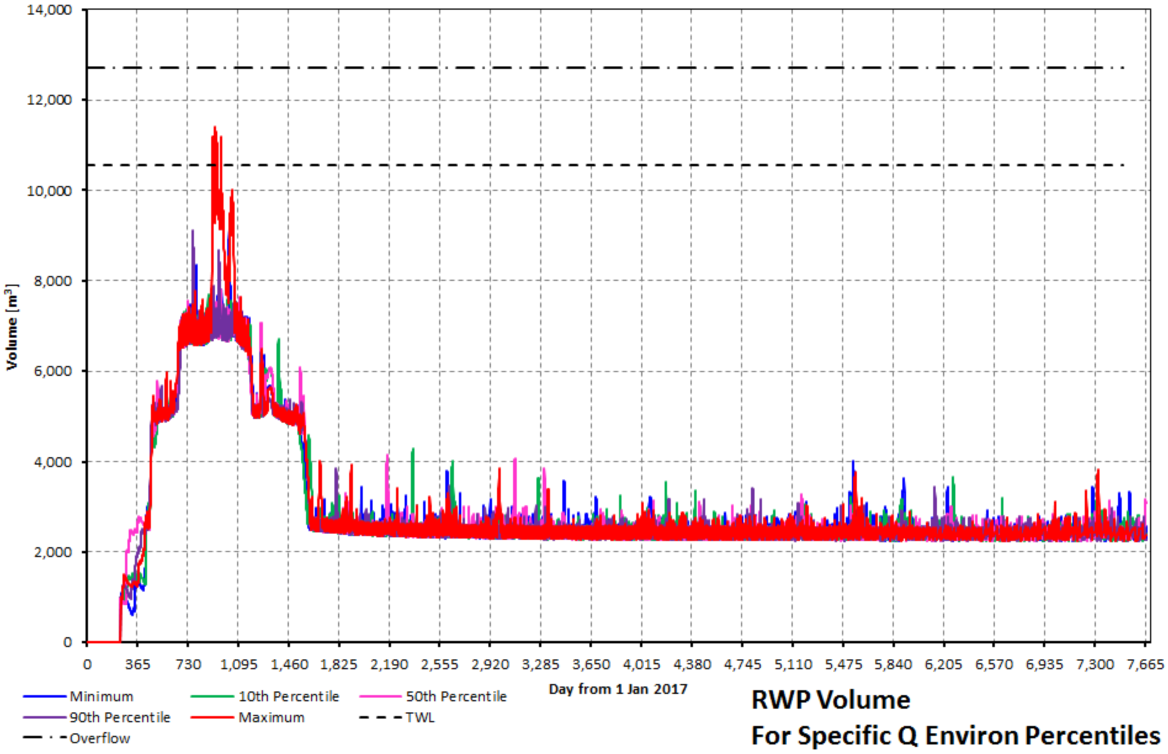


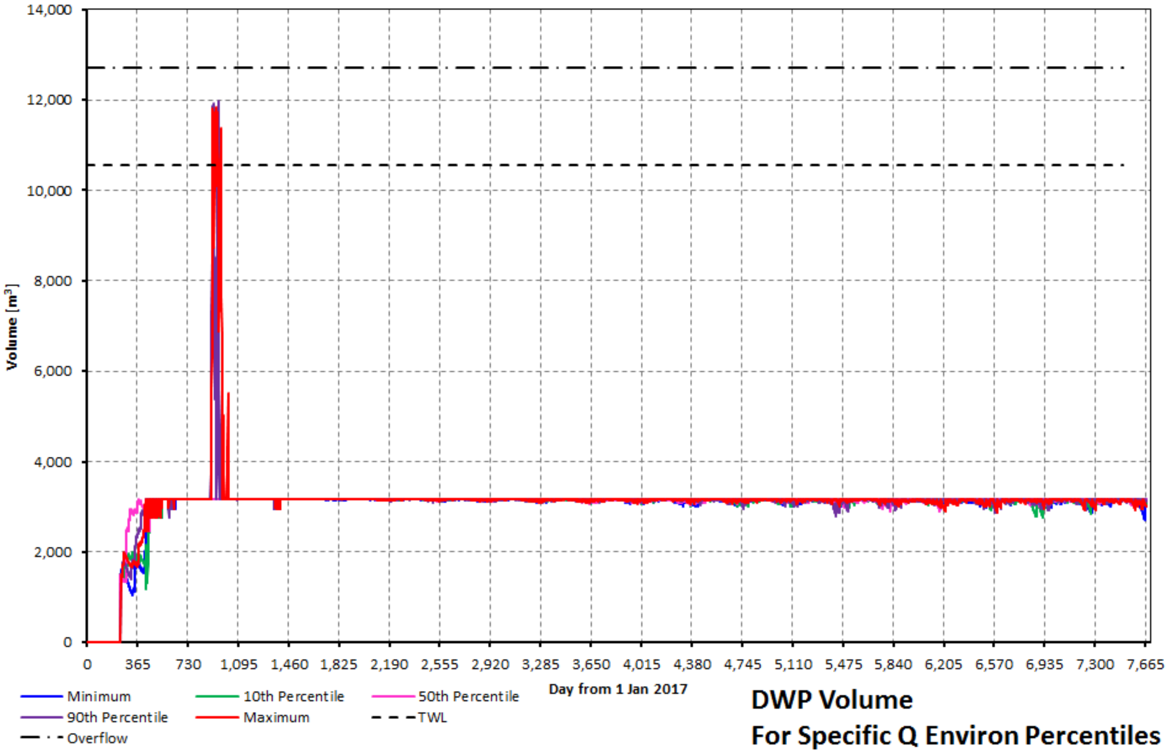
Total flow to River
For Specific Q Environ Percentiles

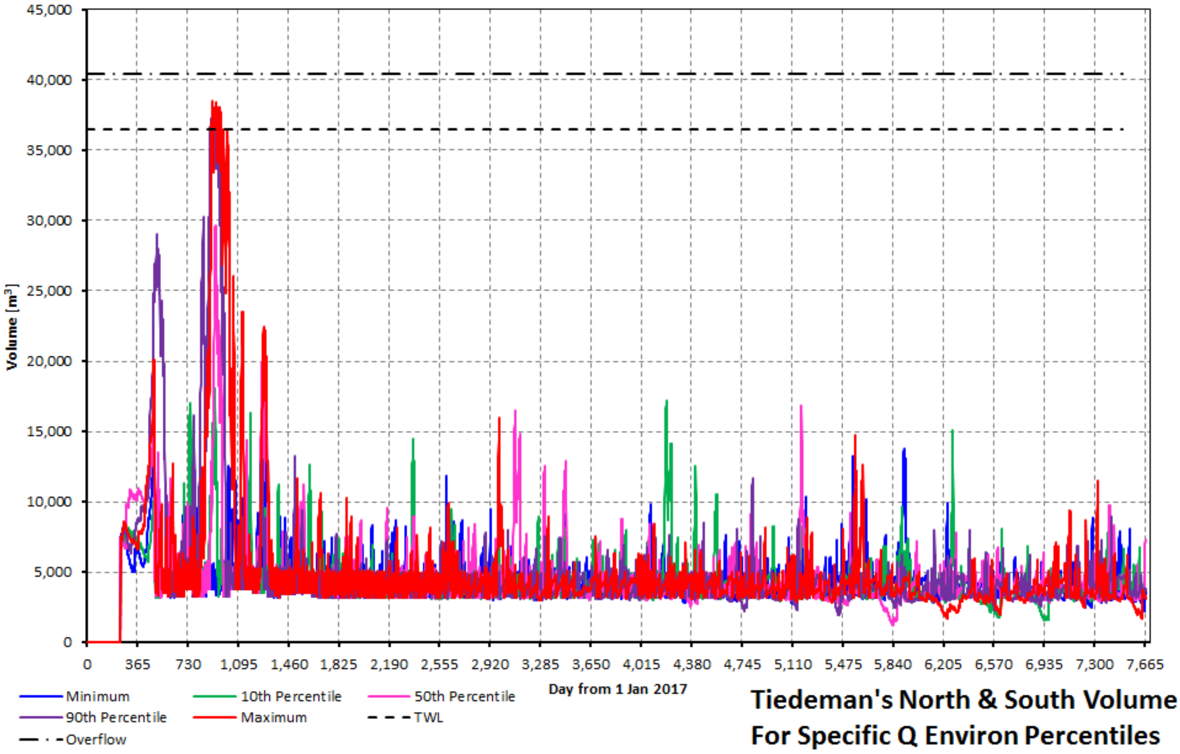

9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Flowrate [m3]
0 365 730 1,095 1,460 1,825 2,190 2,555 2,920 3,285 3,650 4,015 4,380 4,745 5,110 5,475 5,840 6,205 6,570 6,935 7,300 7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
Summation of total flows to River
For Specific Q Environ Percentiles

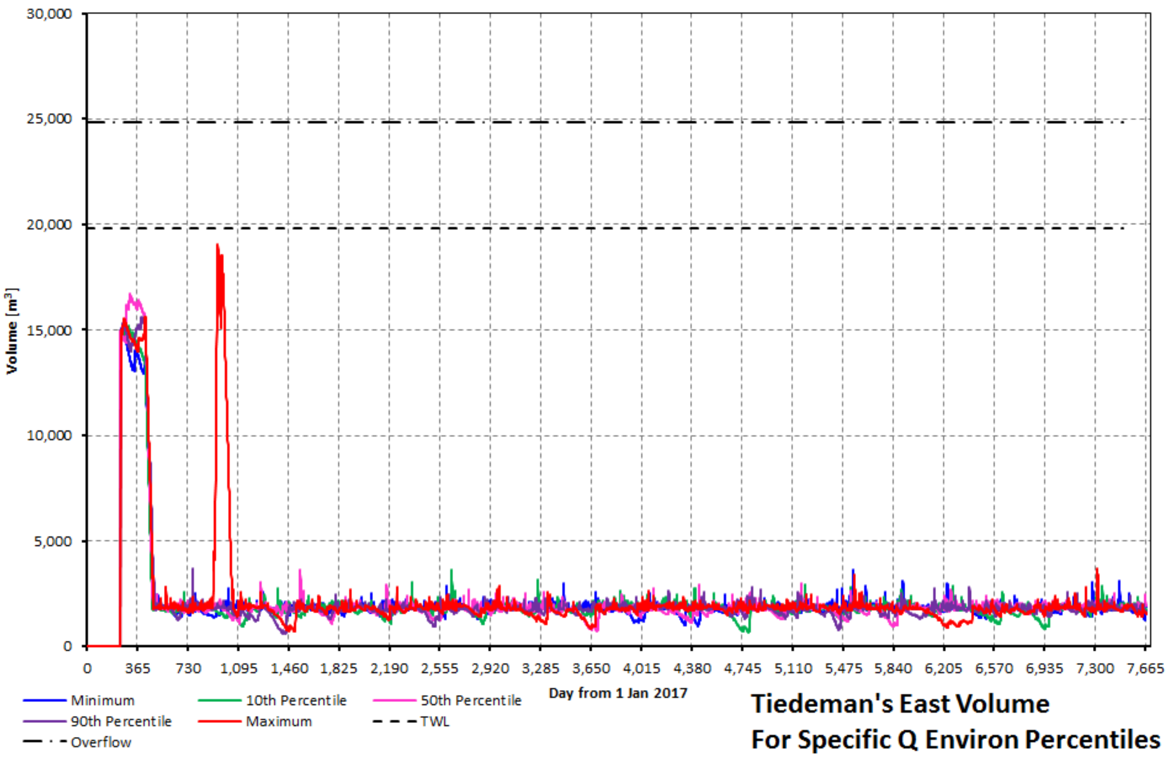
Appendix 10 Simulation Scenario 12: P90 Extracted Water Production: Light Frost

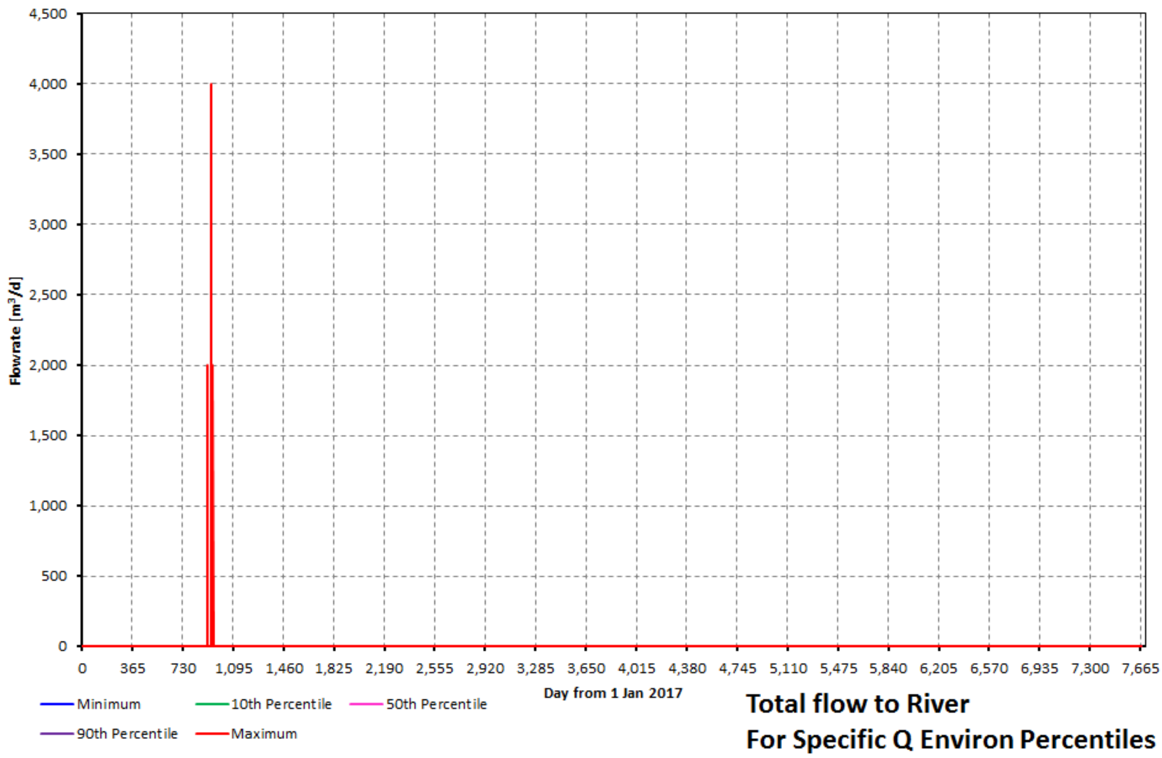

Flowrate [m³/d]
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
0 365 730 1,095 1,460 1,825 2,190 2,555 2,920 3,285 3,650 4,015 4,380 4,745 5,110 5,475 5,840 6,205 6,570 6,935 7,300 7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
RWP Flows In
For Specific Q Environ Percentiles

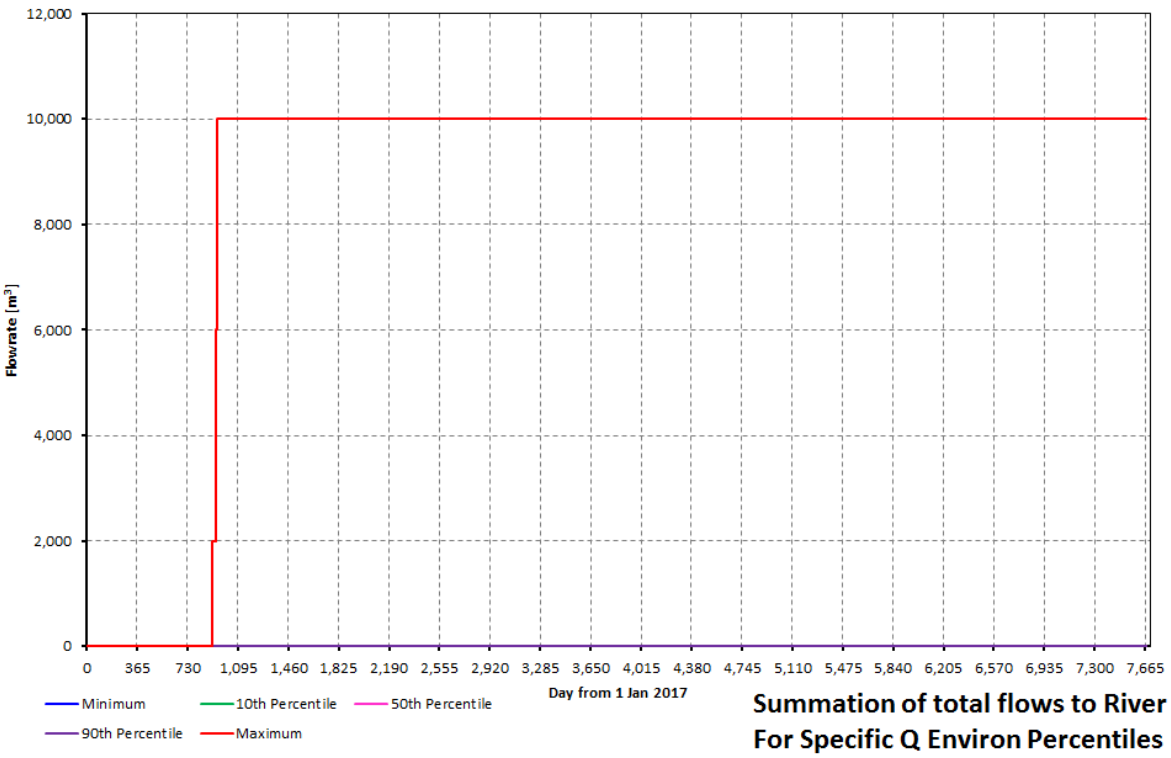

Volume [m³]
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
0 365 730 1,095 1,460 1,825 2,190 2,555 2,920 3,285 3,650 4,015 4,380 4,745 5,110 5,475 5,840 6,205 6,570 6,935 7,300 7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
TWL
Overflow
RWP Volume
For Specific Q Environ Percentiles


14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Volume [m³]
0
365
730
1,095
1,460
1,825
2,190
2,555
2,920
3,285
3,650
4,015
4,380
4,745
5,110
5,475
5,840
6,205
6,570
6,935
7,300
7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
TWL
Overflow
DWP Volume
For Specific Q Environ Percentiles

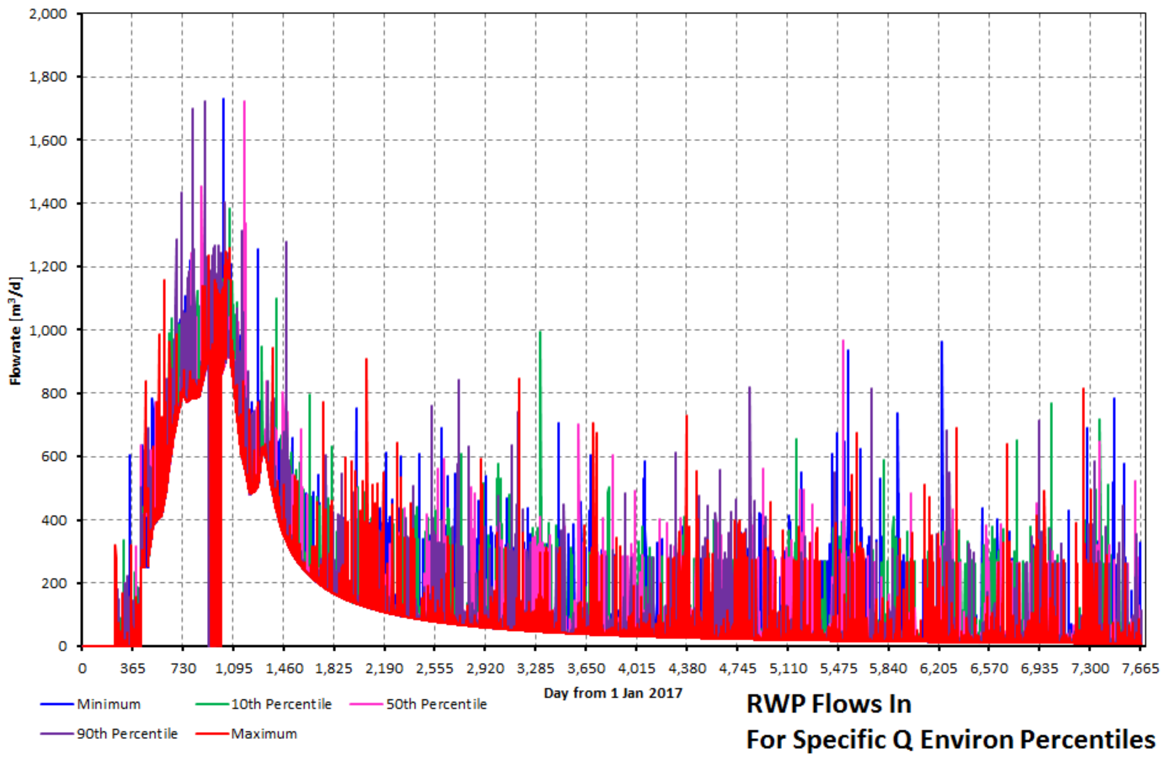

45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Volume [m³]
0
365
730
1,095
1,460
1,825
2,190
2,555
2,920
3,285
3,650
4,015
4,380
4,745
5,110
5,475
5,840
6,205
6,570
6,935
7,300
7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
TWL
Overflow
Tiedeman's North & South Volume
For Specific Q Environ Percentiles


Volume [m³]
30,000
25,000
20,000
15,000
10,000
5,000
0
0 365 730 1,095 1,460 1,825 2,190 2,555 2,920 3,285 3,650 4,015 4,380 4,745 5,110 5,475 5,840 6,205 6,570 6,935 7,300 7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
TWL
Overflow
Tiedeman's East Volume
For Specific Q Environ Percentiles

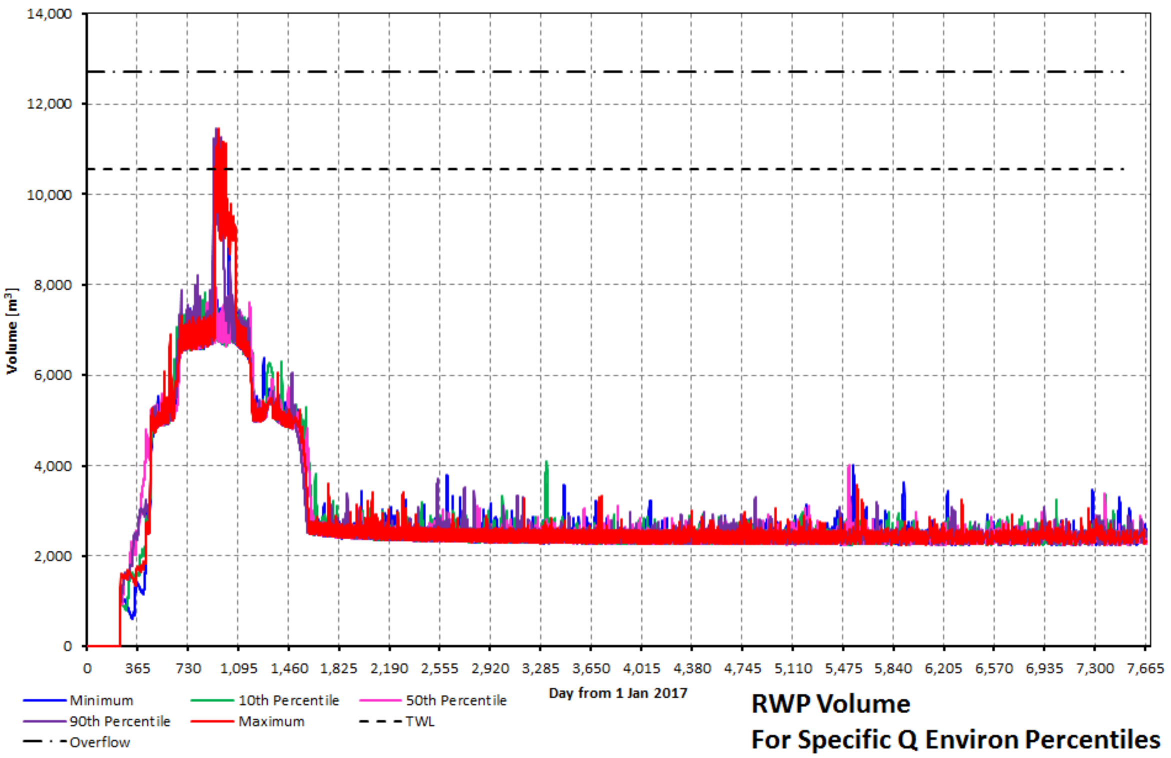

Flowrate [m³/d]
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
0 365 730 1,095 1,460 1,825 2,190 2,555 2,920 3,285 3,650 4,015 4,380 4,745 5,110 5,475 5,840 6,205 6,570 6,935 7,300 7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
Total flow to River
For Specific Q Environ Percentiles


12,000
10,000
8,000
6,000
4,000
2,000
0
Flowrate [m3]
0
365
730
1,095
1,460
1,825
2,190
2,555
2,920
3,285
3,650
4,015
4,380
4,745
5,110
5,475
5,840
6,205
6,570
6,935
7,300
7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
Summation of total flows to River
For Specific Q Environ Percentiles

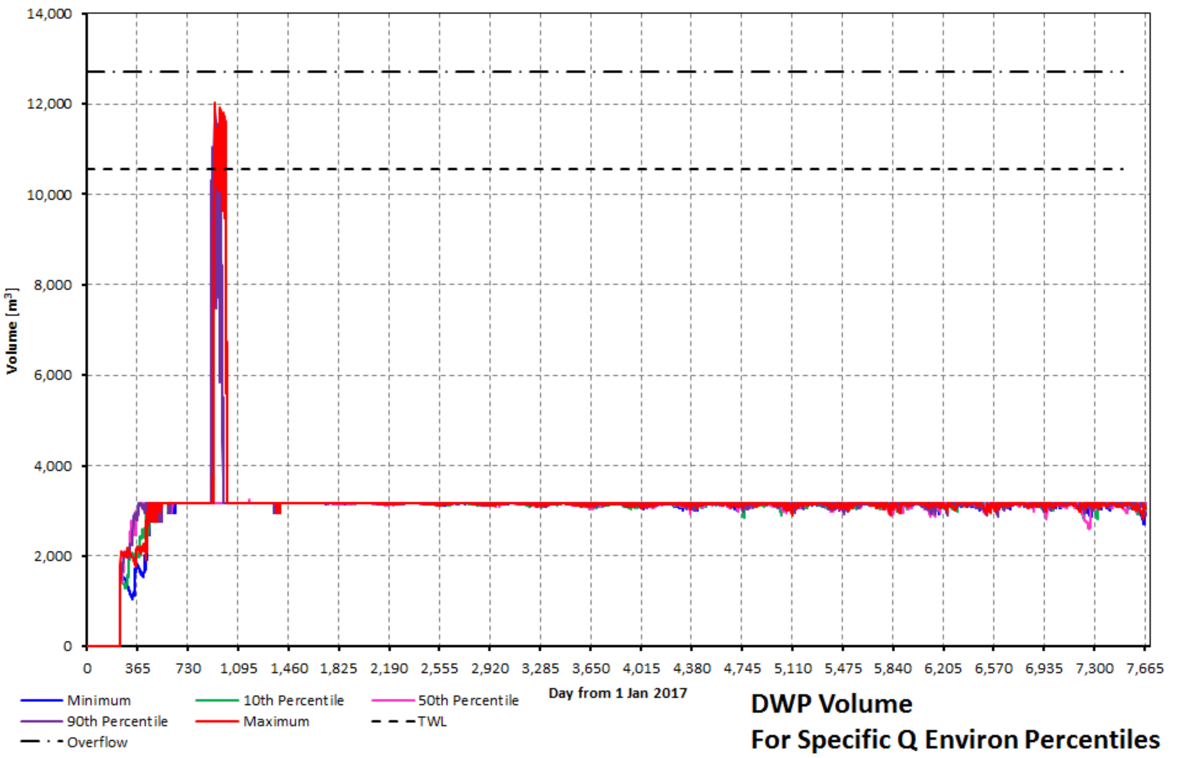
Appendix 11 Simulation Scenario 12: P90 Extracted Water Production: Heavy Frost

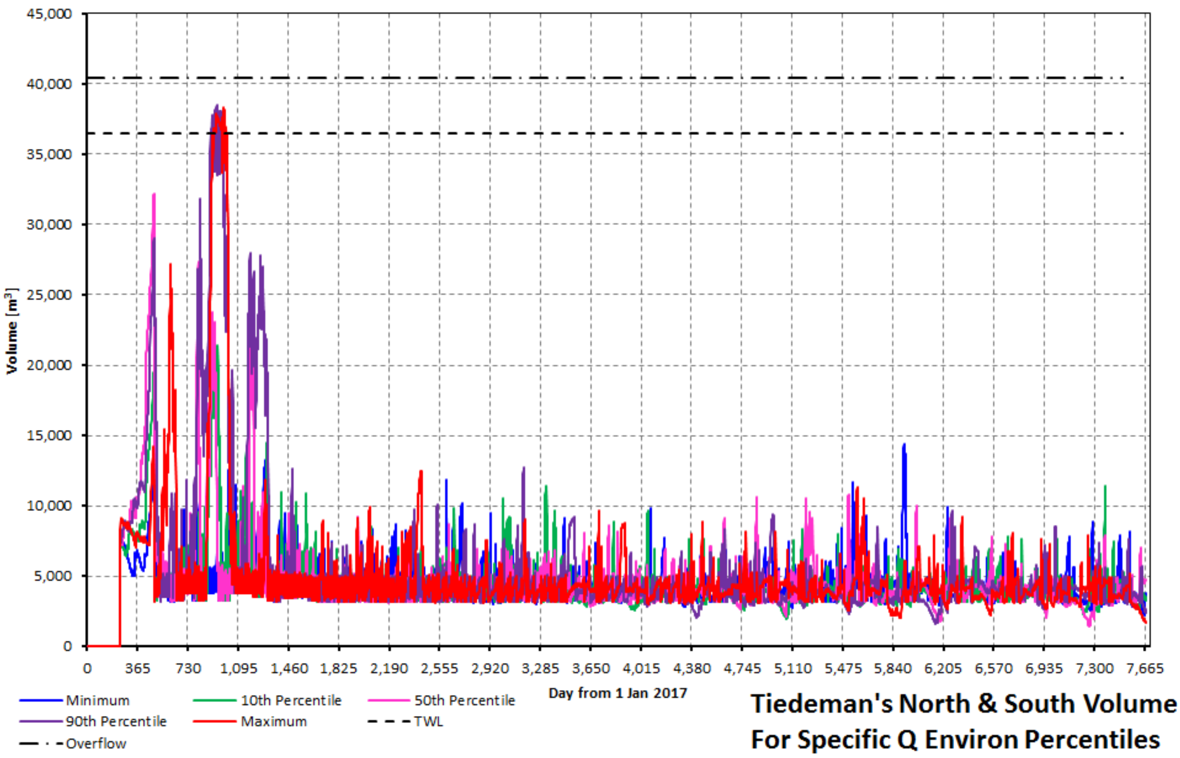


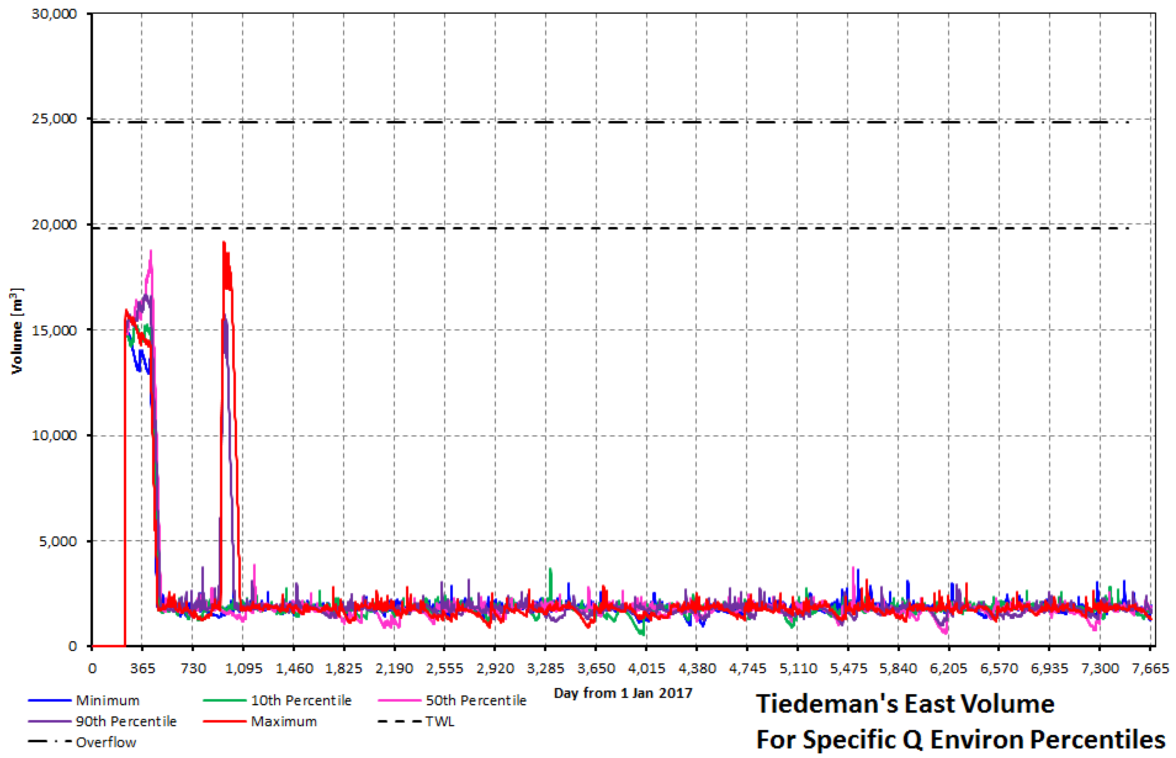
RWP Flows In
For Specific Q Environ Percentiles

