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Pike Floodplain Extraction Limit
Hydraulic Modelling Investigation

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Table of Contents

List of Figures

List of Tables

1. Introduction

The Pike anabranch complex is located on the eastern bank of the River Murray adjacent to Lock 5. The anabranch supplies water to a local irrigation community and is significantly regulated via man-made embankments and regulating structures. This regulation has resulted in an altered flow path through the anabranch compared to that under natural conditions. Effects of drought, elevated groundwater level and altered flow regime have combined to cause a significant decline in the health of the system.

The Pike Floodplain element of the Riverine Recovery Project (RRP) has been instigated to restore the health of the anabranch complex, consistent with the long term management objectives identified in the Pike Implementation Plan (Hollis et al., 2011). Planned works under this project include upgrade or replacement of existing embankments and infrastructure within the floodplain that will enable the return of flows through the anabranch towards natural conditions, facilitate fish passage and allow artificial inundation of the floodplain under controlled events while maintaining supply to the Pike irrigation community.

Additional flows to the anabranch complex for achieving ecological benefits are proposed through upgrades of inlet structures at Margaret Dowling and Deep Creek. As these additional flows will increase water volumes throughout the Pike system, importance has been placed on establishing an irrigation extraction limit in the Upper Pike River anabranch (between Margaret Dowling and Deep Creek inlets and Col Col embankment) consistent with the Pike Implementation Plan (Hollis et al., 2011). This will have multiple benefits for both the environment and the irrigation community who rely on the river system.

The following report summarises a hydraulic modelling investigation into the impact of various irrigation extraction scenarios on the hydraulic characteristics of the Pike anabranch complex under current conditions (i.e. no upgraded structures implemented). The hydraulic model used in the investigation is based on the same model used in previous investigations into the determination of a Pike extraction limit (i.e. Water Technology, 2012(a, b)), with various updates and upgrades applied to the configuration. These updates and upgrades address concerns raised by DEWNR and members of the community regarding the validity of model results in previous investigations. Similar criteria to those used for the previous investigations were also used for analysing the impact of increased extractions on the hydraulic condition of the anabranch complex. The following sections detail the model configuration, changes and updates applied to the model and the results analysis.

2. Model Summary

A detailed one-dimensional (1D) model was developed by Water Technology using the MIKE11 software package by DHI, which describes all the permanent waterways in the Pike anabranch complex and the section of the River Murray between Lock 4 (downstream) and Lock 6 (upstream). The model also includes the Chowilla Creek outlet below Lock 6, allowing model inflow to be specified at both Lock 6 and Chowilla Creek if required. This model includes all existing regulating structures, culverts and banks in the anabranch system and Lock 5 in the River Murray, incorporating modifiable operating schemes for regulating structures. Figure 1 shows the details of the model network, including bank locations.

The model includes extraction points representing the nominal irrigation areas in the floodplain that can be independently adjusted (see Figure 1 for locations) and also includes the optional "Advection-Dispersion" module in its configuration, which allows analysis of residence time in the floodplain via the specification of a tracer substance in the waterways.

Several updates and additions to the original Water Technology model were employed to ensure the latest data was used in the model (e.g. current extraction data and additional survey results), while also tailoring the configuration to the aims of the current investigation. The model was also recalibrated in order to better reflect the hydraulic characteristics of the anabranch based on actual monitored data from the State water archive and recent survey data. The following sections detail the changes implemented.

2.1 Anabranch Network

Two additional streams were added to the network that were missing from the original model setup, namely streams at Bank E and Bank F. These were included given that Bank F in particular supplies some minor flows to Tanyaca Creek under normal flow conditions. Channel cross-sections and culverts (Bank F only) were also included for each stream based on recent bank surveys that included part of the channel upstream and downstream of each bank and any culverts embedded in each bank.

2.2 Cross-sections

Stream cross-sections and culvert dimensions in the existing model were updated with the latest bank survey results, conducted as part of the detailed design process for proposed infrastructure modifications via the RRP Pike Floodplain Element.

Stability issues with the model were encountered when using the Advection-Dispersion[1] module, preventing completion of the simulation runs. These instability issues prompted some further adjustments of cross-sections. Cross-section estimates were added to the start and end of each network branch to allow minimum bed elevations to be matched at branch junctions; the original model possessed a mismatch of bed elevations at branch junctions throughout the model, which can cause model instabilities at low flow rates. Spacing of cross-sections at certain locations in the model was also found to be insufficient in comparison to the 10 second time step used – spacing was therefore increased as required. These changes significantly improved stability of the model and hence simulation outcomes.

[1] The Advection-Dispersion module enables simulation of a dissolved or suspended tracer material in the model waterways, allowing for calculation of travel time in the various reaches of the anabranch.

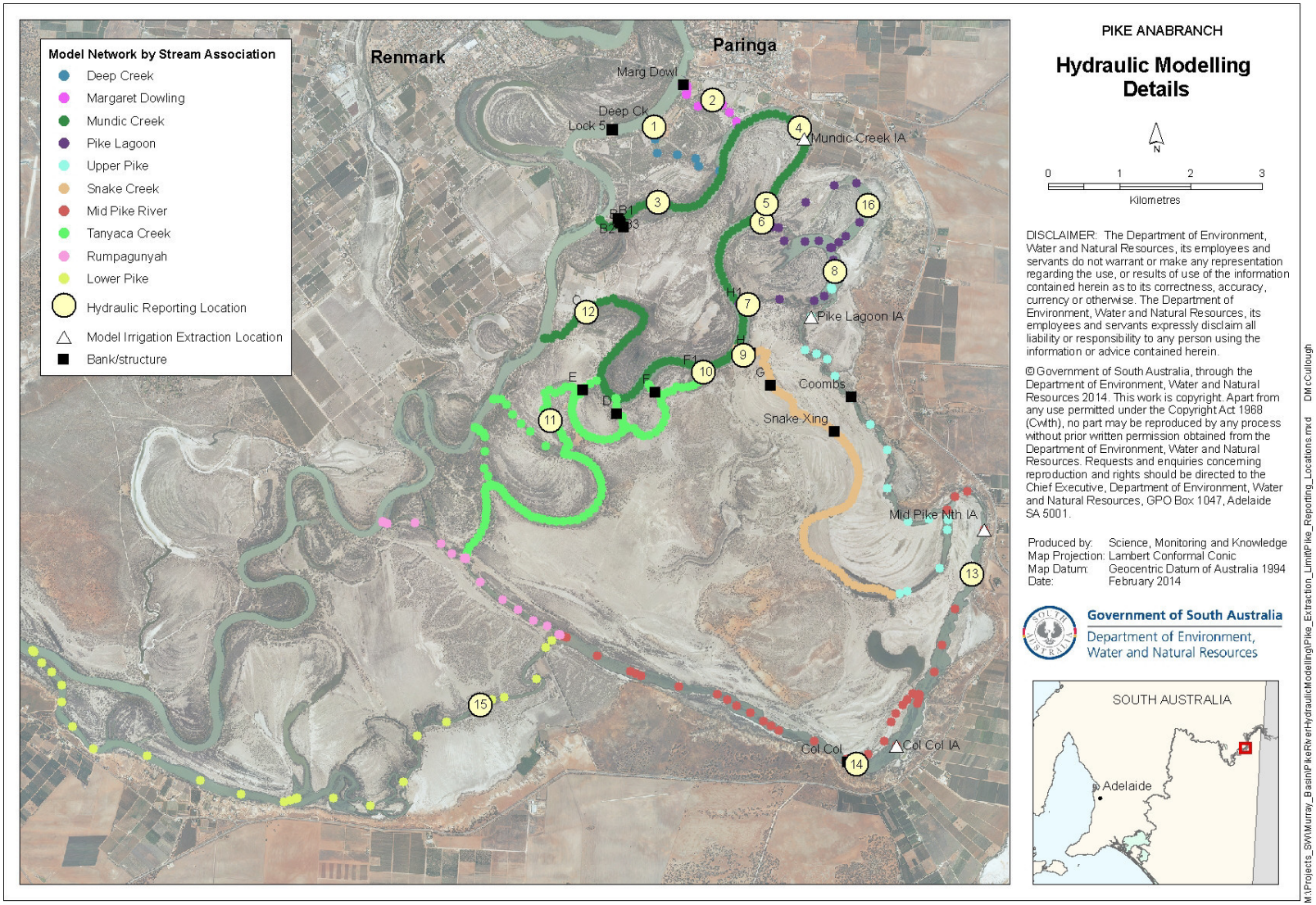

Figure 1. Hydraulic modelling details including the Pike model network by stream association, hydraulic reporting locations and modelled irrigation extraction points.

2.3 Pike Anabranch Control Structures

The original model configuration specified culvert and channel dimensions for Margaret Dowling and Deep Creeks and allowed the model to calculate the inflows based on water level in the River Murray. This resulted in discrepancies between the calculated flows and gauged flows on record, resulting in higher than average inflows to the anabranch. Control definitions were therefore added on each inlet stream to set flow to 150 ML/d (i.e. 300 ML/d total inflow), which reflects the average of gauged flows at a River Murray upper pool level of approximately 16.3 m AHD.

