5.4 PREDICTED TUNNEL INFLOW

5.4.1 BASECASE (M5 EAST ONLY)

Table 5-2 presents the inflow as simulated to the existing M5 East tunnel over the model duration. It is observed that the long term inflow rate to the existing M5 East tunnel gradually declines over time, as is expected with the spread of drawdown from the nearby New M5.

Table 5-2 Predicted tunnel inflows M5 East (Scenario 1)

	M5 East*		
YEAR	Inflow ML/day	Inflow L/sec/km	Total Tunnel Length (km)
2016	0.45	0.86	6.00
2017	0.44	0.85	6.00
2018	0.43	0.83	6.00
2019	0.42	0.82	6.00
2020	0.42	0.81	6.00
2021	0.41	0.80	6.00
2022	0.41	0.79	6.00
2023	0.41	0.79	6.00
2024	0.41	0.78	6.00
2025	0.40	0.78	6.00
2030	0.39	0.76	6.00
2041	0.39	0.74	6.00
2051	0.38	0.74	6.00
2100	0.38	0.73	6.00

5.4.2 PROJECT SPECIFIC INFLOWS

The WCX tunnels are being constructed as leaky tunnels (unlined) with design criteria of a maximum of 1L/sec/km of on-going “drainage” water into each tunnel during operation. **Table 5-3** summarises the predicted annual inflow rates simulated by the model for the M4-M5 Link (inclusive of the mainline tunnel, Rozelle interchange and adjoining ramps from St Peters Interchange and Haberfield where tunnelled), and the ventilation tunnel system to be excavated at Rozelle. Inflow rates (calculated as inflow volume to the entire tunnel) peaks at 2.45 ML/day for the M4-M5 Link in 2021 corresponding with the end of trafficable tunnel construction, when the greatest length of tunnel is excavated (approximately 37 km for the M4-M5 Link project inclusive of both directions along the mainline and interchanges). Inflow to the ventilation tunnels represents a much lesser volume, peaking at 0.14 ML/day in 2022, again coinciding with the finalisation of excavation of these tunnels.

Table 5-3 Predicted tunnel inflows M4-M5 (Scenario 3 minus Scenario 2)

	Trafficable Tunnels			Ventilation Tunnels		
YEAR	Inflow ML/day	Inflow L/sec/km	Total Tunnel Length (km) #	Inflow ML/day	Inflow L/sec/km	Total Tunnel Length (km)
2016	0.00	0.00	0.00	0.00	0.00	0.00
2017	0.00	0.00	0.00	0.00	0.00	0.00
2018	0.16	0.72	2.51	0.00	0.00	0.00
2019	1.34	0.85	18.10	0.00	0.00	0.00
2020	2.21	0.87	29.34	0.00	0.00	0.52
2021	2.45	0.77	36.81	0.10	0.37	3.02
2022	2.00	0.63	36.81	0.14	0.33	4.89
2023	1.68	0.53	36.81	0.13	0.31	4.89
2024	1.49	0.47	36.81	0.11	0.25	4.89
2025	1.36	0.43	36.81	0.10	0.23	4.89
2030	1.06	0.33	36.81	0.08	0.20	4.89
2041	0.92	0.29	36.81	0.08	0.19	4.89
2051	0.86	0.27	36.81	0.08	0.19	4.89
2100	0.81	0.25	36.81	0.08	0.18	4.89

represents tunnelling in both directions and at interchanges
Colours in table indicate the following project phases:

Tunnel excavation

Project opening

Surface works / fit out

Ongoing operation

5.4.3 M4 EAST AND NEW M5 TUNNELLING INFLOWS

Predicted inflows for the New M5 and M4 East components of the WestConnex program of works are shown in **Table 5-4**. It should be noted that the volumes tabulated only reflect the extent of the tunnels that have been included in the current model for the purposes of cumulative drawdown impact assessment, and therefore the values of inflow may differ when averaged over the full length of the tunnels including that which is not modelled. Peak inflows for the New M5 and M4 East tunnels are predicted to be 1.3 ML/day and 0.91 ML/day respectively. The maximum rate in L/sec/km for each tunnel is predicted to be 0.69 L/sec/km for the New M5, similar to that predicted by CDM Smith (2015) of 0.67 L/sec/km. The maximum rate of 1.05 L/sec/km for the M4 East tunnel is at the lower end of reported values for the M4 East modelling undertaken by GHD (2015) where a range of possible inflows between 0.16 L/sec/km and 3.76 L/sec/km were reported, however the inflow is restricted by the MODFLOW-DRN package conductance in this model to not exceed the design criteria of 1 L/sec/km. Tunnelling along the M4 East alignment has a simulated inflow rate approximating the maximum allowable 1L/sec/km for the duration of tunnelling, indicating that shotcreting is likely to be required to reduce the inflows to an acceptable level.

Table 5-4 Predicted tunnel inflows for New M5 and M4 East (Scenario 2)

	New M5 Tunnels*			M4 East Tunnels*		
YEAR	Inflow ML/day	Inflow L/sec/km	Total Tunnel Length (km) #	Inflow ML/day	Inflow L/sec/km	Total Tunnel Length (km)#
2016	0.20	0.35	6.66	0.06	0.61	1.18
2017	0.84	0.69	14.06	0.31	1.05	3.44
2018	1.24	0.68	21.06	0.56	1.01	6.49
2019	1.30	0.68	22.17	0.91	1.03	10.28
2020	1.21	0.63	22.17	0.70	0.79	10.28
2021	1.15	0.60	22.17	0.58	0.65	10.28
2022	1.10	0.58	22.17	0.52	0.59	10.28
2023	1.07	0.56	22.17	0.48	0.54	10.28
2024	1.05	0.55	22.17	0.45	0.51	10.28
2025	1.03	0.54	22.17	0.43	0.48	10.28
2030	0.97	0.51	22.17	0.37	0.42	10.28
2041	0.93	0.49	22.17	0.34	0.39	10.28
2051	0.92	0.48	22.17	0.33	0.37	10.28
2100	0.91	0.47	22.17	0.32	0.36	10.28

*represents the portion of tunnelling included in current model only
represents tunnelling in both directions and at interchanges
Colours in table indicate the following project phases:

- Tunnel excavation
- Project opening
- Surface works / fit out
- Ongoing operation

5.4.4 CUMULATIVE INFLOWS

Table 5-5 presents the cumulative tunnel inflows for the WCX program of works (to the extent simulated). Total inflow volumes are predicted to peak at 4.28 ML/day in 2021, corresponding with final tunnelling at Rozelle (minor excavation of ventilation tunnels is expected to occur into the start of 2022). The declining inflow rate with time indicates that the modelled recharge does not supply enough water to the system to maintain the initial inflow rates. It is possible long term inflows may be slightly higher if rainfall recharge is higher than simulated, or if additional recharge is induced to the system due to the lowered hydraulic head along the tunnel alignment.

Table 5-5 Cumulative tunnel inflows for entire WCX program of works (Scenario 3)

	Cumulative WCX*		
YEAR	Inflow ML/day	Inflow L/sec/km	Total Tunnel Length (km) #
2016	0.26	0.39	7.84
2017	1.15	0.76	17.50
2018	1.96	0.76	30.05
2019	3.54	0.81	50.54
2020	4.11	0.76	62.31
2021	4.28	0.68	72.28
2022	3.76	0.59	74.15
2023	3.36	0.53	74.15
2024	3.10	0.48	74.15
2025	2.92	0.46	74.15
2030	2.48	0.39	74.15
2041	2.27	0.35	74.15
2051	2.18	0.34	74.15
2100	2.12	0.33	74.15

*represents the portion of M4 East and New M5 tunnelling included in current model only
represents tunnelling in both directions and at interchanges
Colours in table indicate the following project phases:

- Tunnel excavation
- Project opening
- Surface works / fit out
- Ongoing operation

5.4.5 INFLOW DUE TO DESIGN CHANGE

The modelling has been undertaken for EIS Option A therefore above results reflect this original design. If Option B of the construction program occurs there will likely be a slight increase in inflow volume due to the increased tunnel length required for the construction access tunnel. It is expected that the change to the rate of inflow (in L/sec/km) will be negligible due to the additional tunnelling occurring in the Ashfield Shale (i.e. there will be no increased inflow from alluvium/unconsolidated sediments).

Similarly the bifurcation of tunnels at Wattle Street, the Mid-West interchange and north of St Peters Interchange are also likely to increase the total volume of inflow over a given time period due to the addition of extra length of drained tunnels. This will be partly offset by a reduction in inflow to the mainline tunnels due to a decreased tunnel width, however it is expected that there will be a minimal overall net increase in flow due to an increased extent of tunnelling leading to increased groundwater drainage. All of the proposed bifurcation tunnel lanes are to be constructed in Hawkesbury Sandstone and Ashfield Shale therefore no increased connectivity of the project to the alluvium or unconsolidated sediments is expected.

5.5 PREDICTED CAPTURE AREA

MODPATH3DU (Muffels *et al.,* 2014) was used to simulate particle tracking in order to determine the capture area of the tunnels during operation, with the main aim of this analysis being to identify the potential for saline intrusion due to water being drawn from tidal regions towards the tunnels. The calibrated steady-state model (as opposed to the transient model) was used for this investigation. The steady-state model represents equilibrium conditions with constant stresses applied to the model, whereas transient models represent variable groundwater stresses and groundwater conditions dependant on the length of each stress-period in the model. The use of the transient model was not suitable for this analysis due to many of the particle traces generated indicating total travel times much greater than the 85 year duration simulated in the transient model. The steady-state model includes averaged groundwater stresses (e.g. recharge and evapotranspiration) based on long term climatic conditions, and includes all the operational tunnels (M5 East and all stages of WCX), thereby demonstrating the greatest possible capture area (as constrained by hydraulic parameters used in the calibrated model).

Backwards tracking of particles set at the tunnel inverts shows the “path” each “particle” of water would take from its origin (at the water table or a model boundary condition e.g. river). Thus the time displayed at the point along the path-line indicates the travel time from that point to its entry (via seepage) into the tunnel.

The travel time (but not overall capture area) is sensitive to the effective porosity values applied in the model. Total porosity values obtained from core testing are shown in **Table 5-6** (greater detail can be found in **Section 3.2.6**), averaging between 10 to 20% for the Hawkesbury Sandstone and around 6% for the Ashfield Shale. The effective porosity is less than the total porosity, as it includes only interconnected porosity through which water is able to be transmitted (i.e. excludes isolated voids and “dead-end” pore space). The effective porosity values applied in this analysis are also summarised in **Table 5-6.** It is assumed that the effective porosity is close to the total porosity typical of unconsolidated sands in model Layer 1.

Table 5-6 Total porosity values from laboratory testing and simulated effective porosity

Layer	Unit	Total Porosity (%)	Effective Porosity (%)
1	Alluvium/Botany Sands/Regolith	20 – 30	20
2	Weathered Ashfield Shale		18
3	Ashfield Shale	6	3
4	Hawkesbury Sandstone	10 - 20	15
5	Hawkesbury Sandstone	10 - 20	20
6	Hawkesbury Sandstone	10 - 20	10
7	Hawkesbury Sandstone	10 - 20	8
8	Hawkesbury Sandstone	10 - 20	5

A total of 5310 particles were simulated from the base of the tunnels. **Figure 5-10** shows the travel time for the particles, and **Figure 5-11** shows the layers that the particles pass through along their path. Comparing these figures shows that the particles that travel from regions of groundwater mounding (corresponding with topographic highs) have the longest travel times (greater than 1000 years) and pass through the deepest model layers before emerging at the tunnel. Water originating at the water table closer to the tunnel alignment does not pass through the deep layers and therefore takes significantly less time to reach the tunnel (less than 100 years).

The implications for potential saline intrusion are discussed in **Section 6.7**.

The capture area is not expected to be affected by the late design changes described in **Section 2.2.1**.