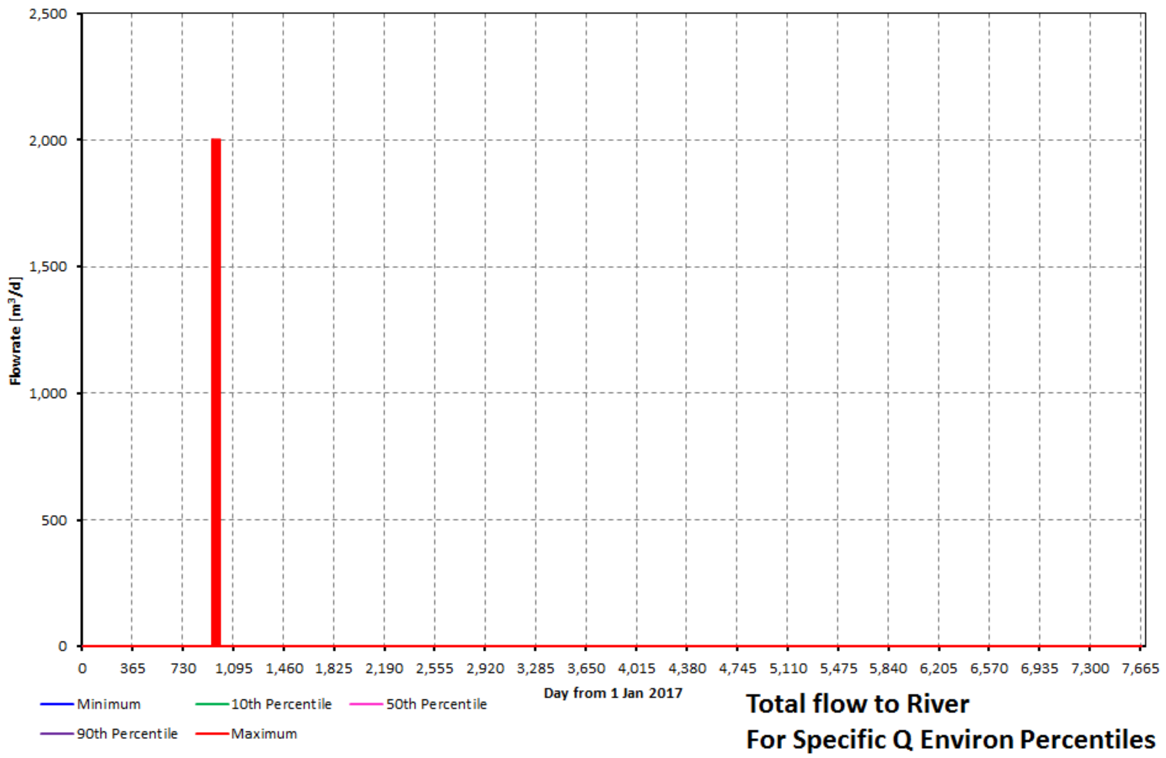


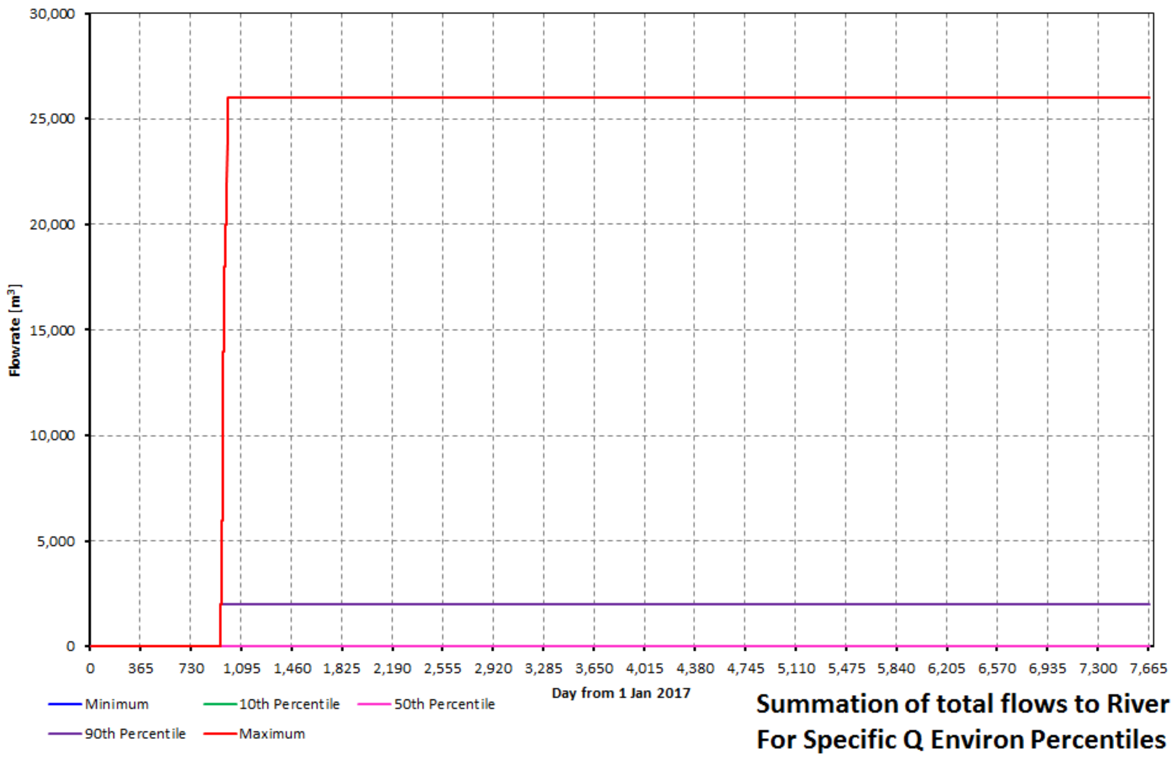
RWP Volume
For Specific Q Environ Percentiles


14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Volume [m³]
0
365
730
1,095
1,460
1,825
2,190
2,555
2,920
3,285
3,650
4,015
4,380
4,745
5,110
5,475
5,840
6,205
6,570
6,935
7,300
7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
TWL
Overflow
DWP Volume
For Specific Q Environ Percentiles

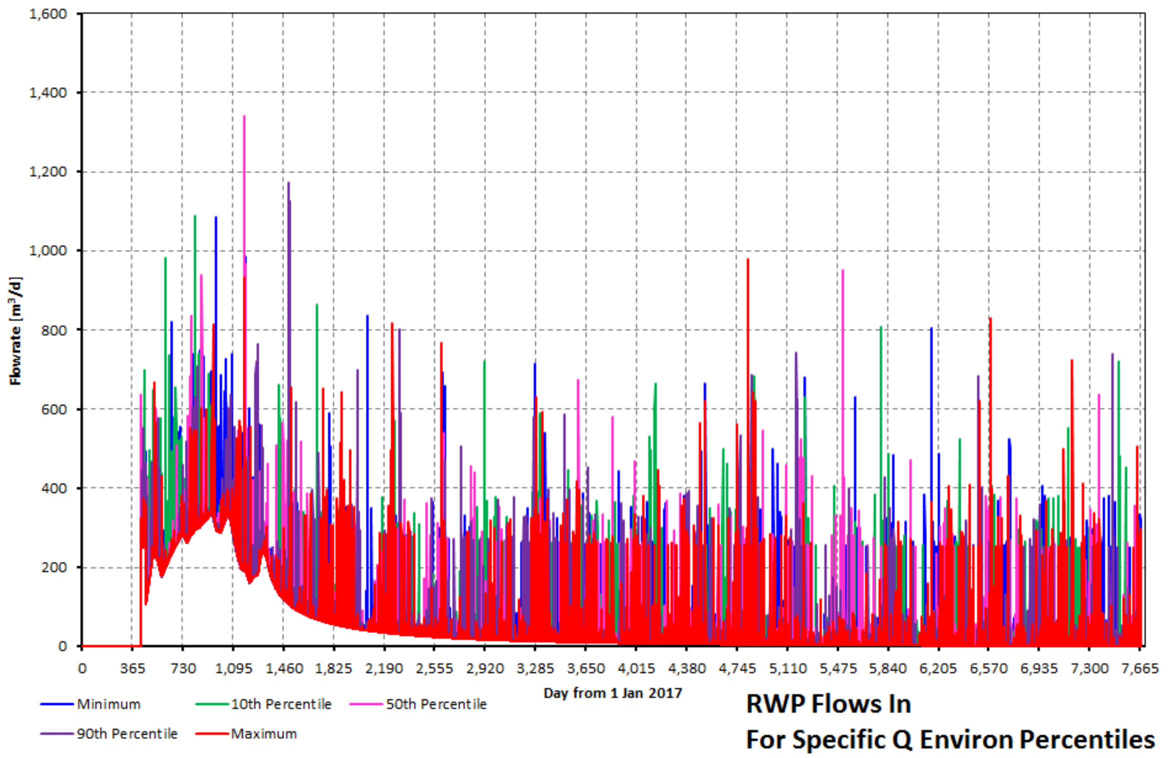

45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Volume [m³]
0
365
730
1,095
1,460
1,825
2,190
2,555
2,920
3,285
3,650
4,015
4,380
4,745
5,110
5,475
5,840
6,205
6,570
6,935
7,300
7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
TWL
Overflow
Tiedeman's North & South Volume
For Specific Q Environ Percentiles

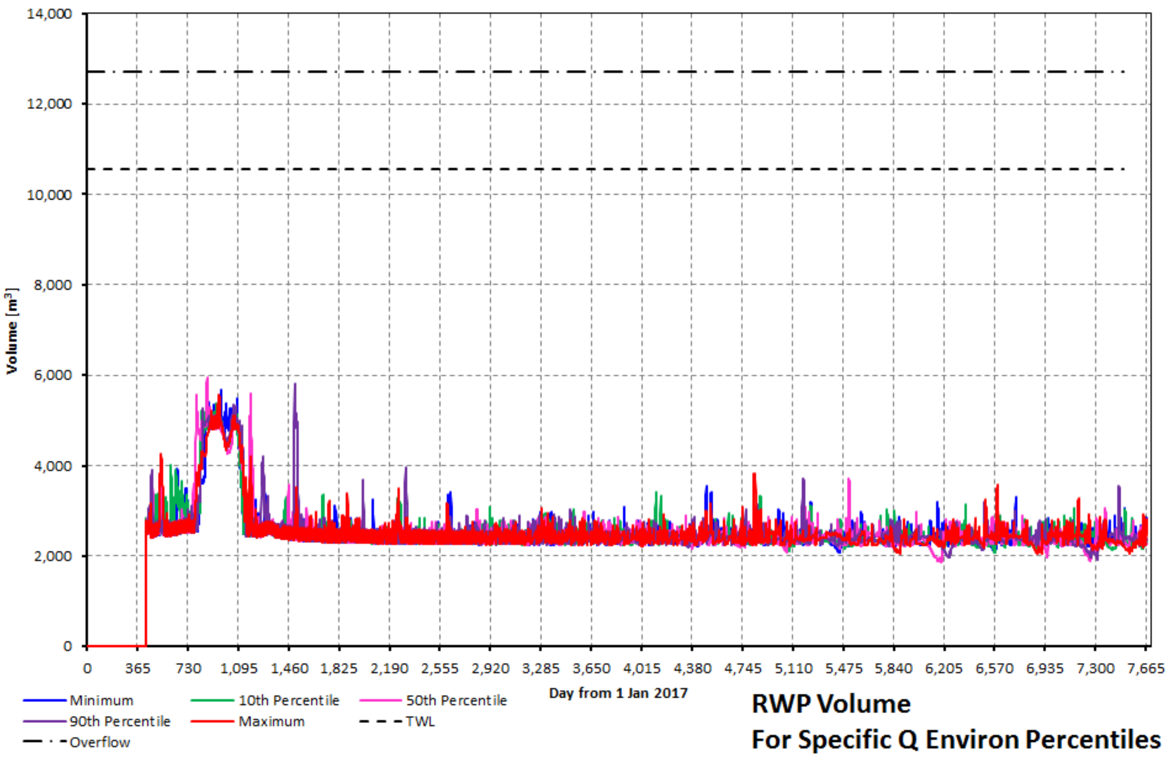

Volume [m³]
0
5,000
10,000
15,000
20,000
25,000
30,000
0 365 730 1,095 1,460 1,825 2,190 2,555 2,920 3,285 3,650 4,015 4,380 4,745 5,110 5,475 5,840 6,205 6,570 6,935 7,300 7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
TWL
Overflow
Tiedeman's East Volume
For Specific Q Environ Percentiles

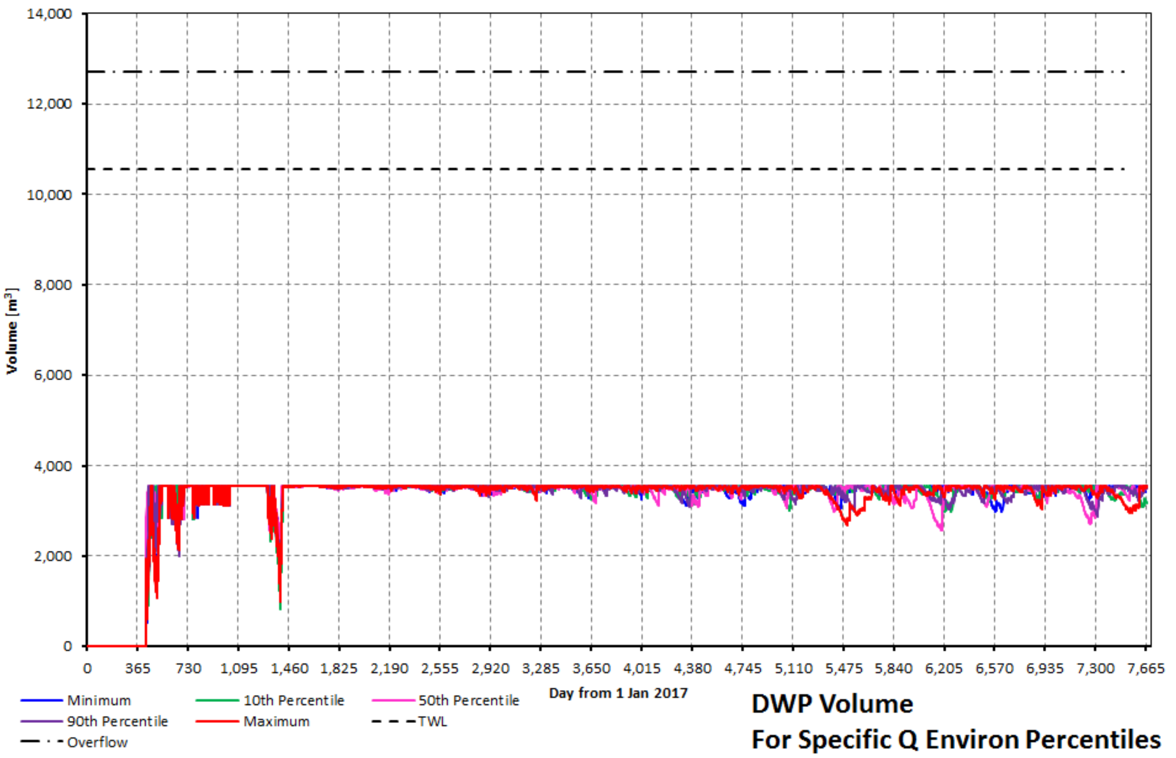

Flowrate [m³/d]
0
500
1,000
1,500
2,000
2,500
0 365 730 1,095 1,460 1,825 2,190 2,555 2,920 3,285 3,650 4,015 4,380 4,745 5,110 5,475 5,840 6,205 6,570 6,935 7,300 7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
Total flow to River
For Specific Q Environ Percentiles

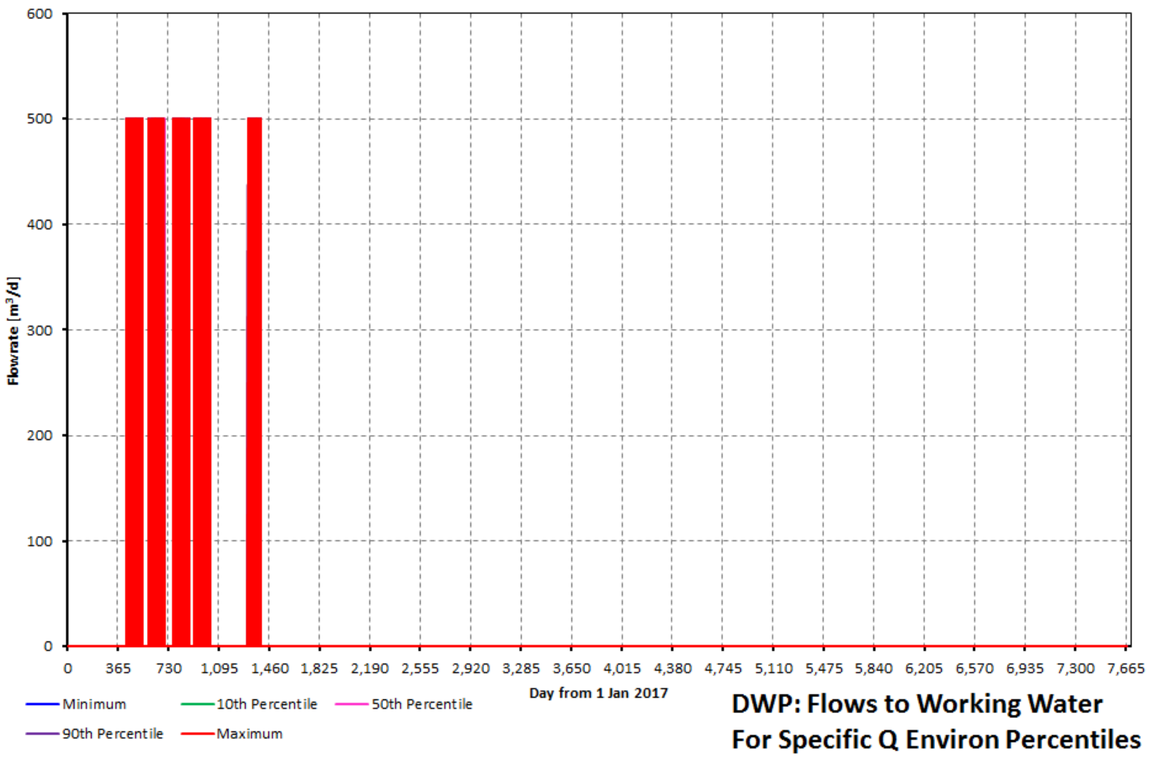

30,000
25,000
20,000
15,000
10,000
5,000
0
Flowrate [m³]
0
365
730
1,095
1,460
1,825
2,190
2,555
2,920
3,285
3,650
4,015
4,380
4,745
5,110
5,475
5,840
6,205
6,570
6,935
7,300
7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
Summation of total flows to River
For Specific Q Environ Percentiles

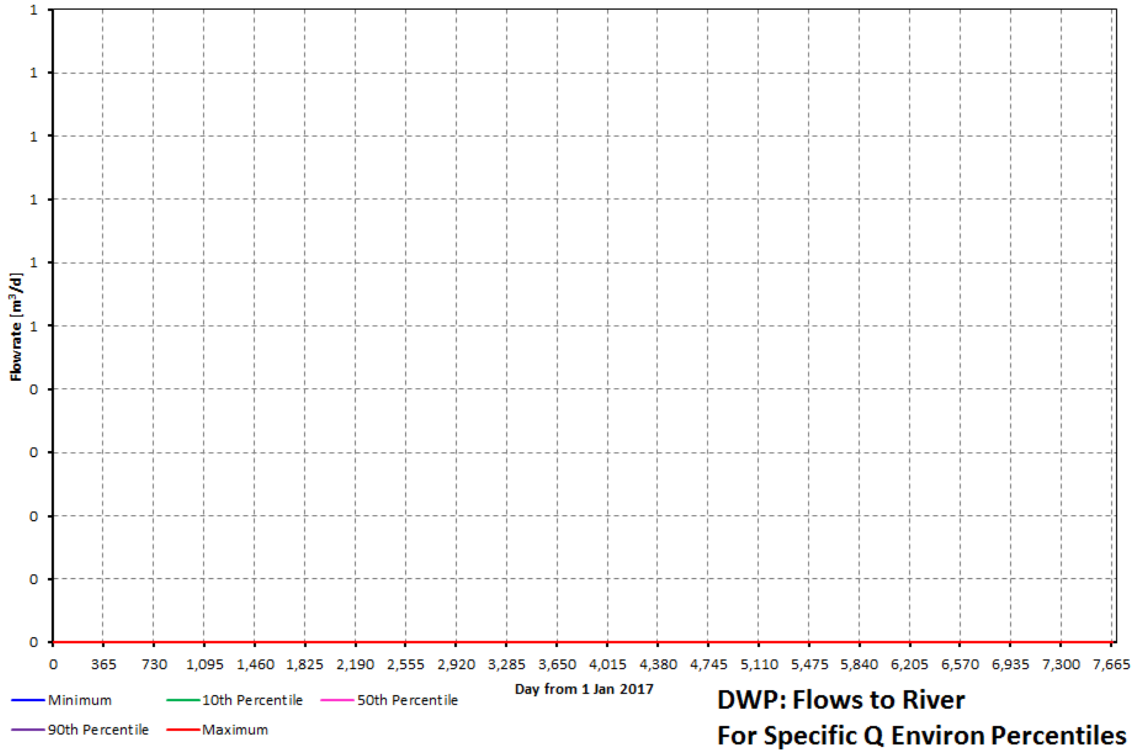
Appendix 12 Simulation Scenario 15: P10 Extracted Water Production: Base Case

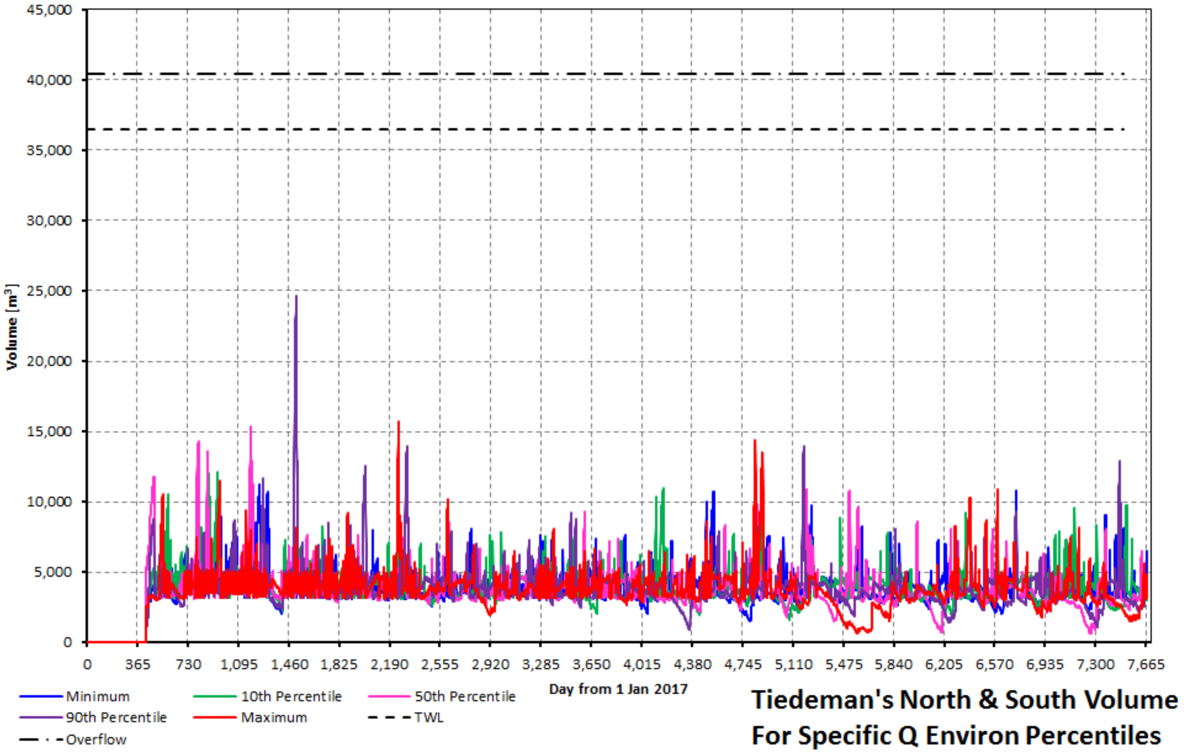

Flowrate [m³/d]
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
RWP Flows In
For Specific Q Environ Percentiles

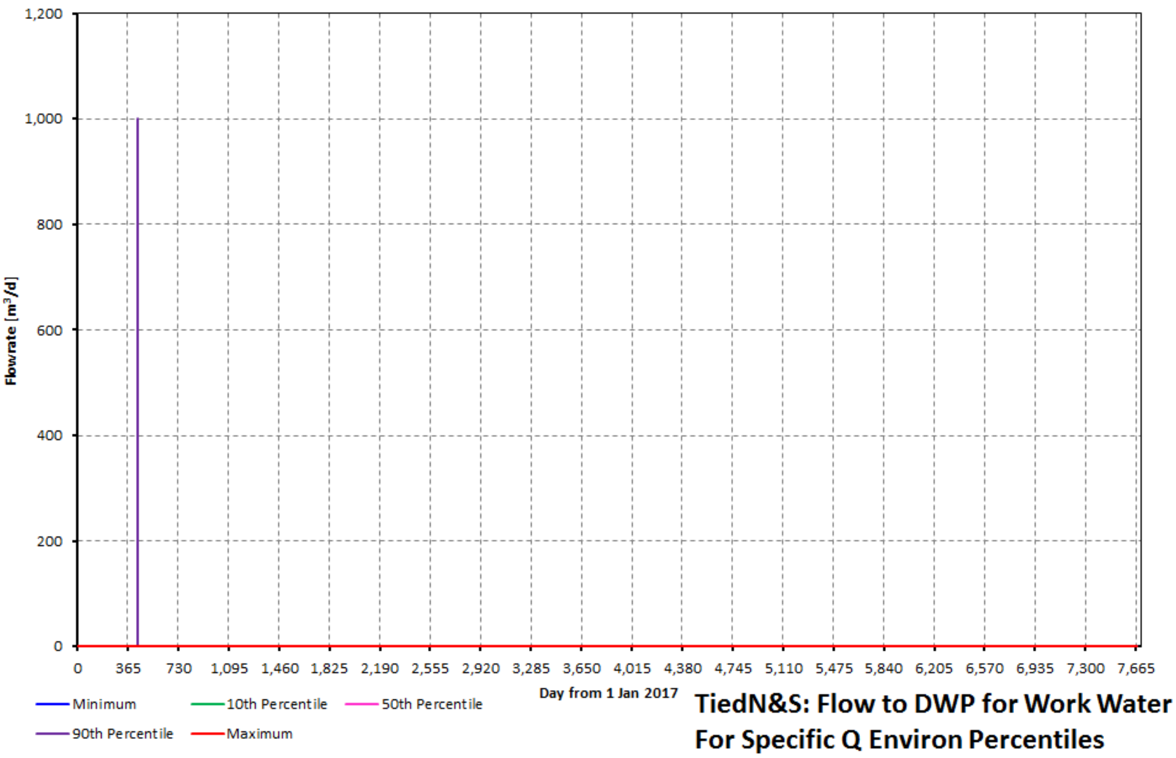

Volume [m³]
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
TWL
Overflow
RWP Volume
For Specific Q Environ Percentiles

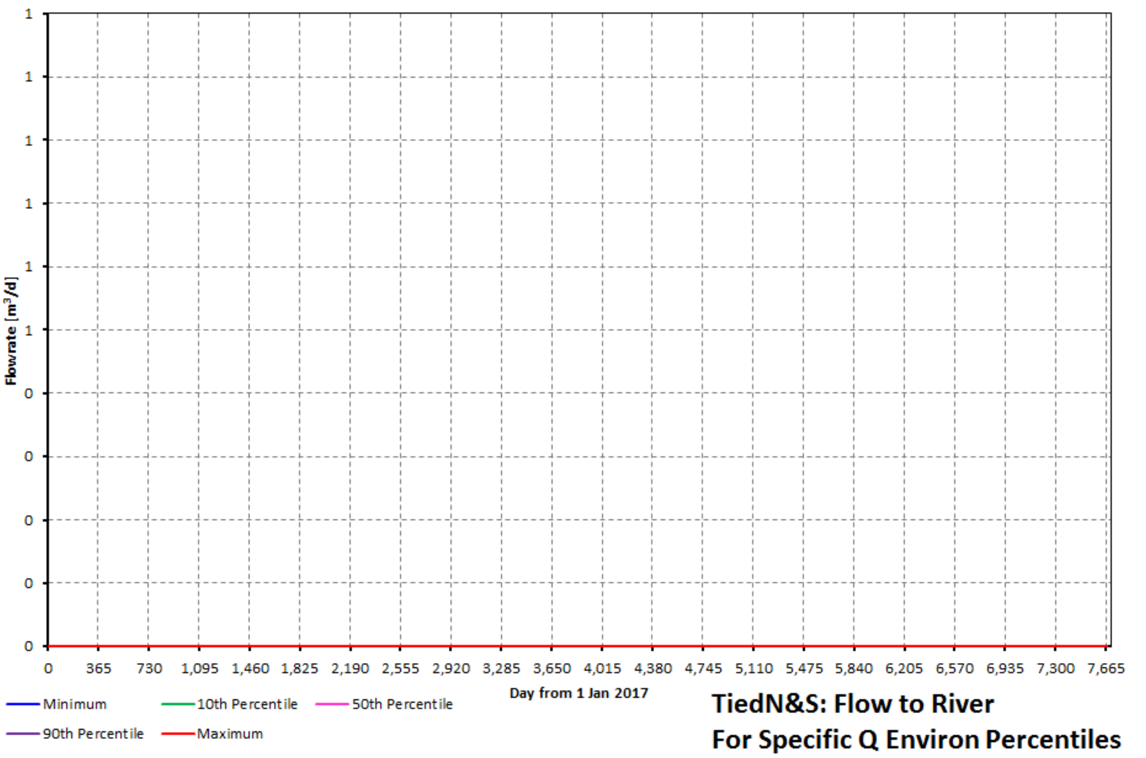

14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Volume [m³]
0 365 730 1,095 1,460 1,825 2,190 2,555 2,920 3,285 3,650 4,015 4,380 4,745 5,110 5,475 5,840 6,205 6,570 6,935 7,300 7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
TWL
Overflow
DWP Volume
For Specific Q Environ Percentiles