Furthermore, a control definition was added at Col Col embankment to maintain level at 14.35 m AHD (the original model only included a culvert structure). Setting level upstream of Col Col to 14.35 m AHD better reflects the actual mode of operation of the structure, which is manipulated regularly to control the level within the range of approximately 14.3 to 14.4 m AHD.

2.4 Model Boundary Conditions

The inflow to the model (downstream of Lock 6) in the original model configuration was set at 7000 ML/d, which does not typically correspond to Flow to South Australia (QSA) of 7000 ML/d due to system losses. The long term average of flows at Lock 5 for the month of January, at a QSA of 7000 ML/d, is approximately 5750 ML/d as indicated in Figure 2 (N.B. the long term average of all flows from January to December is slightly greater at approximately 5840 ML/d at Lock 5). Accounting for 300 ML/d flowing into the Pike anabranch complex, the model inflow boundary condition was subsequently set to 6050 ML/d to represent an average January condition. This flow was applied at Lock 6, with the Chowilla Creek inflow set to zero. For the downstream boundary condition, Lock 4 pool level of 13.2 m AHD was used.

2.5 Updating of Extraction Rates

Previous modelling conducted by Water Technology (2012a,b) was based on extractions representing 2007 licenses and 2007 licenses plus prior commitment conditions. Extraction rates were updated to reflect current figures for 2012-13, focusing on peak extraction rates for (i) current peak extractions, (ii) current full allocations, and (iii) site use approval volumes. Further intermediate extraction rates between these quantities were also calculated to increase the resolution of the analysis. Note also that only extraction rates in the Upper Pike were included in the modelling to focus on extraction limits in the area of the floodplain upstream of Col Col Embankment.

Note that a dynamic method of increasing extractions in a single modelled scenario was used by Water Technology (2012b) in the previous investigation. Using this methodology, extractions were increased through a weekly step change to allow equilibrium to be reached following each change. This method was not used for the current investigation however as it was found that one week was insufficient to attain model equilibrium (N.B. over one month was required to reach model equilibrium with the updated model configuration). It was therefore considered more practical to develop several scenarios at various extraction rates, with each scenario allowed to reach equilibrium at a constant rate of extraction.

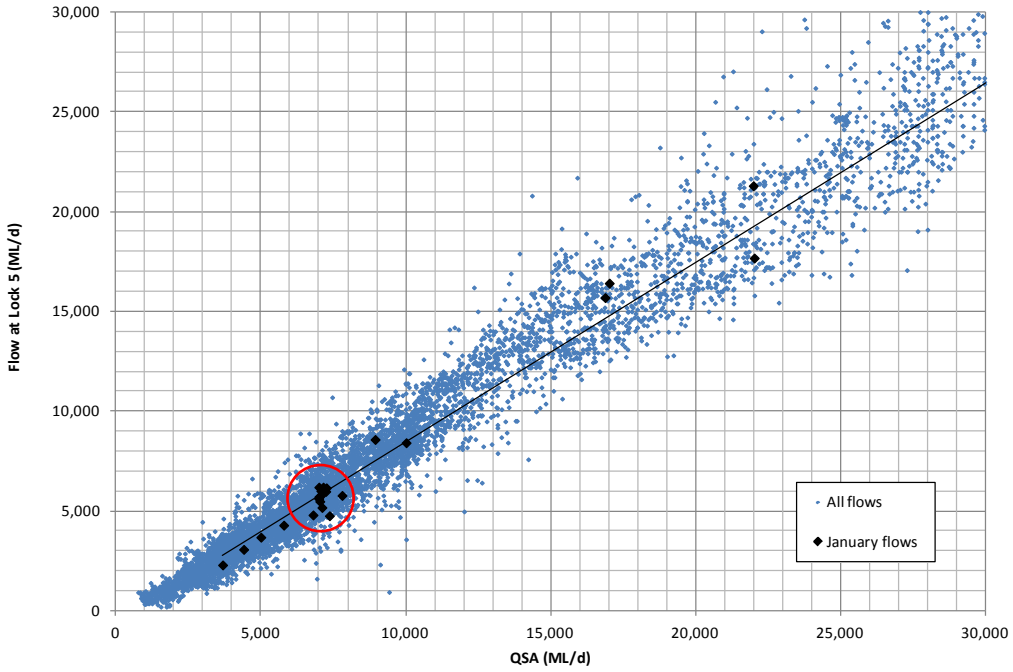

Figure 2. Flow at Lock 5 versus Flow to South Australia (QSA) for January compared to all flows (N.B. trendline corresponds to January flows only). Lock 5 flows at 7000 ML/d QSA (red circle).

2.6 Recalibration

The original model was found to significantly underestimate water levels throughout the anabranch complex under existing conditions, in particular in Mundic lagoon, which is typically maintained at a level of approximately 14.75 m AHD but was being estimated as only 14.47 m AHD in the previous investigations. River Murray water level downstream of Lock 5 was also found to be underestimated, shown as approximately 13.32 m AHD in the previous modelling results (for a flow at Lock 5 of 7000 ML/d) compared to an actual value of approximately 13.5 m AHD under Lock 5 flows corresponding to 7000 ML/d QSA.

Bed resistances were increased throughout the model in order to raise water levels to expected values, and compared against available data from surface water monitoring sites, and water level surveys. Monitoring sites referenced include:

- A4260512 & A4260513 – Lock 5 upstream (U/S) and downstream (D/S) (daily flow and water level)
- A4261079 – Deep Creek D/S of Lock 5 Road (gauged flow and water level)
- A4261080 – Margaret Dowling D/S of walking bridge (gauged flow and water level)
- A4261055 & A4261054 – Coombs Bridge U/S and D/S (continuous water level and gauged flow)
- A4261053 & A4261052 – Col Col U/S and D/S (continuous water level and gauged flow)
- RRP00111 – Rumpagunyah Creek (gauged flow and water level)
- A4260644 – Lettons (continuous water level and gauged flow)
- A4260645 – Pike outlet (continuous water level)

Gauged water level at various bank locations was also available for reference, collected in November 2004 by DEWNR Resource Monitoring Unit.

3. Model Simulations

Similar flow conditions to the previous investigations (Water Technology, 2012a,b) were used for this study, namely:

- 7000 ML/d QSA
- Lock 5 Upper Pool Level (UPL) at 16.3 m AHD
- Lock 4 UPL at 13.2 m AHD
- Col Col U/S level at 14.35 m AHD

An evaporation rate of 9.5 mm/d was also maintained for calculations as used in the original investigation, representing the mean daily evaporation rate in Loxton during January.

The following six criteria for determining the extraction limit were used for analysis of results, namely:

1. Increase in the proportion of no-flow and slow flowing habitats
2. 50 mm reduction in water level at any location
3. Water depth at critical sill must be >150 mm
4. 10% reduction of flow over Col Col
5. 10% reduction of flow in Lower Pike into River Murray
6. 10% increase in retention time (i.e. e-folding time)

The threshold listed in Criterion 1 differs from that used by Water Technology (2012a,b), which was originally stated as a 10% reduction in length of reaches exceeding 0.18 m/s. This threshold was amended to focus on the change in proportion of no-flow and slow flowing velocities after initial analysis indicated that very few of the waterways in the anabranch possessed reaches with velocities exceeding 0.18 m/s at current peak extraction rates and 7000 ML/d QSA. Note that an increase in the proportion of no-flow and slow flowing habitats is expected to increase the risk of thermal stratification and related problems (e.g. algal blooms), while also potentially reducing the diversity of flow mosaics throughout the anabranch and negatively impacting on local fish populations (AWE and Riverwater Life, 2013).

As noted in AWE and Riverwater Life (2013), the extraction limit criteria represent arbitrary thresholds, but do provide a basis for evaluating the extent of change of hydrological parameters as extractions increase. However AWE and Riverwater Life (2013) also acknowledge that "*Given the prevailing condition of the Pike Anabranch, any deterioration in key hydrological parameters is likely to cause some level of harm".*

Three main extraction scenarios were tested based on daily extraction data for 2012-13, namely:

1. Current peak extraction rates[2] (total of 68 ML/d)
2. Current full allocations (total of 77 ML/d)
3. Site use approval volumes (total of 122 ML/d)

The current peak extraction rates for 2012-13 were used as the base scenario for measuring the impact of extractions against the defined threshold criteria.

[2] Daily extraction rates were calculated using a peaking factor which relates the annual allocation to the crop requirement during a peak period. Details of the methodology are provided in AWE (2008).