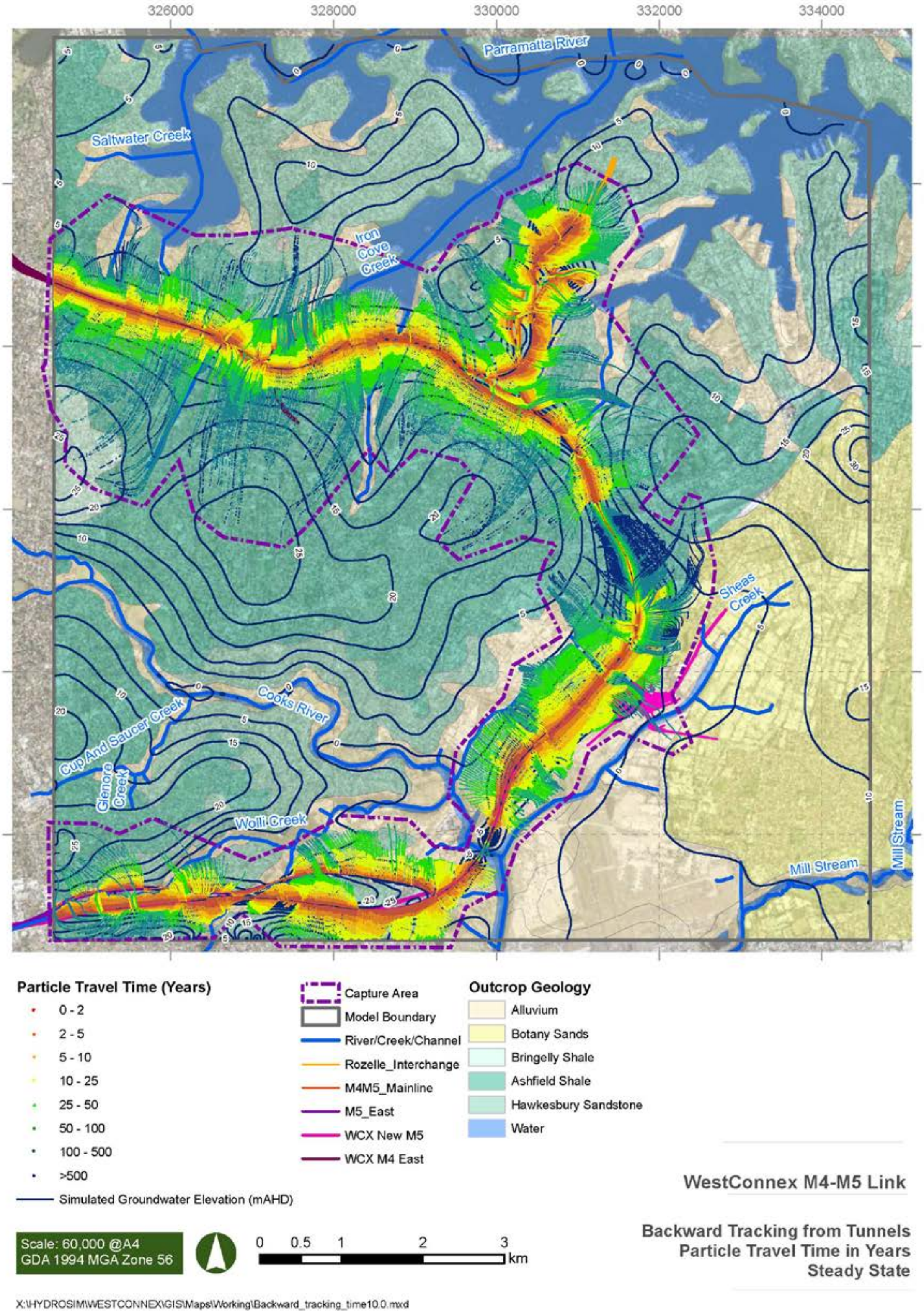

Figure 5-10 Pathlines and travel times

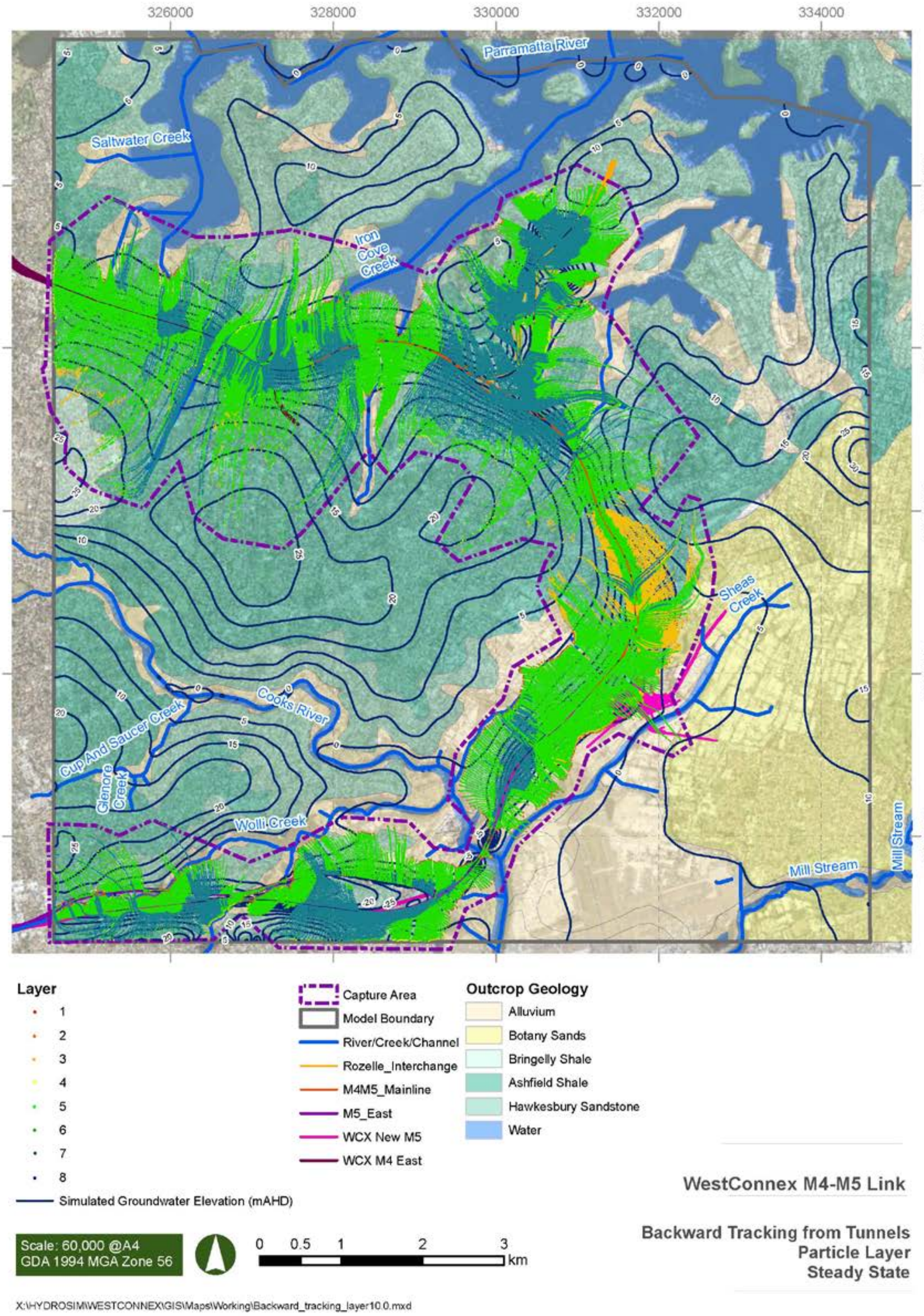

Figure 5-11 Pathlines and model layer

6 POTENTIAL IMPACTS OF THE PROJECT

The main effect of the construction of the tunnels on the groundwater regime is groundwater inflow and subsequent pumping out of groundwater that enters the tunnel void at variable rates not exceeding 1L/sec/km. This localised extraction of groundwater from the system has a number of possible effects that may arise during both the construction phase and on-going operation of the tunnels. These can be summarised as follows:

- inflow of groundwater to the tunnels and water management;
- drawdown of groundwater levels and depressurisation of groundwater, both within the Triassic hard rock strata and the Quaternary alluvium/Botany Sands;
- saline intrusion where the tunnel inflow is hydraulically connected to surface water bodies either directly or via the alluvium; and
- effects on baseflow to nearby non-tidal rivers including the upper reaches of Cooks River, Wolli Creek, Bardwell Creek, Alexandra Canal, Iron Cove Creek, Hawthorne Canal, Whites Creek and Johnstons Creek.

6.1 PREDICTED INFLOW TO TUNNELS

6.1.1 PROJECT SPECIFIC INFLOW

The predicted annual inflow and cumulative inflow with time for the M4-M5 Link tunnelling are presented in **Table 6-1**. Maximum inflows for the project peak at 930 ML/year in 2021, coinciding with the finalization of construction of trafficable tunnels. A total of 3.7GL of water is expected to inflow to the tunnels by project opening in 2023. Long-term inflow rates decline due to declining storage, with inflows at 2100 predicted to have reduced to 323 ML/yr.

Table 6-1 Predicted annual and cumulative tunnel inflows for the M4-M5 Link

YEAR	Annual Inflow			Cumulative Total Inflow		
	M4-M5 Link Trafficable Tunnels Inflow (ML/yr)	M4-M5 Link Ventilation Tunnels Inflow (ML/yr)	M4-M5 Link Combined Inflow (ML/yr)	M4-M5 Link Trafficable Tunnels Cumulative Inflow (ML)	M4-M5 Link Ventilation Tunnels Cumulative Inflow (ML)	M4-M5 Link Cumulative Combined Inflow (ML)
2016	0	0	0	0	0	0
2017	0	0	0	0	0	0
2018	57	0	57	57	0	57
2019	487	0	487	544	0	544
2020	805	0	805	1,350	0	1,350
2021	895	35	930	2,245	35	2,280
2022	730	51	780	2,975	86	3,061
2023	613	48	661	3,587	134	3,721
2024	543	39	582	4,130	173	4,303
2025	497	35	532	4,627	208	4,835
2030	387	31	417	6,561	361	6,922
2041	335	29	364	9,909	651	10,560
2051	312	29	341	13,030	938	13,968
2100	295	28	323	27,784	2,356	30,141

Colours in table indicate the following project phases:

- Tunnel excavation
- Project opening
- Surface works / fit out
- Ongoing operation

6.1.2 CUMULATIVE INFLOW

The maximum annual inflow for the M4 East and New M5 peaks at 806 ML/year in 2019, which is the final year of tunnel construction for these projects. The cumulative inflow to tunnels at the end of all WCX trafficable tunnel excavation (2021) is 5.6 GL, and 8.2 GL of groundwater is predicted to have drained to the greater WCX tunnels by the time of M4-M5 Link opening in 2023. Annual inflow volumes decrease with time after the peak inflows are reached, as water in storage is drained and recharge does not replenish the volumes lost.

Table 6-2 Predicted annual and cumulative tunnel inflows for the WCX program of works

	Annual Inflow			Cumulative Total Inflow		
YEAR	M4 East and New M5 (ML/yr)	M4-M5 Link (ML/yr)	Combined Cumulative Inflow (ML/yr)	M4 East and New M5 (ML)	M4-M5 Link (ML)	Combined Cumulative Inflow (ML)
2016	96	0	96	96	0	96
2017	421	0	421	517	0	517
2018	660	57	717	1,176	57	1,233
2019	806	487	1,293	1,982	544	2,526
2020	696	805	1,501	2,678	1,350	4,028
2021	630	930	1,561	3,309	2,280	5,589
2022	593	780	1,374	3,902	3,061	6,962
2023	567	661	1,228	4,469	3,721	8,190
2024	548	582	1,130	5,017	4,303	9,320
2025	533	532	1,065	5,549	4,835	10,384
2030	489	417	907	7,997	6,922	14,918
2041	465	364	829	12,649	10,560	23,209
2051	455	341	796	17,201	13,968	31,169
2100	449	323	773	39,673	30,141	69,814

Colours in table indicate the following project phases:

- Tunnel excavation
- Project opening
- Surface works / fit out
- Ongoing operation

6.1.3 INFLOW DUE TO DESIGN CHANGES

As discussed in **Section 5.4.5** the inflow volume is expected to increase slightly due to the proposed increase in total tunnel length, however this increase is expected to be negligible in the scale of the overall project inflows.

6.2 PREDICTED DRAWDOWN DUE TO THE M4-M5 LINK

Project specific drawdowns related to the construction of the M4-M5 Link are shown in **Figure 6-1** to **Figure 6-8**. Zoomed in images for these maps can be found in **Annexure C**. This drawdown was calculated by subtracting the results of model Scenario 3 (inclusive of the M5 East, M4 East, New M5 and M4-M5 Link project) from model Scenario 2 (inclusive of the M5 East, M4 East, New M5 only). Model Scenario 2 forms an appropriate “baseline” for calculating drawdown due to the M4-M5 project as this project will not go ahead without the earlier WCX tunnels. Drawdowns are presented for the modelled water table which represents the change in the water table surface due to the project, and may exist in any model layer (the uppermost partially saturated layer).

Drawdown is also presented for Layer 1 restricted to the lateral and vertical extent of the alluvium and Botany Sands (unconsolidated sediments) to aid in the calculation of potential settlement in these units. Therefore, the maximum drawdown shown in these figures is limited to the base of the unconsolidated material, even if the predicted water levels are deeper (as shown in the water table figures). Maximum drawdown for the Ashfield Shale and Hawkesbury Sandstone are also shown. Layer 3 represents the greater thickness of Ashfield Shale and Layer 6 represents the mid-layer of the Hawkesbury Sandstone. Layer 6 also contains the majority of drain cell boundary conditions representing the WCX tunnel inverts. The drawdown in the other Ashfield Shale and Hawkesbury Sandstone model layers may vary slightly from those depicted, however not significantly.

6.2.1 DRAWDOWN AT PROJECT OPENING

At the proposed time of project opening (June 2023) the drawdown on the water table is expected to be up to 42 m with major drawdown centred over the Rozelle Interchange. Drawdown extends up to 500 m either side of the tunnel alignment, with the widest areas being mid-way along the M4-M5 mainline around Newtown and at the interchanges as shown in **Figure 6-1**. The lateral extent of drawdown is narrower where the alignment passes under watercourses due to the transmission of water through the higher hydraulic conductivity of the alluvium preventing the drawdown from propagating far. Drawdown centres are discontinuous along the alignment and are a reflection of tunnel depth and timing of excavation, as well as geological boundaries. There is no drawdown in the area surrounding Cooks River in Layer 1 partly due to the tunnel being lined in the Hawkesbury Sandstone beneath the Cooks River, and partly due to the large alluvial channel continually feeding tidal water to replenish storage removed by tunnelling.

Drawdown that is limited to the base of the alluvium/Botany Sands (**Figure 6-2**) suggests that there may be substantial drawdown in the alluvium at Rozelle in the Whites Creek paleochannel. This indicates that there is a hydraulic connection between the Hawkesbury Sandstone and the alluvium, with the significant drawdown in the Hawkesbury Sandstone creating a local sink drawing groundwater downwards from the alluvium. Water levels directly beneath and adjacent to the Whites Creek drainage channel are not significantly impacted due to the low volumes of recharging water simulated from the tidally influenced channel (that is assumed to be slightly leaky).

Within the Ashfield Shale (**Figure 6-3**) the drawdown is presented from the top of the shale extending into the underlying Hawkesbury Sandstone. The drawdown distribution reflects that of the overlying layer, but with a greater lateral extent (about 700 m either side of the M4-M5 alignment at Newtown).

In the Hawkesbury Sandstone (**Figure 6-4**) drawdowns of up to 55 m occur at Rozelle, with drawdown shown to undercut Whites Creek in the sandstone. Along the mainline the sporadic drawdown epicentres observed in the upper geological units are becoming more continuous with depth and following the tunnel alignments, with a maximum extent of approximately 800 m drawdown either side of the alignment around Newtown/Erskineville.

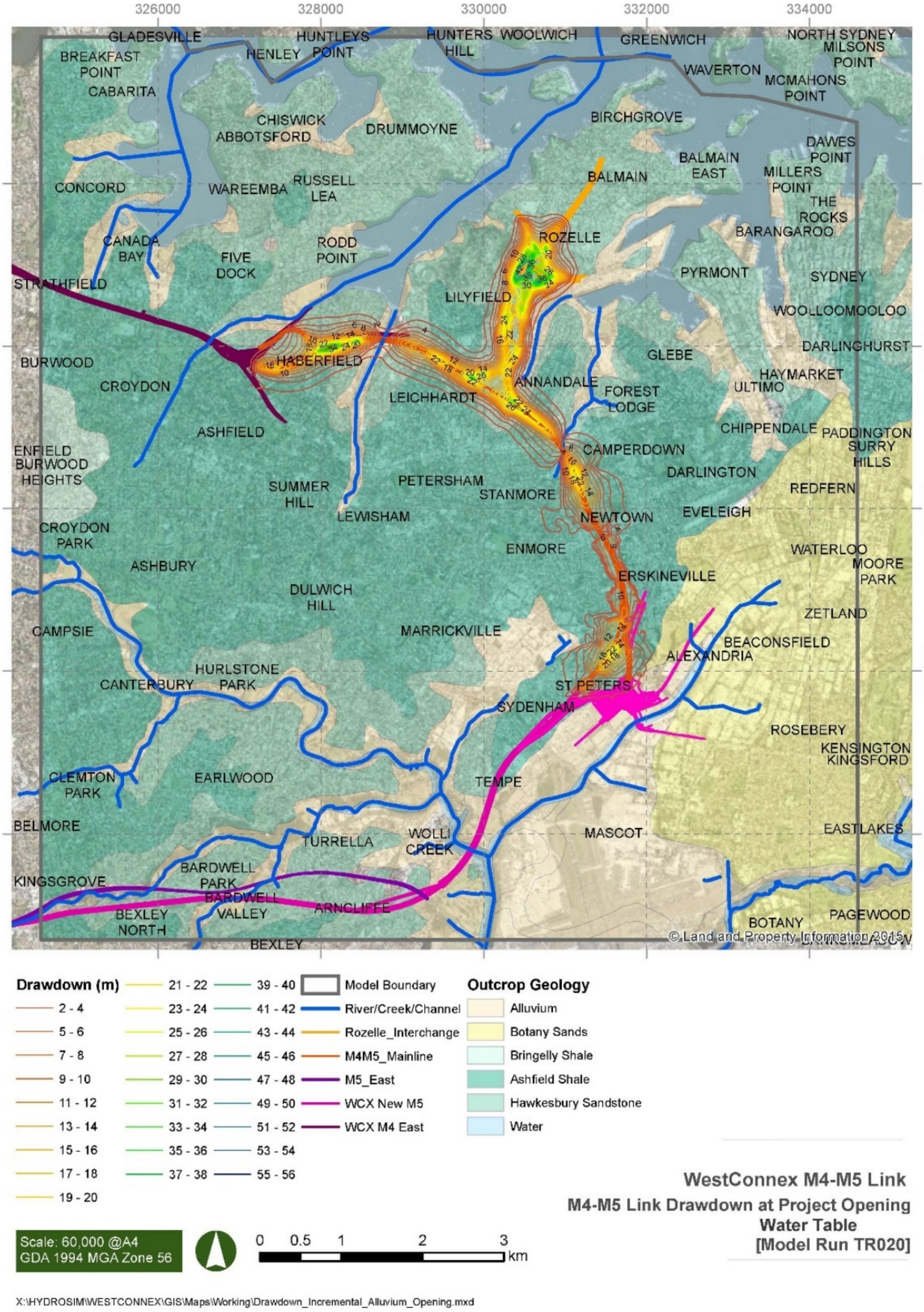

Figure 6-1 M4-M5 Link water table drawdown at project opening (June 2023)