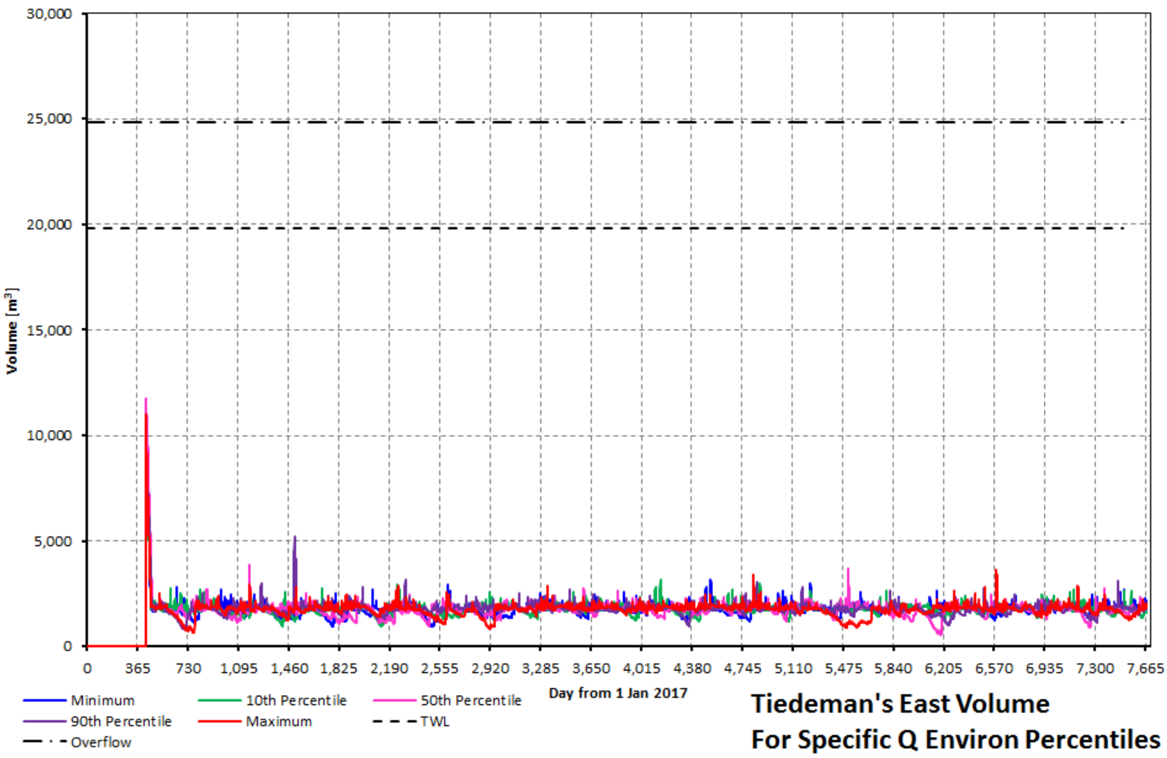

600
500
400
300
200
100
0
Flowrate [m³/d]
0 365 730 1,095 1,460 1,825 2,190 2,555 2,920 3,285 3,650 4,015 4,380 4,745 5,110 5,475 5,840 6,205 6,570 6,935 7,300 7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
DWP: Flows to Working Water
For Specific Q Environ Percentiles

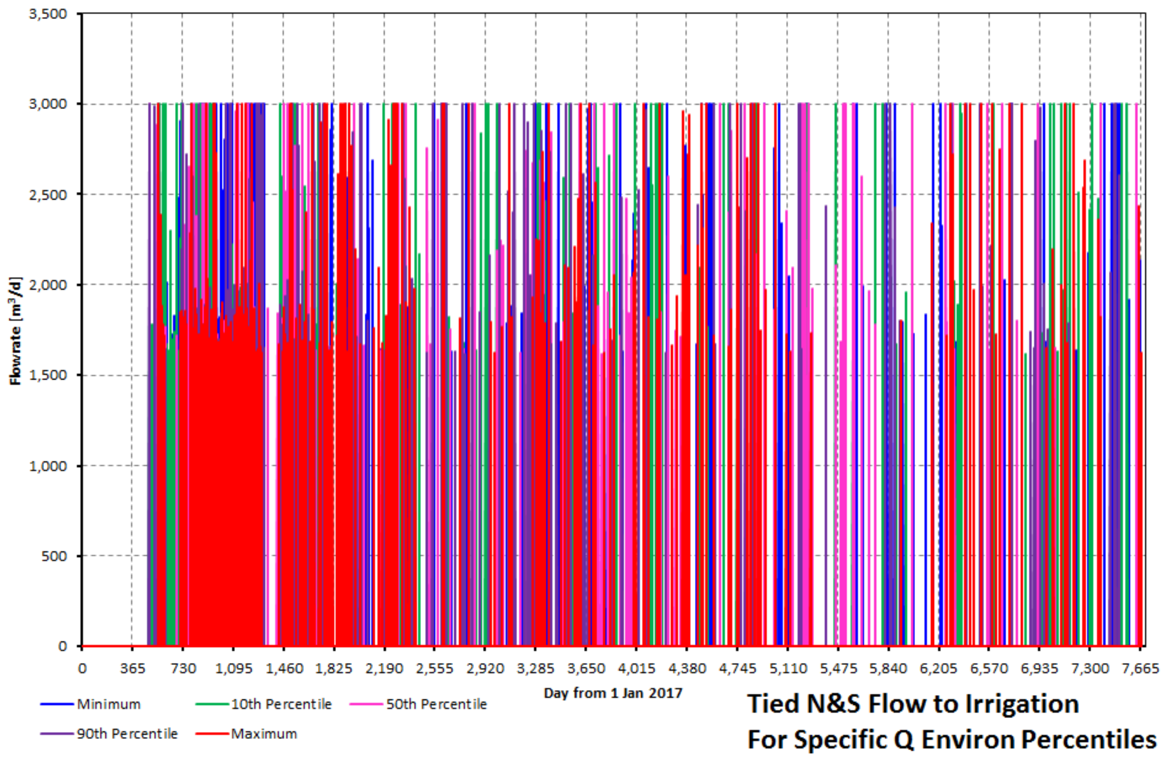

Flowrate [m³/d]
1
1
1
1
1
1
0
0
0
0
0
0
365
730
1,095
1,460
1,825
2,190
2,555
2,920
3,285
3,650
4,015
4,380
4,745
5,110
5,475
5,840
6,205
6,570
6,935
7,300
7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
DWP: Flows to River
For Specific Q Environ Percentiles

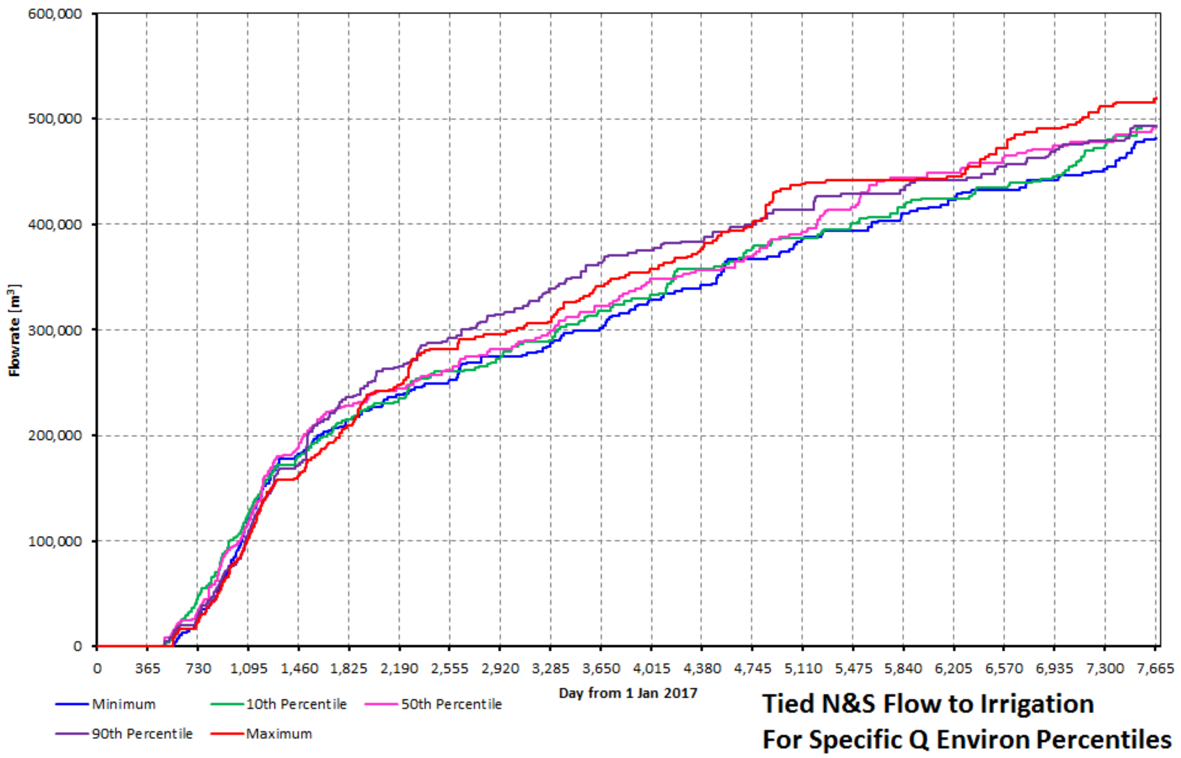

Volume [m³]
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
365
730
1,095
1,460
1,825
2,190
2,555
2,920
3,285
3,650
4,015
4,380
4,745
5,110
5,475
5,840
6,205
6,570
6,935
7,300
7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
TWL
Overflow
Tiedeman's North & South Volume
For Specific Q Environ Percentiles

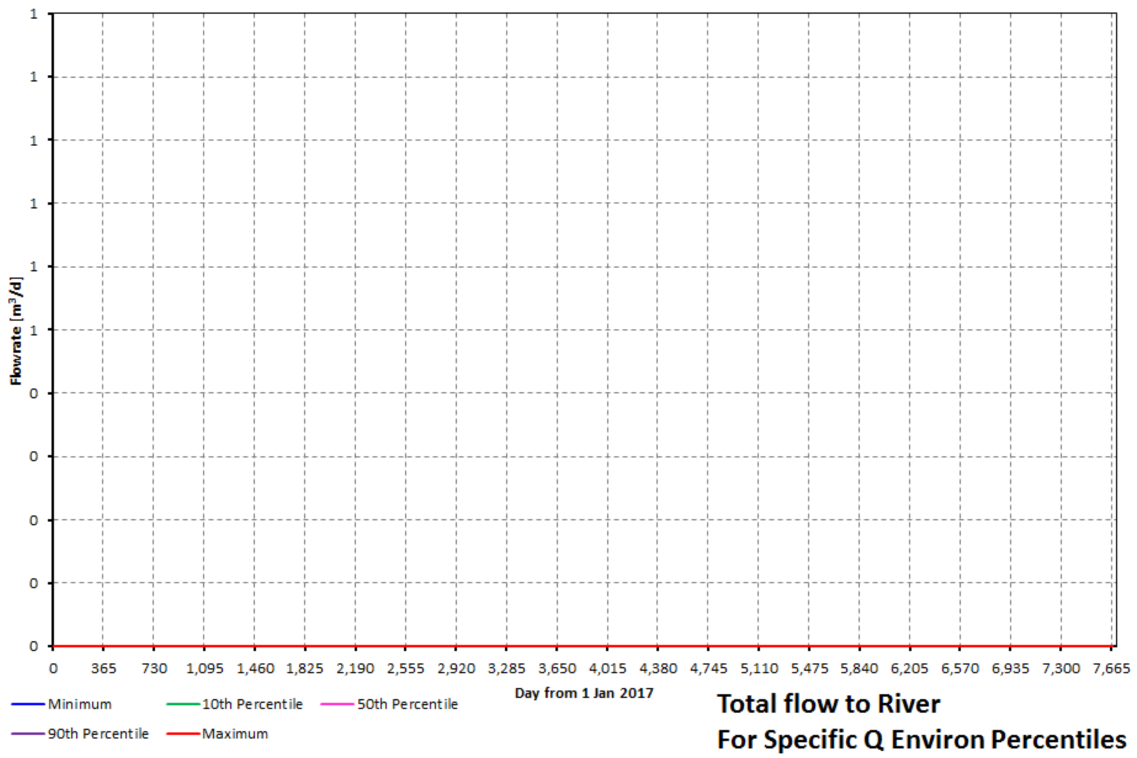

Flowrate [m³/d]
1,200
1,000
800
600
400
200
0
0 365 730 1,095 1,460 1,825 2,190 2,555 2,920 3,285 3,650 4,015 4,380 4,745 5,110 5,475 5,840 6,205 6,570 6,935 7,300 7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
TiedN&S: Flow to DWP for Work Water
For Specific Q Environ Percentiles

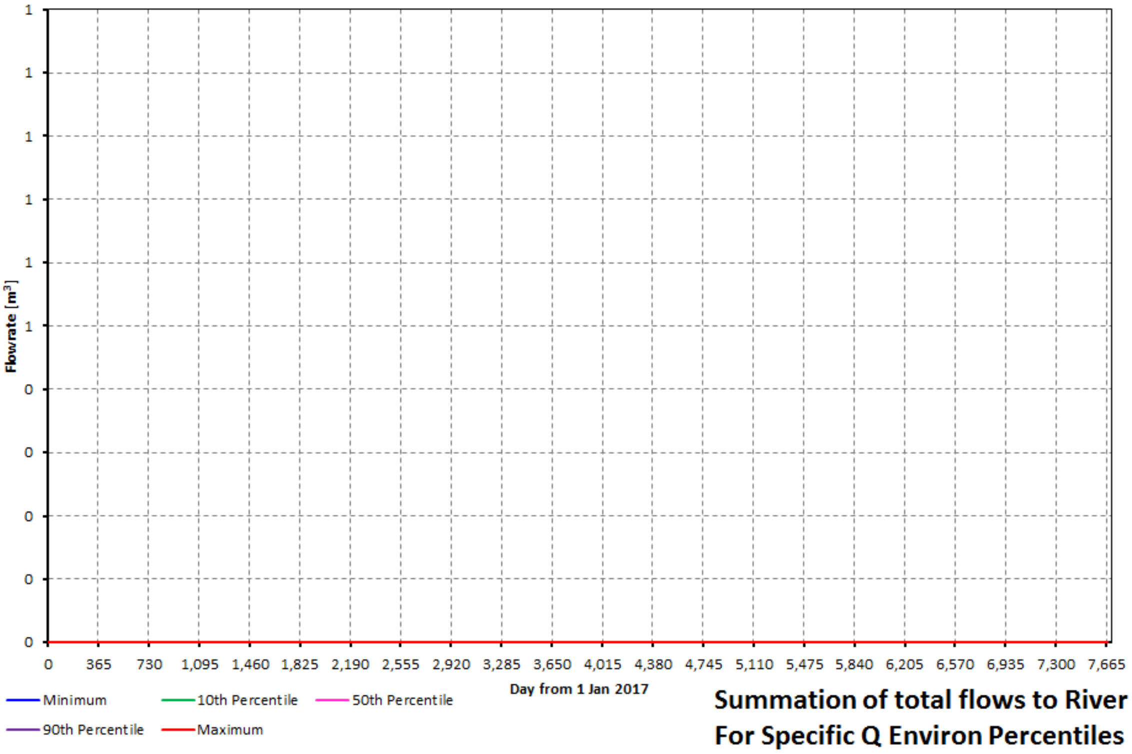

Flowrate [m³/d]
1
1
1
1
1
1
0
0
0
0
0
0 365 730 1,095 1,460 1,825 2,190 2,555 2,920 3,285 3,650 4,015 4,380 4,745 5,110 5,475 5,840 6,205 6,570 6,935 7,300 7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
TiedN&S: Flow to River
For Specific Q Environ Percentiles

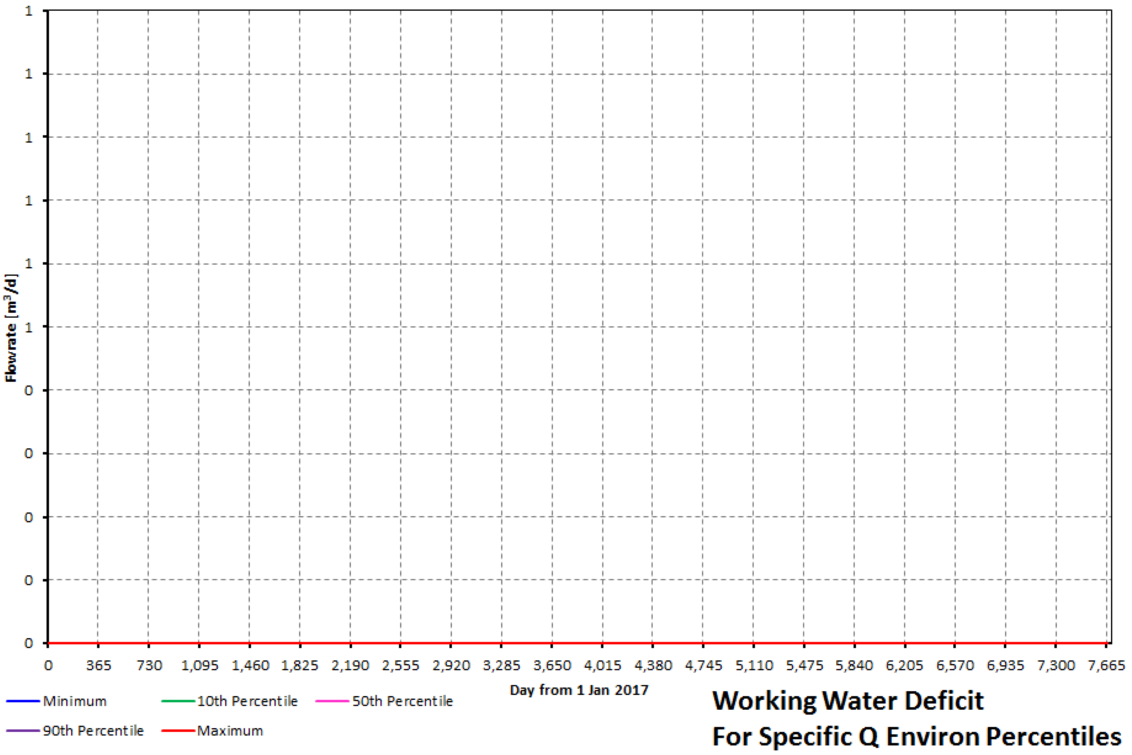

Volume [m³]
30,000
25,000
20,000
15,000
10,000
5,000
0
0 365 730 1,095 1,460 1,825 2,190 2,555 2,920 3,285 3,650 4,015 4,380 4,745 5,110 5,475 5,840 6,205 6,570 6,935 7,300 7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
TWL
Overflow
Tiedeman's East Volume
For Specific Q Environ Percentiles

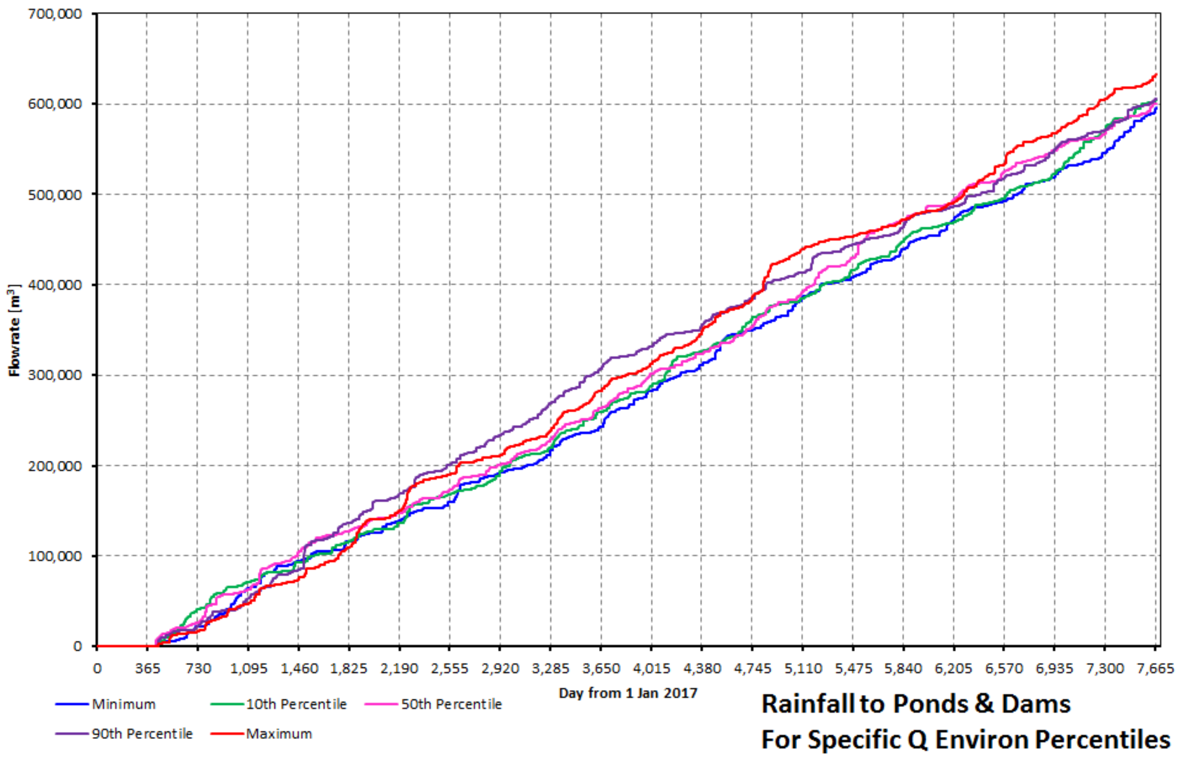

Flowrate [m³/d]
3,500
3,000
2,500
2,000
1,500
1,000
500
0
0 365 730 1,095 1,460 1,825 2,190 2,555 2,920 3,285 3,650 4,015 4,380 4,745 5,110 5,475 5,840 6,205 6,570 6,935 7,300 7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
Tied N&S Flow to Irrigation
For Specific Q Environ Percentiles


600,000
500,000
400,000
300,000
200,000
100,000
0
Flowrate [m³]
0 365 730 1,095 1,460 1,825 2,190 2,555 2,920 3,285 3,650 4,015 4,380 4,745 5,110 5,475 5,840 6,205 6,570 6,935 7,300 7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
Tied N&S Flow to Irrigation
For Specific Q Environ Percentiles

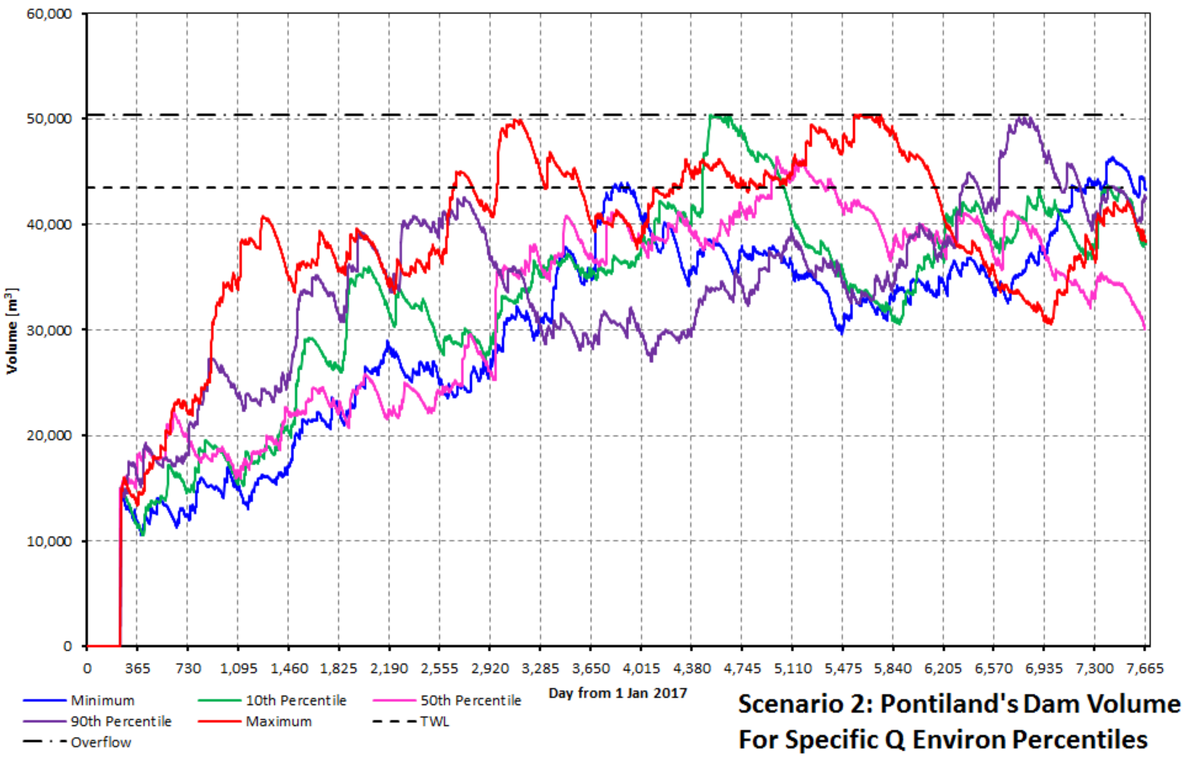

1
1
1
1
1
1
0
0
0
0
0
Flowrate [m³/d]
0 365 730 1,095 1,460 1,825 2,190 2,555 2,920 3,285 3,650 4,015 4,380 4,745 5,110 5,475 5,840 6,205 6,570 6,935 7,300 7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
Total flow to River
For Specific Q Environ Percentiles

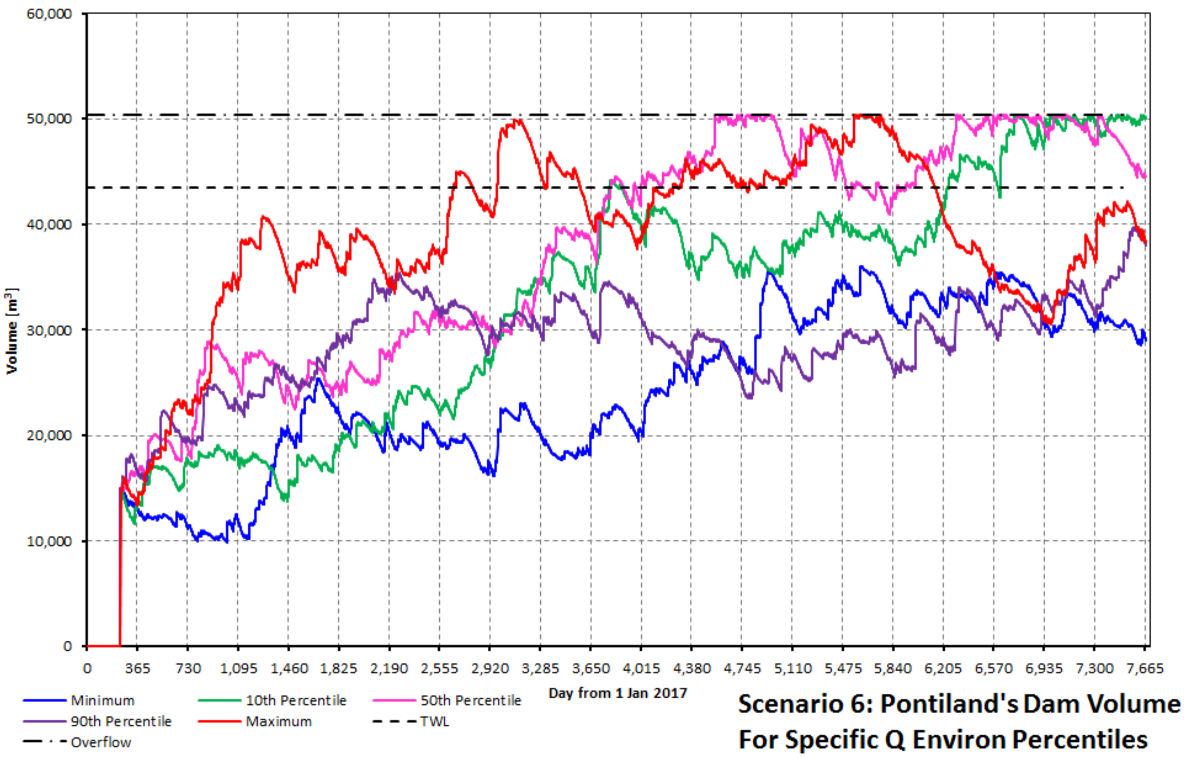

Flowrate [m³]
1
1
1
1
1
1
0
0
0
0
0
0
365
730
1,095
1,460
1,825
2,190
2,555
2,920
3,285
3,650
4,015
4,380
4,745
5,110
5,475
5,840
6,205
6,570
6,935
7,300
7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
Summation of total flows to River
For Specific Q Environ Percentiles

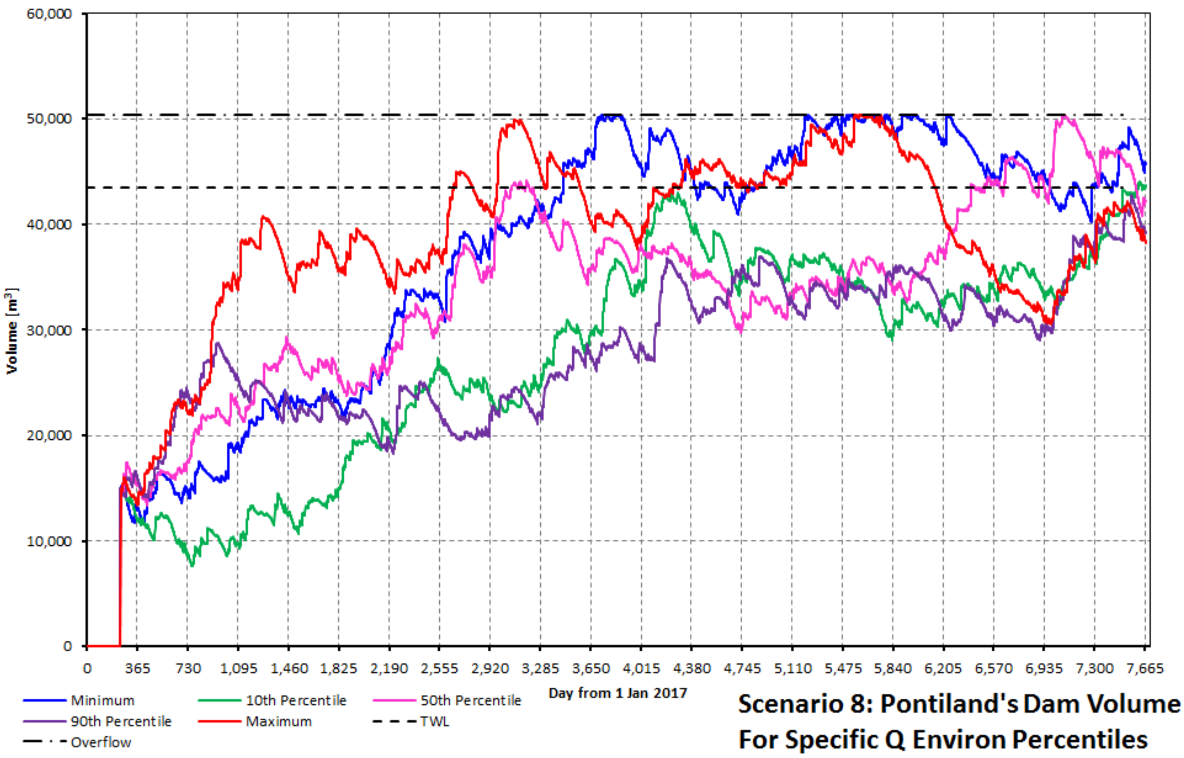

Flowrate [m³/d]
1
1
1
1
1
1
0
0
0
0
0
0
365
730
1,095
1,460
1,825
2,190
2,555
2,920
3,285
3,650
4,015
4,380
4,745
5,110
5,475
5,840
6,205
6,570
6,935
7,300
7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
Working Water Deficit
For Specific Q Environ Percentiles