As noted above, extractions were only applied to the section of the Pike anabranch system upstream of Col Col embankment in order to focus on the effects of irrigation extractions in this area. The same locations as used in the previous investigations (minus locations downstream of Col Col) were used, with extraction points representing the following nominal irrigation areas:

- Mundic Creek Irrigation Area
- Pike Lagoon Irrigation Area
- Mid-Pike North Irrigation Area
- Col Col Irrigation Area

Table 1 indicates the extraction rates from each irrigation area per extraction scenario, while Figure 1 shows the location of each irrigation area. Note that the extraction rates between current full allocations and site use approval volumes were calculated from a linear interpolation between these two quantities, enabling the analysis to be conducted at a greater resolution.

Table 1. Current peak extraction, current full allocation and site use approval volumes for Upper Pike irrigation areas. (N.B. Intermediate extraction rates are based on linear interpolation between current allocation and site use approval rates.)

Extraction Rate Scenario	Mundic ML/d	Pike Lagoon ML/d	Mid Pike North ML/d	Col Col ML/d	Total ML/d
Current peak extraction – 68 ML/d	11.8	8.8	0.9	46.7	68.1
Current full allocation – 77 ML/d	15.0	11.3	1.6	48.6	76.6
Calculated – 86 ML/d	19.5	13.8	1.8	50.6	85.7
Calculated – 95 ML/d	23.9	16.2	2.0	52.6	94.8
Calculated – 104 ML/d	28.4	18.7	2.3	54.6	103.9
Calculated – 113 ML/d	32.8	21.1	2.5	56.6	113.0
Site Use Approval – 122 ML/d	37.3	23.6	2.7	58.5	122.1

3.1 Threshold Analysis

For Criterion 1, velocity at each node in the model network was categorised in several velocity classes, with the length of stream calculated by summing the branch chainages falling within each velocity category. Velocity categories used were the same as that used in the previous investigations, namely:

- No flow: 0 m/s
- Very slow flow: 0–0.03 m/s
- Slow flow: 0.04–0.10 m/s
- Slow-moderate flow: 0.11–0.17 m/s
- Moderate flow: 0.18–0.30 m/s
- Moderate-fast flow: 0.31–0.50 m/s
- Fast flow: >0.50 m/s

Each of the network branches in the model were consolidated under the various creek names as shown in Figure 1.

Criteria 2, 4 and 5 were based on the steady state outputs of water levels, velocities and discharges as extracted from the results at the reporting locations shown in Figure 1. The reporting locations used were identical to those used in the previous investigations for consistency.

For Criterion 3, depths were determined throughout the anabranch for each extraction scenario as per previous investigations (Water Technology, 2012a,b) by calculating the difference between minimum bed level and water level in the applicable 1D cross-section. These depths were then used to identify locations at which water levels existed below 150 mm, which were subsequently assessed as to whether these reduced depths represented "critical sills" in the anabranch (i.e. defined as the minimum depth in a given reach, representing a potential barrier to fish passage).

For Criterion 6, residence time of water in the floodplain was assessed using 'e-folding' times, which are used to measure "*the time interval taken for a certain volume of water on the floodplain to be exchanged with new water. The e-folding time is defined as the time interval in which an initial quantity decays to 1/e or 36% of its initial value*" (Water Technology, 2012b). An initial concentration of tracer substance was embedded into the model at all locations in the anabranch (not including the River Murray), and e-folding time was assessed as 36% of the initial concentration.

4. Results

4.1 Criterion 1: Increase in the Proportion of No-Flow and Slow Flowing Habitats

Figure 3 shows the velocity distribution throughout the floodplain for current peak extraction rates, while Figure 4 indicates the velocity distribution under full site use approval volume. Faster flowing reaches in the anabranch exceeding 0.18 m/s are limited to the inlets (Margaret Dowling and Deep Creek), at banks or structures (due to flow restrictions) and a relatively short length of creek at the top of the Mid Pike River Reach (for the current peak extraction scenario).

Velocities between current peak extraction rates and full site use approvals are observed to reduce predominantly in Upper and Mid Pike River Reach areas and in Tanyaca Creek (downstream of Banks E, D, F and F1). This effect can be attributed to the reduction in Mundic Creek water level as extractions increase, thereby decreasing the rate of discharge through the outlets. Conversely, velocities are observed to increase in Rumpagunyah Creek, which is a result of reduced flow over Col Col creating a steeper flow gradient from the River Murray through Rumpagunyah Creek.

Plots of the reach length per velocity category for each extraction rate tested are shown in Figure 5 to Figure 8. Tabulated data indicating length of creek in each area for the entire floodplain is shown in Appendix 1 for reference.

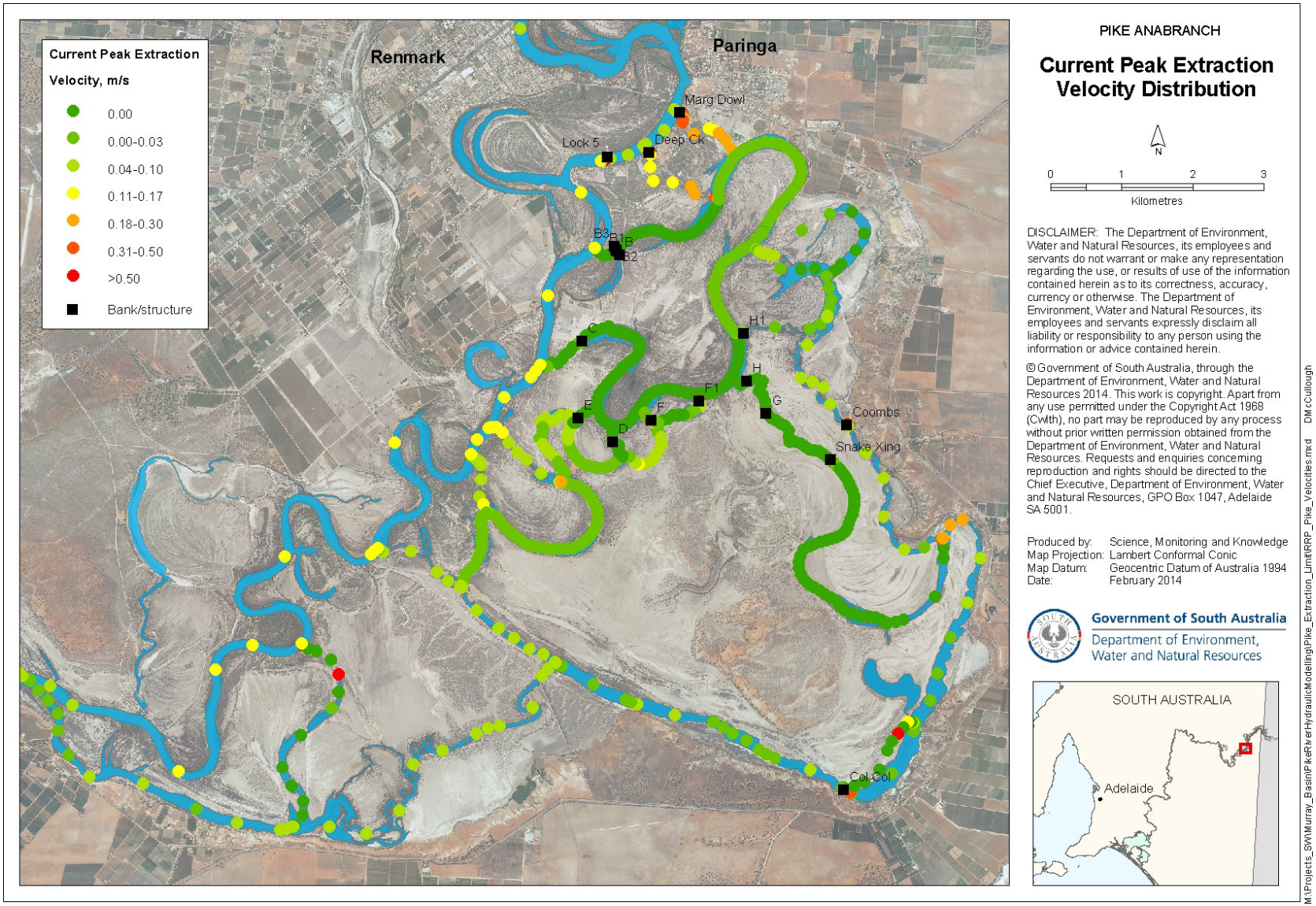

Figure 3. Velocity distribution at current peak extraction rates.