![HydroSimulations logo]

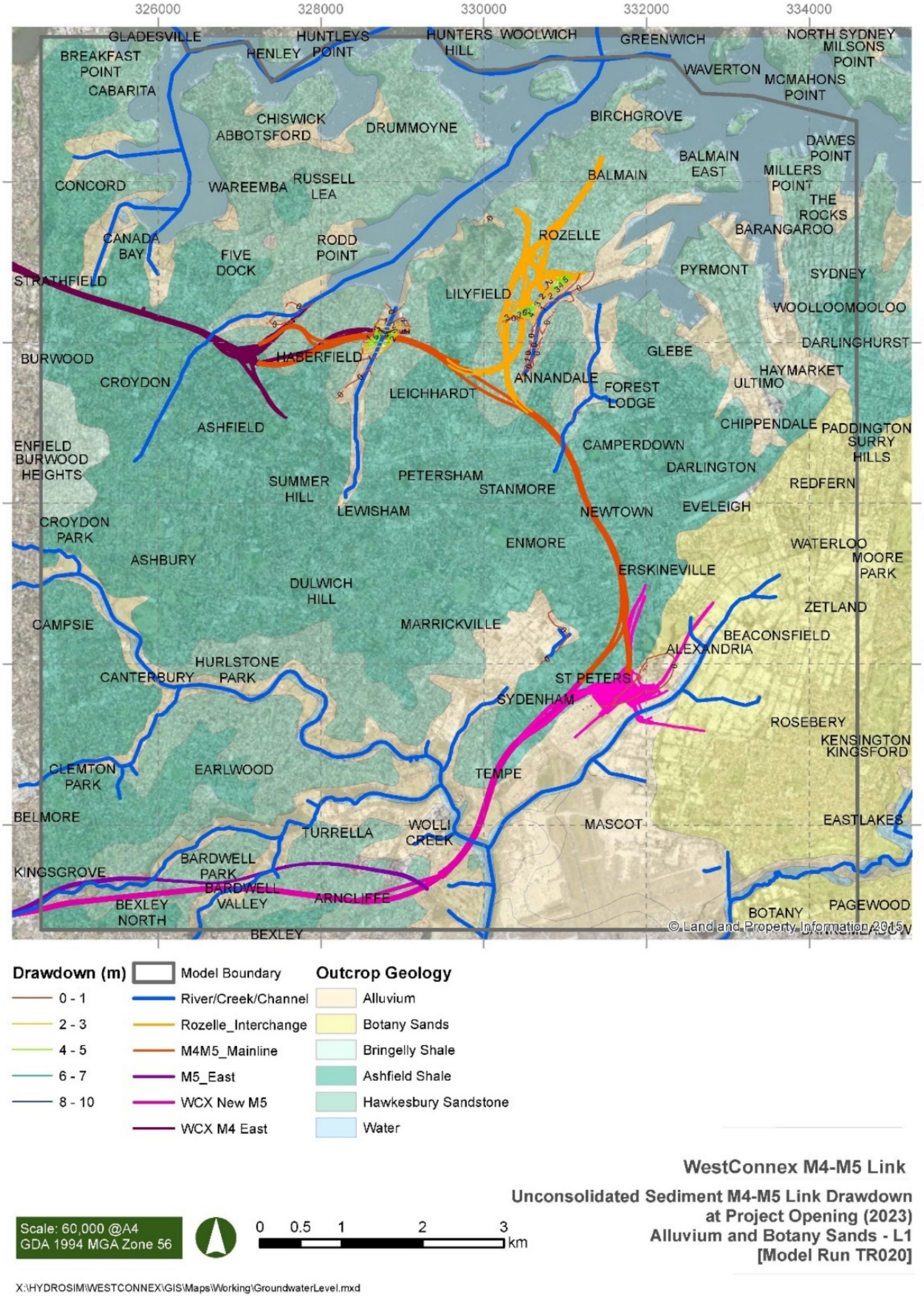

Figure 6-2 M4-M5 Link drawdown in alluvium at project opening (June 2023)

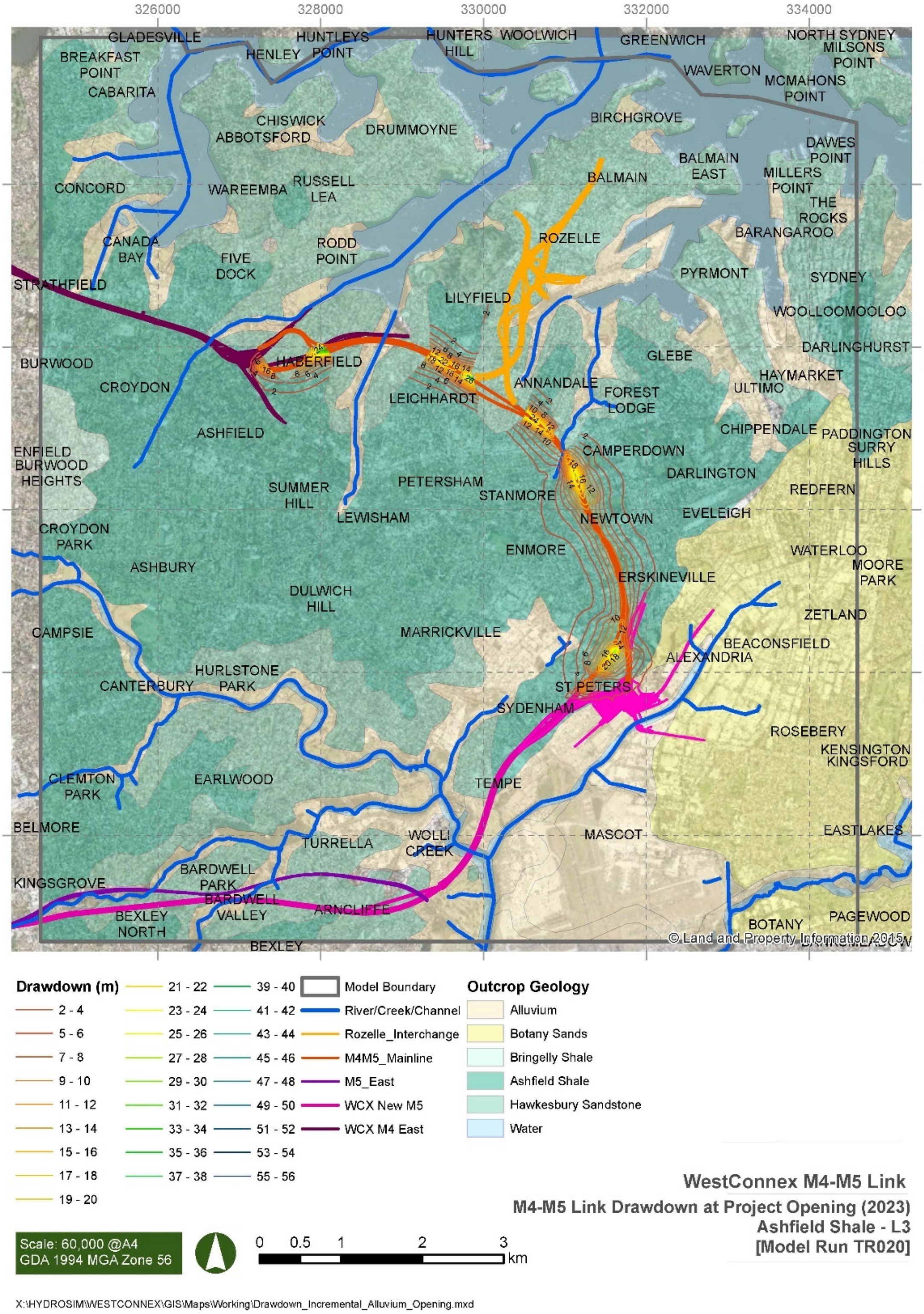

Figure 6-3 M4-M5 Link drawdown in the Ashfield Shale at project opening (June 2023)

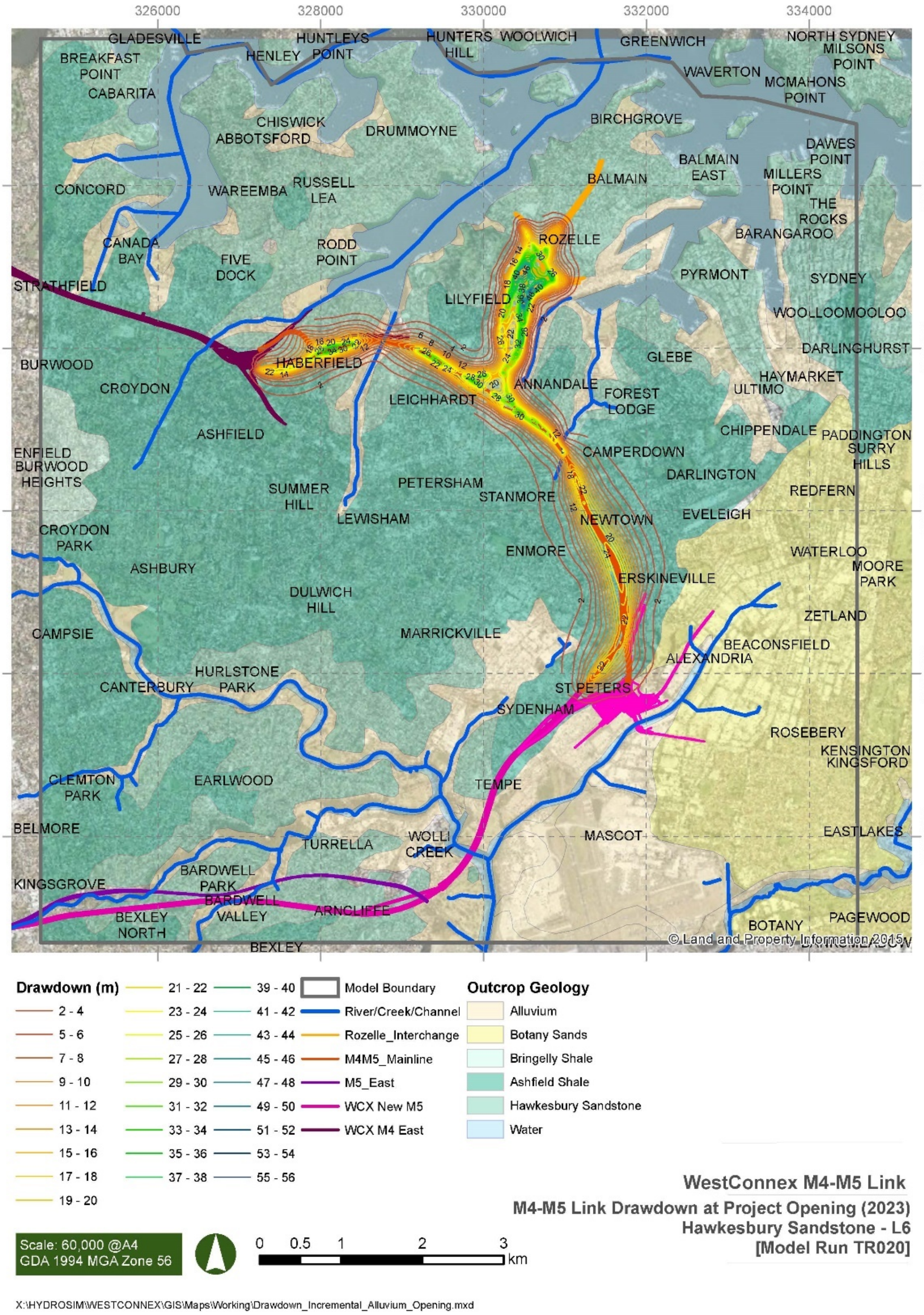

Figure 6-4 M4-M5 Link drawdown in the Hawkesbury Sandstone at project opening (June 2023)

6.2.2 LONG TERM

Drawdown at the end of the long-term simulation (extending to year 2100) shows that the drawdown depth has reached the tunnel inverts and the extent continues to spread with time. It is expected that these water levels represent a pseudo steady-state condition due to the inflows to tunnels stabilising (see **Section 5.4**); however it is possible the drawdown cone may continue to propagate further than has been simulated in the transient model. Drawdown to the water table has a maximum depth of 55 m at Rozelle and a maximum extent at the end of the long-term simulation of 1.4 km either side of the tunnel at Newtown (**Figure 6-5**). Drawdown in the alluvium at Rozelle continues to propagate away from the network of tunnels and extends underneath Whites Creek, indicating the recharge through the alluvium and directly from the creek is less than that removed from the alluvium due to drainage from the tunnels. In the Ashfield Shale (**Figure 6-7**) the maximum extent is 1.5 km towards Enmore and Darlington, and is the same in the Hawkesbury Sandstone (**Figure 6-8**).