Flowrate [m³]
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
0 365 730 1,095 1,460 1,825 2,190 2,555 2,920 3,285 3,650 4,015 4,380 4,745 5,110 5,475 5,840 6,205 6,570 6,935 7,300 7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
Rainfall to Ponds & Dams
For Specific Q Environ Percentiles

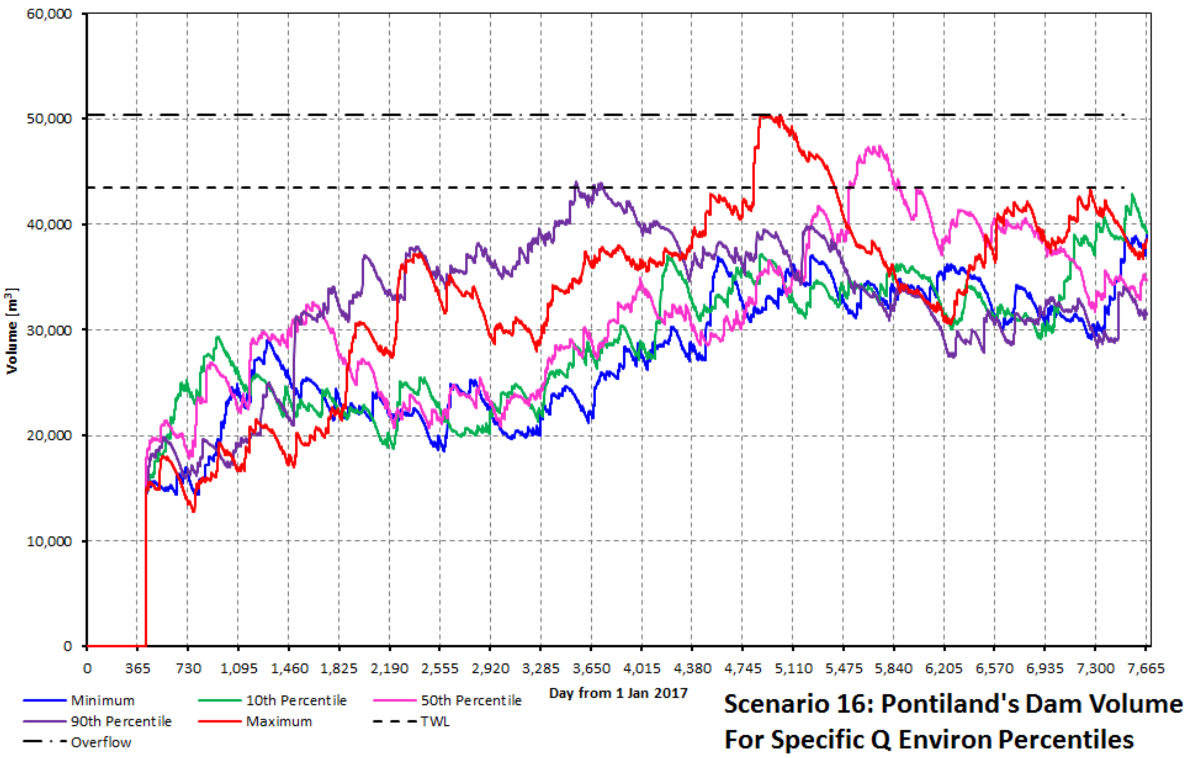
Appendix 13 Pontiland's Dam Profiles


60,000
50,000
40,000
30,000
20,000
10,000
0
Volume [m³]
0
365
730
1,095
1,460
1,825
2,190
2,555
2,920
3,285
3,650
4,015
4,380
4,745
5,110
5,475
5,840
6,205
6,570
6,935
7,300
7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
TWL
Overflow
Scenario 2: Pontiland's Dam Volume
For Specific Q Environ Percentiles


60,000
50,000
40,000
30,000
20,000
10,000
0
Volume [m³]
0
365
730
1,095
1,460
1,825
2,190
2,555
2,920
3,285
3,650
4,015
4,380
4,745
5,110
5,475
5,840
6,205
6,570
6,935
7,300
7,665
Day from 1 Jan 2017
Minimum
10th Percentile
50th Percentile
90th Percentile
Maximum
TWL
Overflow
Scenario 6: Pontiland's Dam Volume
For Specific Q Environ Percentiles



Scenario 8: Pontiland's Dam Volume For Specific Q Environ Percentiles



Scenario 16: Pontiland's Dam Volume For Specific Q Environ Percentiles

Appendix C – Environmental Assessment and Design of High Flow Discharge Location for Treated Water (Cardno)

Gloucester Gas Project

Environmental Assessment and Design of High Flow Discharge Location for Treated Water

59915194

Prepared for
AGL Energy Limited

14 August 2015

Cardno
Shaping the Future

Contact Information

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Trading as Cardno NSW/ACT Pty Ltd

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Date Approved:	14.08.15

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A	24.07.15	Draft for review	Kate Reeds Emma Maratea Scott Brisbin	Andrew Simon Chris Holloway
B	11.08.15	Final for review	Kate Reeds Scott Brisbin	Chris Holloway
0	14.08.15	Final for use	Kate Reeds	Chris Holloway

Executive Summary

AGL is proposing to build the Gloucester Gas Project (GGP) which comprises several stages of development facilitating the extraction of coal seam gas (CSG) from the Gloucester Basin. As part of the GGP and associated Extracted Water Management Strategy (EWMS), AGL commissioned Cardno NSW/ACT Pty Ltd (Cardno) to undertake an investigation into the potential environmental impacts and engineering requirements associated with a high flow discharge outlet downstream of the GGP Central Processing Facility (CPF) and close to AGL's proposed irrigation reuse areas.

The proposed high flow discharge outlet for treated water will facilitate the release of water associated with the Stage 1 Gas Field Development Area (GFDA) gas extraction activities in the initial years of operation, when volumes of extracted water from the well field are high and when extended wet weather conditions preclude irrigation and/or stock re-use. In developing the EWMS, further investigations were considered necessary to determine the optimum location of the high flow discharge outlet and where any potential downstream impacts (if any) can be minimised.

Cardno undertook a desk and field based study of the geomorphological and ecological characteristics of the Study Area to assist in the identification of one or more suitable high flow discharge locations. Preliminary designs of the discharge structure/outlet were also required, including consideration of any flood or scour protection works.

Location selection and development of a preliminary design was carried out in a staged approach. Information relevant to the study area was initially compiled as part of a desktop review. This information was then used to identify potential reaches within the Study Area (including Avon River and Dog Trap Creek) for more detailed field inspection. The field inspection was carried out on 30 June 2015 along a one kilometre reach of each watercourse. Four sites were identified as potentially suitable for placement of the high flow discharge outlet and were subject to detailed geomorphological and ecological assessments. All relevant information from the literature review and field investigation was then compiled to inform a semi-quantitative Multi-Criteria Analysis (MCA). The aim of the MCA was to determine the preferred discharge location on the basis of key assessment criteria including: the predicted increase in flow (ml/day), observed bank stability, habitat condition, loss of native riparian habitat, fish habitat class, suitability of bank formation to accept headwall and discharge flows, pipe route length and resulting construction and restoration costs. Each criterion was weighted and sensitivity tested to ensure a robust outcome was achieved.

Results of the field investigation and MCA suggested that any of the four locations considered (AV1, AV2, AV3 and DT1) would be potentially suitable for placement of the outlet. While no measurable impacts to the geomorphological or ecological integrity of the receiving waterways were expected at any of the four locations, location AV2 was considered to represent the lowest level of risk.

The preliminary design for the high flow discharge outlet was therefore drafted on the basis of the preferred AV2 location. The proposed design would consist of a gravity pipe line running from the rising main to the west toward the Avon River, a pit near the top of creek bank, headwall and discharge outlet. Rock scour protection consisting of sandstone boulders and geotextile is also proposed downstream of the headwall.

Several measures are recommended to minimise habitat disturbance during the construction process, in particular, erosion and sediment controls and rehabilitation of existing habitat (consisting predominantly of introduced species) with native bank-stabilising vegetation. Native vegetation may also be incorporated into the rock scour protection.

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Glossary

Term or Acronym	Definition
AGL	AGL Energy Limited
CPF	Central Processing Facility
CSG	Coal Seam Gas
DoPE	NSW Department of Planning and Environment
DSEWPaC	Department of Sustainability, Environment, Water, Population and Communities
DWP	Discharge Water Pond
EP&A	NSW Environmental Planning and Assessment Act
EPBC	Commonwealth Environmental Protection and Biodiversity Conservation Act
EWMS	Extracted Water Management Strategy
GFDA	Gas Field Development Area
GGP	Gloucester Gas Project

1 Introduction

1.1 Background

AGL is proposing to build the Gloucester Gas Project (GGP) which comprises several stages of development facilitating the extraction of coal seam gas (CSG) from the Gloucester Basin. Concept plan and project approval (Part 3A Approval) for the Stage 1 Gas Field Development Area (GFDA) was granted on 22 February 2011 under Part 3A of the Environmental Planning and Assessment Act (1979) (EP&A Act). In addition, the project received approval under the Environment Protection and Biodiversity Conservation Act (1999) (EPBC Act) (EPBC Approval) on 11 February 2013.

The current GGP includes the construction, operation and decommissioning of not more than 110 CSG wells and associated infrastructure, including gas and water gathering lines within the Stage 1 GFDA. The GGP will involve depressurising of deep groundwater and the extraction of gas from multiple coal seams within the Gloucester coal measures. The dewatering of deep coal seams will result in produced water and managing the extracted water (i.e. flowback water and produced water) from the Stage 1 gas well field is a critical aspect of the development.

As part of the approvals process for the GGP, AGL has developed a draft Extracted Water Management Strategy (EWMS) for the Stage 1 GFDA. The draft EWMS outlines the preferred processes for the treatment, re-use and discharge of water associated with Stage 1 GFDA gas extraction activities, including summaries of background technical studies. The primary beneficial uses of treated extracted water would be storage for irrigation and stock re-use, although in the initial years of the Stage 1 development, treated water will also need to be discharged into suitable adjacent waterways (either the Avon River or Dog Trap Creek) when volumes of extracted water from the wellfield are high and when extended wet weather conditions preclude irrigation and/or stock re-use. In developing the EWMS, further investigations were considered necessary to determine the optimum location of the high flow discharge outlet where any potential downstream impacts (if any) will be minimised.

AGL commissioned Cardno NSW/ACT Pty Ltd (Cardno) to undertake an investigation of the potential environmental impacts and engineering requirements associated with a high flow discharge location downstream of the Central Processing Facility (CPF) for the GGP.

The scope of work specifically includes a geomorphological and ecological assessment of the downstream study area to assist in the identification of one or more suitable discharge locations. Preliminary designs of the discharge structure/outlet are also required, including consideration of any flood or scour protection works.

1.2 Aims and Objectives

The specific aims of the study were to:

> Provide an overview of the hydrology of the streams and the water quality of the receiving waters at the investigation site;

> Undertake a geomorphological assessment of the Avon River and Dog Trap Creek areas along the southern and western boundaries of AGL's Tiedmans property and the western boundary of AGL's Atkins (Avondale) property south of Gloucester ;

> Undertake an ecological assessment of the same riverine areas to determine the impacts of discharge on ecosystem conditions and assets, and the impacts on biota and the immediate downstream environment;

> Consider the temperature of discharge water and the risk of thermal pollution and associated impacts on the local aquatic ecosystem;

> Identify a preferred discharge location (and any alternatives) that would be suitable to discharge 0.5 to 2 ML per day of treated water directly into a high flow event occurring along the Avon River;

> Provide a preliminary design of the proposed discharge/outlet structure together with flood protection and any scour protection measures required to protect the structure, stream banks and riparian vegetation.

1.3 Proposal to Discharge to Surface Waters

It is understood that the quality, frequency and volume of produced water for discharge into surface waters will be managed to ensure similar conditions and flow regimes are maintained within the receiving waterway, thereby minimising the potential for downstream environmental impacts.

In order to achieve this, AGL propose the following:

> Water discharged from the CPF and/or storage dams will have been conditioned and treated to meet the surface water quality targets as provided by AGL, July 2015 (refer Section 3.3). Any discharges will also be managed in accordance with the necessary EPA and NSW Office of Water (NOW) approvals.

> No discharges of treated water are expected if average to dry seasons prevail as all water would be beneficially reused though stock and irrigation use. After the first three years, AGL does not expect to use this option as there will be sufficient storage for produced water and treated water in all but the wettest years.

> It is expected that most water would be discharged during periods of higher flow when irrigation is not possible because of preceding wet weather conditions.

> The annual discharge of treated water into the receiving waterways is expected to be of the order of 1% of the total extracted water flowrate (less than 20 ML/yr). These projections only occur for the worst case climate conditions and occur near to the peak of the extracted water production period in Year 3 of the project (Worley Parsons 2015).

> It is expected that the maximum discharge rate would be up to 2 ML/d but average less than 1 ML/d.

1.4 High Flow Outlet Design Considerations

Selection of a proposed high flow discharge location should aim to minimise construction related and operational downstream impacts on scouring and erosion, bank stability, aquatic habitat quality and associated aquatic biota. The high flow discharge structures would therefore be designed to ensure:

> Adequate dispersion and mixing within a relatively short distance;

> Dissipation of energy associated with the new inflow;

> Compatibility with upstream and downstream water quality; and

> Appropriate scour protection on the creek banks and bed local to and immediately downstream of the outlet.

2 Study Methodology

2.1 Overview

Location selection and development of a preliminary design was carried out in a staged approach. Information relevant to the study area was initially compiled as part of a desktop study. More detailed location specific information was then collected at four potential discharge locations during a one day field investigation. All relevant information was then compiled and disseminated to inform a semi-quantitative Multi-Criteria Analysis (MCA) with the aim of determining the preferred discharge on the basis of key assessment criteria. A preliminary engineering design was then developed for the preferred location. This process is summarised in **Figure 2-1**.

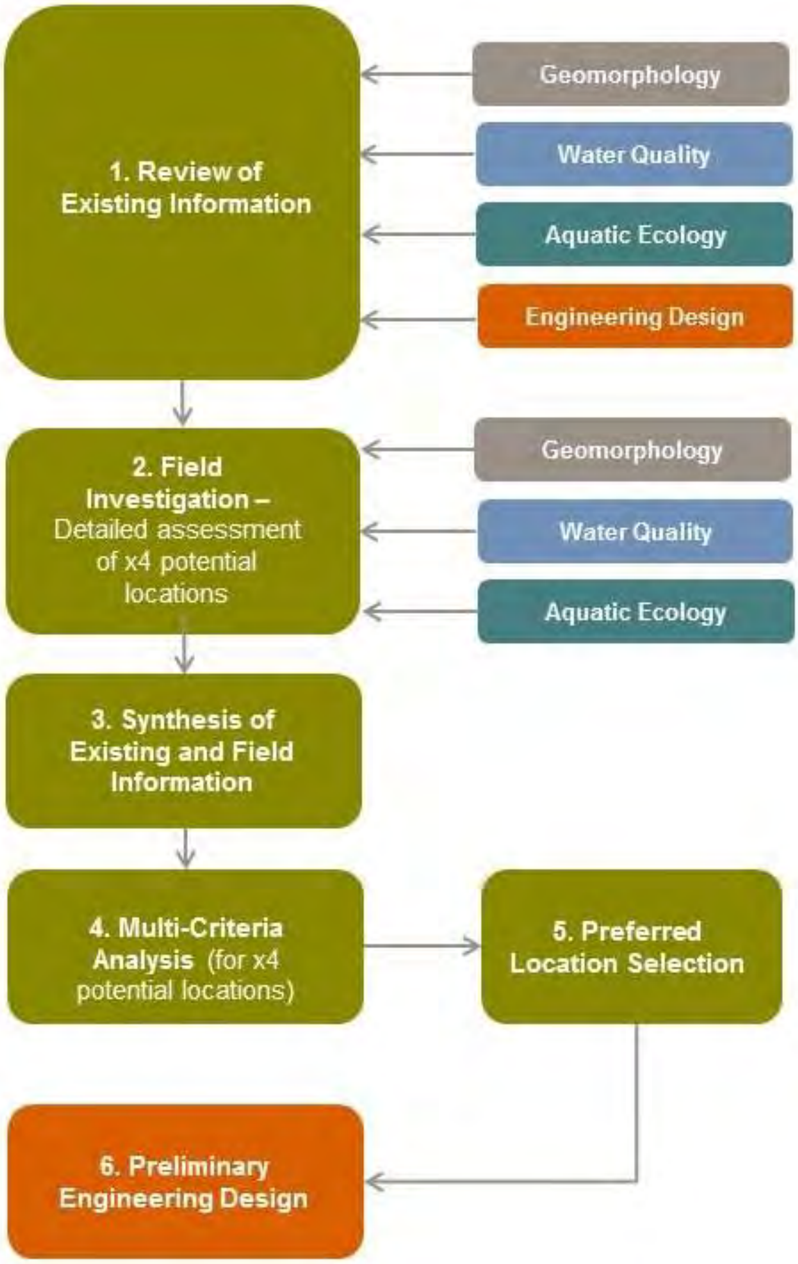


Figure 2-1 Approach to study methodology

2.2 Study Area

The Study Area for the high flow discharge location assessment is indicated in **Figure 2-2** below.

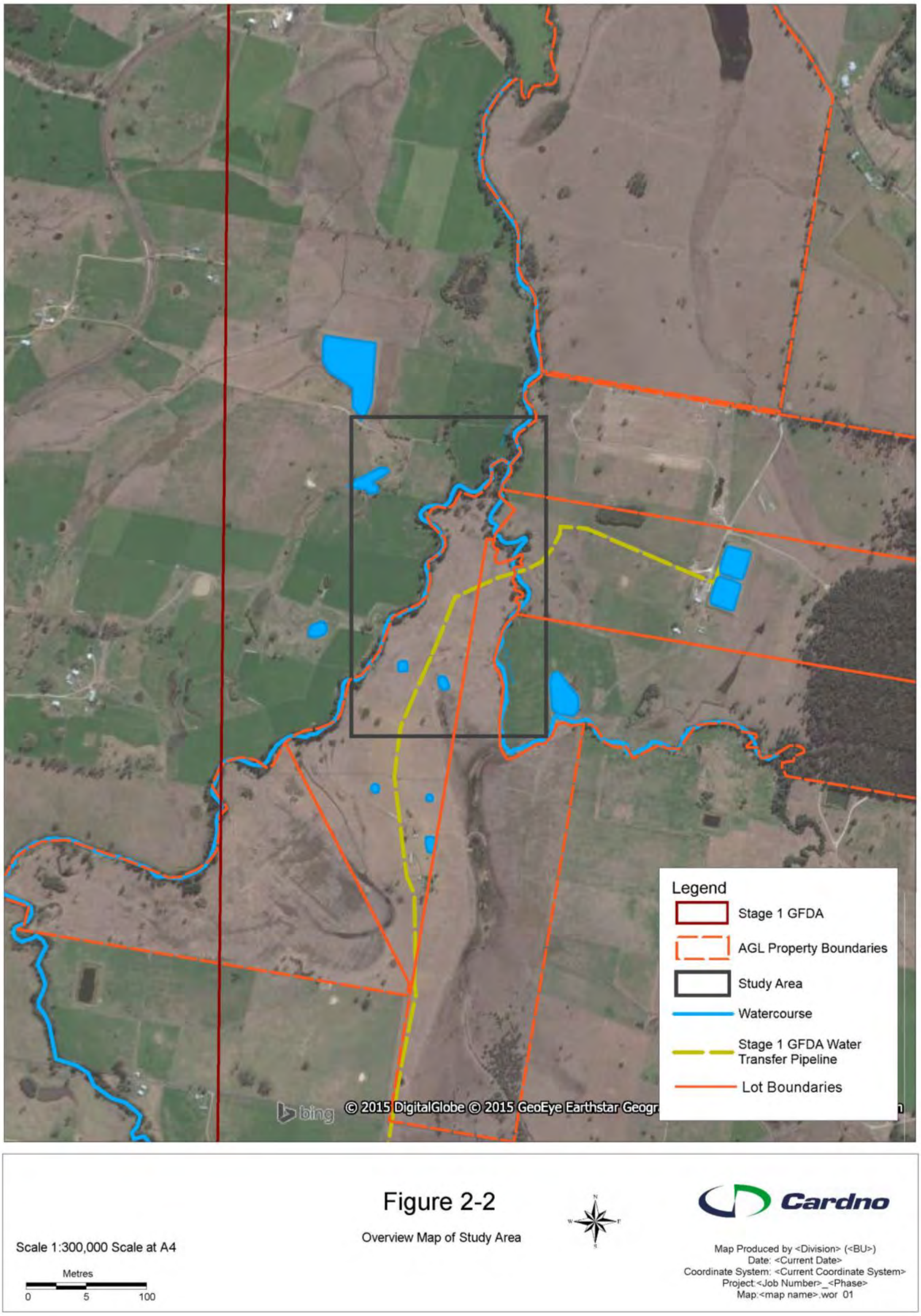


Figure 2-2 Overview map of Study Area

2.3 Review of Existing Information

2.3.1 Geomorphology

Existing information on geomorphology of the streams within the Study Area was obtained by review of aerial photography (Google Earth images), technical reports and relevant literature using the internet and the Cardno library/database. The review of this data was important to identify the key geomorphological characteristics of the Study Area and enable an initial evaluation of several potential discharge locations to be assessed in detail on-site.

The key technical reports that were used in this review comprised of:

> AGL (2014) - Consultation Draft: Extracted Water Management Strategy;

> BMT WBM (2015) –Gloucester and Avon Rivers Flood Study (report to Gloucester Shire Council); and

> Parsons Brinckerhoff (2014) – Gloucester Gas Project - Hydrological Study (report to AGL).

Water level data for the period 2011 to 2015 was supplied by AGL and utilised in the assessments.

2.3.2 Water Quality

Existing information on water quality of the streams within the Study Area was reviewed to determine the compatibility of the discharge water quality with the natural surface waters. Long –term monitoring data and relevant technical reports were reviewed, particular the long-term water quality data from AGLs surface water monitoring locations, TSW01, TSW02, ASW01, ASW02, and FSW01 (**Figure 3-1)**.

2.3.3 Aquatic Ecology

Existing information on aquatic habitats and associated aquatic biota within the Study Area was obtained by review of aerial photography (Google Earth images), technical reports and relevant literature using the internet and the Cardno library/database.

Aquatic flora and fauna listed under the EPBC Act, the *Threatened Species Conservation Act 1995* (TSC Act) *Fisheries Management Act 1994* (FM Act) and *National Parks and Wildlife Act 1974* (NPW Act) (including threatened and protected species, populations and ecological communities) that are known or likely to occur within the investigation area were identified from the existing literature and publicly available databases including:

> The EPBC Protected Matters Search Tool (search area = Gloucester LGA);

> The Atlas of NSW Wildlife Bionet Database (search area =Gloucester LGA);

> The Atlas of Living Australia (search area = Gloucester LGA);

> NSW DPI Fisheries Records Viewer (search area = Gloucester LGA); and

> Threatened species listed by the Gloucester Shire Council Comprehensive State of Environment Report (2009).

Key threatening processes (KTPs) as listed under relevant schedules of the EPBC, TSC and FM Acts were also reviewed for those with relevance to the proposed discharge to surface waters.

2.4 Field Investigations

2.4.1 General

The stretch of the Avon River and Dog Trap Creek within the proposed Study Area was initially assessed on foot with the exception of densely vegetated and or very winding reaches of waterways which were considered unsuitable (due to greater potential for instability and loss of riparian habitat). Four potentially suitable locations were selected from the remaining reaches of the Avon River and Dog Trap Creek for a comprehensive site assessment. As a minimum, these locations were considered to provide reasonably good bank stability, have minimal native riparian vegetation (but enough to provide stability) and be easily accessed.

At each of the four locations, the time, date, GPS position (datum WGS84; accuracy <5 m) were recorded. An inventory of dominant riparian taxa was listed and site photographs taken.

2.4.2 Geomorphology

Field investigation were undertaken to confirm desktop geomorphological assessments and to note any other factors not previously evident. Detailed location assessments were undertaken at four locations and included the collection of the following data:

> Indices of channel dimensions and form;
> Indices of bank condition;
> Existing flow level (at the time of inspection);
> Evidence of scour and erosion from previous flow events; and
> Floodplain characteristics.

2.4.3 Water Quality

Water quality was measured in-situ with a YSI 6920 water quality probe and meter that were calibrated prior to sampling. The following variables were recorded just below the surface:

> Temperature (°C);
> Electrical Conductivity (µs/cm);
> pH;
> Dissolved oxygen (% saturation);
> Oxidation reduction potential (ORP) (mV); and,
> Turbidity (ntu).

Duplicate readings of each variable were taken in accordance with Australian Guidelines for protection of aquatic ecosystems (ANZECC/ARMCANZ 2000).

2.4.4 Aquatic Ecology

A standardised description of adjacent land and condition of riverbanks, channel and bed was recorded using the ‘Riparian, Channel and Environmental Inventory’ (RCE), developed by DECCW (Chessman *et al*. 1997) and adapted from Petersen (1992) for NSW conditions. RCE is used to scale and quantify the environmental state of particular locations based on surrounding land use, geomorphology, channel bed forms, and riparian and instream vegetation. The RCE score for each location is calculated by summing the scores for 13 descriptors (**Appendix A**).

The highest possible score (52) is assigned to streams with no obvious physical disruption; the lowest score (13) is assigned to heavily disturbed streams. Overall these scores are categorised as follows:

40-52 (Very good);
27-39 (Good);
14-26 (Moderately impaired); and
0-13 (Highly disturbed).

The potential for locations to provide fish habitat was assessed according to criteria developed by NSW DPI Policy and Guidelines for Fish Habitat Conservation and Management (Fairfull 2013 Update)(**Appendix A**).

2.5 Data Analysis

2.5.1 Geomorphology

The data and literature reviewed for the Study Area was qualitatively assessed to provide a regional and historical setting for the existing geomorphological condition of the Avon River and Dog Trap Creek. The likely capacity of the receiving waters to accommodate the volume of flow and water quality of the proposed discharge to downstream uses was also considered.

Data gathered in the field was assessed using the "River Styles" methodology to identify the key factors influencing the river condition. This task included a review of the reaches within the project boundary to help assess whether any existing erosion is due to local factors only or is more representative of a wider catchment response and whether this would have implications for the proposed discharge structure.

The likely impacts of the proposed discharge on the base flow conditions of the receiving streams would be assessed through analysis of existing water flow gauging and channel size of the receiving streams and contribution of flows within the Avon River and Dog Trap Creek to the Manning River downstream. The existing hydrological investigations and monitoring results were used to estimate instream flood levels at the proposed discharge location for use in the development of a suitable engineering design.

2.5.2 Water Quality

Mean water quality measurements recorded in the field and baseline data derived from the literature review were compared with the (ANZECC/ARMCANZ 2000) default trigger values (DTVs) for protection of aquatic ecosystems for physical and chemical stressors for lowland rivers in southeast Australia as well as AGL water quality targets for treated water. It is noted that the *in-situ* water quality readings were used to provide a snap-shot of water quality at the time of sampling only and should not be extrapolated beyond this.

2.5.3 Aquatic Ecology

Results of the literature review and site investigation were used to compile an inventory of flora and fauna (including fish, macroinvertebrates and aquatic vegetation) occurring at the shortlisted locations. Habitat information relating to location condition and quality was summarised to feed into the overall assessment of location suitability.

2.6 Multi-Criteria Analysis

Information collected as part of the literature review and field investigation was collated for use in a Multi-Criteria Analysis (MCA). The purpose of the MCA was to objectively evaluate each of the four locations identified as part of the field investigation to determine the most optimal outlet location. This was based on a set of criteria considered important in minimising the potential construction and operational impacts of water releases. The following criteria were considered:

> **Predicted % increase in flow (ML/day)**. Assumption is that a location allowing surface discharge scenarios closest to the natural flow regime are preferable for impacts on scour, water quality and existing habitat.

> **Observed bank stability**. Assumption is that stable banks will be less susceptible to potential scouring or erosion and therefore preferable.

> **Habitat condition (as per RCE scores)**. Assumption is that a location with sensitive or ecologically important habitat is less preferable than that not containing such habitat.

> **Loss of native riparian habitat (m^2)**. Assumption is that a location requiring minimal removal of native riparian habitat is considered preferable.

> **Fish habitat class (as per Fairful 2013)**. Assumed that locations with potential key fish habitat are less preferable than those unlikely to support native fish populations.

> **Suitability of bank formation to accept headwall and discharge flows:** Assumed that steeply sloping, high banks will be more difficult to access than easily accessible low banks. This may also have cost implications in regards to engineering and labour requirements.

> **Pipe route length and resulting construction and restoration costs:** Assumed that the longest pipe route would be the most expensive construction option.

Water quality was not considered as a parameter within the MCA as it is assumed that approved water quality targets will be met and that the quality of discharged water will be similar to that of the receiving waters. The hydrological flow data calculated as part of the geomorphological assessment has also been utilised to assess the capacity of the receiving streams to accept the proposed discharge flows and associated water quality.

For each criteria a metric was developed to score each factor from 1 – 4. In order to represent the relative importance of each factor, a weighting between 1 and 3 was then applied. Sensitivity testing was undertaken of the weightings to ensure a robust outcome was achieved. Note that the MCA is a semi-quantitative and partly subjective tool to assist in the decision making process and should be considered a guide rather than providing an absolute result.

3 Results

3.1 Study Area and Environmental Setting

The Study Area is located within the Lower North Coast Subregion of the Hunter – Central Rivers Catchment, in the southern section of the Manning River system (Cardno 2010). The Study Area is within the Avon River catchment approximately 6 km south-southwest of Gloucester. Normal flows within both Dog Trap Creek and the Avon River are at an elevation of approximately 100 to 110 m AHD and flow northwards through the centre of the valley (**Figure 2-2**). The Avon is a perennial stream originating in the Avon River State Forest and Running Creek Nature Reserve, to the east of the Chichester State Forest. It flows east to Stratford and then turns north past the town until its confluence with Dog Trap Creek (approximately 6 km south of Gloucester), Oaky Creek, Waukivory Creek and Mograni Creek. The Avon River joins the larger Gloucester River approximately one kilometre downstream (north) of the confluence with Mograni Creek north of Gloucester town. The Gloucester River is joined almost immediately by the Barrington River and eventually discharges into the Manning River 20 km to the north-east, which flows to the ocean, passing the towns of Wingham and Taree. Dog Trap Creek is an intermittent stream originating in the south east of the Study Area near the Glen Nature Reserve where it flows north-west to the confluence with the Avon River and fed by a number of minor tributaries.