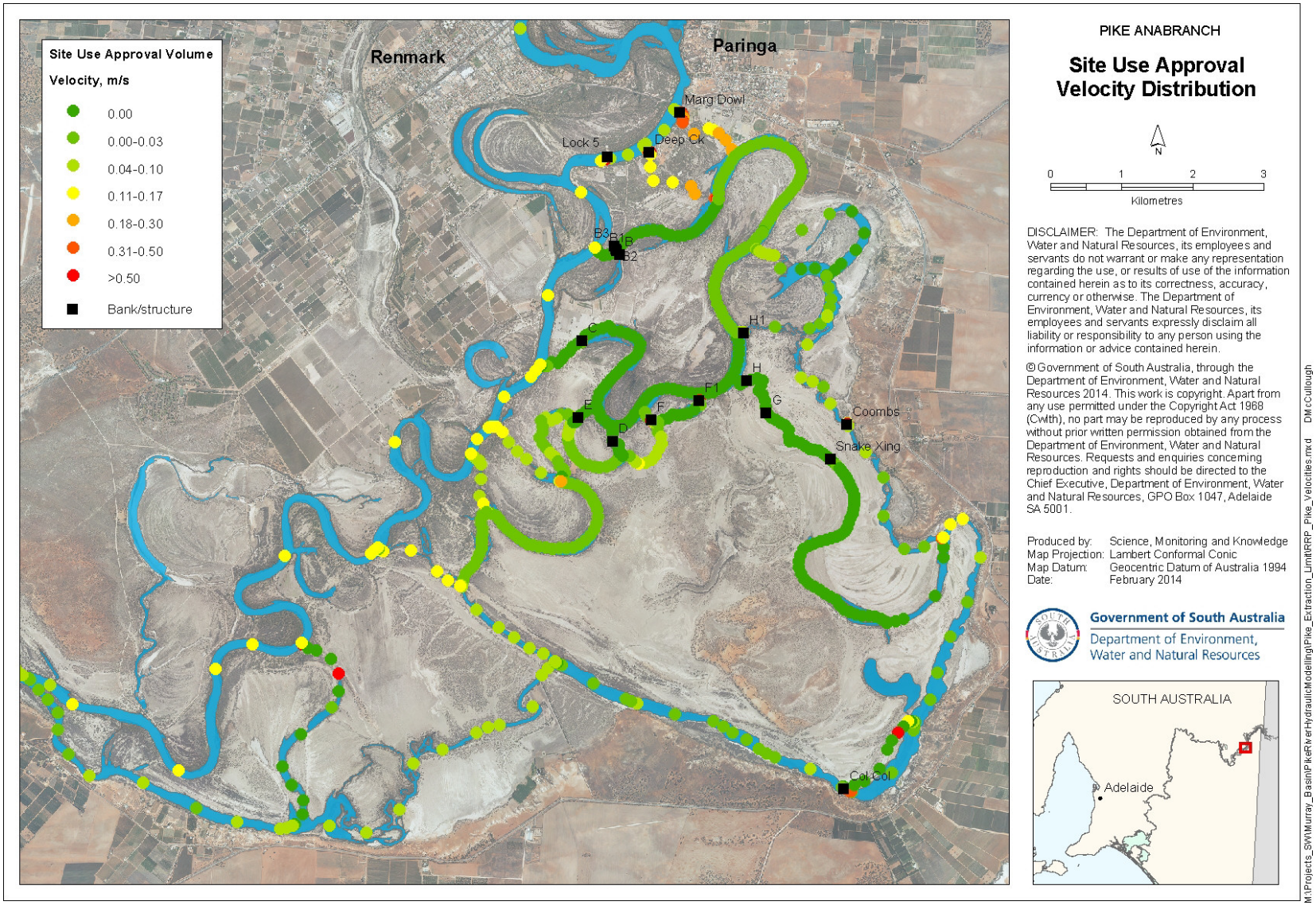

Figure 4. Velocity distribution at full Site Use Approval volume extraction rates.

Tanyaca Creek (Figure 5) shows that as extraction rate increases, the length of stream in the no flow to very slow flow categories (0 to 0.03 m/s) increases, while the length of reach in the slow flow category (0.04 to 0.10 m/s) concurrently decreases. These changes begin to occur from an extraction rate of approximately 86 ML/d.

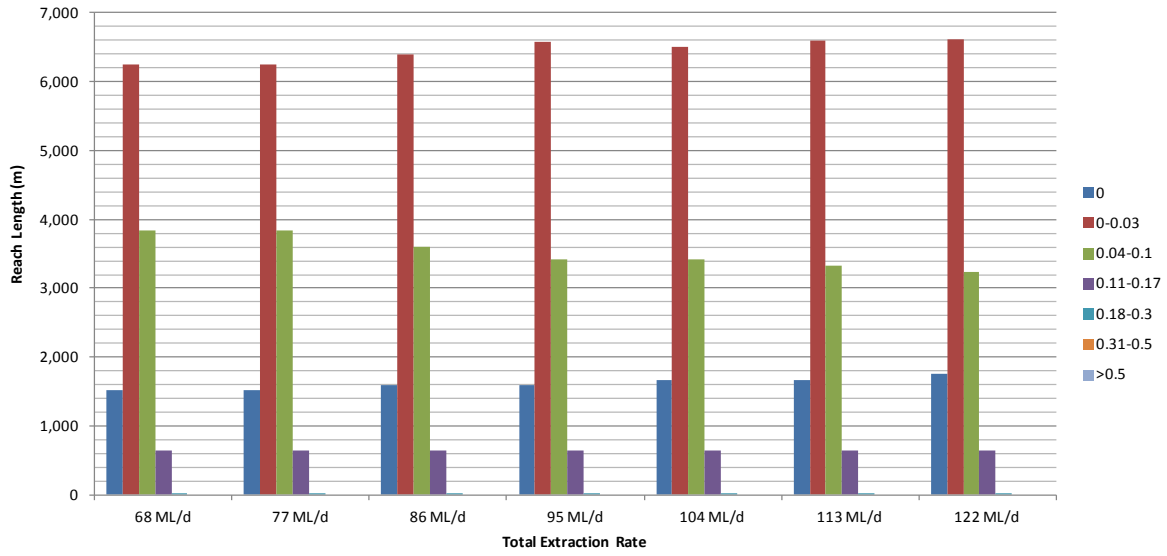

Figure 5. Tanyaca Creek, length of reach by velocity category for each extraction rate simulated

The Mid Pike River velocity distribution (Figure 6), which includes the reach of river between Col Col and the Rumpagunyah Creek junction, shows stream length in the moderate velocity category (0.18 to 0.30 m/s) decreasing at the 86 ML/d total extraction rate, corresponding to an increase in stream length under the slow to moderate flow category (0.11 to 0.17 m/s). Length of stream in the very slow to no velocity categories increases at the 95 ML/d total extraction rate, while the length of creek at the slow flow velocity category (0.04 to 0.10 m/s) correspondingly decreases. Note that reach length identified under the moderate to fast flow category (0.31 to 0.50 m/s) in the plot can primarily be attributed to velocities through the Col Col Bank structure.

In the Upper Pike River (Figure 7), stream length in the slow flow category begins to decrease from an extraction rate of approximately 86 ML/d, while creek length correspondingly increases in the very slow flow category. Stream length in the other categories remain constant up to the full site use approval volume, indicating the velocities are generally moving from slow to very slow flow categories above the current full allocation extraction rate.

Rumpagunyah Creek (Figure 8) is shown to fall predominantly in the slow to moderate categories, with velocities gradually increasing as velocities fall within the Mid Pike River area. As these are increasing velocities, no threshold is reached in this creek. Note that the increasing velocity in the Rumpagunyah reach appears to be countering the decrease in flow velocities in Mid Pike River and therefore contributes to a largely unchanged velocity profile in the Lower Pike region with increasing extractions (N.B. no extraction rates are applied in the Lower Pike region for any of the current scenarios and so decreases in velocities due to extractions in this area are not considered for this analysis).

Overall, the main increases in length of stream in slow to no flow velocity categories throughout the floodplain appear to occur once extractions exceed the current full allocation extraction rate (i.e. 77 ML/d).

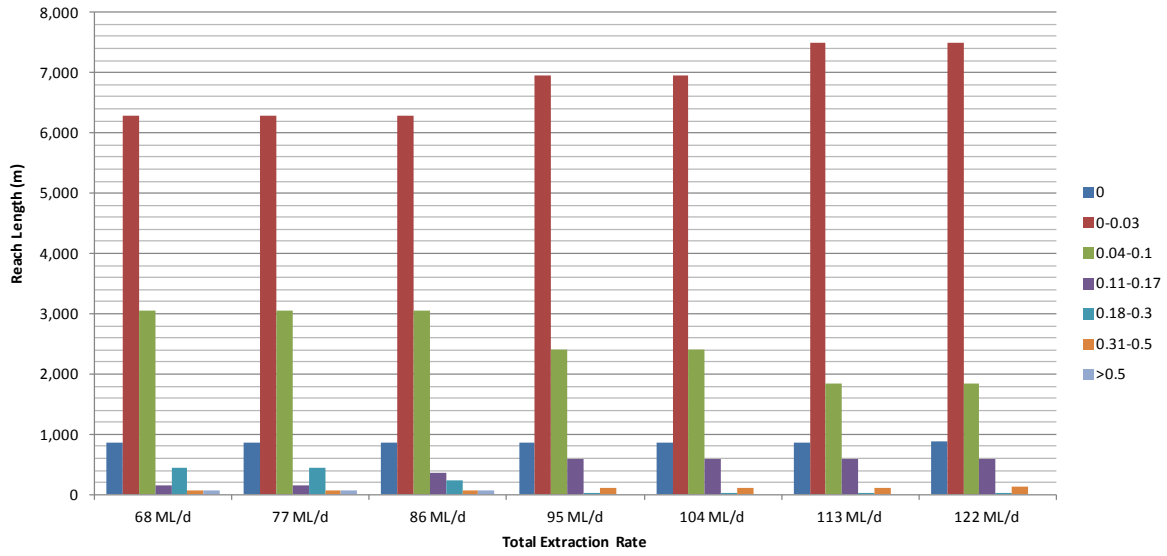

Figure 6. Mid Pike River, length of reach by velocity category for each extraction rate simulated