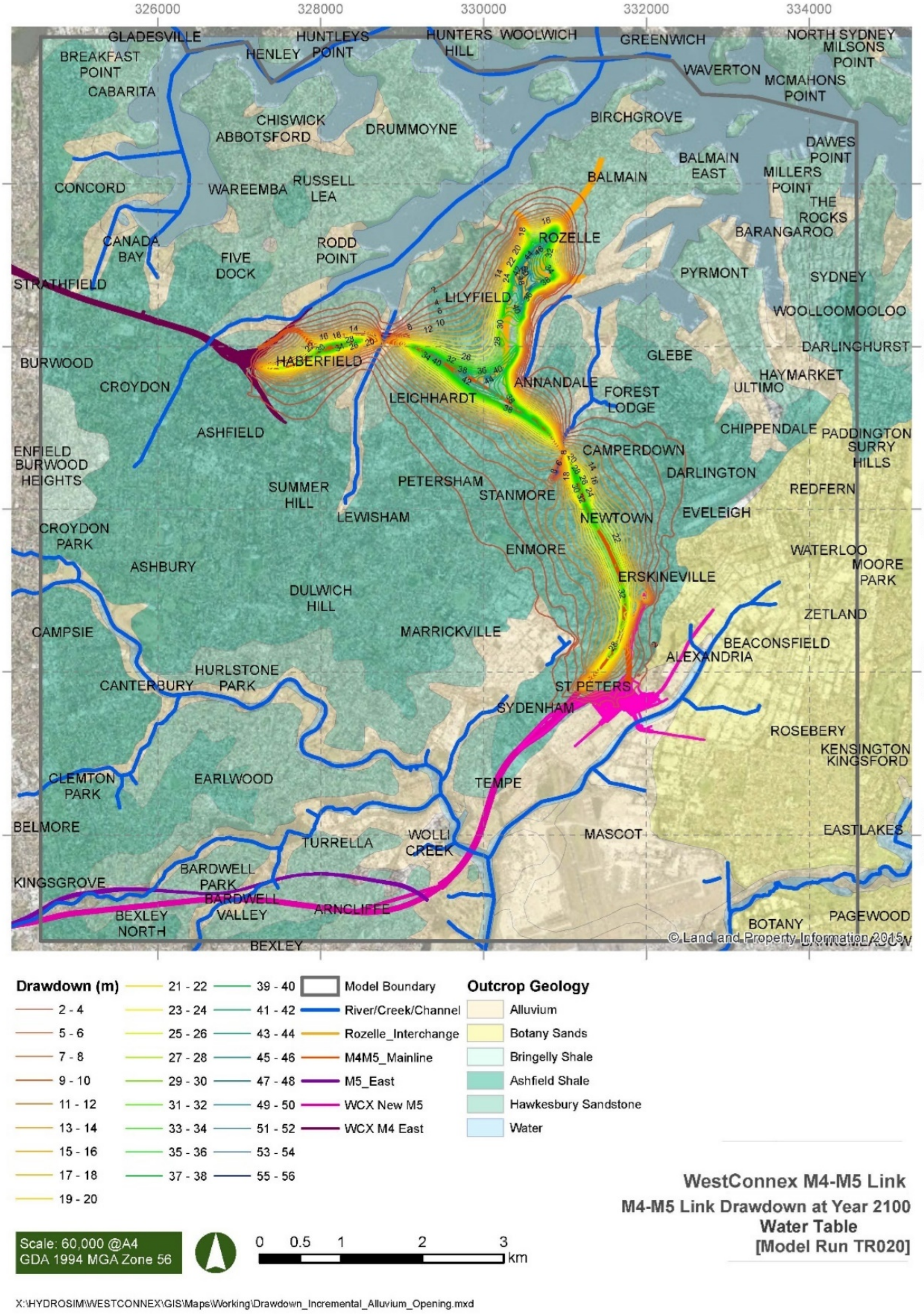

Figure 6-5 M4-M5 Link water table long term drawdown (year 2100)

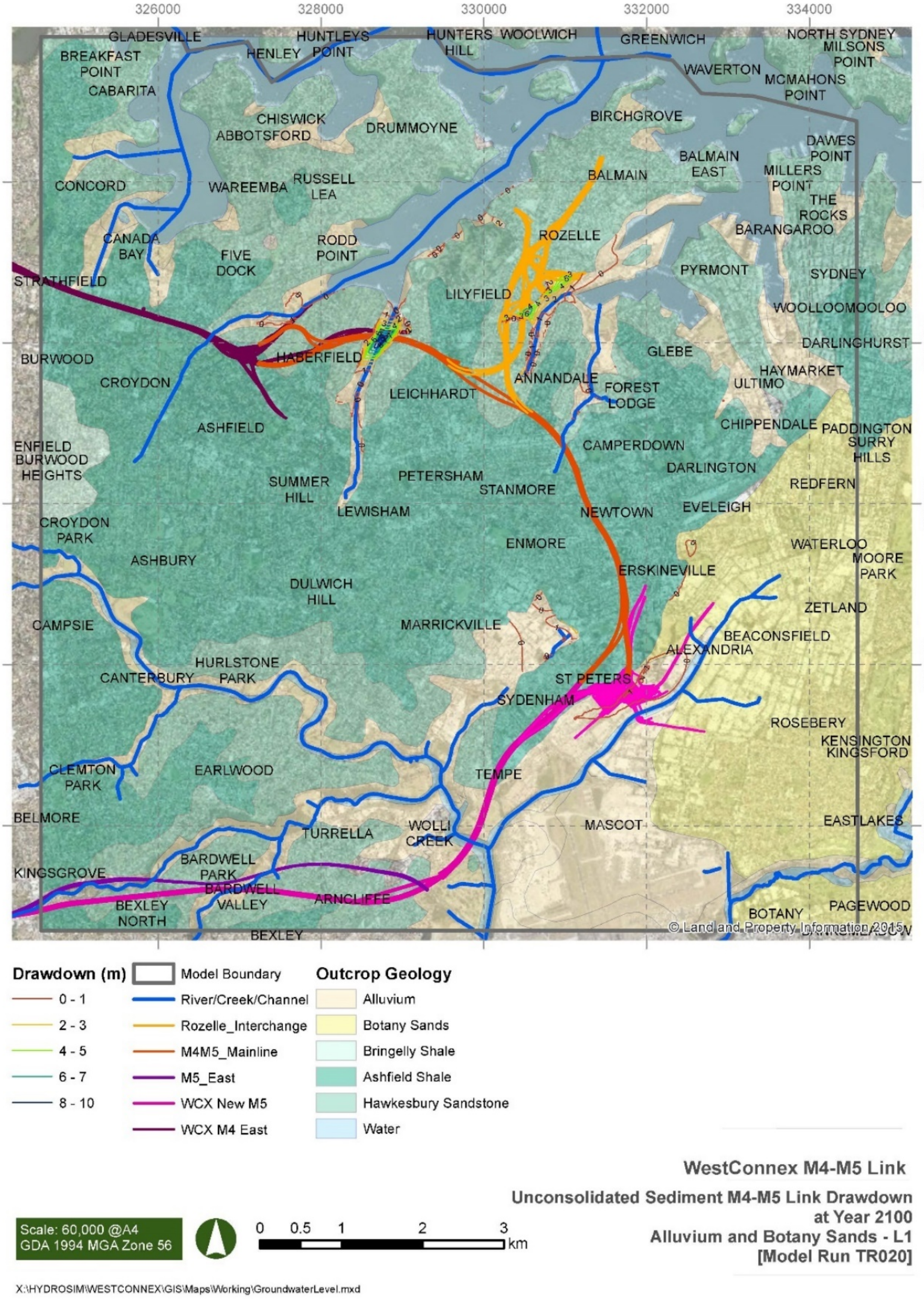

Figure 6-6 M4-M5 Link long term drawdown in alluvium (year 2100)

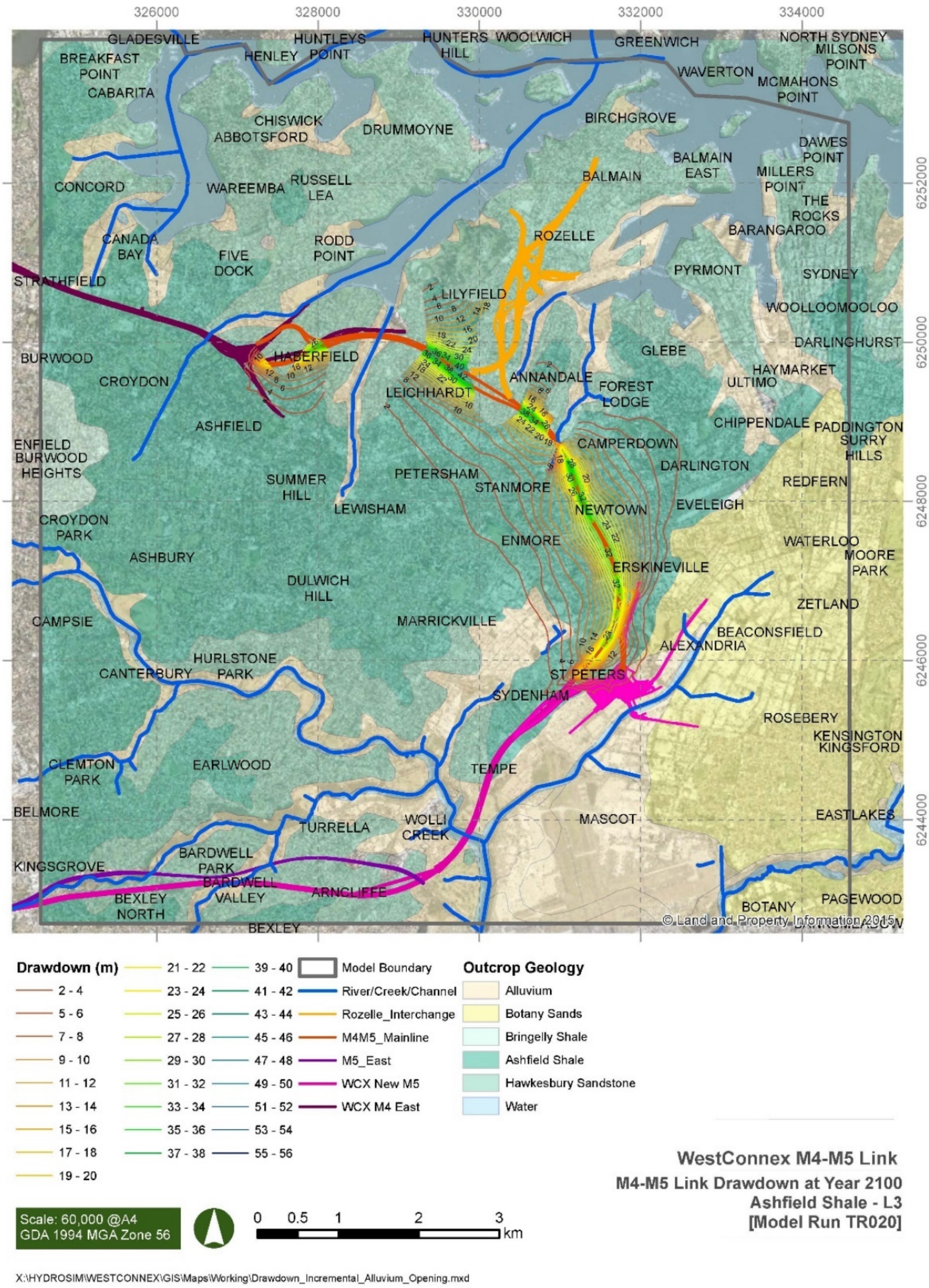

Figure 6-7 M4-M5 Link long term drawdown in the Ashfield Shale (year 2100)

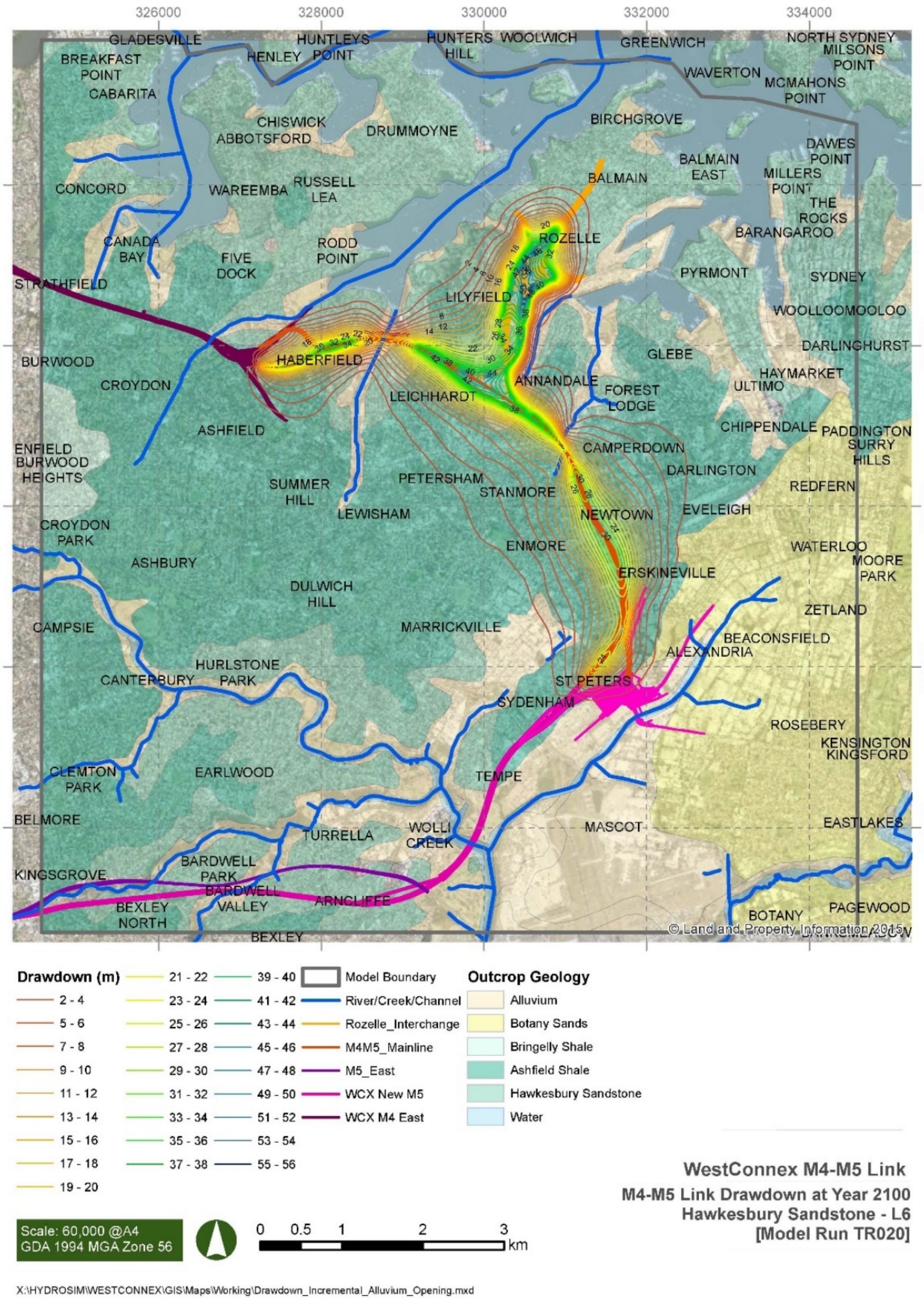

Figure 6-8 M4-M5 Link long term drawdown in the Hawkesbury Sandstone (year 2100)

6.2.3 DRAWDOWN DUE TO DESIGN CHANGES

Additional drawdown due to the extension of exit ramp tunnelling at Haberfield under Option B is expected to be minimal due to the shallow depth of tunnelling. The extent of drawdown to the 2m contour along Parramatta Road will likely shift slightly south of the existing drawdown extent to follow the additional line of tunnels but this is not likely to be significant in terms of potential impacts due to the shallow depth of the tunnels and the lack of nearby environmental receptors or anthropogenic groundwater uses.

Bifurcation of tunnelling is also expected to slightly increase the overall extent of drawdown local to the secondary tunneling due to increased overall project width. The depth of drawdown is expected to approach the tunnel inverts for all tunnels with time. Again, this slight increase in drawdown is not expected to be significant in terms of potential impacts due to the shallow depth of the tunnels and the lack of nearby environmental receptors or anthropogenic groundwater uses. The increased extent of drawdown will only occur on the side of the mainline tunnel at which the bifurcation tunnels are proposed as drawdown resulting from the mainline will act as a hydraulic barrier to prevent the propagation of drawdown on both sides (assuming the inverts of the bifurcation tunnels are not deeper than the mainline).

6.3 PREDICTED CUMULATIVE DRAWDOWN

6.3.1 DRAWDOWN AT PROJECT OPENING

Cumulative drawdown to the water table at June 2023 for the greater WCX program of works is most significant over the Rozelle Interchange (**Figure 6-13**), which isn't unexpected given the complex multi-level tunnelling network to be constructed here. Other key areas of water table drawdown include the Haberfield Interchange (up to 34 m of drawdown), and south of St Peters Interchange at Sydenham (up to 44 m of drawdown). The extent of drawdown is fairly consistent along the entire project, with typically between 200 m and 600 m of drawdown extent either side of the alignment. The depth and extent of drawdown are reduced under the watercourses due to recharge directly from the leaking channels and from the higher conductivity alluvium.