Land use in the region is predominantly agricultural (with much of the land cleared for cattle grazing) or used for forestry, tourism and mining. Two open cut coal mines (Stratford and Bowens Road Mines) are located immediately to the south of the Study Area (Cardno 2011).

3.2 Geomorphology Assessment

3.2.1 Review of Existing Information

3.2.1.1 Valley Setting

The GGP Stage 1 GFDA lies within a regional setting that represents a transition from rounded foothills at the base of the Mograni Range to lowland plains along the valley floor of the Avon River. The reaches of the Avon River and Dog Trap Creek lie within a laterally un-confined valley setting, characterised by less than 10 percent of the channel abutting the valley margin (Brierley and Fryirs 2006).

Sinuosity and gradient were calculated by Parsons Brinckerhoff and can assist in the characterisation of the Avon River and Dog Trap Creek. The sinuosity calculations have been provided below in **Table 3-1**.

Table 3-1 Sinuosity calculations (Parsons Brinckerhoff 2014)

	Stream Length (m)	Straight Length (m)	Sinuosity	Description*
Avon River	29,070	21,645	1.34	Meandering
Dog Trap Creek	11,940	7,838	1.52	Meandering

*Sinuosity is considered low if the degree of calculated sinuosity is between 1.06 and 1.30 and meandering between 1.31 and 3.0 (Brierley and Fryirs 2006).

The Avon River is deeply entrenched resulting in containment under the majority of flow conditions. Although deeply entrenched, connectivity to the floodplain is evident at all locations.

3.2.1.2 Sediment Characteristics

Parsons Brinkerhoff (2014) reported approximate median sediment particle size at sites TSW01, TSW02, DTC01 and ASW01 (**Figure 3-1**). Particle sizes at the monitoring sites were composed predominantly of a combination of fine grained material such as clay/silt and sand sediment particles and are shown in more detail in **Table 3-2**. The dominance of sand in the channel material could indicate a lack of cohesive material making the banks susceptible to erosion. However, the size and weight of sand can make it less mobile to lower velocities than finer grained material such as silt and clay.

Table 3-2 Sediment composition (approximated from Parsons Brinckerhoff 2014)

Gauge ID	Sand	Fine Sand	Silt and Clay
TSW01	70%	0%	30%
TSW02	70%	0%	30%
DTC01	22.5%	55%	22.5%
ASW01	100%	0%	0%

3.2.1.3 Geomorphic Condition

The geomorphic condition has been assessed in detail as an outcome of this study, primarily as a product of the field investigations. However, to gain an understanding of the study area prior to scoping the field work, it is useful to review any existing assessments of the geomorphic condition. The hydrology study undertaken by Parsons Brinkerhoff (2014) provided the following assessment of geomorphic condition:

> The Avon River is subject to a variety of land management pressures that determines resilience or fragility when subjected to damaging impacts. A majority of the Avon River sub-catchment was classified as medium fragility where damage only occurs when a high threshold of damaging impact is exceeded (such as a catastrophic flood, mobilisation of a sediment slug or vegetation clearing).

> Generally, geomorphic condition was identified as being in moderate condition in the mid and lower reaches of the Avon River catchment and poor towards the south of the catchment. The geomorphic condition of the Avon River within the GFDA was found to be in moderate condition. Dog Trap Creek was found to be in poor condition. Moderate condition reaches were defined as areas were degradation is recoverable by re-vegetation or small scale bed control works. Poor reaches are typically dominated by over-widened stream channels and significant erosion of the bed and banks.

3.2.1.4 Preliminary Location Identification

Utilising aerial photographs and the review of existing reports (outlined in **Section 3.2.1.1** to **3.2.1.3**), a preliminary understanding was gained of stream behaviour and existence of riparian vegetation. The following criteria were developed from this understanding to identify reaches within the study area as being the most likely to contain an appropriate discharge location:

> Low sinuosity. Locations near or on ‘outside-bends’ are more likely to be impacted by hydraulic forces potentially causing erosion and changing stream form. Reaches were therefore selected that had low sinuosity (i.e. were straighter).

> Lack of hydraulic controls. The presence of features such as tributary entrances, vehicle crossings and the like can cause increased turbulence and more complex hydraulic characteristics. These can be more difficult to assess with regards to likely impacts on or from the proposed discharge outlet.

> Minimal riparian vegetation. Locations with dense riparian vegetation were not considered preferable for the location of the discharge structure due to the likely disturbance to the vegetation (and related instability for the bank sediments) associated with the construction of the outlet. However, it is noted that careful construction techniques can be employed to maintain as much of the existing vegetation as possible, thereby providing enhanced stability.

As well as the reaches identified through the criteria above, an additional location was identified downstream of the confluence of Avon River and Dog Trap Creek for consideration during the field investigations. This location was considered to be useful in provided a contrasting reference to the upstream locations and validating the assessment outcomes.

3.2.2 Results of Field Investigation

Based on the outcomes of the existing data review and site investigation, two preferable locations on the Avon River and one on Dog Trap Creek were selected for detailed assessment with one additional location downstream of the confluence of Dog Trap Creek and Avon River was selected for assessment and comparison with the other three locations (**Figure 3-1**).

3.2.2.1 Location AV1

Location AV1 was located downstream of the confluence of the Avon River and Dog Trap Creek (see photo at **Figure 3-2 a**)).

The channel was deeply incised within the floodplain with a top of bank width to channel depth ratio of 0.1 and steep banks approximately 4 m high and a distance of approximately 30 m between the top of banks. The banks were well vegetated with a combination of ground, shrub and tree cover. Very little riparian vegetation existed beyond the confines of the channel. The banks appeared to be comprised of fine sediment, primarily silt and fine sand. The channel bed width was approximately 10 m wide with ponded water (i.e. zero velocity) to a likely depth of less than 1 m. Visual confirmation of depth and bed material was not possible due to lack of visibility through the water.

Erosion was evident on the banks in the form of benches formed from slumped material from the upper banks on both sides of the channel. The benches, however, were well vegetated and appeared stable. More recent erosion was evident in the form of scour of the lower bank at the observed water level and some dislodged trees and exposed bank material on the upper banks. The tree damage was likely the result of a recent high flow event. Some leaning trees were noted, indicating ongoing erosion, possibly undercutting of the banks. The trees were likely more than 5 years old, indicating that the erosion had occurred within this timeframe. A high flow event could further mobilise the bank through undercutting, scour and possible dislodgement of trees. Cattle access was also noted on the right bank with some damage to vegetation resulting in exposed bank sediment.

3.2.2.2 Location AV2

This location was originally intended to be to the north of AV2 where the banks have been cleared of vegetation. The intention was that this would reduce the impact of the construction of the outlet on riparian vegetation. However, when this section of the stream was inspected on site, it was identified to be unstable due to the lack of vegetation. As such, a more suitable location was identified at AV2 (see photos at **Figure 3-2 b)** and **c)**).

The channel was deeply incised within the floodplain with steep banks approximately 5 m high and a distance of approximately 35 m between the top of banks with a top of bank width to channel depth ratio of 0.2. The banks were well vegetated with a combination of ground, shrub and tree cover. Very little riparian vegetation existed beyond the confines of the channel. The banks were comprised of fine sediment, primarily silt and fine sand. The channel bed was approximately 5 m wide with slow moving flow to a likely depth of less than 1 m. Visual confirmation of depth and bed material was not possible due to lack of visibility through the water.

Evidence of erosion was noted on the banks in the form of benches formed from slumped material from the upper banks on both banks. However, the benches were well vegetated and appeared stable. More recent erosion was evident in the form of scour of the lower bank at the observed water level. Cattle access was also noted on both banks with some damage to vegetation resulting in exposed bank sediment.

Overall, AV2 was very similar to AV1 but with slightly less tree cover, a narrower channel bed and less evidence of recent significant erosion.

3.2.2.3 Location AV3

At this location the channel was deeply incised within the floodplain with steep banks approximately 5 m high and a distance of approximately 35 m between the top of banks with a top of bank width to channel depth ratio of 0.2. The banks were well vegetated with a combination of ground, shrub and tree cover. Very little riparian vegetation existed beyond the confines of the channel. The banks were comprised of fine sediment, primarily silt and fine sand. The channel bed was approximately 4 m wide with slow moving flow to a likely depth of less than 1 m. Visual confirmation of depth and bed material was not possible due to lack of visibility through the water.

Evidence of erosion was noted on the banks in the form of benches formed from slumped material from the upper banks on both banks. However, the benches were well vegetated and appeared stable. More recent erosion was evident in the form of scour of the lower bank at the observed water level and scour caused by a flow obstruction (fallen tree). Cattle access was also noted on the both banks with some damage to vegetation resulting in exposed bank sediment.

Location AV3 was very similar to AV2 (see photos at Figure 3-2 d) and e).

3.2.2.4 Location DT1

Location DT1 is located approximately 700m upstream of the confluence with the Avon River (see photo at **Figure 3-2 f)**). The channel at this location was less incised than those locations assessed on the Avon River. Although it was noted that Dog Trap Creek becomes much more incised downstream towards its confluence with the Avon River, possibly in response to the incised nature of the Avon River. The banks were approximately 2.5 m high with a good cover of pasture grass. There was a distance of approximately 12 m between the top of banks. The top of bank width to channel depth ratio was 0.1. There were some isolated shrubs and no trees present. The banks were comprised of fine sediment, primarily silt and fine sand. The channel bed width was approximately 1m wide with base flow of less than 0.2 m depth and approximately 0.5 m/s velocity. The bed material appeared to be of a similar nature to the bank material.

Evidence of erosion was noted in the form of slumped material, which had good grass cover and appeared relatively stable. Undercutting of the bank was noted, although not severe. Some dislodged bank material was noted, which may have been the result of undercutting just upstream of the proposed discharge location. The flow was clear and did not appear to be carrying mobilised sediments at the time of inspections.

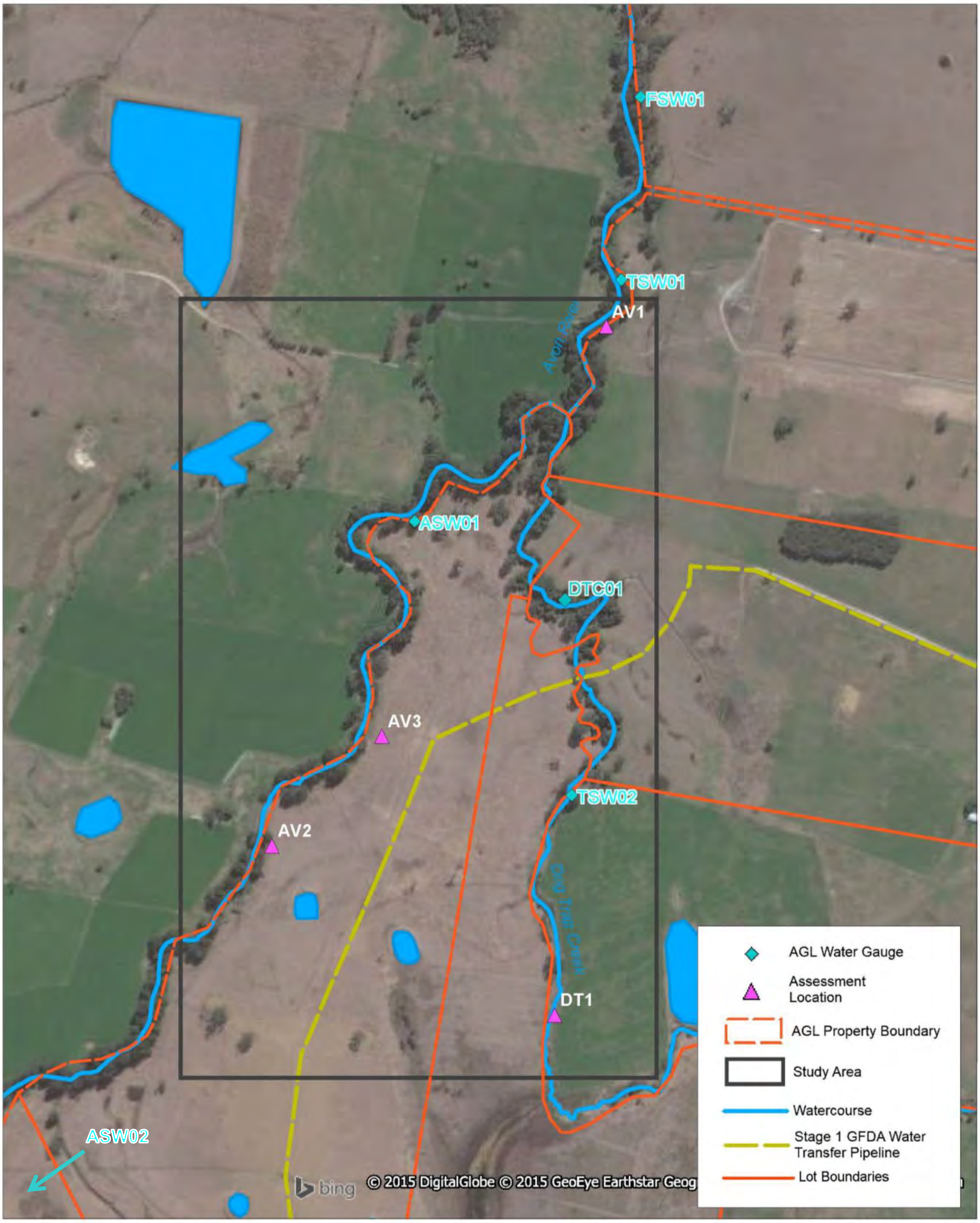


Figure 3-1

Location of detailed geomorphology and aquatic ecology field investigations and water quality gauges

Scale 1:300,000 Scale at A4

Metres

0 5 100

Map Produced by <Division> (<BU>)
Date: <Current Date>
Coordinate System: <Current Coordinate System>
Project:<Job Number>_<Phase>
Map:<map name>.wor 01

Figure 3-1 Location of detailed geomorphology and aquatic ecology field investigations

a)

b)

c)

d)

e)

f)

Figure 3-2 Location photos (geomorphology) a) AV1 – Left bank looking downstream b) AV2 – looking downstream c) AV2 – upper right bank d) AV3 – looking downstream e) AV3 – upper right bank f) DT1 – looking downstream

3.2.3 Flow Analysis

Estimates of the flow characteristics were undertaken for each location based on water level and channel cross sectional data available for locations nearby to the assessment locations. The water level data was supplied by AGL and the cross section data was obtained for the same monitoring locations from Parsons Brinckerhoff (2014). The discharge was estimated for a range of water levels in the channel including an estimate of 'low flow' conditions based on the observation of the low flow channel dimensions measured on location. 'High flow records' are determined by the NOW gauges to be the flow rate that occurred for only 20% of the time. It was assumed that the top 20th percentile water levels recorded from the AGL loggers would represent the 20th percentiles flows. This is consistent with the approach adopted by Parsons Brinckerhoff (2014). It should be noted that no detailed hydraulic modelling was undertaken to determine flows. The estimated flow are representative only and have been used to assess the likely capacity of the streams to accept the proposed discharge with regards to changes to shear stress and water quality mixing potential.

The flow and associated shear stress values are shown in **Table 3-3**. It can be seen that the high flow conditions (i.e. based on 20th percentile water levels) in Dog Trap Creek are less than 1 m^3/s. This reflects its small catchment. In contrast, the 20th percentile flow conditions at the locations on the Avon River range from 8 to 10 m^3/s.

The percentage increase in the flows by the maximum proposed flow (2 ML/day) is also shown. It can be seen that for a high flow condition (20th percentile) the increase in flow as a result of the proposed discharge is less than 1 percent at all three locations on the Avon River and less than 5 percent at the location on Dog Trap Creek.

In order to ensure that the discharge flow is less than 5 percent of the total flow in the receiving streams, the stream flow should be no less than 0.5 m^3/s. A flow gauge or water level gauge (correlated to the appropriate flow) may be required at the discharge location if an adequate corresponding gauge is not available.

Table 3-3 Flow estimates

TSW01 (downstream of AV1 and AV2)			Bank full	0.75 Bank full	0.5 Bank full	0.25 Bank full	Low Flow	20th percentile
Manning's n=	0.06	Top width (m)=	13.5	11.9	10.9	9.6	9.3	9.9
channel slope (%) =	0.18	Flow area (m2)=	45.6	29.6	20.1	9.4	7.1	11.3
base width (m) =	8.32	Perimeter (m) =	18.1	15.2	13.2	10.8	10.2	11.3
depth (m)=	4.18	Hyd radius (m) =	2.5	1.9	1.5	0.9	0.7	1.0
depth (m)= 0.75bankfull	2.93	Velocity (m/s) =	1.3	1.1	0.9	0.6	0.6	0.7
depth (m)= 0.5bankfull	2.09	Flow (m3/s)=	59.5	32.7	18.8	6.0	3.9	8.1
depth (m)= 0.25bankfull	1.05	Froude No	0.23	0.22	0.22	0.21	0.20	0.21
depth (base flow)	0.80	VxD ratio =	5.46	3.23	1.95	0.67	0.44	0.89
20th percentile depth (m)	1.25	Impact of Additional Flow (2ML/Day)	0.04%	0.07%	0.12%	0.38%	0.59%	0.29%
side slope (1 in x)=	0.62	Shear stress	44.34	34.43	26.80	15.35	12.21	17.80
ASW01 (downstream of AV3)								
Manning's n=	0.06	Top width (m)=	12.1	10.3	9.1	7.6	6.8	8.1
channel slope (%) =	0.18	Flow area (m2)=	49.8	31.3	20.7	9.3	4.5	12.9
base width (m) =	6.04	Perimeter (m) =	18.6	14.8	12.3	9.2	7.6	10.2
depth (m)= (bankfull)	5.49	Hyd radius (m) =	2.7	2.1	1.7	1.0	0.6	1.3
depth (m)= 0.75bankfull	3.84	Velocity (m/s) =	1.4	1.2	1.0	0.7	0.5	0.8
depth (m)= 0.5bankfull	2.75	Flow (m3/s)=	67.9	36.5	20.7	6.7	2.2	10.7
depth (m)= 0.25bankfull	1.37	Froude No	0.21	0.21	0.21	0.21	0.20	0.21
depth (base flow)	0.70	VxD ratio =	7.49	4.48	2.75	0.98	0.35	1.51
20th percentile depth (m)	1.83	Impact of Additional Flow (2ML/Day)	0.03%	0.06%	0.11%	0.34%	1.03%	0.22%
side slope (1 in x)=	0.55	Shear stress	47.30	37.36	29.74	17.95	10.40	22.29

TSW02 (upstream of DT1)			Bank full	0.75 Bank full	0.5 Bank full	0.25 Bank full	Low Flow	20th percentile
Manning's n=	0.03	Top width (m)=	4.6	3.9	3.4	2.8	2.3	2.6
channel slope (%) =	0.30	Flow area (m2)=	8.1	5.1	3.3	1.5	0.2	0.8
base width (m) =	2.21	Perimeter (m) =	7.5	5.9	4.9	3.5	2.4	3.0
depth (m)= (bankfull)	2.39	Hyd radius (m) =	1.1	0.9	0.7	0.4	0.1	0.3
depth (m)= 0.75bankfull	1.67	Velocity (m/s) =	1.9	1.6	1.4	1.0	0.4	0.8
depth (m)= 0.5bankfull	1.20	Flow (m3/s)=	15.5	8.4	4.8	1.5	0.1	0.7
depth (m)= 0.25bankfull	0.60	Froude No	0.46	0.46	0.46	0.45	0.38	0.44
depth (base flow)	0.10	VxD ratio =	4.58	2.75	1.70	0.61	0.04	0.28
20th percentile depth (m)	0.35	Impact of Additional Flow (2ML/Day)	0.15%	0.28%	0.48%	1.49%	27.19%	3.47%
side slope (1 in x)=	0.49	Shear stress	31.63	25.16	20.20	12.43	2.73	8.28

3.2.4 Synthesis

> Collating the field data and observations with the review of valley setting and sinuosity it is determined that the RiverStyle (Brierley and Fryirs 2006) of the reaches of the Avon River and Dog Trap Creek containing the subject locations are all 'Meandering Fine Grained'. This RiverStyle is characterised by a laterally un-confined valley setting, continuous single channel, high sinuosity, laterally stable channel containing pools and point benches with a fine grained bed and bank material.

> The three locations on the Avon River (AV1, AV2 and AV3) did not vary significantly in their geomorphological characteristics or conditions. Slightly more instability was noted at AV1, this location appeared to be impacted by its location within a meandering section of the stream. However, all locations exhibited moderate evidence of recent and past erosion. The vegetation present at the locations reduced the impacts of ongoing fluvial erosion.

> Despite the lack of complex riparian vegetation at DT1, the presence of pasture grass appeared to also provide stability to the banks.

> When the stream side slope factors are removed, the channel stability ranking scheme scored all locations as having moderate instability. This, combined with the high, steep banks at the Avon River locations, would indicate that bank undercutting or further incision could lead to instability. This should be considered in the design of the outlet.

> The stream flow within the Avon River is considerably greater than within Dog Trap Creek resulting in the proposed discharge flow representing a smaller increase in flow.

3.3 Water Quality

3.3.1 Review of Existing Information

In general, the Avon River catchment has naturally high soil and groundwater salinity which is attributed to the geology of the area i.e. coal and shale deposits (Cardno 2010) and saline groundwater contributions to baseflow, particularly during low rainfall periods, which elevate Electrical Conductivity (EC). Anthropogenic causes of surface water salinity are also present within the Study Area, such as the diffuse but potentially significant contribution from agricultural practices. Downstream of the Avon River, the receiving waters of the Gloucester River have a much lower salinity (Turak *et al*. 2000).

Water quality within the Avon River and Dog Trap Creek has been continuously monitored at several sites as part of AGL's water quality network program from 2011 to 2015. A summary of the data collected at monitoring gauges relevant to the study area are provided below and in **Table 3-4**. Maximum and minimum ranges and percentile data (20^{th} and 80^{th} percentile) have been reported and these data have been used with engineering judgement to determine surface water quality at relevant sites to help identify a suitable discharge location. It is noted that Cardno have not undertaken any quality assurance of this data as part of this assessment.

TSW01

This monitoring site is located on the Avon River within the Tiedman property, approximately 0.3 km downstream of the confluence with Dog Trap Creek. Monitoring at this location has been occurring continuously at 15 minute intervals since 2011. Based on monitoring data collected from March 2011 to March 2015, water temperature ranged between 6.9 and 28.4°C. Salinity levels varied from 1.0 to 1337 µS/cm. Limited data is available for Dissolved Oxygen (DO) and pH levels at this location. The DO levels vary from 13 to 150% sat and pH is near neutral (6-8).

TSW02

This monitoring site is located on the Dog Trap Creek within the Tiedman property, approximately 0.4 km upstream of the confluence with Avon River. Monitoring at this location has been occurring continuously at 15 minute intervals since 2012. Based on monitoring data collected from April 2012 to March 2015, water temperature ranged between 0.1 and 41.7°C. Salinity levels based on monitoring data varied from 5 to 6570 µS/cm. Limited data is available for DO and pH levels at this location. The DO levels vary from 22 to 135%sat and pH is near neutral (7-8).

ASW01

This monitoring site is located on the Avon River within the Atkins property, approximately 0.1 km upstream of the confluence with Dog Trap Creek. Monitoring at this location has been occurring continuously at 15 minute intervals since 2011. Based on monitoring data collected from March 2011 to March 2015 water temperature varied between 5.8 and 26.0°C. Salinity levels based on monitoring data varied from 0 to 1288 µS/cm. Limited data is available for DO and pH levels at this location. The DO levels vary from 14 to 115% sat and pH varies from 6 to 9.

ASW02

This monitoring site is located on the Avon River within the Atkins property, approximately 1.7 km upstream of the confluence with Dog Trap Creek. Monitoring at this location has been occurring continuously at 15 minute intervals since 2011. Based on monitoring data collected from March 2011 to March 2015, water temperature varied between 5.2 and 26.0°C. The salinity levels based on monitoring data vary from 4.2 to 1,307 µS/cm. No other monitored water quality data is available for this location.

FSW01

This monitoring site is located on Avon River, approximately 1.2 km downstream from TSW01. Monitoring at this location commenced in 2012 as part of the Tiedman Irrigation Trial monitoring network. Water quality data for this site were available for Feb 2012, June 2012, Sept 2012, Nov 2013, Mar 2014, Aug 2014, Nov 2014, Dec 2014, Feb 2015, April 2015 and May 2015. Based on these data, salinity levels and temperature at this location vary from 80 to 728 µS/cm and t from 11°C to 28°C respectively. The Dissolved Oxygen (DO) levels at this location vary from 12 to 176 % sat and pH varies from 6 to 9.

Table 3-4 Summary of water quality data recorded from gauges in Avon River and Dog Trap Creek between March 2011 and May 2015. Data sourced from AGL (July 2015). Refer to Figure 3-1 for location of water quality monitoring locations. Highlighted values are outside the ANZECC/ARMCANZ (2000) guideline range.

	Variable	Temperature (^{0}C)	Conductivity (µS/cm)	pH	DO (%sat)
ANZECC (2000) guidelines for lowland (<100 m AHD) rivers			125 - 2200 (lowland river)	6.5-8.0	85-110
AGL Target Water Criteria		Ambient **	<800	6.5 - 8.0	>25
TSW01	Max	28.4	1337	8.1	150*
	Min	6.9	1*	6.1	13*
	80th percentile	20.7	539	7.6	98.2
	20th percentile	11.18	241	7.0	31.6*
TSW02	Max	41.7	6570*	7.8	135*
	Min	0.1	5*	6.6	21.6*
	80th percentile	20.6	585	7.5	103.2
	20th percentile	10.6	215	7.0	57*
ASW01	Max	26.0	1288	8.7	115.4
	Min	5.8	0*	5.9	14*
	80th percentile	20.7	414	7.8	83.3*
	20th percentile	11.1	206	7.0	41.5*
ASW02	Max	26.0	1307	Data not available	
	Min	5.2	4*		
	80th percentile	20.5	438		
	20th percentile	10.8	229		
FSW02	Max	27.9	728	8.8	176.1*
	Min	11.0	80*	5.5	11.9*
	80th percentile	23.3	481.6	8.4	112.2
	20th percentile	14.1	215.2	6.9	15.2*

* - These values are outside the ANZECC guidelines;
** - temperatures will be the same as for water stored in the Tiedman irrigation dams or discharge water pond at the CPF
Note: Max and Min have not been reported for *Temperature* due to some erroneous data in the time series

3.3.2 Results of Field Investigations

Field measurements recorded on 30 June 2015 are presented in **Table 3-5** below. Mean values highlighted in bold indicate that the variable measured is outside of ANZECC guidelines and/or the AGL target values for treated water. However it is also worthwhile noting that the natural baseline water quality for the Avon River does not align with the ANZECC water quality criteria so these criteria should not be taken as the ultimate criteria for stream discharges. Further details are provided in the EWMS.

Table 3-5 Water quality measures collected within the Avon River and Dog Trap Creek on 30 June 2015

Variable				Temperature (^{0}C)	Conductivity (µS/cm)	Salinity (ppt)	pH	ORP (mV)	DO (%sat'n)	DO (mg/L)	Ave Turbidity (ntu)
ANZECC (2000) guidelines for lowland (<100 m AHD) rivers					125 - 2200 (lowland river)		6.5-8.0		85-110		6-50
AGL Target Water Criteria				Ambient	<800		6.5 - 8.0		>25		<15
Avon River (Approx. 150 m downstream of the confluence with Dog Trap Creek)	AV1	Bottom	Rep 1	9.60	401.00	0.19	7.00	179.80	70.00	7.80	7.60
			Rep 2	9.70	428.00	0.21	6.99	177.00	69.60	7.83	7.40
			Mean	**9.65**	**414.50**	**0.20**	**7.00**	**178.40**	**69.80**	**7.82**	**7.50**
			SE	0.05	13.50	0.01	0.00	1.40	0.20	0.02	0.10
Avon River (Approx. 600 m upstream of the confluence with Dog Trap Creek)	AV2	Bottom	Rep 1	11.37	359.00	0.17	7.46	147.00	82.10	8.99	6.90
			Rep 2	10.60	361.00	0.17	7.41	147.70	77.40	8.59	7.20
			Mean	**10.99**	**360.00**	**0.17**	**7.44**	**147.35**	**79.75**	**8.79**	**7.05**
			SE	0.39	1.00	0.00	0.02	0.35	2.35	0.20	0.15
Avon River (Approx. 400 m upstream of the confluence with Dog Trap Creek)	AV3	Bottom	Rep 1	10.13	357.00	0.17	7.53	175.50	80.00	8.99	6.50
			Rep 2	10.08	355.00	0.17	7.40	169.80	76.90	8.62	6.50
			Mean	**10.11**	**356.00**	**0.17**	**7.47**	**172.65**	**78.45**	**8.81**	**6.50**
			SE	0.03	1.00	0.00	0.06	2.85	1.55	0.19	0.00
Dog Trap Creek (Approx. 700 m upstream of confluence with Dog Trap Creek)	DT1	Bottom	Rep 1	12.00	608.00	0.30	7.36	139.00	88.30	9.52	6.60
			Rep 2	11.83	608.00	0.30	7.28	135.70	87.10	9.40	6.50
			Mean	**11.92**	**608.00**	**0.30**	**7.32**	**137.35**	**87.70**	**9.46**	**6.55**
			SE	0.09	0.00	0.00	0.04	1.65	0.60	0.06	0.05

3.3.3 Synthesis

> The proposed high flow water discharge into the receiving environment will be treated to meet the water quality targets as shown in **Table 3-6** below. The majority of these targets are within the ANZECC guidelines.

> Due to large variations identified for salinity across all the locations from the long term monitoring data, the target guideline of <800 μS/cm) may limit the opportunity for discharging if salinities are at the top of this range.

> Based on the monitoring data assessed, the target value for surface water DO is lower than the recommended ANZECC guidelines and generally lower than the 80^{th} percentile for long-term monitoring data at all long term monitoring locations. This may mean that DO in discharge water may be significantly lower than ambient conditions. That considered, given the limited frequency, relatively low volumes and naturally high flow conditions of planned releases, it is unlikely that there would be any measureable downstream effect.

> The 80^{th} percentile for DO at AV2 across all years of data appears to be lower overall than other locations and may therefore be closest to ambient conditions if a release takes place when DO of discharge water is closer to the lowest target value (i.e. 25% saturation).

> Considering that monitoring station TSW01 is most representative of conditions at AV1, ASW01 is representative of AV2 and AV3 there are little differences in temperature, pH or salinity between the Avon River locations with all being subject to similar seasonal variation. Dog Trap Creek, however, is subject to more pronounced extremes, likely due to its lower flows and ephemeral nature.

Table 3-6 AGL discharge water quality targets

Water Quality Parameter	Unit	AGL Target range *	ANZECC (2000) guidelines for lowland (<100 m AHD) rivers
Salinity (EC)	µS/cm	<800	125-2200
Temperature	°C	Ambient temperatures as per storage dam/ponds	-
pH	pH units	6.5 - 8	6.5 - 8
Dissolved Oxygen	% saturation	>25% saturation	85-110
Turbidity	NTU	<15	6-50
TDS	mg/L	<500	-
Sodium	mg/L	<80	-
Calcium	mg/L	<10	-
Magnesium	mg/L	<2	-
Suspended Solids	mg/L	<10	-
Iron	mg/L	<1	Insufficient data
Manganese	mg/L	<0.5	1.9
Aluminium	mg/L	<0.2	0.055
Chloride	mg/L	<100	-
Sulphate	mg/L	<40	-
Phosphorus	mg/L	<5	0.05
Fluoride	mg/L	<1	-
Boron	mg/L	<0.5	0.37
Residual disinfectant (monochloramine)	mg/L	<0.05	-
Ammonia	mg/L	<0.05	20
Total alkalinity (as CaCO3)	mg/L	<60	-

Note: * - Taken from Final Draft of Extracted Water Management Strategy (AGL, 2015)

3.4 Aquatic Ecology

3.4.1 Review of Existing Information

3.4.1.1 Aquatic Habitat Condition

Many of the watercourses within the Study Area have been cleared to the bank, with the few remaining strips of native riparian vegetation restricted to sections of larger rivers, such as the Gloucester River (AECOM 2009). Riparian habitat has also often been heavily disturbed by weeds including camphor laurel (*Cinnamomum camphora*), lantana (*Lantana camara*), privet (*Ligustrum* sp.) and willow (*Salix* sp.) for example.