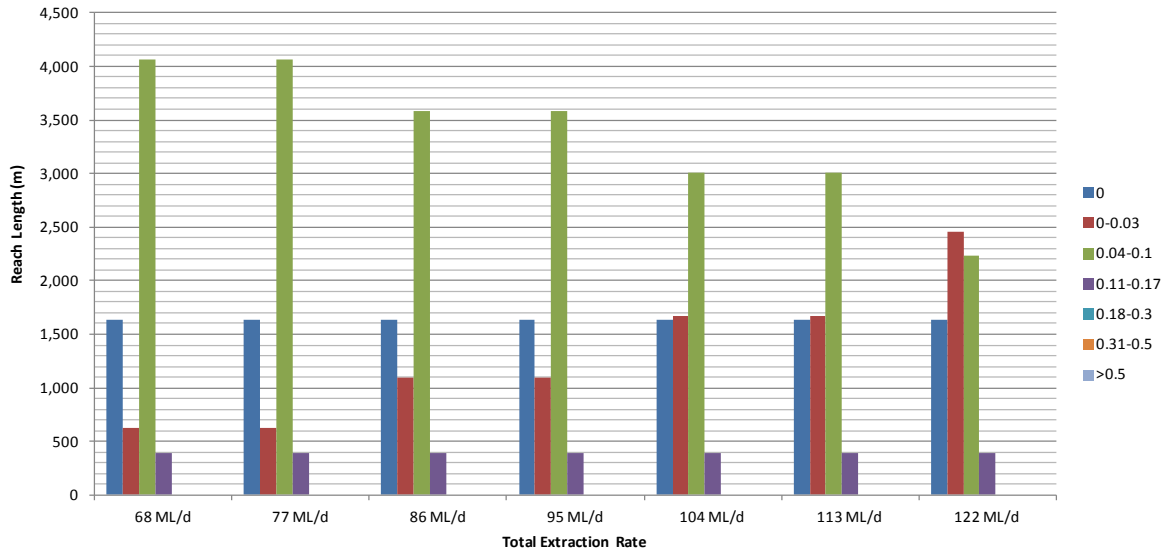

Figure 7. Upper Pike River, length of reach by velocity category for each extraction rate simulated

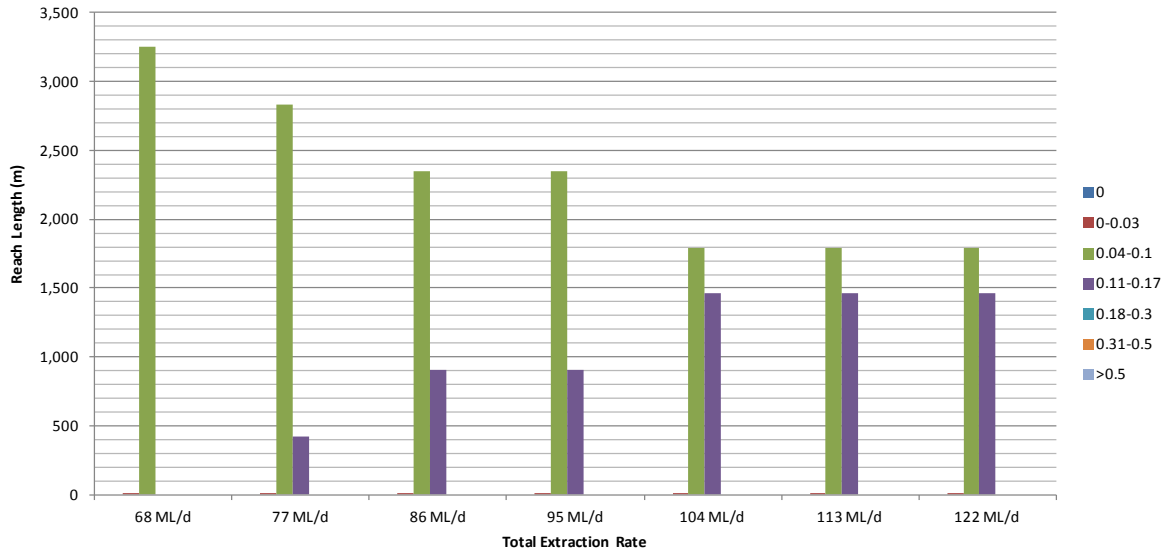

Figure 8. Rumpagunyah Creek, length of reach by velocity category for each extraction rate simulated

4.2 Criterion 2: 50 mm reduction in water level at any location

Water levels at the various reporting locations are shown in Table 2 and Table 3. The results indicate that the majority of reporting locations in the Upper Pike area show a gradual decrease in water level with increasing extraction rates.

The 50 mm reduction in water level threshold is reached in Mundic Lagoon and the Upper and Mid Pike River at a total extraction rate of approximately 113 ML/d. Note that locations in Tanyaca Creek show little to no significant decrease in level up to the full Site Use Approval volume.

4.3 Criterion 3: Water depth at critical sill must be >150 mm

Depths throughout the anabranch for all extraction scenarios tested were calculated in order to identify areas of concern as extraction rates increase. Maps indicating depths at current peak extraction rates, and at full site use approval volumes, are shown in Figure 9 and Figure 10, respectively. Depths less than 150 mm are shown to be predominantly contained in sections of Snake Creek and Tanyaca Creek (N.B. zero depth is indicated on the maps in the bypass directly upstream of Col Col and in the section of stream directly upstream of the Pike outlet). The only reduction in stream depths below 150 mm, from current to full site use approval extraction rates, is observed at a single point directly downstream of Bank F1. As this location is not considered a critical sill in the anabranch as no fish passage is currently possible through this bank, the Criterion 3 threshold can be assumed as not being exceeded for the extraction scenarios tested.

Table 2. Water level (h), discharge (Q) and velocity (v) for selected reporting locations from total current extraction rate (68 ML/d) to calculated extraction rate (95 ML/d total).

		Current Extractions - 68 ML/d			Current Allocations - 77 ML/d			Calculated - 86 ML/d			Calculated - 95 ML/d		
		h m AHD	Q ML/d	v m/s	h m AHD	Q ML/d	v m/s	h m AHD	Q ML/d	v m/s	h m AHD	Q ML/d	v m/s
1	Deep Creek	15.35	150	0.15	15.35	150	0.15	15.35	150	0.15	15.35	150	0.15
2	Margaret Dowling	14.90	150	0.13	14.89	150	0.13	14.89	150	0.13	14.88	150	0.13
3	Mundic Lagoon - Bank B	14.70	0	0.00	14.69	0	0.00	14.68	0	0.00	14.67	0	0.00
4	Mundic Lagoon	14.70	295	0.02	14.69	295	0.02	14.68	295	0.02	14.67	295	0.02
5	Mundic Lagoon Outlet 1	14.70	19	0.00	14.69	19	0.00	14.68	18	0.00	14.67	17	0.00
6	Mundic Lagoon Outlet 2	14.70	110	0.03	14.69	109	0.03	14.68	108	0.03	14.67	106	0.03
7	Mundic Lagoon Outlet 3	14.69	121	0.06	14.68	120	0.06	14.67	118	0.06	14.66	116	0.06
8	Upper Pike River	14.67	125	0.01	14.66	123	0.01	14.65	121	0.01	14.64	119	0.01
9	Snake Creek - Bank G	14.70	0	0.00	14.69	0	0.00	14.68	0	0.00	14.67	0	0.00
10	Tanyaca Creek - Bank F1	14.70	1	0.00	14.69	1	0.00	14.68	1	0.00	14.67	1	0.00
11	Tanyaca Ck u/s of Tanyaca Lagoon	13.32	16	0.04	13.32	16	0.04	13.31	15	0.04	13.31	15	0.04
12	Mundic Lagoon - Bank C	14.70	3	0.00	14.69	3	0.00	14.68	2	0.00	14.67	2	0.00
13	Pike River	14.35	228	0.04	14.35	222	0.04	14.35	216	0.04	14.35	210	0.03
14	Pike River	14.35	177	0.02	14.35	169	0.02	14.35	161	0.02	14.35	152[a]	0.02
15	Lower Pike River	13.27	615	0.05	13.28	617	0.05	13.28	609	0.05	13.27	602	0.05
16	Northern Pike Lagoon	14.67	18	0.00	14.66	17	0.00	14.65	17	0.00	14.64	16	0.00

[a] Exceeds 10% reduction in flow over Col Col from the base scenario.