Drawdown that is limited to the base of the unconsolidated sediments (**Figure 6-14**) shows that there is no change to drawdown at Rozelle due to the cumulative tunnelling (i.e drawdown in the alluvium at Rozelle is entirely attributable to the M4-M5 Link project), and only a negligible change for the sediments at Hawthorne Canal and Haberfield with the intersection of the M4 East and M4-M5 Link, however an increase in drawdown of up to 3 m can be seen in alluvial sediments along Iron Cove due to the combined projects. At the St Peters Interchange, less than 1 m of drawdown in the alluvium occurs due to M4-M5 Link tunnelling, however with the inclusion of the New M5 drawdowns of up to 1.5 m occur at the location of the interchange, and up to 3 m of drawdown occurs in the Cooks River alluvium to the south of the interchange due to the New M5.

Drawdown in the Ashfield Shale (**Figure 6-15**) is presented from the top of the shale extending into the underlying Hawkesbury Sandstone. The drawdown in the shale is predicted to be greatest at Sydenham where 44 m of drawdown in predicted. Other deep areas of drawdown in the Ashfield Shale occur at Haberfield and Strathfield.

Drawdown in the Hawkesbury Sandstone again shows a more continuous pattern along the complete WCX program of works (**Figure 6-8**), with the greatest drawdowns observed over Rozelle. Significant drawdown depths are also expected in the deepest parts of the New M5 alignment, being the areas adjacent to the tanked tunnels passing under Cooks River, and the south of the St Peters Interchange at Sydenham. The greatest horizontal extent of drawdown is largely associated with the M4-M5 Link tunnels at Newtown extending to the St Peters Interchange with the cumulative drawdown from the New M5 tunnelling.

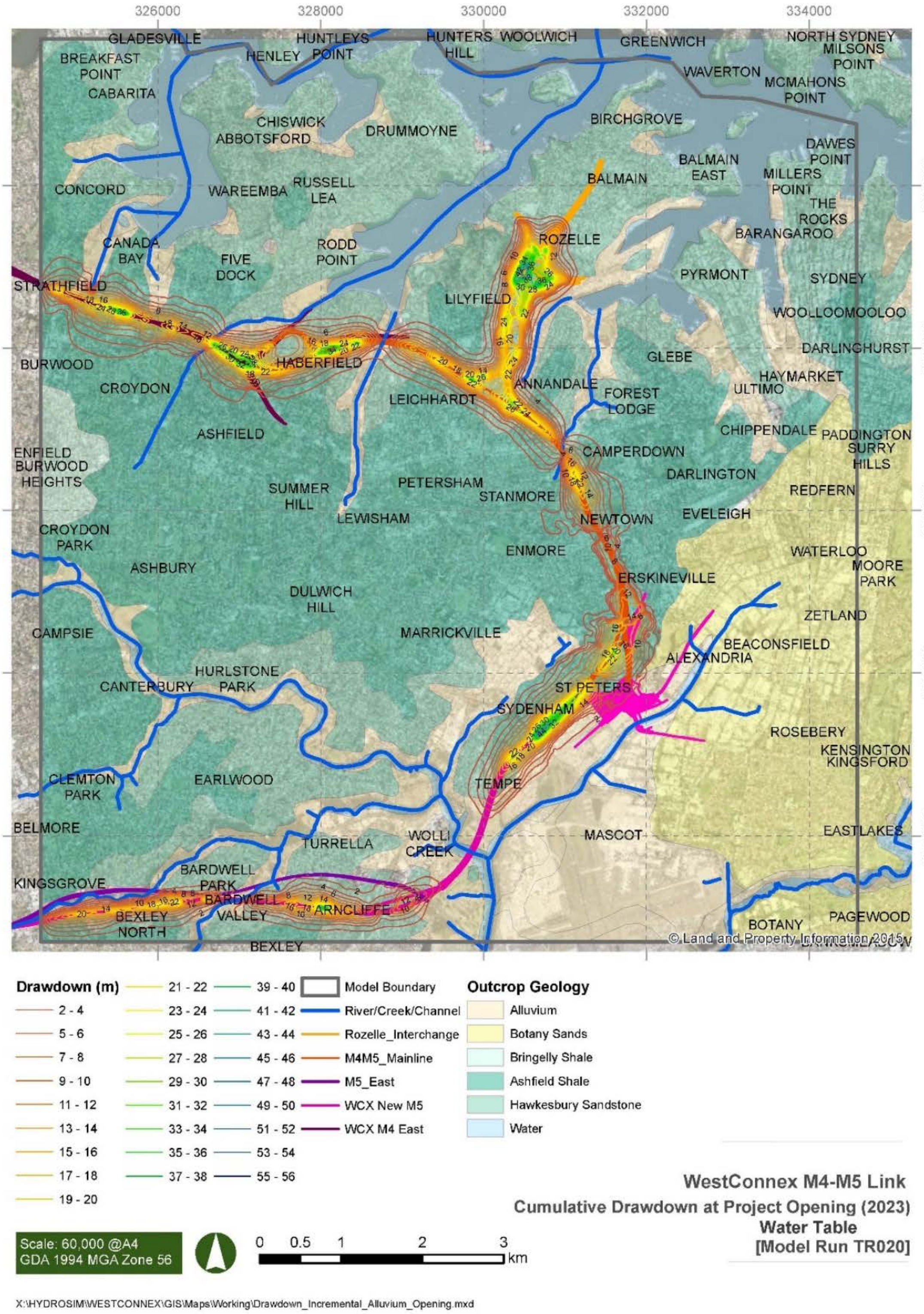

Figure 6-9 Cumulative WCX works water table drawdown at project opening (June 2023)

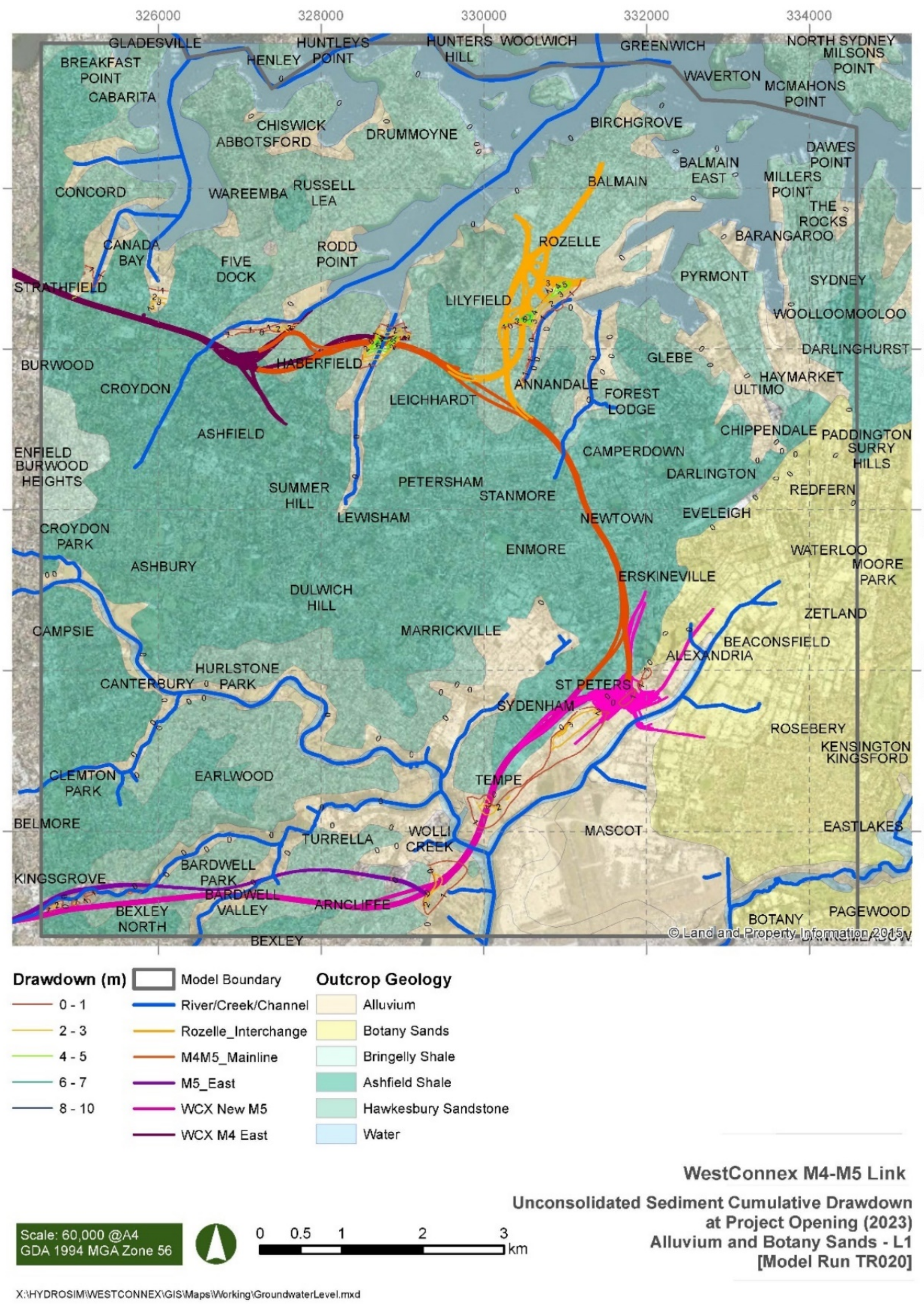

Figure 6-10 Cumulative WCX works drawdown in the alluvium at project opening (June 2023)

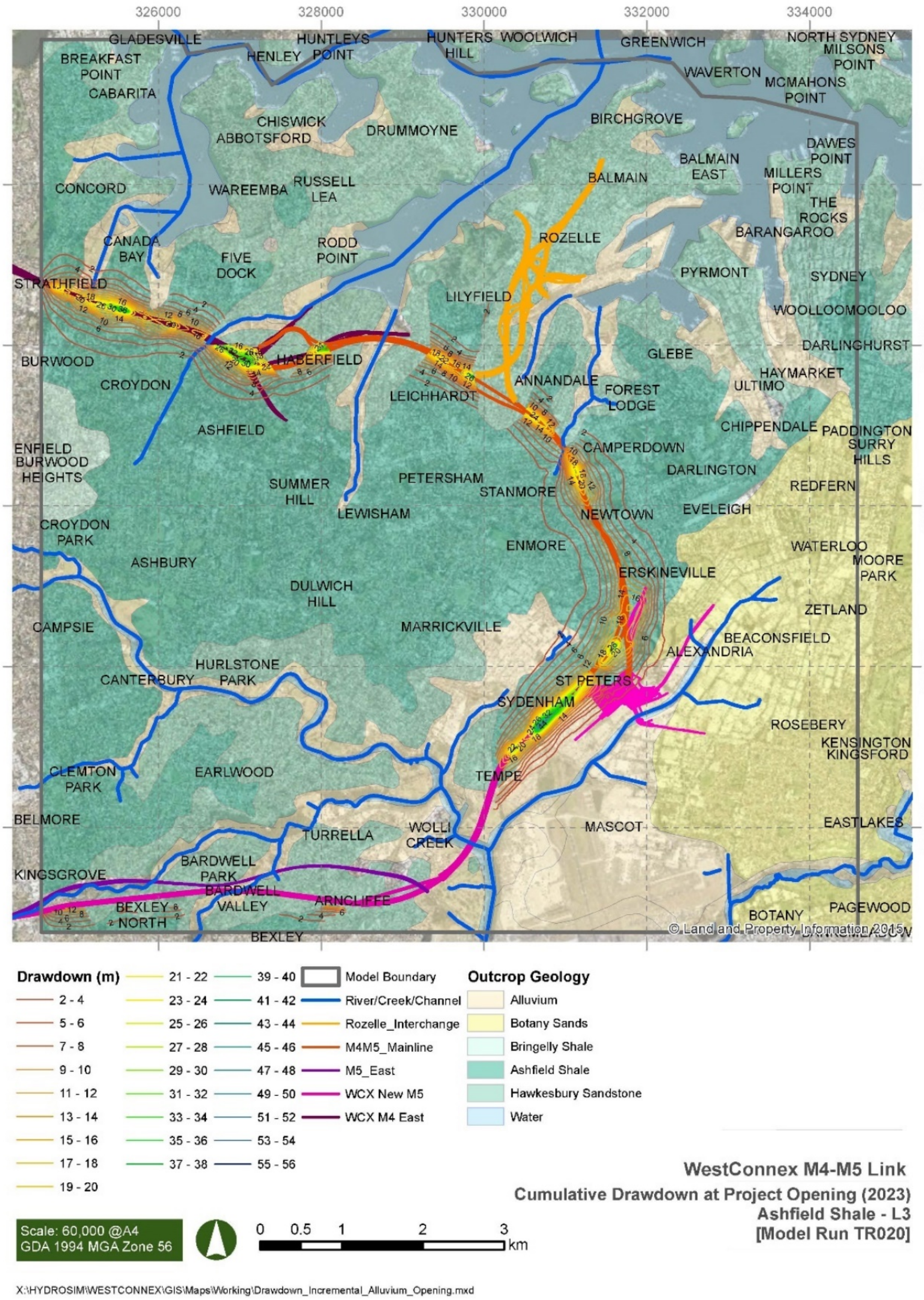

Figure 6-11 Cumulative WCX works drawdown in the Ashfield Shale at project opening (June 2023)