Macroinvertebrates have been previously sampled in riffle and pool edge habitat in Avon River as part of a wider assessment of river health in NSW (Turak *et al*. 2000). Ausrivas methods were used to assess the health of the Avon River reach downstream of Stratford during surveys in autumn (pool edge habitat only) and spring (pool edge and riffle habitat) of 1997. The Ausrivas protocol uses a predictive model to determine the environmental condition of a waterway by comparing the observed freshwater macroinvertebrate assemblages (i.e. those collected in the field) with macroinvertebrate assemblages expected from reference (undisturbed) waterways of the same type. The Ausrivas assessments indicated some impairment to the aquatic macroinvertebrate community of the Avon River, consistent with habitat degradation and poor water quality. In contrast, the same study of river health in NSW surveyed three sites in the Gloucester River, two upstream of the Avon River confluence and one downstream

Cardno has carried out surveys of river health within the Gloucester basin as part of impact assessments for coal mining activities. Results indicated that sites were 'generally impaired' (at Oakey Creek) to 'near reference condition' (within Gloucester River), although sites within the Avon River (closest to the Study Area) were recorded as 'good' (RCE scores between 27 and 32) for the disturbed agricultural landscape. Exotic trees, pasture grasses and annual weeds were however, a dominant feature of the riparian habitat with some areas affected by vegetation clearing and bank erosion. Diversity of macrophytes was also relatively low and included a high proportion of introduced and exotic species. Frc environmental (2012) also reported a lack of submerged and floating macrophytes at most sites within the Avon River suggesting that water levels fluctuate considerably and/or that the water column is likely to be highly turbid which reduces light levels. Several introduced and exotic species were also recorded.

Long-term monitoring of the Stratford Mining Complex (IIA 2001 – 2010) found that macroinvertebrate communities from six sites, including two on the Avon River downstream of Stratford were dominated by pollution-tolerant taxa indicating that water quality was 'very poor' to 'poor' and that for the majority of sites and years sampled the assemblages were moderately to grossly impaired (IIA 2009). Water chemistry (particularly salinity) and flow levels were considered to have the greatest influence on macroinvertebrate biological diversity, with the lowest diversity recorded during periods of prolonged periods of low flows and high EC (IIA 2010). Results of the 2013 survey indicated that habitat condition at Site 2 (located within the Study Area) was below reference, but had fair water quality and a healthy assemblage of pollution sensitive taxa present i.e. (mayflies, stoneflies and caddisflies) (IIA 2014).

Little information is available in regard to the condition of Dog Trap Creek, although IIA (2014) reported the downstream area to be heavily impacted by cattle grazing with some bank erosion and minimal riparian vegetation apart from eucalypt and Casuarina trees. Habitat condition was recorded as below reference, water quality as 'poor' and the assemblage of pollution sensitive taxa to be 'slightly impaired'.

3.4.1.2 Fish and Mobile Macroinvertebrates

The Manning river system does not contain large dams, or barriers to fish movement and hence maintains connectivity between the watercourses of the Study Area and the Pacific Ocean. As such, fish are able to migrate between the upper reaches of rivers and estuaries or the sea, which potentially leads to a relatively diverse assemblage within the upper catchment. Minor causeway crossings can be located upstream of the confluence of the Avon and Gloucester Rivers however, which may impede fish passage under low flow conditions.

Cardno (2011) recorded nine species of fish in the Avon River including longfinned eel (*Anguilla reinhardtii*), small native gudgeons and the introduced mosquitofish (*Gambusia holbrooki*). Mosquitofish are a Class 1 noxious species outside the greater Sydney area and have been associated with the decline in abundance of native species as they are tolerant of impaired environmental conditions and able to outcompete native species for food and resources (NSW DPI 2015). Frc environmental (2012) also found mosquitofish to be the most abundant and widespread species (as well as the firetail gudgeon (*Hypseleotris galii*) caught in both the Avon River and Dog Trap Creek.

Other species recorded in the lower Avon River and Manning River catchment include eels (Anguillidae), freshwater herring (*Potamalosa richmondia*), various types of native gudgeons (Eleotridae), mullet (Mugilidae), Australian Bass (*Macquaria novemaculeata*), freshwater catfish (*Tandanus tandanus*), Australian smelt (*Retropinna semoni*), Pacific blue-eye (*Pseudomugil signifier*), rainbow trout (*Oncorhynchus mykiss*) and bullrout (*Notesthes robusta*) (frc environmental (2012), Howell and Creese (2010) and Harris and Gerke (1997). In addition to those species already listed above, a search of the Atlas of Living Australia also returned records of the common galaxias (*Galaxias maculatus*), freshwater herring (*Potamalosa richmondia*) and the introduced goldfish (*Carrasius auratus*).

Mobile macroinvertebrates including high abundances of freshwater shrimp and prawns (Family: Atyidae and *Machrobrachium* sp.) and yabbies (*Cherax destructor*) have also been recorded within the Avon River (Cardno 2011, frc environmental 2012).

Overall, previous studies have categorised the Avon River was as a moderate (Class 2) key fish habitat as per the criteria outlined in Fairful (2013). Policy and Guidelines for Fish Habitat Conservation and Management.

3.4.1.3 Other Vertebrates

Several other aquatic animals are known or considered likely to occur within the Manning River catchment, including eastern snake-necked turtles (*Chelodina longicollis*), Manning River snapping turtle (*Myuchelys purvisi*), platypus (*Ornithorhynchus anatinus*), eastern water dragon (*Physignathus lesueurii*) and frogs.

These species are not listed as threatened but are protected under the NPW Act (as is the case with all native species).

The Eastern snake-necked turtle is common in most of NSW where it inhabits freshwater ponds, lakes and streams. It may also make burrows in riverbanks during dry conditions. The Manning River snapping turtle has only been found in the Manning River Catchment and it is unknown whether it would occur in the Study Area. Platypus and water dragons have been observed to occur within the Study Area (Cardno 2010, frc environmental 2012) and are commonly found throughout the freshwater reaches of the Manning River.

River or streams with earth banks and native vegetation that provides shading and cover is ideal habitat for platypus which make burrows in stream banks, although coarse cobble and /or gravel substratum is preferred. Eastern water dragons also dig burrows to lay eggs, but generally prefer sandy dry soils.

A number of native frog species have also been detected in high numbers throughout gullies and water bodies immediately south of the Study Area including Dog Trap Creek (Ecobiological 2010). Species recorded included striped marsh frog (*Limnodynastes peronii)*, spotted grass frog (*Limnodynastes tasmaniensis)*, eastern dwarf tree frog (*Litoria fallax)*, Peron's Tree Frog (*Litoria peronii)* and dusky toadlet (*Uperoleia fusca*) in particular.

3.4.1.4 Threatened and Protected Species, Populations and Ecological Communities

A total of 35 species of amphibian, three species of aquatic reptile and one species of aquatic mammal were recorded as known or likely to occur within the Gloucester LGA. No species of threatened or protected fishes or macroinvertebrates were listed. Two of the frog species (green and golden bell frog (*Litoria aurea*) and the giant barred frog (*Mixophyes iterates*)), were highlighted as species of concern within the GFDA by the Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC). As such, detailed assessments of significance were completed for these species (AH Ecology 2012) and concluded that it would be unlikely for these species to occur within the GDFA as neither species has been recorded within the Gloucester LGA and limited extent of potentially suitable intact riparian vegetation.

The population of tusked frog (*Adelotus brevis*) in the Nandewar and New England Tableland Bioregions was also listed as potentially occurring in the Gloucester LGA. None of the species listed, however, have been recorded to have occurred within watercourses of the Avon River or Dog Trap Creek within the boundary of the Study Area.

Two Endangered Ecological Communities: 'Freshwater Wetlands on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions' and Swamp Oak Floodplain Forest of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions are mapped as being 'known' to occur within the Gloucester LGA and has potential to occur within the Study Area.

Table 3-7 Species listed under the EPBC, TSC and FM Acts with relevance to the study area

Scientific Name	Common Name	TSC/ NP&W Act	EPBC Act
Amphibians			
Adelotus brevis	Tusked Frog	P	
Crinia signifera	Common Eastern Froglet	P	
Crinia tinnula	Wallum Froglet	V,P	
Lechriodus fletcheri	Fletcher's Frog	P	
Limnodynastes dumerilii	Eastern Banjo Frog	P	
Limnodynastes peronii	Brown-striped Frog	P	
Limnodynastes tasmaniensis	Spotted Grass Frog	P	
Mixophyes balbus	Stuttering Frog	E1,P	V
Mixophyes fasciolatus	Great Barred Frog	P	
Mixophyes iteratus	Giant Barred Frog	E1,P	E
Philoria sphagnicolus	Sphagnum Frog	V,P	
Pseudophryne australis	Red-crowned Toadlet	V,P	
Pseudophryne bibronii	Bibron's Toadlet	P	
Pseudophryne coriacea	Red-backed Toadlet	P	
Uperoleia fusca	Dusky Toadlet	P	
Uperoleia laevigata	Smooth Toadlet	P	
Litoria aurea	Green and Golden Bell Frog	E1,P	V
Litoria booroolongensis	Booroolong Frog	E1,P	E
Litoria brevipalmata	Green-thighed Frog	V,P	
Litoria caerulea	Green Tree Frog	P	
Litoria chloris	Red-eyed Tree Frog	P	
Litoria daviesae	Davies' Tree Frog	V,P	
Litoria dentata	Bleating Tree Frog	P	
Litoria ewingii	Brown Tree Frog	P	
Litoria fallax	Eastern Dwarf Tree Frog	P	
Litoria latopalmata	Broad-palmed Frog	P	
Litoria lesueuri	Lesueur's Frog	P	
Litoria nasuta	Rocket Frog	P	
Litoria pearsoniana	Pearson's Green Tree Frog	P	
Litoria pearsoniana/phyllochroa	Leaf Green Tree Frog species complex	P	
Litoria peronii	Peron's Tree Frog	P	
Litoria phyllochroa	Leaf-green Tree Frog	P	
Litoria revelata	Revealed Frog	P	
Litoria tyleri	Tyler's Tree Frog	P	
Litoria verreauxii	Verreaux's Frog	P	
Aquatic Reptiles			
Chelodina longicollis	Eastern Snake-necked Turtle	P	
Emydura macquarii	Macquarie Turtle	P	
Intellagama lesueurii	Eastern Water Dragon	P	
Aquatic Mammals			
Ornithorhynchus anatinus	Platypus	P	
Endangered Population			
Adelotus brevis	Tusked Frog population in the Nandewar and New England Tableland Bioregions	E2,P	

Endangered Ecological Communities		
Freshwater Wetlands on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions	Freshwater Wetlands on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions	E3
Swamp Oak Floodplain Forest of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions	Swamp Oak Floodplain Forest of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions	E3

**Results of database searches are only indicative and cannot be considered a comprehensive inventory.*

3.4.1.5 Key Threatening Processes

A key threatening process (KTP) is something that threatens, or could potentially threaten, the survival or evolutionary development of a species, population or ecological community as listed under the TSC Act, FM Act or EPBC Act. KTPs potentially applicable to the proposed construction and operation of the high flow discharge outlet are listed in **Table 3-8**. A brief description of these KTPs is also provided below and their relevance to the high flow discharge is discussed in **Section 3.4.3**.

Table 3-8 Key threatening processes relevant to the proposed high flow discharge outlet

Key Threatening Processes	TSC Act	FM Act	EPBC Act
Alteration to the natural flow regimes of rivers and streams and their floodplains and wetlands	✓		
Clearing of native vegetation	✓		
Land Clearing			✓
Removal of dead wood and dead trees	✓		
Predation by *Gambusia holbrooki* Girard, 1859 (Plague Minnow or Mosquito Fish)	✓		
Installation and operation of instream structures and other mechanisms that alter natural flow regimes of rivers and streams.		✓	
Removal of large woody debris from New South Wales rivers and streams.		✓	
Degradation of native riparian vegetation along New South Wales water courses.		✓	

'Alteration to natural flow regimes' refers to reducing or increasing flows, altering seasonality of flows, changing the frequency, duration, magnitude, timing, predictability and variability of flow events, altering surface and subsurface water levels, changing the rate of rise or fall of water levels and by altering water temperatures. Alteration to the natural flow regimes of rivers and streams and their floodplains and wetlands is recognised as a major factor contributing to loss of biological diversity and ecological function in aquatic ecosystems, including floodplains. Impacts potentially associated with altering natural flow regimes can include:

> riparian zone degradation where changes to flows increases erosion, leading to sedimentation impacts upon aquatic communities;

> deeper and more permanent standing water conducive to the establishment and spread of exotic species; and

> changes to the physical, chemical and biological conditions of rivers and streams which alters biota.

Temperature in particular, is considered an important factor in the development and growth of fish (Astles *et al.* 2003). Metabolism, respiration, feeding, reproduction, larval development and migratory behaviour of native fish are all strongly influenced by temperature. Fish eggs, larvae and juveniles are critical growth stages that can also be strongly temperature dependent. In spring and summer the rising temperature of the water becomes an important environmental cue, triggering spawning or migratory behaviour in native fish with a significant release of cold water suppressing spawning in some species for up to 300 km downstream (NSW DPI – Water 2015). As a result, the ability of native fish to reproduce, grow and maintain sustainable numbers may potentially be affected. Introduced species, competing with native fish for food and habitat may flourish under altered conditions.

A related process, 'the installation and operation of instream structures and other mechanisms that alter natural flow regimes of rivers and streams' is listed as a key threatening process under the FM Act. Instream structures that modify natural flow may include dams, weirs, canals, navigation locks, floodgates, culverts, flow regulators, levee banks, erosion control structures and causeways.

Clearing of native vegetation, refers to the destruction of a sufficient proportion of one or more strata (layers) within a stand or stands of native vegetation. Potential impacts may include loss of habitat and biological diversity, fragmentation of populations and riparian zone degradation, such as bank erosion leading to sedimentation that affects aquatic communities, the establishment and spread of exotic species and loss of leaf litter which is an important resource for a variety of aquatic species. 'Land Clearing' is also listed as a key threatening process under the Environmental Protection and Biodiversity Conservation Act 1999.

Dead wood and trees including large woody debris present in streams and rivers (snags) provide essential habitat for a wide variety of native animals (including native fish, invertebrates, reptiles and amphibians) and are important to the functioning of many ecosystems.

3.4.2 Results of Field Investigation

Results of the ecological field assessment for locations AV1, AV2, AV3 and DT1 are summarised in the following sections. Sampling locations are indicated in **Figure 3-1**. Some representative photos of the investigation sites are provided **in Figure 3-3**. Representative species recorded at each location are listed in **Table 3-9**.

3.4.2.1 Location AV1

AV1 was characterised by a relatively deep channel shaded by mature Casuarina trees forming a moderately dense riparian corridor along both banks (**Figure 3-3 (a)**). *Lomandra longifolia (*mat rush) was also a predominant macrophyte along the bank edges with occasional *Juncus* sp. (**Figure 3-3 (b)**) providing additional shading and habitat. Several exotic trees and shrubs such as tobacco (*Solanum mauritianum)* and privet (*ligustrum* sp.) were also present. The understorey was comprised of a mix of native and exotic grasses. No in-stream aquatic macrophytes were visible. Occasional snags and rocks also provided some instream habitat for fish and macroinvertebrates.

Surrounding land use was primarily for cattle grazing and access of livestock to bank edges was evident by trampling. The gravel causeway across the Avon River immediately upstream of the site may cause a minor barrier to upstream fish passage, however, only in very low flow conditions. Overall, this location would be considered to have the best potential for fish habitat of the four locations assessed.

RCE Score: 31 (Good)

Fish Habitat Class: 2 (Moderate key fish habitat)

Fish Habitat Sensitivity: II (Moderately sensitive fish habitat)

3.4.2.2 Location AV2

AV2 was characterised by moderately sloping banks consisting predominantly of exotic weeds, grasses and the occasional mature Casuarina which provided some shading (**Figure 3-3 (c)**). The exotic weed *Sida rhombifolia* was prolific, forming a dense understorey (**Figure 3-2 (c)**). In-stream aquatic macrophytes were sparse, apart from slender knotweed (*Persicaria* sp.), water ribbons (*Triglochin* sp.) observed at the water's edge (**Figure 3-3 (d)** and **(e)**), although the presence of other in-stream vegetation was difficult to confirm due to poor visibility. Occasional large snags were observed up and downstream of the assessment location potentially providing habitat for small fish and invertebrates. Surrounding land use was again primarily for cattle grazing and access of livestock to bank edges was evident by trampling.

RCE Score: 29 (Good)

Fish Habitat Class: 2 (Moderate key fish habitat)

Fish Habitat Sensitivity: II to III (Moderately sensitive fish habitat)

3.4.2.3 Location AV3

AV3 was similar to AV2 in terms of habitat composition, but was located approximately 200 m downstream. As for AV2, AV3 was characterised by moderately sloping banks consisting of exotic shrubs (mainly privet), grasses and the occasional mature and young Casuarina trees which provided some in-stream shading (**Figure 3-2 (d)**). Dense clumps of mat rush were predominant along the stream edges. In-stream macrophytes or snags did not appear to be present although, again this was difficult to confirm due to poor visibility. Livestock have also accessed the stream edge at this location likely increasing the turbidity.

RCE Score: 30 (Good)

Fish Habitat Class: 2 (Moderate key fish habitat)

Fish Habitat Sensitivity: II (Moderately sensitive fish habitat)

3.4.2.4 Location DT1

Dog Trap Creek was distinctly different from the three Avon River locations in that any significant riparian corridor was absent and the waterway itself was much narrower and shallower than the Avon River locations (**Figure 3-2 (f)**). Bank vegetation consisted primarily of grasses, occasional exotic shrubs and emergent macrophytes only, including native species such as mat rush, common rush (*Juncus* sp.) and canegrasses. Beds of typha (*Phragmites australis*) and spikerushes (*Eleocharis* sp.) were also abundant downstream of the assessment location. The stream itself was comparatively shallow (varying between 0.05 and 0.3 m) and relatively clear allowing identification of in-stream macrophytes including the introduced starwort (*Calitriche stagnalis*), water ribbons, pondweed (*Pomatogeton* sp.) and *Persicaria* sp. Several exotic weeds and grasses were also noted. This location clearly provided habitat for frogs (as evident by the chorus of calls), although the calls of either the green and golden bell frog or the giant barred frog were not recognised.

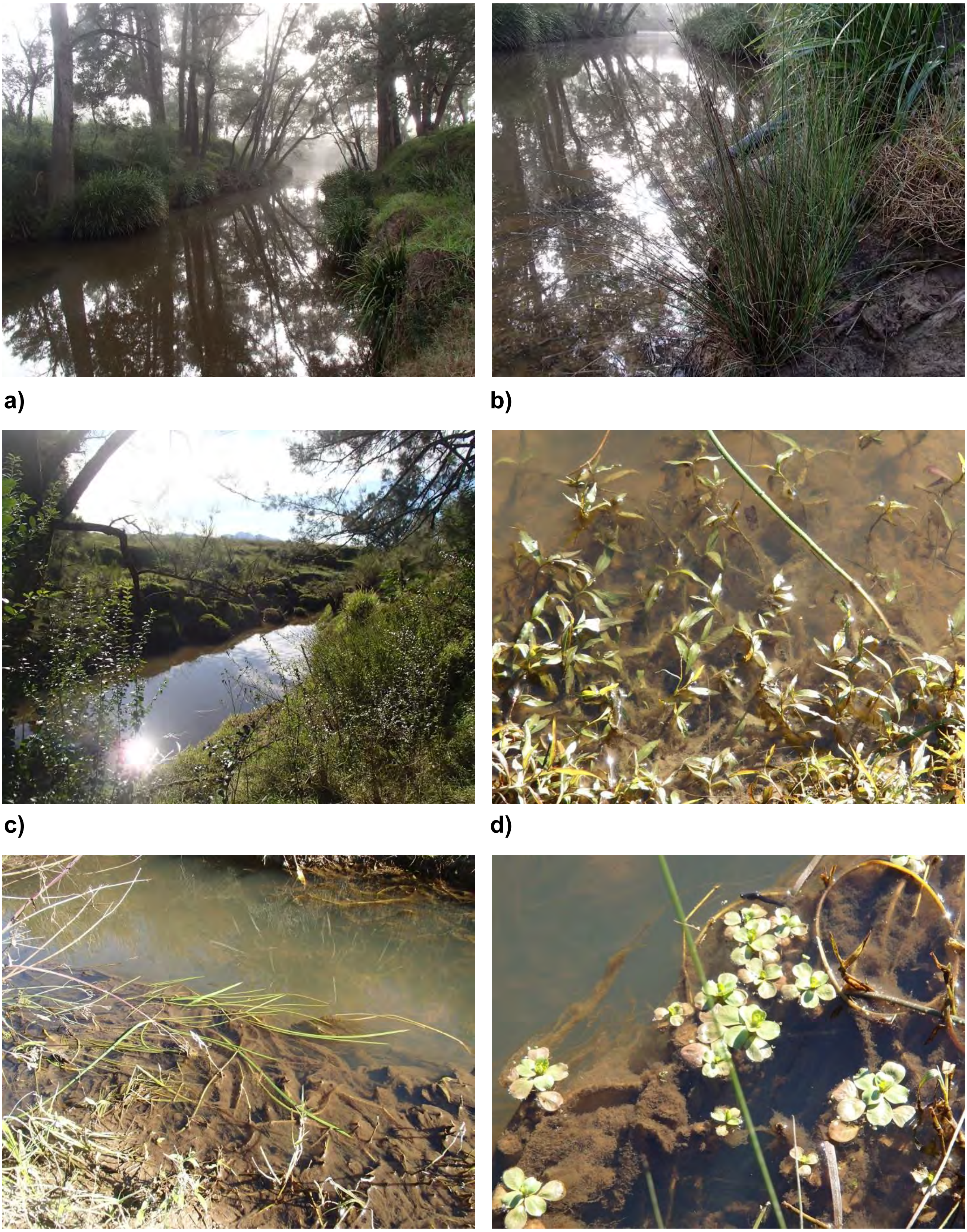
RCE Score: 27 (Good)

Fish Habitat Class: 3 (Minimal key fish habitat)

Fish Habitat Sensitivity: II to III (Moderate to minimally sensitive fish habitat)

Table 3-9 Species recorded within the study area on 30.06.15

Common Name	Scientific Name	AV1	AV2	AV3	DT1
Wild tobacco*	*Solanum mauritianum**	✓	✓	✓	
Small leaf privet	*Ligustrum sinense*	✓	✓	✓	
She-oak	*Casuarina* sp.	✓	✓	✓	
Paper bark	*Melaluca* spp.	✓			
Common rush	*Juncus usitatus*	✓			✓
Mat rush	*Lomandra longifolia*	✓	✓	✓	
Wattle	*Acacia sp.*	✓	✓	✓	✓
Creek lilli pilly	*Acmea smithi*	✓			
Paddy's lucerne*	*Sida rhombifolia**		✓		
Starwort*	*Callitriche stagnalis**				✓
Fireweed*	*Senecio madagasgarensis**		✓	✓	
Pondweed	*Pomatogeton* sp.				✓
Water ribbons	*Triglochin procerum*		✓		✓
Slender knotweed	*Persicaria* sp.				✓
Filamentous green algae	*Cladophora* sp.				✓
Common reed	*Phragmites australis*				✓
Mixed exotic weeds and grasses*	*n/a*	✓	✓	✓	✓
Dock Leaf	*Rumex* sp.			✓	✓



a) b) c) d) e) f)

Figure 3-3 Location photos (aquatic ecology) a) AV1 looking downstream b) Juncus usitatus c) DT1 looking downstream d) DT1 *Persicaria* sp. e) DT1 *Triglochin* sp. f) DT1 *Calitriche stagnalis* (starwort)

3.4.3 Synthesis

> Despite the surrounding land use and significant amount of exotic and introduced weeds and shrubs within the riparian corridor, the overall habitat condition of the investigation locations was relatively good. On the basis of the literature review and field assessment, it is likely that the reaches of Avon River and Dog Trap Creek within the Study Area would provide habitat for small native fish (such as gudgeons) and mobile invertebrates including freshwater prawns, shrimps and yabbies. Larger diadromous fish including eels and potentially other species may also occur at the Avon River locations, although the lack of clean gravel and/or riffle habitat would limit the diversity of fish and some macroinvertebrates.

> The earthy but relatively stable banks of the Avon River may provide habitat for eastern snake-necked turtle, yabbies and potentially platypus, whereas Dog Trap Creek appeared to provide significant habitat for frogs.

> A large number of threatened and protected species (mostly frogs) were listed as having potential to occur within the Study Area, however there were no records of these particular species occurring within watercourses of the Avon River or Dog Trap Creek within the boundary of the Study Area.

> Given the limited frequency, relatively low volumes and naturally high flow conditions of planned releases, it is unlikely that there would be any measureable downstream effect on aquatic flora or fauna to the extent that any sensitive aquatic species would be affected. It is also unlikely that the proposed high flow discharge would result in the exacerbation of any Key Threatening Processes, however, measures to minimise any construction or operational impacts are recommended (**Section 4**).

> Water to be released during high flow discharge events would be from Discharge Water Ponds (DWPs) where it would be collected over time (and not directly from the reverse osmosis or Water Treatment Plant). Providing that the discharge water is ambient to the receiving waters as per the AGL discharge water quality targets, no measurable effect on aquatic fauna or flora downstream of the discharge location would be expected.

> The area cleared for the pipeline and discharge outlet installation would benefit from removal of introduced weeds and replanting of native riparian vegetation. Scour protection works may also provide habitat diversity for aquatic biota.

3.5 Preliminary Location Selection

As discussed in **Section 2.6**, four preferred locations (AV1, AV2, AV3 and DT1), were initially selected on the basis of existing information and the field investigation. A Multi-Criteria Analysis (MCA) was then undertaken to help determine which of the four locations would be optimal (**Table 3-10**). This was done according to a set of eight criteria relating to geomorphological and ecological conditions and potential design constraints of the preferred locations. Assumptions and rationale for selecting these criteria are outlined in **Section 2.6**.

All of the locations assessed were considered to be relatively similar in terms of the key criteria considered and all would be potentially suitable for a high flow discharge outlet. In determining a preferred location, however, location AV2 was considered optimal in representing minimal environmental risk balanced with the design constraints (**Table 3-10**). While the advantages of discharging into Dog Trap Creek would be that the banks are more accessible and lower than the Avon River locations (potentially requiring less engineering work and habitat disturbance), locations within the Avon River were likely to provide a greater buffer to the additional flow of the discharge water, particularly in the instance of an unforseen low-flow release event. Ecologically, all locations were similar in terms of habitat condition and providing that minimal native habitat is disturbed and re-vegetated, the differences between locations would be minor. The bank slope at AV2 was also considered to be slightly lower and shallower than AV1 or AV3 making the engineering works more accessible. Removal of excessive weed growth, replanting of native vegetation and scour protection (e.g. sandstone rocks) at AV2 would also improve the local habitat condition and provide habitat complexity for small fish and invertebrates.

Table 3-10 Multi-Criteria Analysis (MCA) of locations proposed for high flow discharge outlet

Criteria - Geomorphology	Weighting	Overall Weighting	Non-Weighted Scores AV1	AV2	AV3	DT1	Weighted Scores AV1	AV2	AV3	DT1
Impact of additional flow from proposed discharge on existing 'high flow' conditions 1 = Greater than 20% increase in flows 2 = 5% to 20% increase in flows 3 = 1% to 5% increase in flows 4 = less than 1% increase in flows	**2**	**4**	4	4	4	3	8	8	8	6
Impact of additional flow from proposed discharge on existing 'low flow' conditions 1 = Greater than 20% increase in flows 2 = 5% to 20% increase in flows 3 = 1% to 5% increase in flows 4 = less than 1% increase in flows	**1**		4	4	4	2	4	4	4	2
Existing channel stability 1 = Significant active erosion likely to lead to mass failure of banks. Lack of vegetation providing stabilisation. 2 = Historic evidence of erosion and some evidence of recent scour or undercutting of banks. Good vegetation cover. 3 = Historic evidence of erosion, no active erosion present. Existing vegetation contributing significantly to stabilisation of banks. 4 = Stable channel. No indication of erosion and adequate vegetation cover to provide stability.	**1**		2	2	2	3	2	2	2	3
Criteria - Ecological			**AV1**	**AV2**	**AV3**	**DT1**	**AV1**	**AV2**	**AV3**	**DT1**
Approximate area of native habitat requiring removal (m^2) 1 = >6 m^2 2 = 4-6 m^2 3 = 2-4 m^2 4 = 0-2 m^2	**2**	**4**	2	4	2	4	4	8	4	8

Potential Fish Habitat Class 1 = Major key fish habitat 2 = Moderate key fish habitat 3 = Minimal key fish habitat 4 = Unlikely key fish habitat	**1**		2	2	2	3	2	2	2	3
Riparian Channel and Environmental (RCE) Inventory Scores 1 = RCE Score 40-52 (Very Good) 2 = RCE Score 27-39 (Good) 3 = RCE Score 14-26 (Moderately impaired) 4 = RCE Score 0-13 (Highly disturbed)	**1**		2	2	2	2	2	2	2	2
Criteria – Design			**AV1**	**AV2**	**AV3**	**DT1**	**AV1**	**AV2**	**AV3**	**DT1**
Suitability of bank formation to accept headwall and discharge flows 1 = Difficult and steep bank slope, high bank levels 2 = Moderately accessible bank, moderate bank height 3 = Accessible bank, low to moderate bank height 4 = Easily accessible bank, low bank height	**1**	**3**	1	2	1	4	1	2	1	4
Pipe route length and resulting construction and restoration costs 1 = Longest pipe route and thus likely most expensive construction option 2 = Long pipe route and thus relatively expensive construction and restoration 3 = Moderate length pipe route and thus mid-range construction costs 4 = Shortest pipe route and thus likely lowest construction cost option	**2**		1	3	3	1	2	6	6	2
Total Scores			**18**	**23**	**20**	**22**	**25**	**34**	**29**	**30**
Overall Rank							**4**	**1**	**3**	**2**

3.6 Preliminary Design

The preliminary design for the high flow discharge outlet has been drafted on the basis of the preferred AV2 location. The preliminary design is based upon the following data:

> Peak flow of 2ML/day (equivalent to approximately 23L/s).

> Outlet at location AV2 as per the Multi-Criteria Assessment as discussed in **Section 3.5**.

It is understood that a transfer water pipe line will deliver water from the discharge water pond (DWP) at the water treatment facility at the CPF in the south to the Tiedman holding ponds in the north. Treated water will then be irrigated over dedicated irrigation areas. During periods of high flow and when the holding ponds are at capacity, water will be diverted direct to the high flow outlet at location AV2 from either the DWP via the transfer pipeline or from the Tiedman holding ponds again via the transfer pipeline.

Due to the location topography and ground level variation it is expected that the transfer pipe line will be a pressurised rising main. Preliminary advice from AGL Engineering is that a DN160 transfer pipe is expected.