Table 3. Water level (h), discharge (Q) and velocity (v) for selected reporting locations from calculated extraction rate (104 ML/d total) to full site use approval volume (122 ML/d total).

		Calculated - 104 ML/d			Calculated - 113 ML/d			SUA - 122 ML/d		
		h m AHD	Q ML/d	v m/s	h m AHD	Q ML/d	v m/s	h m AHD	Q ML/d	v m/s
1	Deep Creek	15.35	150	0.15	15.35	150	0.15	15.35	150	0.15
2	Margaret Dowling	14.88	150	0.13	14.87	150	0.13	14.87	150	0.13
3	Mundic Lagoon - Bank B	14.66	0	0.00	14.65[b]	0	0.00	14.64	0	0.00
4	Mundic Lagoon	14.66	295	0.02	14.65[b]	295	0.02	14.64	295	0.02
5	Mundic Lagoon Outlet 1	14.66	17	0.00	14.65[b]	16	0.00	14.64	15	0.00
6	Mundic Lagoon Outlet 2	14.66	105	0.03	14.65[b]	103	0.03	14.63	102	0.03
7	Mundic Lagoon Outlet 3	14.65	115	0.06	14.64[b]	113	0.06	14.63	112	0.06
8	Upper Pike River	14.63	117	0.01	14.62[b]	114	0.01	14.60	112	0.01
9	Snake Creek - Bank G	14.66	0	0.00	14.65[b]	0	0.00	14.64	0	0.00
10	Tanyaca Creek - Bank F1	14.66	1	0.00	14.65[b]	0	0.00	14.64	0	0.00
11	Tanyaca Ck u/s of Tanyaca Lagoon	13.31	14	0.04	13.31	14	0.04	13.31	14	0.03
12	Mundic Lagoon - Bank C	14.66	2	0.00	14.65[b]	2	0.00	14.64	2	0.00
13	Pike River	14.35	203	0.03	14.35	197	0.03	14.35	190	0.03
14	Pike River	14.35	143	0.02	14.35	135	0.02	14.35	127	0.01
15	Lower Pike River	13.27	594	0.05	13.27	587	0.05	13.27	579	0.04
16	Northern Pike Lagoon	14.63	15	0.00	14.62[b]	15	0.00	14.60	14	0.00

[b] Attainment of threshold as per Criterion 2 (i.e. 50 mm decrease in water level from current peak extraction rate).

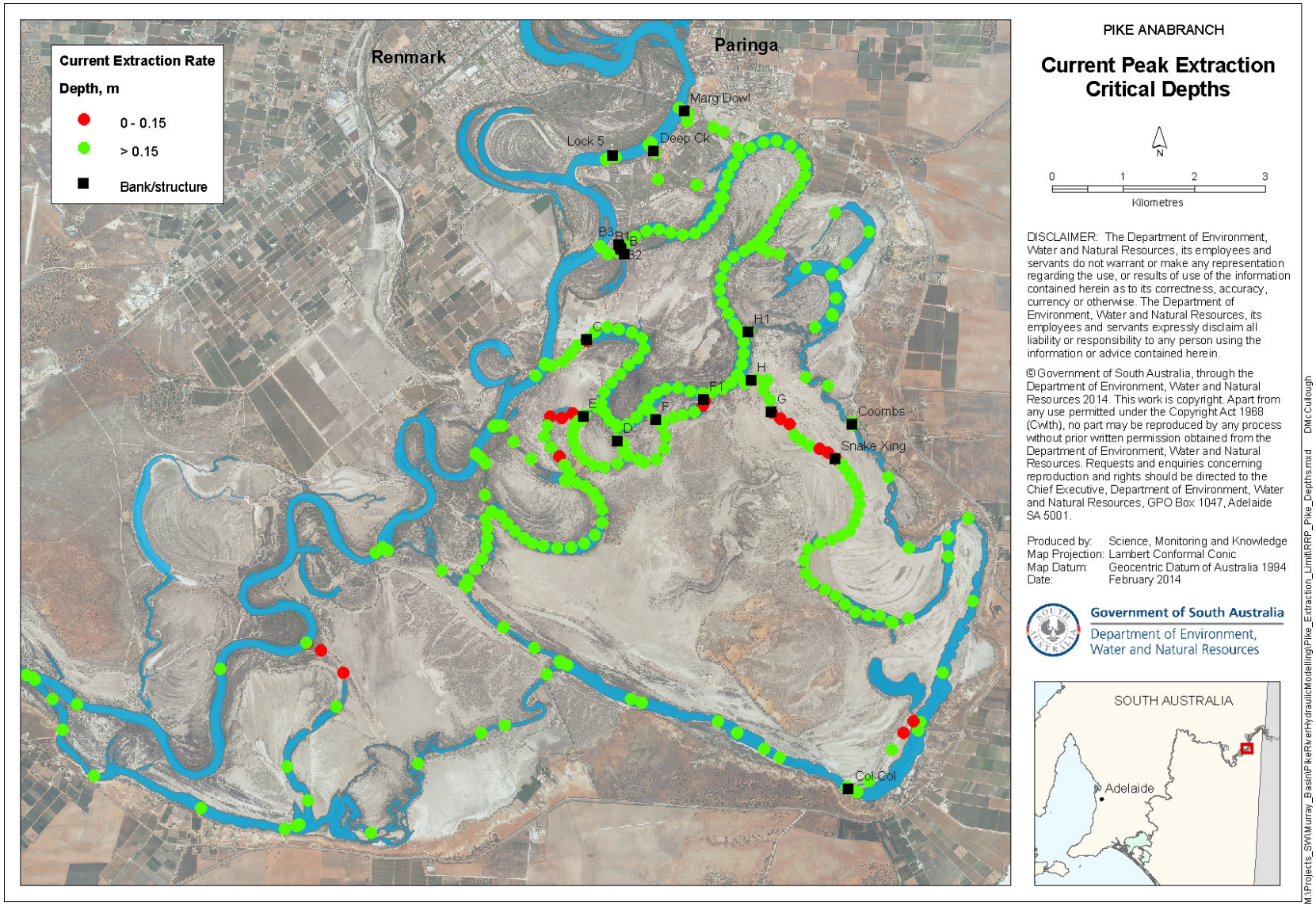

Figure 9. Depths in Pike anabranch at current peak extraction rates.

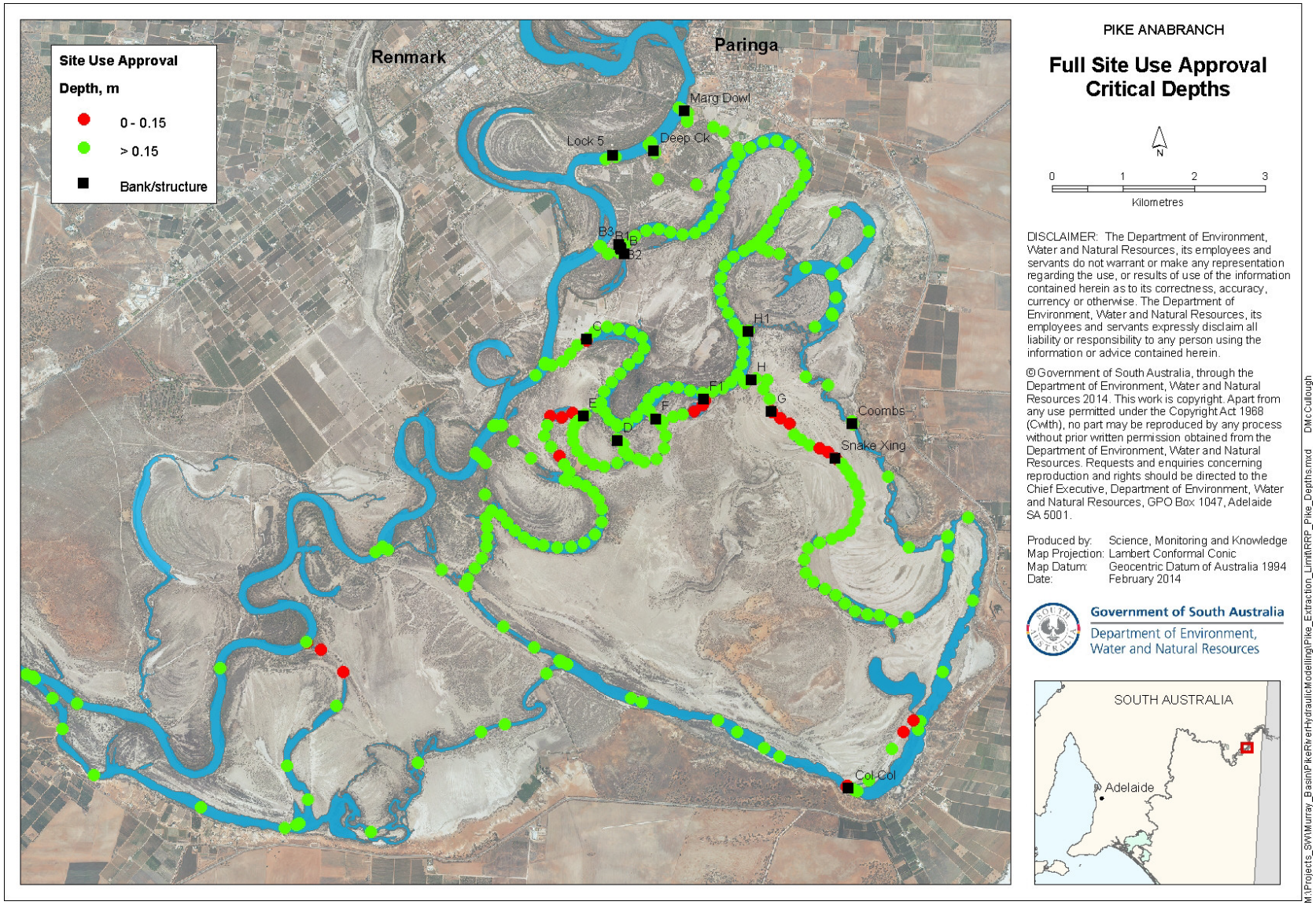

Figure 10. Depths in Pike anabranch at full Site Use Approval volume.