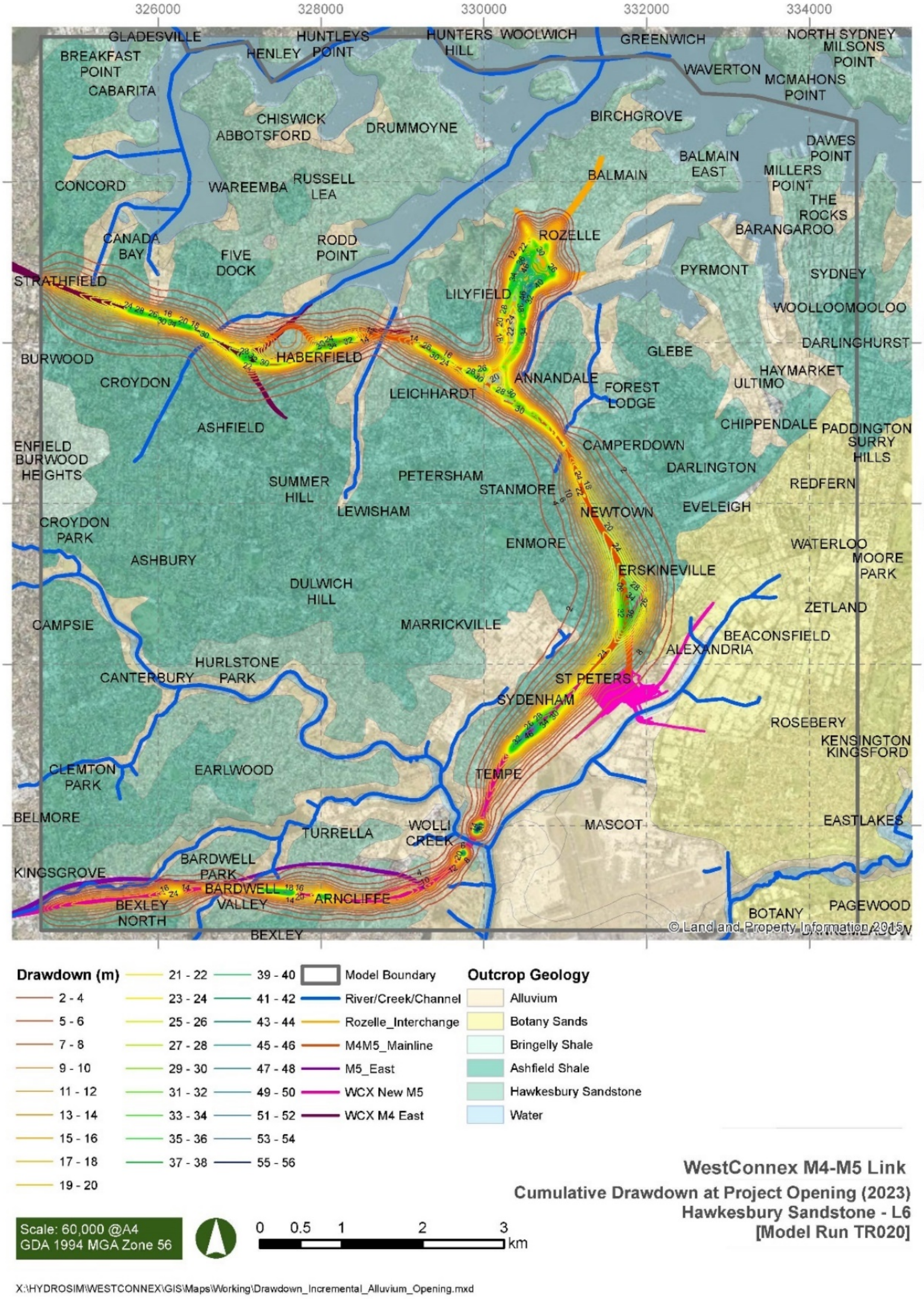

Figure 6-12 Cumulative WCX works drawdown in the Hawkesbury Sandstone at project opening (June 2023)

6.3.2 LONG TERM

Long-term drawdown to the water table (**Figure 6-13**) shows water levels are drawn-down to the tunnel inverts for all components of the WCX program of works, except under watercourses where recharge from the channels is preventing complete drawdown in these locations. Similarly, water table drawdown does not extend into the neighbouring Botany Sands, where higher hydraulic conductivity and recharge replenish any removal of water due to drainage to tunnels. The extent of drawdown is largest along the M4-M5 Link tunnels, with up to 1.4 km of drawdown to the 2 m interval. The M4 East tunnels show a drawdown extent of up to 1 km from the tunnels, greatest to the south of the alignment. It is likely water levels to the north are sustained by tidally influenced water bodies and alluvium. The New M5 has the least simulated drawdown extent, however the southern model boundary is likely to be artificially limiting the simulated drawdown to the south. The existing M5 East tunnel limits the drawdown extent simulated to the north (as drawdown from the M5 East tunnel is already included in the baseline run from which this drawdown is calculated).

Long term drawdowns in the unconsolidated material (**Figure 6-14**) remain as per the M4-M5 Link specific impacts at Rozelle (7 m), and minimal change to long-term drawdown occurs in the Hawthorne Canal sediments at Haberfield due to the combined M4 East and M4-M5 Link project impacts, again indicating the impacts here are largely attributed to the M4-M5 Link tunnelling. There is a very small increase in the drawdown extent in Iron Cove Creek sediments by year 2100. The greatest increase in longterm drawdown in the alluvium is seen at St Peters Interchange and along the Cooks River alluvium on the southern side of the New M5 tunnels. Drawdown reaches over 4 m near Sydenham and Tempe by 2100.

Drawdown in the Ashfield Shale is presented from the top of the shale extending into the underlying Hawkesbury Sandstone. (**Figure 6-15**) Drawdown within the Ashfield Shale and Hawkesbury Sandstone (**Figure 6-16**) again extends down to the tunnel invert levels. They show similar distributions to the water table drawdown with the exception of increased drawdown under watercourses. Drawdown in these deeper units also extends beneath the Botany Sands over the long term, suggesting the drainage to tunnels removes a larger volume of water than is able to be replenished from the overlying sediments (i.e. water is removed at a faster rate than the vertical leakage between the Botany Sands and shale/sandstone).

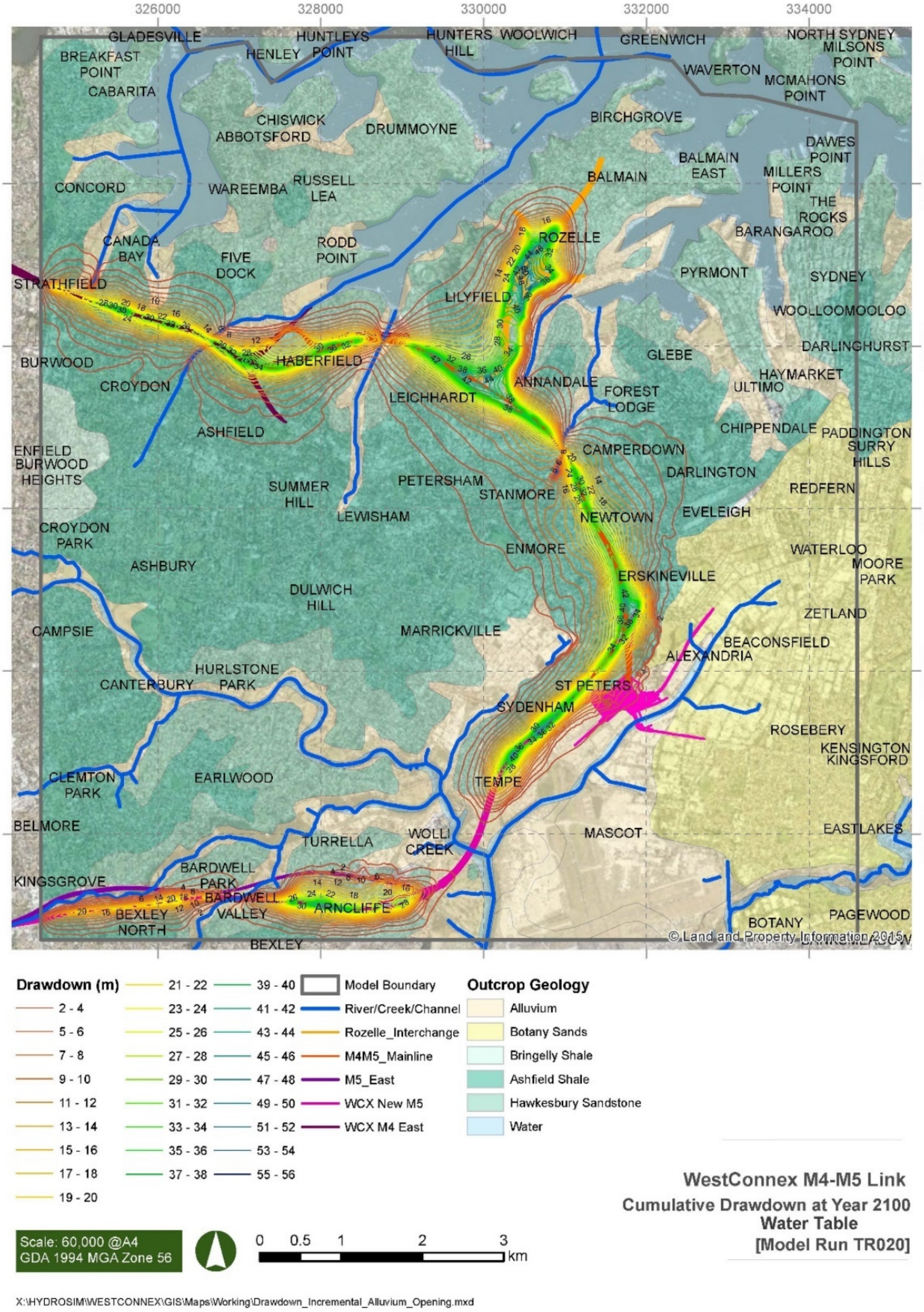

Figure 6-13 Cumulative WCX works water table long term drawdown (year 2100)

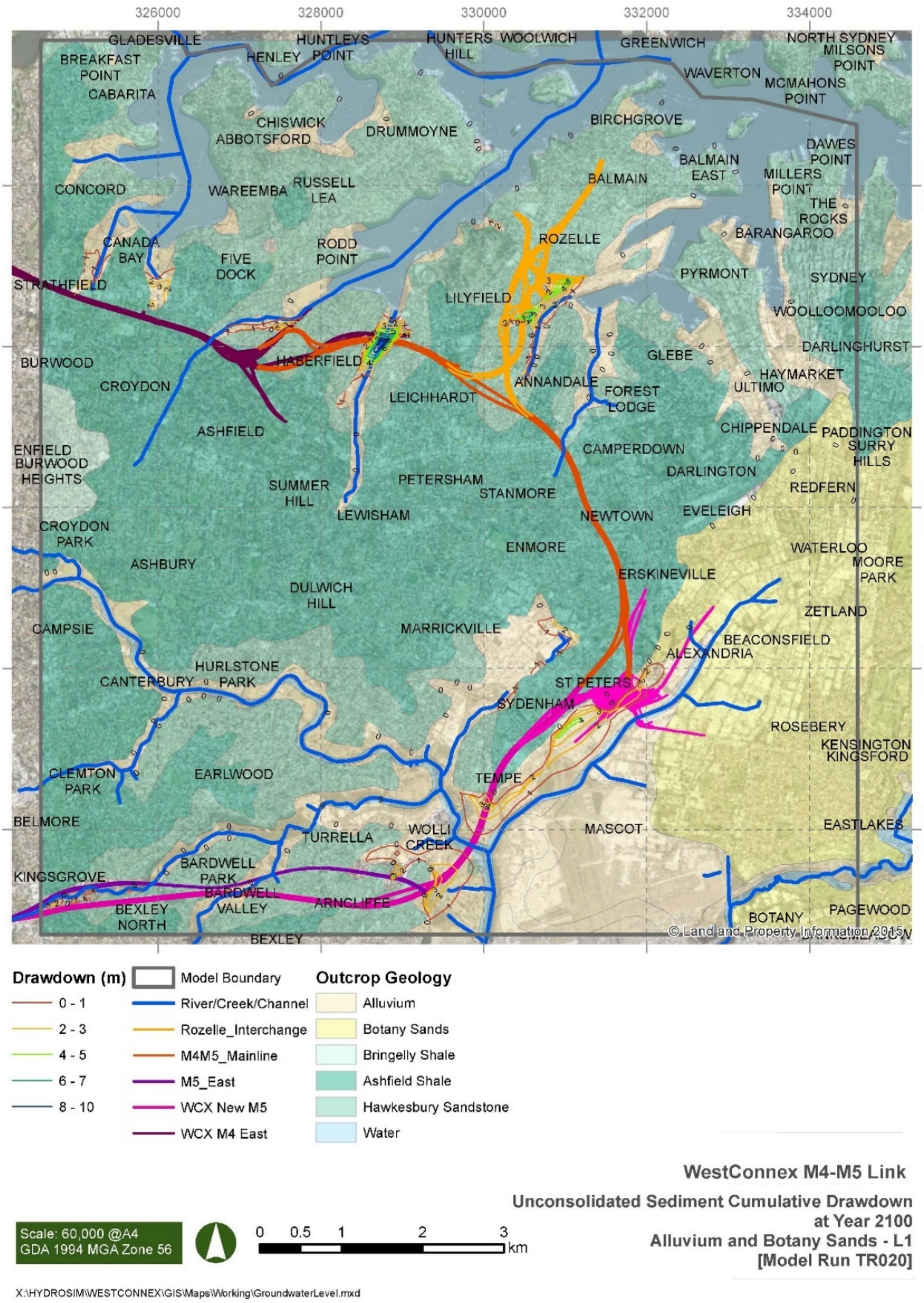

Figure 6-14 Cumulative WCX works long term drawdown in the alluvium (year 2100)

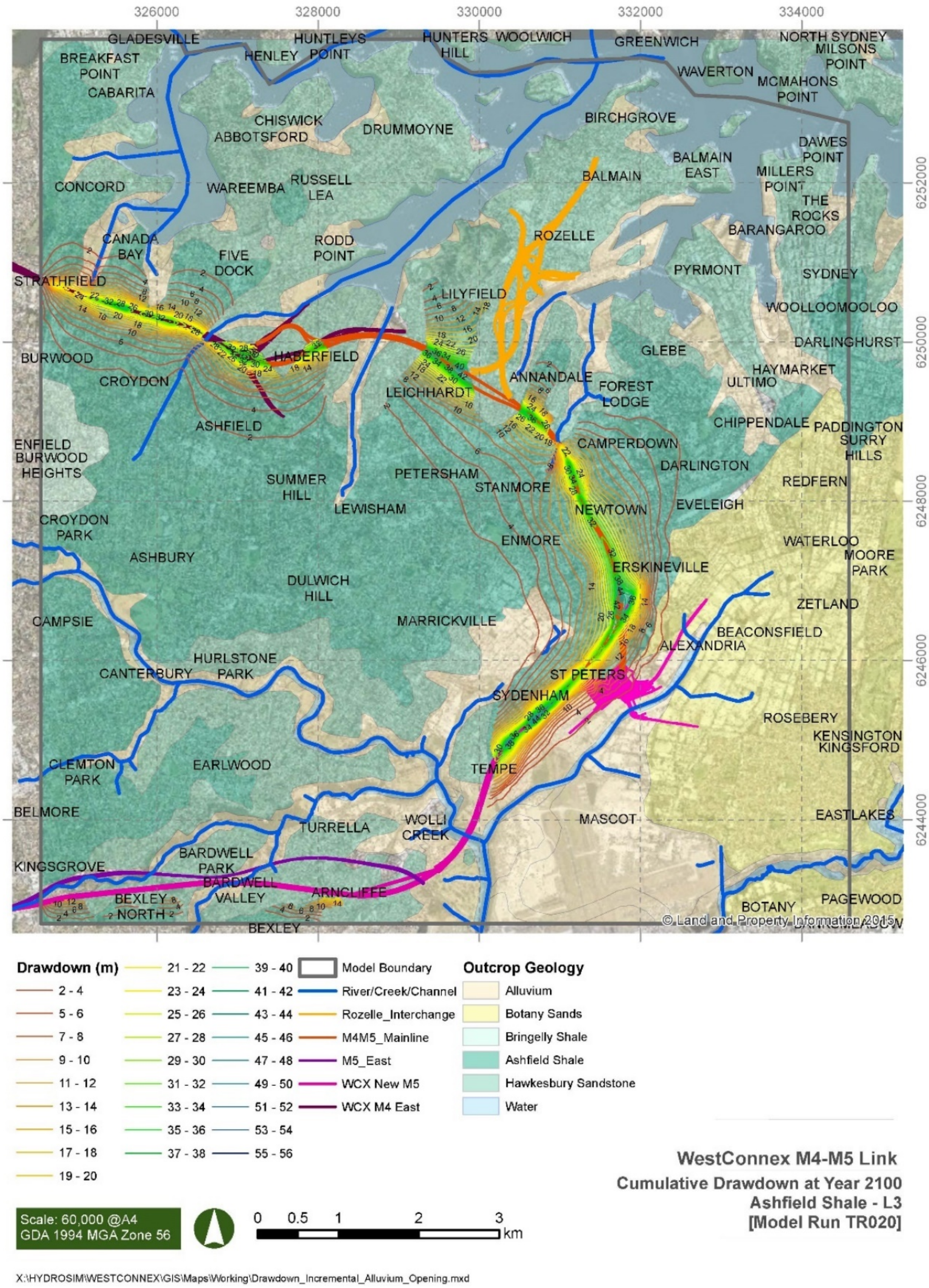

Figure 6-15 Cumulative WCX works long term drawdown in the Ashfield Shale (year 2100)