The rising main will pass through the proposed diversion/offtake pit (Pit A1). The mechanism for diversion will be designed as part of future works by others. It is expected that a valve or hydraulic gate will be utilised. Refer to the concept engineering plans included in **Appendix C** and **Figure 3-4** for concept arrangement including indicative pit locations. It is noted that AGL advise that the rising main will be 'bi-directional'.

A gravity pipe line will run from the rising main to the west toward the Avon River. The trench for the pipe will be clear of the existing dam located to the south of the proposed gravity pipe line. Typical trench depth is expected to be in the order of 1.0 to 1.5 m in depth (subject to future site detailed survey). The trench surface will be restored and revegetated to match existing conditions.

An inspection pit near the existing top of creek bank (Pit A3) will allow a change in pipe direction and discharge to the outlet headwall (Headwall A4). Discharge from the outlet headwall will be at approximately 60 degrees to the main river channel)(**Figure 3-4 (a)**, **Appendix C**). An intermediate pit, Pit A2, is included between Pit A1 and Pit A3 for maintenance purposes).

A typical creek cross section as discussed in **Section 3.2** was reviewed to inform expected gravity pipe line levels. It is expected that between Pit A1 and Pit A3 the gravity pipe will be laid at approximately 0.5% grade (1 in 200). From Pit A3 to Headwall A4 the pipe grade increases significantly to approximately 30% (1 in 3.3) to match the slope of the existing river bank (**Figure 3-4 (a)**). This will necessitate the installation of concrete bulkheads, or similar, around the gravity pipe to prevent piping failure and migration of the trench backfill material.

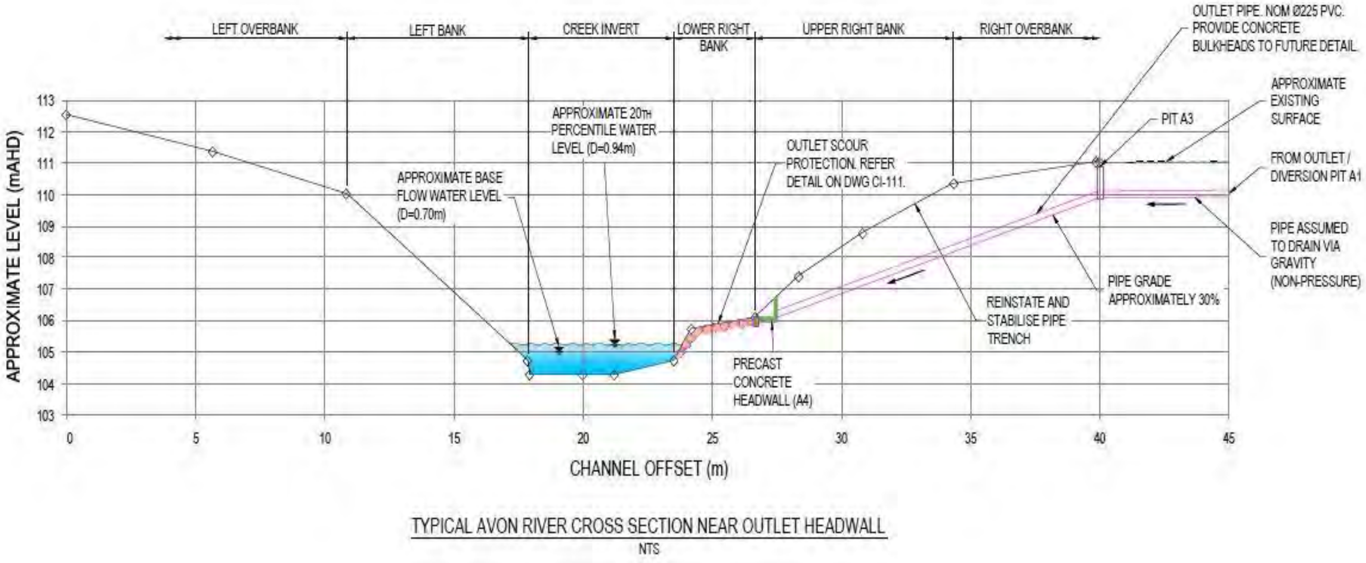
To reduce the grade of the gravity pipe between Pit A3 and Headwall A4 a deeper trench was considered. Where the pipe grade was significantly reduced, trench depths of up to 5 m resulted. This trench depth was considered to be excessive and was not, therefore pursued further.

A concept DRAINS computer model was prepared in order to assess the hydraulic capacity and outlet velocity of the gravity pipe network. The DRAINS model showed that a 225 mm diameter gravity pipe had suitable hydraulic capacity to convey the high flow discharge. The outlet velocity was estimated to be 3.5 m/s.

It is proposed to construct scour protection downstream of Headwall A4 to protect the creek bank from scour and erosion. Scour protection has been designed to consist of hard, durable sandstone with a specific gravity of 2.65. The average rock diameter (d50) is 300 mm. Scour protection will be 600 mm thick and underlain by geotextile to prevent movement of the underlying soil strata. A total of approximately 10 sq. m of rock protection is expected to be required (**Figure 3-4 (b)**, **Appendix C**).

Concept engineering plans for the high flow outlet are presented on Cardno's drawing set 59915194-CI series are included in **Appendix C**.

a)



b)

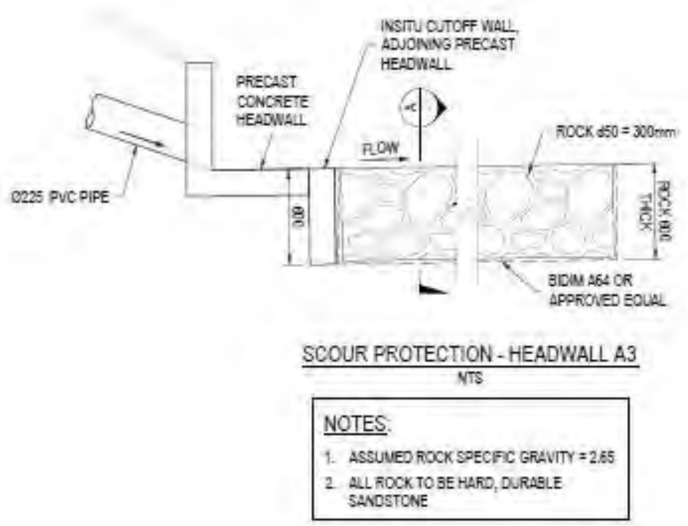


Figure 3-4 a) Typical Avon River cross section near outlet headwall. b) Scour protection – headwall (A3) cross section

4 Conclusion and Recommendations

In terms of geomorphological characteristics of the receiving environment, all sites assessed within the Avon River were relatively similar, consisting of sinuous, laterally stable channels, with pools and fine grained bed/bank material. Moderate bank erosion from past and recent events was evident, although the effects of this appeared to be minimised by stabilising riparian vegetation. Dog Trap Creek was notably different from the Avon River in that it was less incised and had considerably less flow. Water quality at all sites was variable and did not indicate any one site as potentially more suitable than another for the placement of a discharge outlet, although greater extremes in temperature and salinity were apparent at Dog Trap Creek which is naturally ephemeral.

Results of the ecological assessment indicated that the overall habitat condition of the investigation locations was relatively good for small streams situated in an agricultural landscape and likely to provide habitat for a range of native and non-native fish and invertebrates. Other aquatic and semi-aquatic animals including frogs, reptiles and mammals also have potential to occur within the Study Area. Given the limited frequency, relatively low volumes and naturally high flow conditions of the planned releases, any measureable downstream effect on aquatic flora or fauna was considered unlikely. Furthermore, providing that the discharge water is ambient to the receiving waters (as per the AGL discharge water quality targets), no measurable effect on aquatic fauna or flora downstream of the discharge location would be expected e.g. as a result of thermal pollution.

Overall, results of both the field investigation and MCA suggest that any of the four locations considered (AV1, AV2, AV3 and DT1) would be potentially suitable for placement of a high flow outlet for the discharge of treated (freshwater) from the water treatment plant (via DWPs). Although no measurable impacts to the geomorphological or ecological integrity of the receiving waterway would be expected at any of the four locations (based on the maximum daily, and annual discharge rates), location AV2 was considered to represent the least risk in terms of construction and operation. It is assumed that water quality data collected from relevant monitoring sites (within the receiving waterway) will be analysed immediately prior to a high flow release to ensure water quality targets are met. On that basis, impacts to downstream water quality and associated biota are not expected.

Recommendations

The proposed concept design at location AV2 will incorporate concrete bulkheads (or similar) around the gravity pipe, a shallow trench and up to 10 sq. m of scour protection. The following measures are therefore recommended to ensure minimal environmental disturbance:

> The final position of the high flow outlet should avoid the need to remove existing mature trees and other native vegetation;

> Snags or in stream structures (rocks and boulders) should not be removed or displaced from the stream bed;

> Appropriate sediment and erosion controls should be put in place during construction to minimise turbidity within the waterway;

> Introduced weeds should be cleared from the outlet installation site and be re-vegetated with bank stabilising native plants and shrubs; and

> Livestock access should be generally limited where possible to help improve overall habitat condition and water quality as well as limiting further bank erosion.

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Environmental Assessment and Design of High Flow Discharge Location for Treated Water

APPENDIX A

RCE AND FISH HABITAT CRITERIA

Cardno
Shaping the Future

Site Descriptors Used to Calculate RCE Scores (after Chessman *et al*. 1997)

Descriptor and category	Value	Descriptor and category	Value
1 Land use pattern beyond the immediate riparian zone		8 Riffle / pool sequence	
Undisturbed native vegetation	4	Frequent alternation of riffles and pools	4
Mixed native vegetation and pasture/exotics	3	Long pools with infrequent short riffles	3
Mainly pasture, crops or pine plantation	2	Natural channel without riffle / pool sequen	2
Urban	1	Artificial channel; no riffle / pool sequence	1
2 Width of riparian strip of woody vegetation		9 Retention devices in stream	
More than 30 m	4	Many large boulders and/or debris dams	4
Between 5 and 30 m	3	Rocks / logs present; limited damming effe	3
Less than 5 m	2	Rocks / logs present, but unstable, no dam	2
No woody vegetation	1	Stream with few or no rocks / logs	1
3 Completeness of riparian strip of woody vegetation		10 Channel sediment accumulations	
Riparian strip without breaks in vegetation	4	Little or no accumulation of loose sedimen	4
Breaks at intervals of more than 50 m	3	Some gravel bars but little sand or silt	3
Breaks at intervals of 10 - 50 m	2	Bars of sand and silt common	2
Breaks at intervals of less than 10 m	1	Braiding by loose sediment	1
4 Vegetation of riparian zone within 10 m of channel		11 Stream bottom	
Native tree and shrub species	4	Mainly clean stones with obvious interstice	4
Mixed native and exotic trees and shrubs	3	Mainly stones with some cover of algae / si	3
Exotic trees and shrubs	2	Bottom heavily silted but stable	2
Exotic grasses / weeds only	1	Bottom mainly loose and mobile sediment	1
5 Stream bank structure		12 Stream detritus	
Banks fully stabilised by trees, shrubs etc	4	Mainly unsilted wood, bark, leaves	4
Banks firm but held mainly by grass and herb	3	Some wood, leaves etc. with much fine det	3
Banks loose, partly held by sparse grass etc	2	Mainly fine detritus mixed with sediment	2
Banks unstable, mainly loose sand or soil	1	Little or no organic detritus	1
6 Bank undercutting		13 Aquatic vegetation	
None, or restricted by tree roots	4	Little or no macrophyte or algal growth	4
Only on curves and at constrictions	3	Substantial algal growth; few macrophytes	3
Frequent along all parts of stream	2	Substantial macrophyte growth; little algae	2
Severe, bank collapses common	1	Substantial macrophyte and algal growth	1
7 Channel form		**TOTAL**	
Deep: width / depth ratio less than 7:1	4		
Medium: width / depth ratio 8:1 to 15:1	3		
Shallow: width / depth ratio greater than 15:1	2		
Artificial: concrete or excavated channel	1		

NSW DPI Descriptors of Fish Habitat Class (as per Fairful 2013)

Classification	Characteristics of Waterway Type
Class 1 Major key fish habitat	Marine or estuarine waterway or permanently flowing or flooded freshwater waterway (e.g. River or major creek), habitat of a threatened or protected fish species or 'critical habitat'
Class 2 Moderate key fish habitat	Non-permanently flowing (intermittent) stream, creek or waterway (generally named) with clearly defined bed and banks with semi - permanent to permanent waters in pools or in connected wetland areas. Freshwater aquatic vegetation is present. TYPE 1 and 2 Habitats present
Class 3 Minimal key fish habitat	Named or unnamed waterway, intermittent flow and sporadic refuge, breeding or feeding areas for some aquatic fauna (e.g. fish, yabbies). Semi - permanent pools from within the waterway or adjacent wetlands after a rain event. Otherwise any minor waterway that interconnects with wetlands or other Class 1 -3 fish habitats
Class 4 Unlikely key fish habitat	Waterway (generally unnamed), with intermittent flow following rain events only, little or no defined channel, little or no flow or free standing water or pools post rain events (e.g. dry gullies or shallow floodplain depressions with no aquatic flora present).

NSW DPI Fish Habitat Sensitivity (as per Fairful 2013)

Classification	
Type 1 - Highly Sensitive Fish Habitat	Freshwater habitats that contain in-stream gravel beds, rocks greater than 50 cm in two dimensions, snags greater than 30 cm in diameter or 3 m in length, or native aquatic plants.
Type 2 - Moderately Sensitive Fish Habitat	Freshwater habitats and brackish wetlands, lakes and lagoons other than defined in Type 1. Weir pools and dams up to full supply level where the weir or dam is across a natural waterway.
Type 3 - Minimally Sensitive Fish Habitat	Ephemeral aquatic habitat not supporting native aquatic or wetland habitat

Environmental Assessment and Design of High Flow Discharge Location for Treated Water

APPENDIX B

GEOMORPHOLOGY FIELD DATA

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Index of Stream Condition – AV1

Assessment Category	Criterion	Result
Valley Setting	Percentage of channel abutting bed rock or hard material	<10%
Left Bank	Height (m)	4
	Slope	90deg-45deg
	Bank Condition - veg	Trees, Shrubs and Grasses
	Bank Condition - erosion	Eroding
	Bank Material	Silt
	Bank Failure Mode(s)	Slump (old), Scour (recent), Stock access (recent)
Right Bank	Height (m)	4
	Slope	90deg-45deg
	Bank Condition - veg	Trees, Shrubs and Grasses
	Bank Condition - erosion	Eroding
	Bank Material	Silt
	Bank Failure Mode(s)	Slump (old), Scour (recent), Stock access (recent)
Left Bench		Single Continuous
Right Bench		Single Continuous
Channel Width	Top of bank to top of bank (m)	30
Width to Depth Ratio	Bank height / top of bank width	0.1
Channel Bed	Total bed width (m)	10
	Discontinuous / single thread / multi-thread/braided	Single Thread
	Instream Bars	n/a
	Sediment	Unknown - murky water
	Flow - average surface velocity	0m/s
	Estimated Depth	0.8m
Vegetative Cover LEFT BANK	Trees	11%-40%
	Shrubs	1%-10%
	Ground	>60%
	Streamside Zone Width	5m
Vegetative Cover RIGHT BANK	Trees	11%-40%
	Shrubs	1%-10%
	Ground	>60%
	Streamside Zone Width	5m
Stock Access LEFT BANK		Cattle
Stock Access RIGHT BANK		Cattle
Field data Sheet - LEFT BANK		
I - Bank Stability		Limited Erosion

Assessment Category	Criterion	Result
II - Width of Streamside Zone		5-10m
III - Structural Intactness	Tree Layer	20-80%
	Shrub Layer	<20%
	Ground Layer	>80%
IV - Cover of exotic vegetation		40-60%
V - Revegetation of ind woody veg		Very Limited (<1% Cover)
V1 - Livestock access		Yes (Cattle)
Field data Sheet - RIGHT BANK		
I - Bank Stability		Limited Erosion
II - Width of Streamside Zone		5-10m
III - Structural Intactness	Tree Layer	20-80%
	Shrub Layer	<20%
	Ground Layer	>80%
IV - Cover of exotic vegetation		40-60%
V - Revegetation of ind woody veg		Very Limited (<1% Cover)
V1 - Livestock access		Yes (Cattle)
CHANNEL STABILITY RANKING SCHEME		
Slope	0.002 m/m	
Pattern	Meandering	
1. Primary bed material	Silt Clay	4
2. Bed / bank protection	No	1
3. Degree of incision	13%	3
4. Degree of constriction	0-10%	0
5. Streambank erosion LEFT BANK	Fluvial	1
5. Streambank erosion RIGHT BANK	Fluvial	1
6 Streambank instability LEFT BANK	11-25%	0.5
6 Streambank instability RIGHT BANK	11-25%	0.5
7. Established riparian woody-vegetative cover LEFT BANK	11-25%	1.5
7. Established riparian woody-vegetative cover RIGHT BANK	11-25%	1.5
8. Bank Accretion LEFT BANK	0-10%	2
8. Bank Accretion RIGHT BANK	0-10%	2
9. Stage of channel evolution	NA	NA
10. Composition of adjacent side slope LEFT BANK	Fines	2
10. Composition of adjacent side slope RIGHT BANK	Fines	2
11. Percent of slope (length) contributing to sed LEFT BANK	0-10%	0
11. Percent of slope (length) contributing to sed RIGHT BANK	0-10%	0
12. Severity of side-slope erosion LEFT BANK	Low	0.5

Assessment Category	Criterion	Result
12. Severity of side-slope erosion RIGHT BANK	Low	0.5
TOTAL		23

Index of Stream Condition – AV2

Assessment Category	Criterion	Result
Valley Setting	Percentage of channel abutting bed rock or hard material	<10%
Left Bank	Height (m)	5
	Slope	90deg-45deg
	Bank Condition - veg	Trees, Shrubs and Grasses
	Bank Condition - erosion	Eroding
	Bank Material	Silt
	Bank Failure Mode(s)	Slump (old), Lower bank slightly undercut (recent), Stock access (recent)
Right Bank	Height (m)	5
	Slope	90deg-45deg
	Bank Condition - veg	Trees, Shrubs and Grasses
	Bank Condition - erosion	Eroding
	Bank Material	Silt
	Bank Failure Mode(s)	Slump (old), Lower bank slightly undercut (recent), Stock access (recent)
Left Bench		Single Discontinuous
Right Bench		Single Discontinuous
Channel Width	Top of bank to top of bank (m)	35
Width to Depth Ratio	Bank height / top of bank width	0.1
Channel Bed	Total bed width (m)	5m
	Discontinuous / single thread / multi-thread/braided	Single Thread
	Instream Bars	n/a
	Sediment	Unknown - murky water
	Flow - average surface velocity	<0.5m/s
	Estimated Depth	0.6
Vegetative Cover LEFT BANK	Trees	11%-40%
	Shrubs	1%-10%
	Ground	>60%
	Streamside Zone Width	5m
Vegetative Cover RIGHT BANK	Trees	11%-40%
	Shrubs	1%-10%
	Ground	>60%
	Streamside Zone Width	5m

Assessment Category	Criterion	Result
Stock Access LEFT BANK		Cattle
Stock Access RIGHT BANK		Cattle
Field data Sheet - LEFT BANK		
I - Bank Stability		Limited Erosion
II - Width of Streamside Zone		5-10m
III - Structural Intactness	Tree Layer	20-80%
	Shrub Layer	<20%
	Ground Layer	>80%
IV - Cover of exotic vegetation		40-60%
V - Revegetation of ind woody veg		Very Limited (<1% Cover)
V1 - Livestock access		Yes (Cattle)
Field data Sheet - RIGHT BANK		
I - Bank Stability		Limited Erosion
II - Width of Streamside Zone		5-10m
III - Structural Intactness	Tree Layer	20-80%
	Shrub Layer	<20%
	Ground Layer	>80%
IV - Cover of exotic vegetation		40-60%
V - Revegetation of ind woody veg		Very Limited (<1% Cover)
V1 - Livestock access		Yes (Cattle)
CHANNEL STABILITY RANKING SCHEME		
Slope	0.002 m/m	From Lidar
Pattern	Meandering	
1. Primary bed material	Silt Clay	4
2. Bed / bank protection	No	1
3. Degree of incision	9%	4
4. Degree of constriction	0-10%	0
5. Streambank erosion LEFT BANK	Fluvial	1
5. Streambank erosion RIGHT BANK	Fluvial	1
6 Streambank instability LEFT BANK	11-25%	0.5
6 Streambank instability RIGHT BANK	11-25%	0.5
7. Established riparian woody-vegetative cover LEFT BANK	0-10%	2
7. Established riparian woody-vegetative cover RIGHT BANK	0-10%	2
8. Bank Accretion LEFT BANK	0-10%	2
8. Bank Accretion RIGHT BANK	0-10%	2
9. Stage of channel evolution	NA	NA
10. Composition of adjacent side slope LEFT BANK	Fines	2
10. Composition of adjacent side slope RIGHT BANK	Fines	2

Assessment Category	Criterion	Result
11. Percent of slope (length) contributing to sed LEFT BANK	0-10%	0
11. Percent of slope (length) contributing to sed RIGHT BANK	0-10%	0
12. Severity of side-slope erosion LEFT BANK	Low	0.5
12. Severity of side-slope erosion RIGHT BANK	Low	0.5
TOTAL		25

Index of Stream Condition – AV3

Assessment Category	Criterion	Result
Valley Setting	Percentage of channel abutting bed rock or hard material	<10%
Left Bank	Height (m)	5
	Slope	90deg-45deg
	Bank Condition - veg	Trees, Shrubs and Grasses
	Bank Condition - erosion	Eroding
	Bank Material	Silt
	Bank Failure Mode(s)	Slump (old), Lower bank slightly undercut (recent), Stock access (recent), obstruction from fallen tree causing scour just upstream of site.
Right Bank	Height (m)	5
	Slope	90deg-45deg
	Bank Condition - veg	Trees, Shrubs and Grasses
	Bank Condition - erosion	Eroding
	Bank Material	Silt
	Bank Failure Mode(s)	Slump (old), Lower bank slightly undercut (recent), Stock access (recent)
Left Bench		Single Continuous
Right Bench		Single Continuous
Channel Width	Top of bank to top of bank (m)	35
Width to Depth Ratio	Bank height / top of bank width	0.1
Channel Bed	Total bed width (m)	4m
	Discontinuous / single thread / multi-thread/braided	Single Thread
	Instream Bars	n/a
	Sediment	Unknown - murky water
	Flow - average surface velocity	<0.5m/s
	Estimated Depth	0.6
Vegetative Cover LEFT BANK	Trees	11%-40%
	Shrubs	1%-10%

Assessment Category	Criterion	Result
	Ground	>60%
	Streamside Zone Width	5m
Vegetative Cover RIGHT BANK	Trees	11%-40%
	Shrubs	1%-10%
	Ground	>60%
	Streamside Zone Width	5m
Stock Access LEFT BANK		Cattle
Stock Access RIGHT BANK		Cattle
Field data Sheet - LEFT BANK		
I - Bank Stability		Limited Erosion
II - Width of Streamside Zone		5-10m
III - Structural Intactness	Tree Layer	20-80%
	Shrub Layer	<20%
	Ground Layer	>80%
IV - Cover of exotic vegetation		40-60%
V - Revegetation of ind woody veg		Very Limited (<1% Cover)
V1 - Livestock access		Yes (Cattle)
Field data Sheet - RIGHT BANK		
I - Bank Stability		Limited Erosion
II - Width of Streamside Zone		5-10m
III - Structural Intactness	Tree Layer	20-80%
	Shrub Layer	<20%
	Ground Layer	>80%
IV - Cover of exotic vegetation		40-60%
V - Revegetation of ind woody veg		Very Limited (<1% Cover)
V1 - Livestock access		Yes (Cattle)
CHANNEL STABILITY RANKING SCHEME		
Slope	0.002 m/m	From Lidar
Pattern	Meandering	
1. Primary bed material	Silt Clay	4
2. Bed / bank protection	No	1
3. Degree of incision	9%	4
4. Degree of constriction	0-10%	0
5. Streambank erosion LEFT BANK	Fluvial	1
5. Streambank erosion RIGHT BANK	Fluvial	1
6 Streambank instability LEFT BANK	11-25%	0.5
6 Streambank instability RIGHT BANK	11-25%	0.5
7. Established riparian woody-vegetative cover LEFT BANK	0-10%	2
7. Established riparian woody-vegetative cover	0-10%	2

Assessment Category	Criterion	Result
RIGHT BANK		
8. Bank Accretion LEFT BANK	0-10%	2
8. Bank Accretion RIGHT BANK	0-10%	2
9. Stage of channel evolution	NA	NA
10. Composition of adjacent side slope LEFT BANK	Fines	2
10. Composition of adjacent side slope RIGHT BANK	Fines	2
11. Percent of slope (length) contributing to sed LEFT BANK	0-10%	0
11. Percent of slope (length) contributing to sed RIGHT BANK	0-10%	0
12. Severity of side-slope erosion LEFT BANK	Low	0.5
12. Severity of side-slope erosion RIGHT BANK	Low	0.5
TOTAL		25

Index of Stream Condition – DT1

Assessment Category	Criterion	Result
Valley Setting	Percentage of channel abutting bed rock or hard material	<10%
Left Bank	Height (m)	2.5
	Slope	90deg-45deg
	Bank Condition - veg	Grasses
	Bank Condition - erosion	Eroding
	Bank Material	Silt
	Bank Failure Mode(s)	Slump (old), Scour (recent), Stock access (recent)
Right Bank	Height (m)	2.5
	Slope	90deg-45deg
	Bank Condition - veg	Trees, Shrubs and Grasses
	Bank Condition - erosion	Eroding
	Bank Material	Silt
	Bank Failure Mode(s)	Slump (old), Scour (recent), Stock access (recent)
Left Bench		Single discontinuous
Right Bench		Single discontinuous
Channel Width	Top of bank to top of bank (m)	12
Width to Depth Ratio	Bank height / top of bank width	0.2
Channel Bed	Total bed width (m)	1m
	Discontinuous / single thread / multi-thread/braided	Single Thread
	Instream Bars	n/a
	Sediment	silt
	Flow - average surface velocity	0.5m/s

Assessment Category	Criterion	Result
	Estimated Depth	0.2m
Vegetative Cover LEFT BANK	Trees	0%
	Shrubs	0%
	Ground	>60%
	Streamside Zone Width	0m
Vegetative Cover RIGHT BANK	Trees	0%
	Shrubs	0%
	Ground	>60%
	Streamside Zone Width	0m
Stock Access LEFT BANK		Cattle
Stock Access RIGHT BANK		Cattle
Field data Sheet - LEFT BANK		
I - Bank Stability		Limited Erosion
II - Width of Streamside Zone		<5m
III - Structural Intactness	Tree Layer	<20%
	Shrub Layer	<20%
	Ground Layer	>80%
IV - Cover of exotic vegetation		40-60%
V - Revegetation of ind woody veg		Very Limited (<1% Cover)
V1 - Livestock access		Yes (Cattle)
Field data Sheet - RIGHT BANK		
I - Bank Stability		Limited Erosion
II - Width of Streamside Zone		<5m
III - Structural Intactness	Tree Layer	<20%
	Shrub Layer	<20%
	Ground Layer	>80%
IV - Cover of exotic vegetation		40-60%
V - Revegetation of ind woody veg		Very Limited (<1% Cover)
V1 - Livestock access		Yes (Cattle)
CHANNEL STABILITY RANKING SCHEME		
Slope	0.003 m/m	
Pattern	Meandering	
1. Primary bed material	Silt Clay	4
2. Bed / bank protection	No	1
3. Degree of incision	13%	3
4. Degree of constriction	0-10%	0
5. Streambank erosion LEFT BANK	Fluvial	1
5. Streambank erosion RIGHT BANK	Fluvial	1
6 Streambank instability LEFT BANK	11-25%	0.5
6 Streambank instability RIGHT BANK	11-25%	0.5

Assessment Category	Criterion	Result
7. Established riparian woody-vegetative cover LEFT BANK	0-10%	2
7. Established riparian woody-vegetative cover RIGHT BANK	0-10%	2
8. Bank Accretion LEFT BANK	0-10%	2
8. Bank Accretion RIGHT BANK	0-10%	2
9. Stage of channel evolution	NA	NA
10. Composition of adjacent side slope LEFT BANK	Fines	2
10. Composition of adjacent side slope RIGHT BANK	Fines	2
11. Percent of slope (length) contributing to sed LEFT BANK	0-10%	0
11. Percent of slope (length) contributing to sed RIGHT BANK	0-10%	0
12. Severity of side-slope erosion LEFT BANK	Low	0.5
12. Severity of side-slope erosion RIGHT BANK	Low	0.5
TOTAL		24

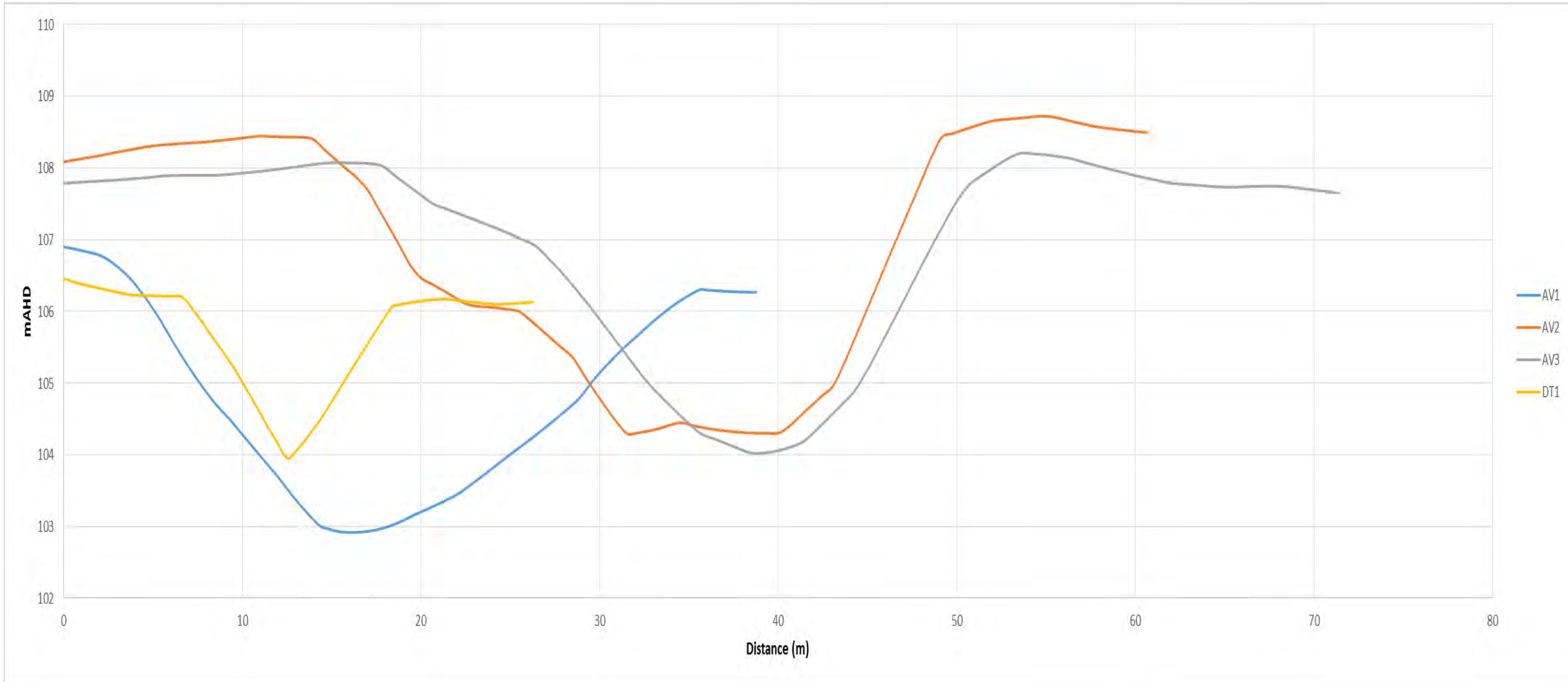

Figure B-1 Estimates of cross sections from Lidar data.