4.4 Criterion 4: 10% reduction of flow over Col Col

Referring to Table 2 and Table 3, the modelled flow over Col Col at current extraction rates (2012-13) is approximately 177 ML/d, indicating that a flow of approximately 159 ML/d will be equivalent to the threshold of 10% reduction in flow over Col Col. This flow reduction is encountered at total extraction rates exceeding approximately 86 ML/d.

4.5 Criterion 5: 10% reduction of flow in Lower Pike into the River Murray

Flow in the Lower Pike at reporting location 15 is modelled at 615 ML/d under current peak extraction rates. Note that this flow is comparable to actual gauged flows at Lettons gauging site (A4260644) conducted during a QSA of approximately 7000 ML/d, providing additional confidence in the model calibration in the Lower Pike area. This flow results in a threshold value of flow at this location of approximately 553 ML/d, while the lowest flow rate reached is 579 ML/d at the full site use approval volume – therefore, Criterion 5 is not met within the extraction rates examined.

4.6 Criterion 6: 10% increase in retention time

As per the previous investigations, e-folding times are used to assess the retention time in the system at the various reporting locations based on a quantity of artificial tracer injected in the system. Tabulated results of e-folding time (in days) at each reporting location for all extraction scenarios are shown in Table 4. Percentage change in e-folding time from the current peak extraction scenario is also shown in Table 5.

Tracer quantity at Margaret Dowling (2) and Deep Creek (1) reporting locations reduces to zero within the first two hours of model run time owing to the relatively rapid velocities in each creek. Tracer quantities upstream of Bank B Complex (3) and Bank C (12) also do not reduce from initial conditions due to negligible flow over each bank and hence do not produce an e-folding time over the duration of the model run length.

The threshold of 10% increase in retention time is observed to be only exceeded in the Tanyaca Creek section of the anabranch. Retention time directly downstream of Bank F1 (10) shows a 10% increase from the base scenario as the total extraction rate reaches approximately 100 ML/d. The residence time through Tanyaca Creek (11) is also found to increase by over 10% as total extractions reach approximately 110 ML/d.

Residence time directly upstream of Col Col (14) is seen to approach the threshold of 10% increase at the full site use approval extraction rate, increasing over the base scenario by approximately 9.3%.

Table 4. e-folding times (in days) at reporting locations (Figure 2) for various extraction rate scenarios.

Extraction rate scenarios	e-folding time (days) at reporting locations															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Current peak extraction – 68 ML/d	<0.08	<0.08	N/A	1.6	2.8	3.1	6.3	6.1	25.2	22.0	33.6	N/A	8.5	10.8	5.3	6.4
Current full allocation – 77 ML/d	<0.08	<0.08	N/A	1.6	2.8	3.1	6.4	6.1	25.4	22.5	34.1	N/A	8.6	10.9	5.2	6.4
Interpolated – 86 ML/d	<0.08	<0.08	N/A	1.6	2.8	3.1	6.4	6.1	25.7	23.2	34.7	N/A	8.7	11.1	5.2	6.5
Interpolated – 95 ML/d	<0.08	<0.08	N/A	1.6	2.8	3.1	6.5	6.1	26.0	23.9	35.5	N/A	8.7	11.2	5.1	6.6
Interpolated – 104 ML/d	<0.08	<0.08	N/A	1.6	2.8	3.1	6.6	6.2	26.3	24.7	36.2	N/A	8.8	11.4	5.1	6.7
Interpolated – 113 ML/d	<0.08	<0.08	N/A	1.6	2.8	3.1	6.6	6.2	26.6	25.8	37.0	N/A	8.9	11.6	5.0	6.7
Site Use Approval – 122 ML/d	<0.08	<0.08	N/A	1.6	2.8	3.1	6.7	6.2	27.0	27.2	37.8	N/A	9.0	11.8	5.0	6.7

Table 5. Percent change in e-folding time from current peak extraction rate scenario at reporting locations (Figure 2).

Extraction rate scenarios	e-folding time (days) at reporting locations															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Current full allocation – 77 ML/d	0.0	0.0	N/A	0.0	0.0	0.0	1.3	0.0	1.0	2.3	1.5	N/A	1.0	1.6	-3.1	0.0
Interpolated – 86 ML/d	0.0	0.0	N/A	0.0	0.0	0.0	1.3	0.0	2.0	5.3	3.5	N/A	2.0	3.1	-3.1	1.3
Interpolated – 95 ML/d	0.0	0.0	N/A	0.0	0.0	0.0	2.6	0.0	3.3	8.7	5.7	N/A	2.9	3.9	-4.7	2.6
Interpolated – 104 ML/d	0.0	0.0	N/A	0.0	0.0	0.0	3.9	1.4	4.6	12.5	7.7	N/A	3.9	6.2	-4.7	3.9
Interpolated – 113 ML/d	0.0	0.0	N/A	0.0	0.0	0.0	3.9	1.4	5.6	17.4	10.2	N/A	4.9	7.8	-6.2	3.9
Site Use Approval – 122 ML/d	0.0	0.0	N/A	0.0	0.0	0.0	5.3	1.4	7.3	23.5	12.7	N/A	5.9	9.3	-6.2	5.2

4.7 Summary of Thresholds

Table 6 shows a summary of the extraction rate for each criterion at which the specified threshold is exceeded. The results indicate that exceedance of thresholds begins to occur from a total extraction rate of approximately 86 ML/d upstream of Col Col embankment.

Table 6. Extraction rates for each criterion, beyond which the threshold is exceeded.

Criterion	Extraction rate at threshold exceedance and applicable reach locations
1 – Increase in the proportion of no-flow and slow flowing habitats	86 ML/d (Upper Pike River, Mid Pike River and Tanyaca Creek) N.B. represents start of increase in reach lengths towards slow flow categories
2 – Reduction in water level >50 mm	113 ML/d (Mundic Creek, Pike Lagoon, Upper Pike, Snake Creek, Tanyaca)
3 – Reduction of depth at sills <150 mm	N/A
4 – 10% reduction of flow over Col Col	86 ML/d
5 – 10% reduction of flow in Lower Pike into the River Murray	N/A
6 – 10% increase in retention time	110 ML/d in Tanyaca Creek (100 ML/d directly downstream of Bank F1)

5. Conclusions

- Observing velocity changes throughout the anabranch, the length of stream in Tanyaca Creek and Upper Pike River at very slow to no flow categories begins to increase at an extraction rate of approximately 86 ML/d, with a corresponding decrease in length of reach in the slow to moderate velocity category. A similar increase in length of slow to no flow reaches to the detriment of higher velocity reaches is observed in the Mid Pike area of the anabranch, occurring above a total extraction rate of 86 ML/d.
- A reduction of 50 mm in water level from the base scenario is observed in the Mundic Creek and Upper Pike area of the anabranch at total extraction rates of 113 ML/d. Note however that any increase of total extraction rate from current extractions results in a corresponding decrease of water level in the majority of reporting locations within the anabranch. Note also that no reduction of depths at critical sills below 150 mm (compared to the base scenario) is observed.
- Flow over Col Col reduces by 10% of the base scenario as total extraction rates increase above 86 ML/d. Flow through Lower Pike however only reduces by approximately 6% of the base case and therefore does not exceed the 10% flow reduction threshold.
- Residence time in Tanyaca Creek is seen to increase above 10% from the base scenario, exceeding the threshold at approximately 100 ML/d extractions directly downstream of Bank F1 and at 110 ML/d extractions for total Tanyaca Creek flow.
- Overall, the hydraulic characteristics of the anabranch exceed the defined thresholds at total extraction rates upstream of Col Col of approximately 86 ML/d and above.