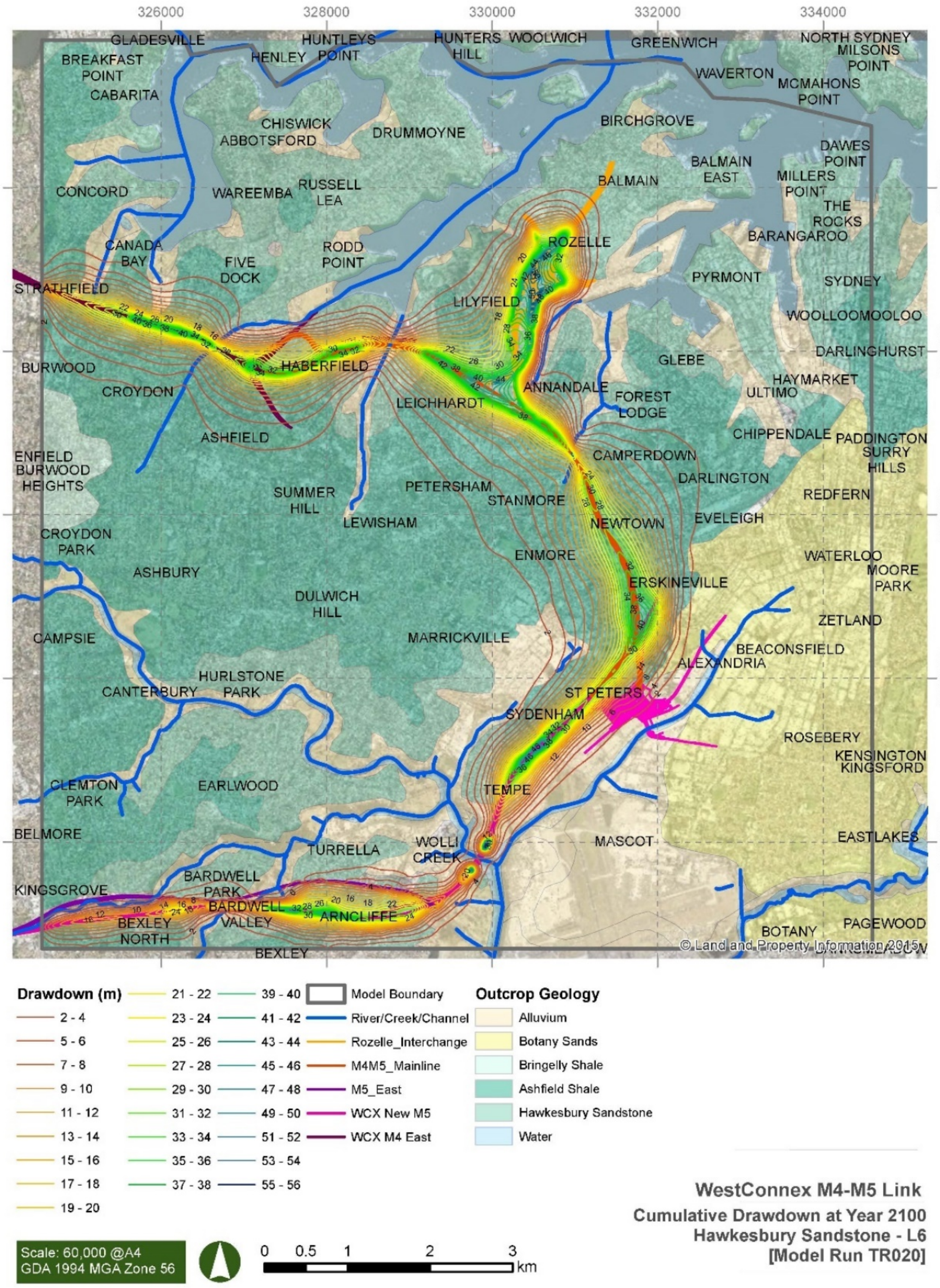

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Figure 6-16 Cumulative WCX works long term drawdown in the Hawkesbury Sandstone (year 2100)

6.3.3 CUMULATIVE DRAWDOWN DUE TO DESIGN CHANGES

Cumulative drawdown extents are likely to increase subtly in locations where the design changes have occurred to the M4-M5 Link (as discussed in **Section 6.2.3**) with drawdown ultimately expected to extend to the revised tunnel inverts. Cumulative effects due to the combined WestConnex program of works will only be observed at the project interfaces (Haberfield Interchange and the St Peters Interchange).

6.4 PREDICTED IMPACTS ON STREAM FLOW

6.4.1 BASEFLOW

Baseflow is defined here as the groundwater that discharges to a creek or a river and occurs when the groundwater elevation is higher than the stage of the river. Modelled changes in baseflow for the major rivers simulated in the model are summarized in **Table 6-3** for the impact on baseflow at project opening in 2023 and **Table 6-4** for the long-term impact on baseflow (at 2100).

The combined M4 East and New M5 projects are expected to reduce the baseflow input to Iron Cove Creek and Bardwell Creek by 38% and 21% respectively, with minimal to no impacts in any of the other streams. The M4-M5 Link project adds a further 5% baseflow reduction to Iron Cove Creek, as well as reducing baseflow to Hawthorne Canal by 32%, Whites Creek by 75% and Johnstons Creek by 20%.

The baseflows to the watercourses continues to reduce over time as the drawdown propagates away from the tunnels, with cumulative impacts of a 48% reduction in baseflow to Hawthorne Canal, 56% reduction to Iron Cove Creek, 28% to Johnstons Creek, 22% to Bardwell Creek and an 83% loss of baseflow to Whites Creek which is situated below the Rozelle Interchange.

It should be noted that although the baseflow component of stream flow is significantly reduced in several of the watercourses, it is expected that the overall contribution to river flow from groundwater input is relatively small due to the streams being mostly lined channels, several of which are tidally influenced near the project. Baseflow simulated in this model only represents the occasions when groundwater reaches the ground surface and enters the drainage system, and it is expected that the majority of stream flow would be derived from the runoff of surface storm water and tidal inflow. The actual proportions of total stream flow attributed to groundwater baseflow was unable to be determined as part of this study due to lack of stream gauging data.

Table 6-3 Predicted changes in baseflow at the end of construction (2023)

June 2023		Hawthorne Canal	Iron Cove Ck	Whites Ck	Johnstons Ck	Cooks River	Wolli Ck	Bardwell Ck
Base Case	Baseflow m3/day	298	281	177	289	666	625	311
Early WCX	Baseflow m3/day	298	174	177	289	664	540	247
	Reduction in baseflow m3/day	0	107	0	0	2	85	64
	% reduction	0	38	0	0	0.3	13	21
All WCX	Baseflow m3/day	202	160	45	230	664	540	247
	Reduction in baseflow m3/day	95	121	132	58	2	85	64
	% reduction	32	43	75	20	0.3	13	21
Change due to M4-M5	Reduction in baseflow m3/day	96	14	132	59	0	0	0
	% reduction	32	5	75	20	0	0	0

Table 6-4 Predicted long-term changes in baseflow (2100)

January 2100		Hawthorne Canal	Iron Cove Ck	Whites Ck	Johnstons Ck	Cooks Rv	Wolli Ck	Bardwell Ck
Base Case	Baseflow m3/day	291	274	174	282	643	613	308
Early WCX	Baseflow m3/day	287	142	174	282	635	516	240
	Reduction in baseflow m3/day	4	132		0	8	96	68
	% reduction	1	48	0	0	1	16	22
All WCX	Baseflow m3/day	150	121	29	203	635	516	240
	Reduction in baseflow m3/day	141	153	145	79	8	96	68
	% reduction	48	56	83	28	1	16	22
Change due to m4m5	Reduction in baseflow m3/day	136	20	145	79	0	0	0
	% reduction	47	7	83	28	0	0	0

6.4.2 LEAKAGE

Leakage is the process of water exiting the surface water flow channel and recharging the groundwater. In this model it is restricted by a low stream bed conductance of 0.001 m/day, a value arbitrarily applied to represent the degraded lining of the majority of water-courses in the study area (except Wolli Creek and Bardwell Creek which are natural). An increase in leakage from rivers occurs when the drawdown due to tunneling lowers the groundwater elevation is below the river stage. All simulated rivers (except Bardwell Creek) have a tidal influence in the areas where WCX tunneling will occur, therefore the leakage from these water courses induced as a result of tunneling is likely to have an electrical conductivity approaching that of sea-water. Modelled changes in leakage for the major rivers simulated in the model are summarized in **Table 6-5** at project opening in 2023 and **Table 6-6** for the long-term change in leakage (at 2100).

The combined M4 East and New M5 projects are expected to induce additional leakage to Iron Cove Creek, Wolli Creek and Bardwell Creek of 128%, 17% and 19% respectively, with minimal to no impacts in any of the other streams. The M4-M5 Link project adds a further 27% leakage to Iron Cove Creek, as well as inducing 26% of additional leakage to Hawthorne Canal, 115% to Whites Creek and 73% to Johnstons Creek.

As drawdown from tunneling continues to increase over time, so does induced leakage from the channels, with cumulative impacts of a 40% additional leakage from Hawthorne Canal, 222% from Iron Cove Creek, 104% from Johnstons Creek, 20% from Bardwell Creek and 189% from Whites Creek.

Table 6-5 Predicted changes in leakage at the end of construction (2023)

June 2023		Hawthorne Canal	Iron Cove Ck	Whites Ck	Johnstons Ck	Cooks River	Wolli Ck	Bardwell Ck
Base Case	Leakage m3/day	16	16	38	30	66	586	436
Early WCX	Leakage m3/day	16	36	38	30	66	686	517
	Increase in Leakage m3/day	0	20	0	0	0	100	81
	%increase	0	128	0	0	0	17	19
All WCX	Leakage m3/day	20	40	81	52	66	686	517
	Increase in Leakage m3/day	4	25	43	22	0	100	81
	% increase	26	155	115	73	0	17	19
Change due to M4-M5	Increase in Leakage m3/day	4	4	43	22	0	0	0
	% increase	26	27	115	73	0	0	0

Table 6-6 Predicted long-term changes in leakage (2100)

January 2100		Hawthorne Canal	Iron Cove Ck	Whites Ck	Johnstons Ck	Cooks Rv	Wolli Ck	Bardwell Ck
Base Case	Leakage m3/day	16	16	38	31	67	591	438
Early WCX	Leakage m3/day	17	46	38	31	67	696	527
	Increase in Leakage m3/day	0	30	0	0	0	106	89
	% increase	1	185	0	0	1	18	20
All WCX	Leakage m3/day	23	52	110	62	67	696	527
	Increase in Leakage m3/day	7	36	72	32	0	106	89
	% increase	40	222	189	104	1	18	20
Change due to m4m5	Increase in Leakage m3/day	6	6	72	32	0	0	0
	% increase	39	37	189	104	0	0	0

6.4.3 BASEFLOW AND LEAKAGE DUE TO DESIGN CHANGES

It is not expected that the project design changes (either construction Option B or the bifurcation of tunneling) would result in significant changes to the above reported predicted impacts to channel flow due to lack of connection with the alluvium.

6.5 PREDICTED TAKE FROM BOTANY SANDS

Groundwater within the Botany Sands is known to have areas of contamination resulting from past and present industrial activities, therefore any groundwater drainage induced from the Botany Sands due to WCX tunneling has the potential to cause localised spreading of contamination. The Ashfield Shale is present in the areas where the tunneling occurs in the vicinity of the Botany Sands (at St Peters Interchange) which, combined with the high hydraulic conductivity and rainfall recharge in the Botany Sands, appears to minimise the drawdown propagation into the Botany Sands (**Section 6.2** and **Section 6.3**). This in turn results in a negligible change in natural groundwater flow direction within the Botany Sands, therefore groundwater take from the Botany Sands aquifer due to tunneling is minimal. Predicted take from the Botany Sands increases with time due to increasing extent of drawdown associated with tunnel operational inflows (1.7 KL/day at project opening and 7.6 KL/day at 2100 for the M4-M5 Link Project and 5.7 KL/day at project opening and 15.5 KL/day at 2100 for the combined WCX program of works (**Table 6-7**)). If all the water drained from the Botany Sands where to reach the tunnels, it would provide a very small relative input to the total inflow to tunnels (**Section 6.1**) for the WCX works (typically less than 0.5%).

Table 6-7 Predicted take from Botany Sands

	M4-M5 Link		Cumulative WCX Works	
YEAR	KL/day	Total ML	KL/day	Total ML
2016	0.0	0	0.0	0
2017	0.0	0	0.0	0
2018	0.0	0	0.0	0
2019	0.1	0	1.8	1
2020	0.8	1	3.5	3
2021	1.7	1	4.9	5
2022	1.6	2	5.2	7
2023	1.7	3	5.7	10
2024	2.1	4	6.4	12
2025	2.4	5	7.0	15
2030	3.8	11	10.5	32
2041	5.2	30	12.7	81
2051	6.1	49	13.9	126
2100	7.6	178	15.5	395

Colours in table indicate the following project phases:

- Tunnel excavation
- Project opening
- Surface works / fit out
- Ongoing operation

There is unlikely to be any change to the above predicted values due to the project design changes (**Section 2.2.1**). The proposed bifurcation at St Peters Interchange is only applied to the north bound tunnel, therefore any minor changes in the groundwater regime/drawdown due to the bifurcation will be limited to the western side of the tunnels only.

6.6 PREDICTED IMPACTS ON GDES

There are no high priority GDEs identified within the study area, however there are several wetlands identified as potential GDEs in the BoM GDE Atlas (**Figure 3-6** to **Figure 3-7**). The potential for drawdown at these locations has been investigated and the results are shown in **Table 6-8**. Six of the 24 potential GDEs located within the model boundary would experience drawdowns of greater than 2 m if they are in direct hydraulic connection with the regional water table. However, the GDEs are more likely to sustain perched water tables in a natural condition. None of the impacted GDEs are considered as having a high potential for groundwater interaction (as per the BoM GDE Atlas). The GDEs that may be affected by WCX works drawdown are all located in the vicinity of the New M5 and all drawdown is due to the New M5 tunnelling, with no additional impacts associated with the M4-M5 Link project works.

Table 6-8 Drawdown >2m at potential GDE locations

BoM Identifier	Easting	Northing	Potential for GW Interaction	Location	Drawdown (m) at June 2023	Drawdown (m) at Jan 2100
1975237	326679	6243362	Moderate potential for GW interaction	Bardwell Valley Golf Club	4.60	5.84
1975206	326645	6243374	Low potential for GW interaction	Bardwell Valley Golf Club	3.40	6.16
1975273	326611	6243342	Low potential for GW interaction	Bardwell Valley Golf Club	4.95	6.15
1975433	326285	6243194	Moderate potential for GW interaction	Stotts Reserve Bardwell Valley	18.35	20.94
1975481	326110	6243151	Moderate potential for GW interaction	Stotts Reserve Bardwell Valley	21.04	23.01
1975262	326892	6243328	Moderate potential for GW interaction	Bardwell Valley Golf Club	2.50	2.96

The design changes discussed in **Section 2.2.1** are not likely to result in any increased potential for impact to the listed GDEs due to the proposed changes being more than 3 km from any listed GDEs. Additionally, Cooks River and Wolli Creek recharge the alluvium which is likely to sustain the GDEs closest to the project changes (at Turrella).