Environmental Assessment and Design of High Flow Discharge Location for Treated Water

APPENDIX C

CONCEPT DESIGN

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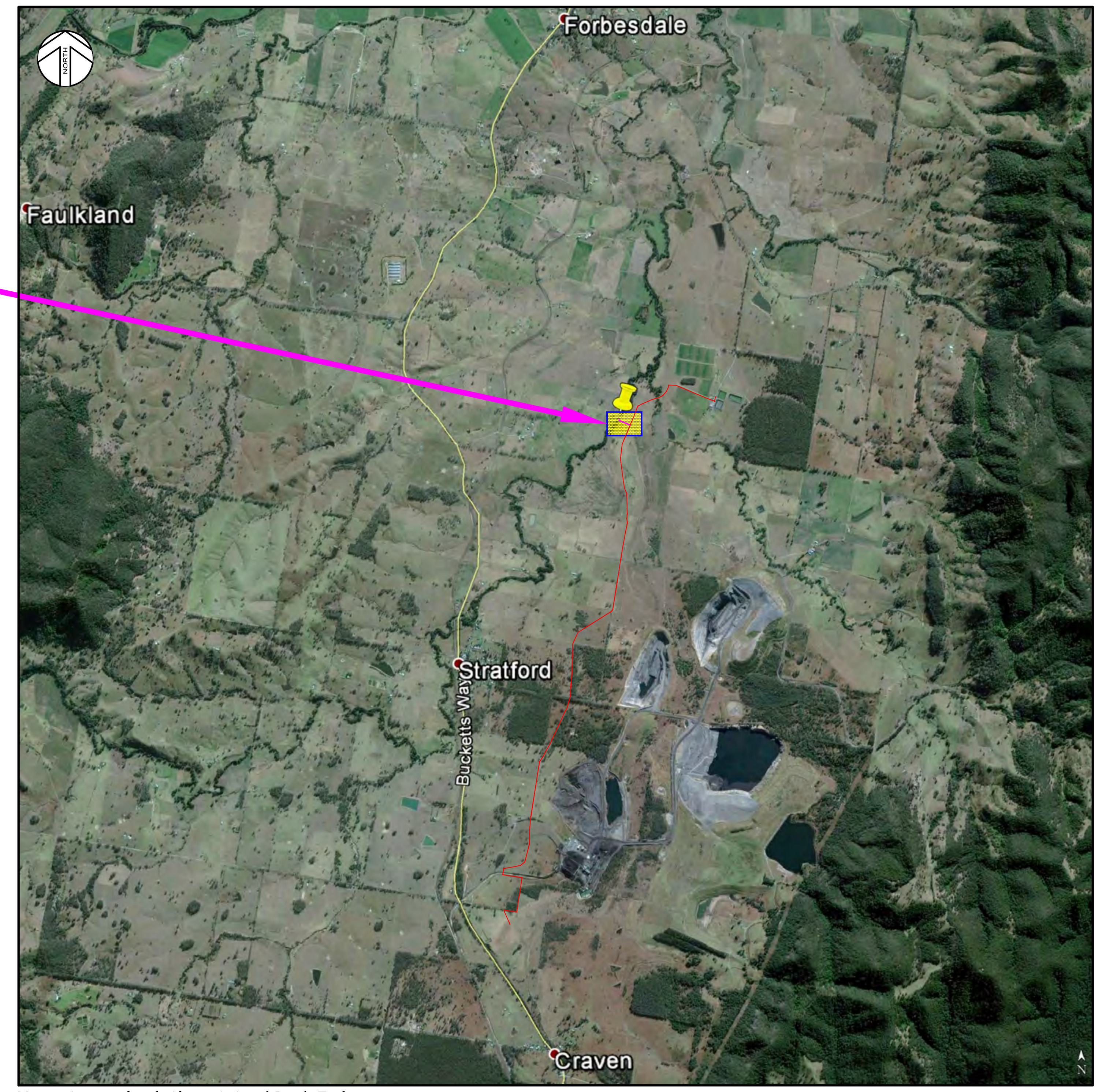
AGL ENERGY LIMITED

GLOUCESTER GAS PROJECT
CONCEPT DESIGN FOR
HIGH FLOW DISCHARGE

COVER SHEET

LOCATION OF WORKS



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LOCALITY PLAN
NTS

CIVIL DRAWINGS	
NUMBER	TITLE
59915194-CI-100	COVER SHEET
59915194-CI-110	CONCEPT DETAILS - SHEET 1
59915194-CI-111	CONCEPT DETAILS - SHEET 2

Rev.	Date	Description	Des.	Verif.	Appd.
1	23/07/15	INITIAL ISSUE	SGB	SJB	-

Drawn LDB	Date 20/07/15
Checked SGB	Date 21/07/15
Designed SGB	Date 20/07/15
Verified SJB	Date 21/07/15
Approved -	-

Status
PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION PURPOSES

Scale N/A
Size A1
Drawing Number 59915194-CI-100
Revision 1

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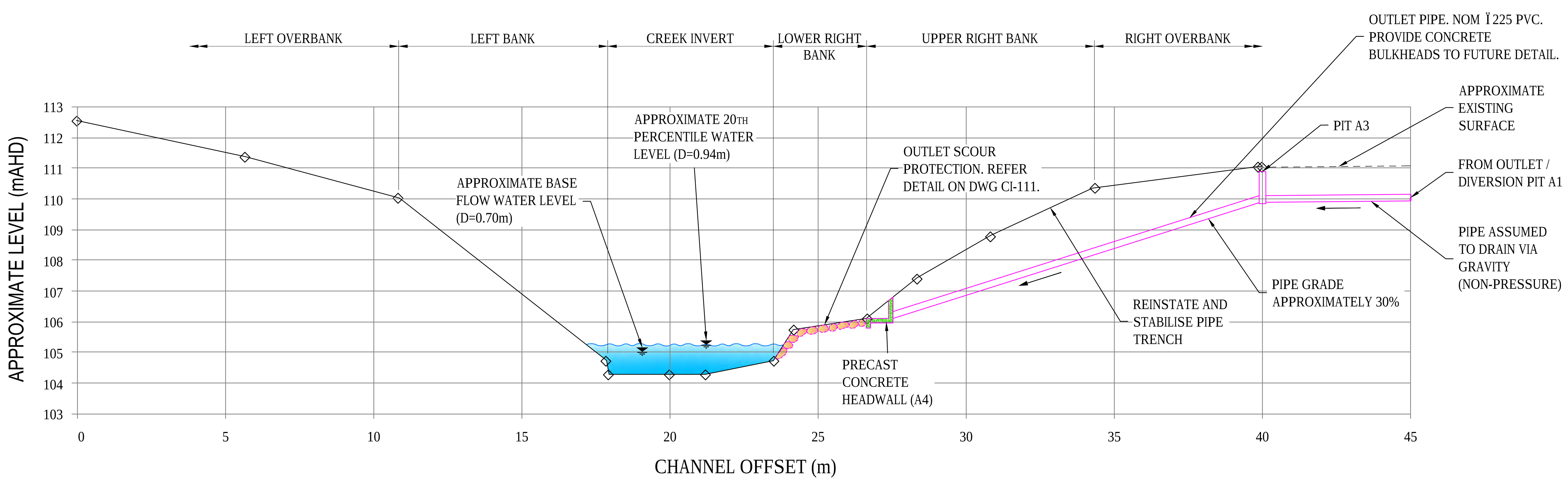
INSET PLAN
SCALE 1:1000

PLAN
SCALE 1:5000



TYPICAL AVON RIVER CROSS SECTION NEAR OUTLET HEADWALL
NTS

CO-ORDINATE TABLE
(APPROXIMATE LOCATION ONLY)

LOCATION	E	N
A1	401 655	6 448 600
A2	401 589	6 448 626
A3	401 523	6 448 652
A4	401 513	6 448 663

Rev.	Date	Description	Des.	Verif.	Appd.
1	23/07/15	INITIAL ISSUE	SGB	SJB	-

THIS DRAWING MUST BE VIEWED IN COLOUR

0 20 40 60 80 100m
SCALE 1:1000 @A1

0 100 200 300 400 500m
SCALE 1:5000 @A1

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		Date
Drawn	LDB	20/07/15
Checked	SGB	21/07/15
Designed	SGB	20/07/15
Verified	SJB	21/07/15
Approved	-	-

Client: AGL ENERGY LIMITED

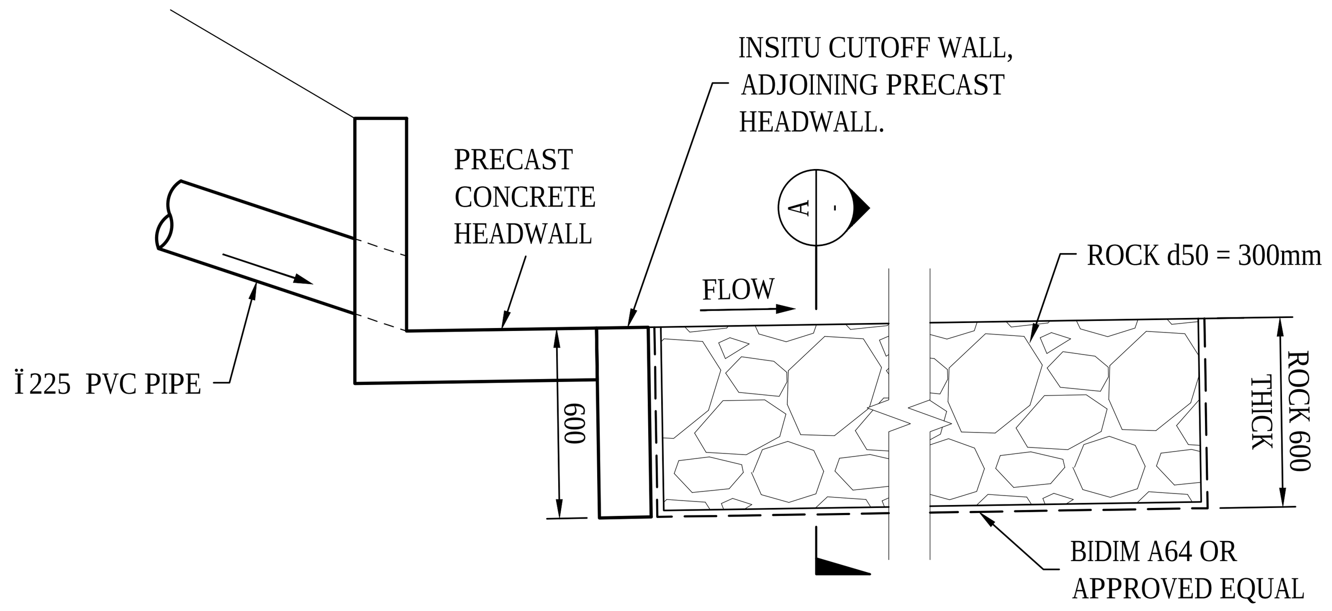
Project: GLOUCESTER GAS PROJECT
CONCEPT DESIGN FOR HIGH FLOW DISCHARGE

Title: CONCEPT DETAILS
SHEET 1

Status: PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION PURPOSES

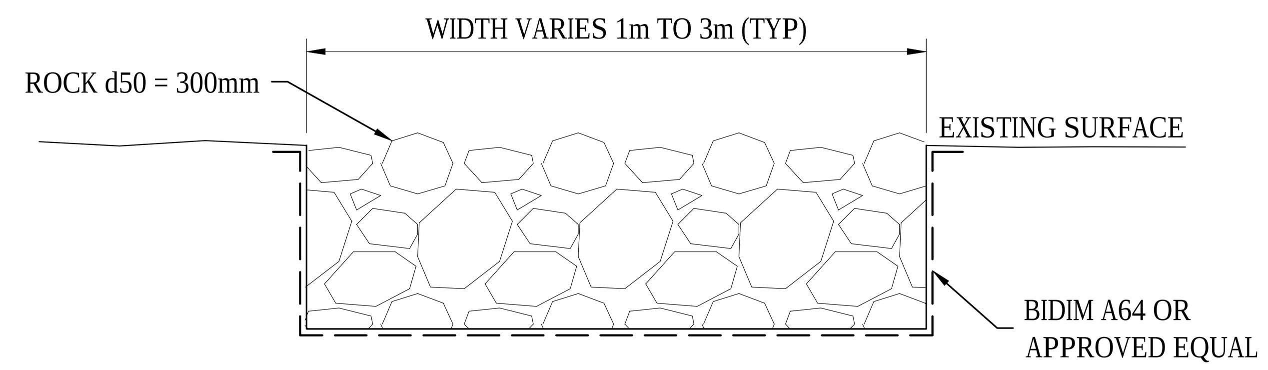
Datum	Register	Scale	Size
-	-	AS SHOWN	A1

Drawing Number: 59915194-CI-110
Revision: 1



SCOUR PROTECTION - HEADWALL A3

NTS



SECTION A -

NTS

NOTES:

1. ASSUMED ROCK SPECIFIC GRAVITY = 2.65
2. ALL ROCK TO BE HARD, DURABLE SANDSTONE

Rev.	Date	Description	Des.	Verif.	Appd.
2	23/07/15	INITIAL ISSUE	SGB	SJB	-

0 1 2 4 6 8 10m

SCALE 1:100 @A1

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		Date
Drawn	LDB	22/07/15
Checked	SGB	22/07/15
Designed	SGB	22/07/15
Verified	SJB	22/07/15
Approved	-	-

Client: AGL ENERGY LIMITED

Project: GLOUCESTER GAS PROJECT
CONCEPT DESIGN FOR HIGH FLOW DISCHARGE

Title: CONCEPT DETAILS
SHEET 2

Status: PRELIMINARY
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Drawing Number: 59915194-CI-111 Revision: 1

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Appendix D – Expected extracted water quality specification

	Analyte	Units	LOR	Flowback Water & Produced Water	
				Min	Max
Laboratory analytes	Total Suspended Solids	mg/L	5	<5	276
	DO mg/L (Field)	mg/L	-	n.d	18.3
	Redox (Field)	mV	-	-218	289.1
	pH (Field)	pH_Units	-	5.73	9.63
	Temperature (Field)	°C	-	11.6	29.32
	Electrical conductivity	µS/cm	1	4450	11349
	Total Dissolved Solids	mg/L	10	2912	8160
	Turbidity	NTU	0.1	46.7	507
	Carbonate Alkalinity as $CaCO_3$/L	mg/L	1	<1	44
	Bicarbonate Alkalinity as $CaCO_3$/L	mg/L	1	1360	5100
	Alkalinity (total) as $CaCO_3$	mg/L	1	1360	5100
	Sulphate as SO_4	mg/L	1	<1	19
	Chloride	mg/L	1	394	1570
	Calcium	mg/L	1	6	71
	Magnesium	mg/L	1	1	6
	Potassium	mg/L	1	5	27
	Sodium	mg/L	1	1090	3480
	Fluoride	mg/L	0.1	0.2	1.8
	Reactive Silica	mg/L	0.05	11.2	37.2
	Bromine	mg/L	0.1	0.3	4.2
Key parameters	Diethanolamine	µg/L	1	3	103
	Ethanolamine	µg/L	1	9	305
	Methyldiethanolamine	µg/L	1	2	40
	THPS	µg/L	50	50	440
	Boron	mg/L	0.05	0.08	22.4
	Chlorine Free (Field)	mg/L	-	nd	0.28
	Chlorine Total (Field)	mg/L	-	nd	0.34
	Nitrogen (Total)	mg/L	0.1	3.6	10
	Total Phosphorus	mg/L	0.01	0.38	5.1
Nutrients	Ammonia as N	mg/L	0.01	1.46	8.12
	Ammonium as N	mg/L	0.01	2.06	7.98
	Nitrite + Nitrate as N	mg/L	0.01	<0.01	0.2
	Kjeldahl Nitrogen Total	mg/L	0.1	3.6	10

	Analyte	Units	LOR	Flowback Water & Produced Water	
				Min	Max
	Reactive Phosphorus as P	mg/L	0.01	<0.01	0.58
	Total Organic Carbon	mg/L	1	2	1200
Dissolved metals	Aluminium	mg/L	0.01	<0.01	0.08
	Antimony	mg/L	0.001	<0.001	0.012
	Arsenic	mg/L	0.001	<0.001	0.007
	Barium	mg/L	0.001	0.227	17.6
	Beryllium	mg/L	0.001	<0.001	4.3
	Cadmium	mg/L	0.0001	<0.001	0.0004
	Chromium	mg/L	0.001	<0.001	0.038
	Cobalt	mg/L	0.001	<0.001	0.002
	Copper	mg/L	0.001	<0.001	0.017
	Iron	mg/L	0.05	0.06	42
	Lead	mg/L	0.001	<0.001	0.001
	Manganese	mg/L	0.001	0.01	0.586
	Mercury	mg/L	0.0001	<0.001	<0.0001
	Molybdenum	mg/L	0.001	0.001	0.045
	Nickel	mg/L	0.001	0.002	0.02
	Selenium	mg/L	0.01	<0.01	<0.01
	Strontium	mg/L	0.001	0.96	10.5
	Tin	mg/L	0.001	<0.001	0.002
	Uranium	mg/L	0.001	<0.001	<0.001
	Vanadium	mg/L	0.01	<0.001	<0.01
	Zinc	mg/L	0.005	0.006	0.169
Oil and Grease	Oil and Grease	mg/L	5	<5	<5
Phenols	2-methylphenol	µg/L	1	<1	13.4
	3-&4-methylphenol	µg/L	2	5.8	200
	Phenol	µg/L	1	4.2	14.9
Polycyclic aromatic hydrocarbons	PAHs (sum)	µg/L	0.5	<0.5	57.4
Total recoverable hydrocarbons	C_6 - C_{10} Fraction	µg/L	20	20	1290
	C_{10} - C_{40} Fraction (Sum)	µg/L	100	890	30300
	TRH >C_{10}-C_{16} less Naphthalene (F2)	µg/L	100	nd	310
Total petroleum hydrocarbons	C_6 - C_9 Fraction	µg/L	20	30	1240
	+C_{10} - C_{36} (Sum of total)	µg/L	50	900	25900

	Analyte	Units	LOR	Flowback Water & Produced Water	
				Min	**Max**
Aromatic hydrocarbons	Benzene	µg/L	1	3	319
	Toluene	µg/L	2	4	356
	Ethyl benzene	µg/L	2	<2	9
	Naphthalene	µg/L	5	<5	<5
	Xylene Total	µg/L	2	4	138
	Sum of BTEX	µg/L	1	15	795

Notes:

1. Modified data is from samples taken between 16/12/2014 and 6/02/2015 from AGL's Waukivory Pilot wells WK11, 12, 13 and 14 (flowback water) and samples taken between 28/06/2013 and 25/06/2014 from AGL's Waukivory 03 and Craven 06 gas wells (produced water), respectively.
2. LOR – limit of reporting.
3. nd - no data available.

Appendix E – Water monitoring program

The proposed water monitoring program is outlined in this EWMS to provide regulators and the community with confidence that extracted water (flowback water and produced water) and treated water will be adequately monitored and managed throughout the life of the Stage 1 GFDA. The monitoring program (locations, data sets and frequency) will be set for two years then reviewed annually.

CPF WTP Infrastructure

The ponds, tanks and liners and associated above ground pipework will be physically inspected on a monthly basis to assess the integrity of these structures.

Water quality monitoring is proposed at each of the following locations on a monthly/quarterly basis for a comprehensive suite of analytes:

- Receiving water pond (monthly);
- Treated water tank (monthly);
- Brine water tank (quarterly); and
- Discharge water pond (monthly).

In addition, it is proposed to place continuous salinity (EC) loggers in the:

- Receiving water pond (final cell before water is sent for pre-treatment);
- Treated water tank; and
- Discharge water pond.

Salinity measurements will be taken every hour and the loggers will have a live feed back to the CPF control room. Loggers would be checked and calibrated quarterly.

A water monitoring network (both water levels and water quality) will be installed around the new water storage infrastructure and brine storage areas that have the potential to impact on underlying groundwater resources. Even though the ponds will be double lined with seepage detection, inspection and control, additional monitoring is proposed downgradient of each of the three new water storages and downgradient of the brine storage tank. In addition, the two existing Rombo monitoring bores (RMB01 and RMB02) which are located downgradient of the proposed WTP infrastructure will be included in any PWMP.

This monitoring network will:

- Identify background perched water levels and quality in the weathered rock zone; and
- Identify background shallow groundwater levels and quality.

It is proposed that a very shallow monitoring bore (to around 6 m depth) and deeper monitoring bore (to the water table at around 30 m depth) will be constructed at each of the three main storage locations (two water ponds and the brine storage tank). There are no nearby surface water receptors so no surface water monitoring is proposed at the CPF site.

These three locations will monitor changes in water levels or water quality to ensure the integrity of site WTP infrastructure and to provide early warning of potential impacts to shallow groundwater from ponded water.

Water quality monitoring and testing for the groundwater sites will be undertaken quarterly for the first two years then reviewed annually on the basis of water level and water quality trends to assess whether water quality sampling frequencies need to change.

Groundwater monitoring will commence after construction of the WTP infrastructure but prior to the commissioning of the WTP and CPF. Some existing monitoring locations will continue as per the

Groundwater Monitoring and Modelling Plan (GMMP) (AGL, in Prep). Further details will be outlined in the PWMP.

Water gathering systems

All water gathering lines will be inspected and integrity (pressure) tested prior to being commissioned.

No monitoring is proposed for the buried water gathering pipeline network from the individual gas wells to the WTP and for the reticulation pipeline from the WTP to the Tiedman storages (apart from monthly physical inspections of the above-ground pipework at each wellhead and similar pipework at the RWP at the WTP).

Tiedman Water Storage Infrastructure

These three ponds are located at the highest point on the Tiedman property beyond the Avon River floodplain and any possibility of flooding. The ponds and liners will be physically inspected on a monthly basis to assess the integrity of these structures and associated liners.

Water quality monitoring is proposed at each of the following locations on a quarterly basis for a basic suite of analytes:

› Irrigation water pond (TSD);

› Irrigation water pond (TND); and

› Produced water storage pond (TED) – only if the storage of produced water occurred during the preceding quarter.

In addition it is proposed to place continuous salinity (EC) loggers in the two irrigation ponds. Salinity measurements will be taken every hour and the loggers will have a live feed back to the CPF control room. Loggers would be checked and calibrated quarterly.

There is already some water monitoring in place at the Tiedman water storage ponds:

› Shallow perched water monitoring bores around each of the single lined ponds (TND-TMB04 and TSD-TMB05); and

› Seepage inspection and control at the TED.

It is proposed to increase the amount of monitoring around each of these ponds to be consistent with the monitoring proposals at the CPF. A deeper monitoring bore (to the water table at around 30 m depth) will be constructed at each of the two existing locations. In addition a very shallow monitoring bore (to around 6 m depth) and deeper monitoring bore (to the water table at around 30 m depth) will be constructed adjacent to the seepage inspection area of the double lined dam (TED).

NOW recommended additional upgradient monitoring bores around the Tiedman holding ponds. It is not possible to construct any upgradient monitoring bores around these storages as the storages are located at the top of a ridgeline. AGL offers another location on the northern side of TND to monitor for any seepage losses in a northerly direction.

These four locations with eight individual monitoring bores will monitor any unusual changes in water levels or water quality to ensure the integrity of the water storage ponds and to provide early warning of any impact to shallow groundwater. There are no nearby surface water receptors so no surface water monitoring is proposed at the Tiedman water storage site.

Water quality monitoring and testing will be undertaken quarterly for the first two years then reviewed on the basis of water level and water quality trends to assess whether water quality sampling frequencies need to change for the groundwater sites.

It is expected that the proposed new sites will be constructed prior to the commissioning of the WTP and delivery of any treated water.

Monitoring Network for Irrigation Areas

AGL will carry out monitoring during irrigation to ensure that water quality thresholds for the irrigation, stock and surface water receptor are not exceeded and the reuse water quality target is being achieved. Water quality targets for treated water are set out in **Table 12.1**.

Water quality will be tested prior to release from the Discharge Water Pond (DWP) to ensure it meets the target water quality. As the water quality will be monitored closely at the WTP, it is only proposed to monitor the water quality within each of the two reuse ponds on Tiedmans. No additional monitoring of adjacent surface water or underlying groundwater receptors is proposed for the new irrigation areas. The monitoring of the existing surface water monitoring sites on the Tiedmans and Avondale properties will continue as outlined in the GMMP (AGL, in prep).

No additional water quality monitoring is proposed because the treated water is expected to be equivalent to or better than Avon River quality that others use for stock use and occasional irrigation of similar crops and pasture.

It is proposed that no catch dams or recycling of waters will be required within any of the proposed irrigation areas. The two existing catch dams around the Stage 1A irrigation area will be removed. Also no soil sampling is proposed across any of the proposed irrigation areas because:

- There is natural variability in soils across the landscape; and
- Minimal salt loads will be applied in the irrigation of treated water.

Also no nutritional or trace metal crop monitoring is proposed given the low salinity water to be applied as irrigation water.

Monitoring Discharges to Surface Waters

AGL will carry out monitoring prior to stream discharge to ensure that water quality thresholds for the surface water receptor are not exceeded and the stream discharge water quality target is being achieved. Water quality targets for treated water to be discharged to the environment (via the Avon River) are set out in **Table 12.1.**

As the water quality will be monitored closely at the RWP, it is only proposed to monitor the water quality upstream and downstream of the Avon River discharge location weekly during periods of discharge. In addition there will be continuous monitoring of salinity (EC) at both these sites. The monitoring of the existing monitoring sites on the Tiedmans and Avondale properties will continue as outlined in the broader Stage 1 Groundwater Monitoring and Modelling Plan (AGL, in prep).

The monitoring network for irrigation and discharge of treated water (comprising existing and proposed monitoring sites) is set out in **Table E.1**. Information is also provided in **Table E.1** on the water quality parameters that will be included for:

- Continuous monitoring;
- Quarterly monitoring; and
- Extra monthly monitoring (when required).

Table E.1 Monitoring network for irrigation, stock and discharge of treated water

Monitoring Site ID	Type - Location	Continuous Monitoring	Monthly Monitoring	Expected Quarterly Monitoring
Irrigation Storage Ponds (Tiedmans)				
Tiedman North (treated water)	Sampling of Water Storage Pond Water	Salinity	Physical inspection of surrounding area	Basic suite
Tiedman South (treated water)	Sampling of Water Storage Pond Water	Salinity	Physical inspection of surrounding area	Basic suite
Tiedman East (extracted water)	Sampling of Water Storage Pond Water	None	Physical inspection of surrounding area	Basic suite (only if water transferred in)
TMB04a and b	Seepage – immediately east of Tiedman North Dam	WLs - Yes WQ - No	Physical inspection of surrounding area	Physical parameters then purge dry and assess inflows on quarterly basis. If inflow within 12 hours then basic suite
TMB05a and b	Seepage – immediately south of Tiedman South Dam	WLs - Yes WQ - No	Physical inspection of surrounding area	Physical parameters then purge dry and assess inflows on a quarterly basis. If inflow within 12 hours then basic suite
TMB06a and b (new site at TND)	Seepage – immediately north of Tiedman North Dam	WLs - Yes WQ - No	Physical inspection of surrounding area	Physical parameters then purge dry and assess inflows on a quarterly basis. If inflow within 12 hours then basic suite
TMB07a and b (new site at TED)	Seepage – immediately south of Tiedman East Dam	WLs - Yes WQ - No	Physical inspection of surrounding area	Physical parameters then purge dry and assess inflows on a quarterly basis. If inflow within 12 hours then basic suite

Monitoring Site ID	Type - Location	Continuous Monitoring	Monthly Monitoring	Expected Monitoring (only when stream discharges are occurring)
Stream Discharge location (Avon River)				
Downstream Gauge	Avon River downstream of discharge site AV2 but upstream of confluence with Dog Trap Creek	WLs - Yes Salinity - Yes	None	Weekly samples taken for basic suite during discharge period
Upstream Gauge	Avon River upstream of discharge site AV2	WLs - Yes Salinity - Yes	None	Weekly samples taken for basic suite during discharge period

Monitoring Site ID	Type - Location	Continuous Monitoring	Monthly Monitoring	Monthly/Quarterly Monitoring
WTP Site and storage ponds (Rombo)				
Receiving water pond (RWP)	Sampling of Water Storage Pond Water	Salinity	Physical inspection of surrounding area	Monthly – Comprehensive suite
Treated water tank (TWT)	Sampling of Water Storage Tank Water	Salinity	Physical inspection of surrounding area	Monthly - Comprehensive suite
Discharge water pond (DWP)	Sampling of Water Storage Pond Water	Salinity	Physical inspection of surrounding area	Monthly - Comprehensive suite Weekly – Basic suite when stream discharges are proposed
Brine Storage tank (BST)	Sampling of Water Storage Pond Water	None	Physical inspection of surrounding area	Quarterly - Comprehensive suite
RMB01 and RMB02 (existing)	Shallow and intermediate groundwater	WLs - Yes WQ - No	None	Quarterly - Basic Suite
RWPa and b	Seepage – immediately downgradient of RWP	WLs - Yes WQ - No	Physical inspection of surrounding area	Physical parameters then purge dry and assess inflows on quarterly basis. If inflow within 12 hours then basic suite
TWTa and b	Seepage – immediately downgradient of TWT	WLs - Yes WQ - No	Physical inspection of surrounding area	Physical parameters then purge dry and assess inflows on quarterly basis. If inflow within 12 hours then basic suite
DWPa and b	Seepage – immediately downgradient of DWP	WLs - Yes WQ - No	Physical inspection of surrounding area	Physical parameters then purge dry and assess inflows on quarterly basis. If inflow within 12 hours then basic suite
BSTa and b	Seepage – immediately downgradient of BST	WLs - Yes WQ - No	Physical inspection of surrounding area	Physical parameters then purge dry and assess inflows on quarterly basis. If inflow within 12 hours then basic suite

Water Quality Parameters for Monitoring Program

Water samples collected at the proposed monitoring sites will be analysed for either a basic or comprehensive suite of analytes as described in **Table E.2**. The proposed parameters and analytes include the following physical parameters and laboratory analytes:

- Physical parameters:
  - pH;
  - Electrical conductivity (EC);
  - Redox (Eh);
  - Dissolved oxygen (DO); and
  - Temperature.
- Laboratory analytes:
  - Major ions;
  - Dissolved metals and trace metals;
  - Miscellaneous other analytes;
  - Nutrients;
  - Dissolved gases; and
  - Hydrocarbons.

Table E.2 Laboratory analytical suites

Category	Suites			Parameters	
	Basic	Intermediate	Comprehensive		
Check on Field Parameters				EC, pH and TDS	
Major ions				*Cations*	*Anions*
				calcium	chloride
				magnesium	carbonate
				sodium	bicarbonate
				potassium	sulphate
Dissolved metals and minor / trace elements				aluminium	lead
				arsenic	manganese
				barium	mercury
				beryllium	molybdenum
				boron	nickel
				bromide	selenium
				cadmium	strontium
				chromium	uranium
				cobalt	vanadium
				copper	zinc
				iron	
Other analytes				Fluoride	Silica
				Total organic carbon	

Category	Suites		Parameters	
Total Suspended Solids			TSS	
Nutrients			Nitrate Nitrite Ammonia	Reactive phosphorus Total phosphorus
Dissolved gases			Methane	
Hydrocarbons			Phenol compounds Polycyclic aromatic hydrocarbons (PAH)	Total petroleum hydrocarbons (TPH)/ benzene, toluene, ethyl benzene and xylenes (BTEX)