6. References

Australian Water Environments, 2008, *Pike River Water Supply Assessment of the Impact of Increased Irrigation Extraction*, prepared for Department of Water, Land and Biodiversity Conservation.

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Appendix 1 – Channel length per flow velocity category for different extraction rates

Table 7. Margaret Dowling length of channel per velocity category

Velocity Category	Current Extraction 68 ML/d total	Current Allocation 77 ML/d total	Intermediate 86 ML/d total	Intermediate 95 ML/d total	Intermediate 104 ML/d total	Intermediate 113 ML/d total	SUA 122 ML/d total
m/s	Length (m)	Length (m)	Length (m)	Length (m)	Length (m)	Length (m)	Length (m)
0	0	0	0	0	0	0	0
0-0.03	0	0	0	0	0	0	0
0.04-0.1	0	0	0	0	0	0	0
0.11-0.17	345	345	345	345	345	345	345
0.18-0.3	889	889	889	889	889	889	889
0.31-0.5	63	63	63	63	63	63	63
>0.5	31	31	31	31	31	31	31
Total	1328	1328	1328	1328	1328	1328	1328

Table 8. Deep Creek length of channel per velocity category

Velocity Category	Current Extraction 68 ML/d total	Current Allocation 77 ML/d total	Intermediate 86 ML/d total	Intermediate 95 ML/d total	Intermediate 104 ML/d total	Intermediate 113 ML/d total	SUA 122 ML/d total
m/s	Length (m)	Length (m)	Length (m)	Length (m)	Length (m)	Length (m)	Length (m)
0	0	0	0	0	0	0	0
0-0.03	0	0	0	0	0	0	0
0.04-0.1	8	8	8	8	8	8	8
0.11-0.17	949	949	949	949	949	949	949
0.18-0.3	782	782	782	782	782	782	782
0.31-0.5	379	379	379	379	379	379	364
>0.5	29	29	29	29	29	29	44
Total	2147	2147	2147	2147	2147	2147	2147

Table 9. Mundic Lagoon length of channel per velocity category

Velocity Category	Current Extraction 68 ML/d total	Current Allocation 77 ML/d total	Intermediate 86 ML/d total	Intermediate 95 ML/d total	Intermediate 104 ML/d total	Intermediate 113 ML/d total	SUA 122 ML/d total
m/s	Length (m)	Length (m)	Length (m)	Length (m)	Length (m)	Length (m)	Length (m)
0	7869	7869	7947	7947	7947	7947	7947
0-0.03	4969	4969	4891	4891	4891	4891	4891
0.04-0.1	0	0	0	0	0	0	0
0.11-0.17	0	0	0	0	0	0	0
0.18-0.3	0	0	0	0	0	0	0
0.31-0.5	0	0	0	0	0	0	0
>0.5	0	0	0	0	0	0	0
Total	12838	12838	12838	12838	12838	12838	12838

Table 10. Tanyaca Creek length of channel per velocity category

Velocity Category	Current Extraction 68 ML/d total	Current Allocation 77 ML/d total	Intermediate 86 ML/d total	Intermediate 95 ML/d total	Intermediate 104 ML/d total	Intermediate 113 ML/d total	SUA 122 ML/d total
m/s	Length (m)	Length (m)	Length (m)	Length (m)	Length (m)	Length (m)	Length (m)
0	1516	1516	1597	1597	1670	1670	1751
0-0.03	6253	6253	6398	6582	6509	6600	6611
0.04-0.1	3832	3832	3606	3422	3422	3330	3239
0.11-0.17	644	644	644	644	644	644	644
0.18-0.3	10	10	10	10	10	10	10
0.31-0.5	0	0	0	0	0	0	0
>0.5	0	0	0	0	0	0	0
Total	12255	12255	12255	12255	12255	12255	12255

Table 11. Pike Lagoon length of channel per velocity category

Velocity Category	Current Extraction 68 ML/d total	Current Allocation 77 ML/d total	Intermediate 86 ML/d total	Intermediate 95 ML/d total	Intermediate 104 ML/d total	Intermediate 113 ML/d total	SUA 122 ML/d total
m/s	Length (m)	Length (m)	Length (m)	Length (m)	Length (m)	Length (m)	Length (m)
0	2331	2331	2331	2331	2331	2331	2331
0-0.03	3199	3199	3210	3210	3210	3210	3210
0.04-0.1	882	882	871	871	871	871	871
0.11-0.17	0	0	0	0	0	0	0
0.18-0.3	0	0	0	0	0	0	0
0.31-0.5	0	0	0	0	0	0	0
>0.5	0	0	0	0	0	0	0
Total	6411	6411	6411	6411	6411	6411	6411

Table 12. Snake Creek length of channel per velocity category

Velocity Category	Current Extraction 68 ML/d total	Current Allocation 77 ML/d total	Intermediate 86 ML/d total	Intermediate 95 ML/d total	Intermediate 104 ML/d total	Intermediate 113 ML/d total	SUA 122 ML/d total
m/s	Length (m)	Length (m)	Length (m)	Length (m)	Length (m)	Length (m)	Length (m)
0	5806	5806	5806	5806	5806	5806	5806
0-0.03	58	58	58	58	58	58	58
0.04-0.1	2	2	2	2	2	2	2
0.11-0.17	0	0	0	0	0	0	0
0.18-0.3	0	0	0	0	0	0	0
0.31-0.5	0	0	0	0	0	0	0
>0.5	0	0	0	0	0	0	0
Total	5866	5866	5866	5866	5866	5866	5866

Table 13. Mid Pike River length of channel per velocity category

Velocity Category	Current Extraction 68 ML/d total	Current Allocation 77 ML/d total	Intermediate 86 ML/d total	Intermediate 95 ML/d total	Intermediate 104 ML/d total	Intermediate 113 ML/d total	SUA 122 ML/d total
m/s	Length (m)	Length (m)	Length (m)	Length (m)	Length (m)	Length (m)	Length (m)
0	862	862	862	862	862	862	873
0-0.03	6288	6288	6290	6946	6946	7501	7491
0.04-0.1	3053	3053	3052	2396	2396	1841	1841
0.11-0.17	146	156	369	583	583	583	583
0.18-0.3	447	437	241	28	28	28	10
0.31-0.5	79	79	62	121	121	121	139
>0.5	60	60	60	0	0	0	0
Total	10936	10936	10936	10936	10936	10936	10936

Table 14. Upper Pike River length of channel per velocity category

Velocity Category	Current Extraction 68 ML/d total	Current Allocation 77 ML/d total	Intermediate 86 ML/d total	Intermediate 95 ML/d total	Intermediate 104 ML/d total	Intermediate 113 ML/d total	SUA 122 ML/d total
m/s	Length (m)	Length (m)	Length (m)	Length (m)	Length (m)	Length (m)	Length (m)
0	1630	1630	1630	1630	1630	1630	1630
0-0.03	625	625	1099	1099	1670	1670	2452
0.04-0.1	4058	4058	3584	3584	3013	3013	2231
0.11-0.17	387	387	387	387	387	387	387
0.18-0.3	0	0	0	0	0	0	0
0.31-0.5	0	0	0	0	0	0	0
>0.5	0	0	0	0	0	0	0
Total	6700	6700	6700	6700	6700	6700	6700

Table 15. Rumpagunyah Creek length of channel per velocity category

Velocity Category	Current Extraction 68 ML/d total	Current Allocation 77 ML/d total	Intermediate 86 ML/d total	Intermediate 95 ML/d total	Intermediate 104 ML/d total	Intermediate 113 ML/d total	SUA 122 ML/d total
m/s	Length (m)	Length (m)	Length (m)	Length (m)	Length (m)	Length (m)	Length (m)
0	0	0	0	0	0	0	0
0-0.03	10	10	10	10	10	10	10
0.04-0.1	3253	2835	2344	2344	1793	1793	1793
0.11-0.17	0	419	910	910	1460	1460	1460
0.18-0.3	0	0	0	0	0	0	0
0.31-0.5	0	0	0	0	0	0	0
>0.5	0	0	0	0	0	0	0
Total	3263	3263	3263	3263	3263	3263	3263

Table 16. Lower Pike River length of channel per velocity category

Velocity Category	Current Extraction 68 ML/d total	Current Allocation 77 ML/d total	Intermediate 86 ML/d total	Intermediate 95 ML/d total	Intermediate 104 ML/d total	Intermediate 113 ML/d total	SUA 122 ML/d total
m/s	Length (m)	Length (m)	Length (m)	Length (m)	Length (m)	Length (m)	Length (m)
0	0	0	0	0	0	0	0
0-0.03	2371	2371	2371	2371	2371	2371	2371
0.04-0.1	8346	8346	8346	8346	8346	8346	8346
0.11-0.17	0	0	0	0	0	0	0
0.18-0.3	0	0	0	0	0	0	0
0.31-0.5	0	0	0	0	0	0	0
>0.5	0	0	0	0	0	0	0
Total	10717	10717	10717	10717	10717	10717	10717

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