6.7 PREDICTED IMPACTS ON EXISTING GROUNDWATER USERS

Drawdown due to the construction and operation of the overall WCX works would affect 11 registered groundwater abstraction bores, screened within the Alluvium and Hawkesbury Sandstone. Only one of these bores (GW110247) is predicted to have drawdown directly attributable to the project. Domestic bore GW110247 (located at Sydney University) is predicted to have a drawdown of approximately 2.4 m to the piezometric head in the Hawkesbury Sandstone by the year 2100, however this would have a negligible effect on the capacity of the bore given its significant depth (210m).

The effects at other bores used for domestic supply or irrigation of recreational areas are attributed to drawdown from the New M5 tunnelling. One domestic bore (GW109966) is predicted to have water levels drawn down below its base (3 m depth) and will therefore no longer be usable without deepening the hole. Assuming the pumps are set at reasonable depths in the boreholes, the only other bore that is likely to have a drawdown impact that will significantly affect its operation is GW107993, which is located at Arncliffe Park and is only 14 m deep. A drawdown of over 10 m at this location will result in an insufficient head of water above the pump for it to remain in operation.

Drawdowns predicted by this modelling project are compared to those predicted by the New M5 Modelling Project (CDM Smith, 2015) in the last column of **Table 6-9**. Drawdown at GW072161 is approximately 5 m greater in this model, but is comparable at the other affected locations. It is unknown why the drawdown differs between the models at this location, but is likely to be an effect of differences in either the model geometry or the invert levels applied for the M5 East tunnel.

Figure 6-17 and **Figure 6-18** show the impacted bores and drawdown in the Alluvium and Hawkesbury Sandstone respectively.

A list of drawdowns predicted at all registered bore locations is presented in **Annexure B**.

Table 6-9 Drawdown >2m at registered abstraction bore locations

Reg. Bore ID	Easting	Northing	Screened Geology	Use	Depth (m)	Drawdown (m)		
						June 2023 (m)	Jan 2100 (m)	Previous M5 Model* Prediction (m)
GW110247#	332357	6248363	Sandstone	Domestic	210	0.21	2.40	NA
GW024109	329430	6243538	Alluvium	Water Supply	2	1.34	2.15	2.2
GW109965	329489	6243467	Alluvium	Domestic	8	1.73	2.62	2.4
GW108406	329510	6243455	Alluvium	Domestic	8	1.70	2.55	2.4
GW109966	329373	6243465	Alluvium	Domestic	3	2.35	3.75	4.5
GW108588	329440	6243429	Alluvium	Domestic	8	2.07	3.14	2.7
GW072161	329636	6243437	Sandstone	Recreation	91	6.14	6.51	1.9
GW109964	329426	6243419	Sandstone	Domestic	8	2.28	3.40	2.8
GW109963	329446	6243406	Sandstone	Domestic	8	2.32	3.40	2.7
GW107993	328242	6243424	Sandstone	Recreation	14	1.71	10.13	11.5
GW109191	325255	6243188	Sandstone	Recreation	186	6.66	6.89	5.7

impacted due to construction of M4-M5 link. All other bores impacted by New M5.

* Previous New M5 modelling was steady-state only, therefore results from previous modelling are more comparable with long-term model results

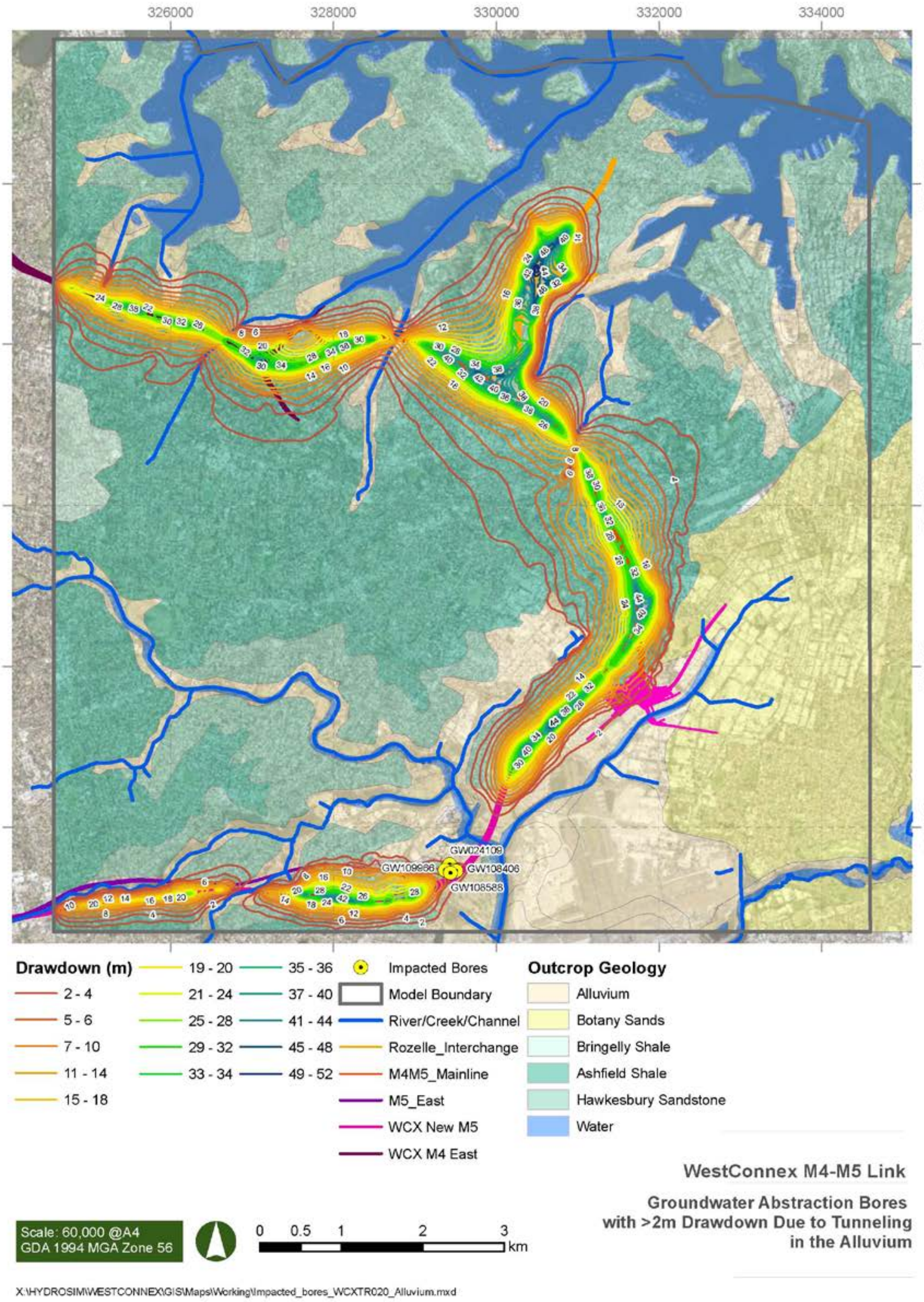

Figure 6-17 Groundwater abstraction bores with >2m drawdown screened in alluvium

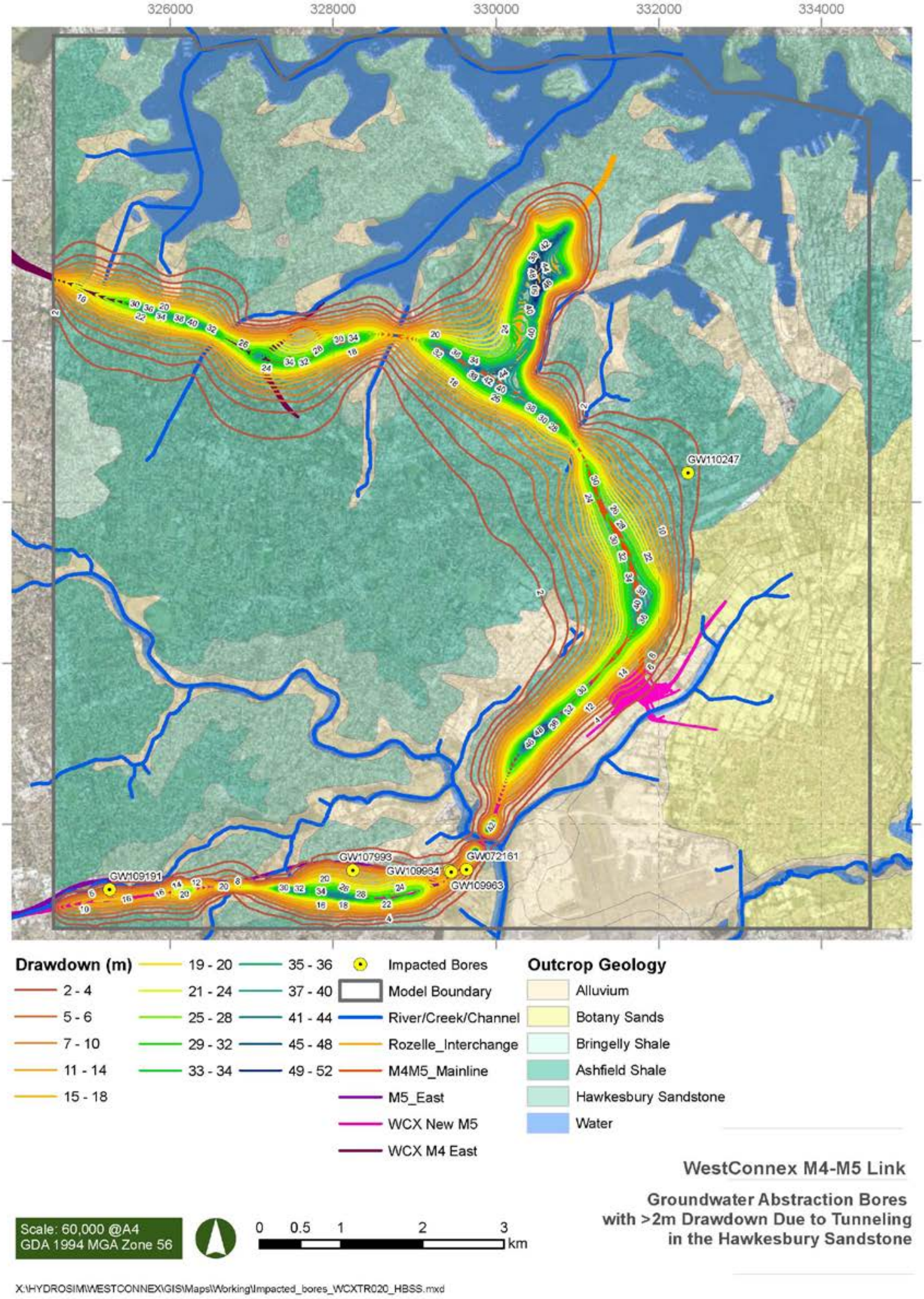

Figure 6-18 Groundwater abstraction bores with >2m drawdown screened in Hawkesbury Sandstone

There are no registered groundwater bores (other than those used for monitoring) near to any of the proposed project changes, therefore no additional bores will be impacted by the late design changes indicated in **Section 2.2.1**.

6.8 PREDICTED IMPACTS ON GROUNDWATER QUALITY

It is not possible to quantify volumes or concentrations of saline[3]/contaminated water entering the tunnels at any given time using the groundwater flow model created for the Project; therefore the following discussion of potential for saltwater intrusion is qualitative only.

The backwards particle tracking analysis undertaken in **Section 5.5** indicates that water from tidal alluvial areas (likely to have similar salinity to seawater) and the western-most area of the Botany Sands (known to have large areas of contamination) will eventually enter the tunnel. The capture zone differs from the drawdown area shown in **Section 6.2.** The reported drawdown reflects the area where the hydraulic gradient has been changed due to tunnelling, while the capture area shows where the water that ultimately enters the tunnel originates from, and is controlled by both regional flow and localised drawdown. All water within the capture zone will at some stage enter the drawdown cone of depression and increase in velocity due to the increased hydraulic gradient towards the tunnel associated with the drawdown. Areas where drawdown brings the groundwater level to below sea level (approximately 0-1 mAHD) will have ingress of water from tidal areas over time due to a reversal of hydraulic gradient away from the natural groundwater discharge areas.

The capture zone indicates that water from the alluvium associated with Parramatta River and its tributaries will be drawn into the M4 East tunnels and the tunnels at Rozelle Interchange. Similarly water from the alluvium associated with Cooks River will enter the New M5 Tunnels and the M4-M5 Link tunnels near St Peters Interchange. The capture for a few particles extends into the very edge of the Botany Sands, however this does not appear to be a dominant source of water to the tunnels (based on a low density of particle traces originating in the Botany Sands).

Table 6-10 summarises the travel times computed from each major alluvial area (and Botany Sands) to the tunnel. These times are based on the end-point time for all path-lines and do not include intermediate times. Saline water from areas of alluvium is predicted to flow into the tunnels in time frames varying from days to thousands of years. Early saline inflows are from water in alluvium directly above and adjacent to the tunnels which is rapidly drained into the tunnels in the areas of Cooks River, Whites Creek and Iron Cove Creek. The volume of saline water is expected to increase with time as water is drawn from more distant areas of the alluvium.

[3] .Note the term “saline” as used in this discussion refers to water of greater quantities of dissolved salts than the average regional water quality due to mixing with tidal waters, and is not representative of a specific range in concentrations

Table 6-10 Travel times from major alluvium areas (backward tracking)

Alluvium Area	Tunnel Entering	Minimum Time	Maximum Time	Average Time
Lower Cooks River / Alexandra Canal	New M5/St Peters Interchange	2 days	150 years	30 years
Wolli Creek	New M5	82 days	150 years	80 years
Parramatta River and Bays	M4 East and M4-M5 Link	>1,000 years	>1,000 years	>1,000 years
Iron Cove Creek	M4 East	15 days	70 years	35 years
Hawthorne Canal	M4-M5 Link	90 days	280 years	75 years
Whites Creek	Rozelle Interchange	8 days	26 years	13 years
Botany Sands	St Peters Interchange, M4-M5 Link	100 days	>1,000 years	>1,000 years

Forward tracking from tidal watercourses has been used to identify where there is potential for water to be drawn towards the tunnels from these saline water bodies, and therefore potential for saline intrusion to occur. **Figure 6-19** and **Figure 6-20** show the travel pathways of water originating in the tidal watercourses. Particle tracking using particles originating at the base of the tidal watercourses verifies the previously discussed backward particle tracking, showing that flow induced towards the tunnels from watercourses ultimately ends up in the tunnels, with the shortest times seen from the lower Cooks River/Alexandra Canal intersection, Whites Creek, Iron Cove Creek and Hawthorne Canal. **Annexure E** contains a series of snapshots in time and highlights the relatively slow migration of saline water towards the tunnels. The majority of water takes over 25 years to travel from the waterways to the tunnels, however there is potential for saline intrusion of water from these watercourses to impact the water quality in areas intermediate between the source and the tunnels within the space of a few years, particularly at Rozelle.

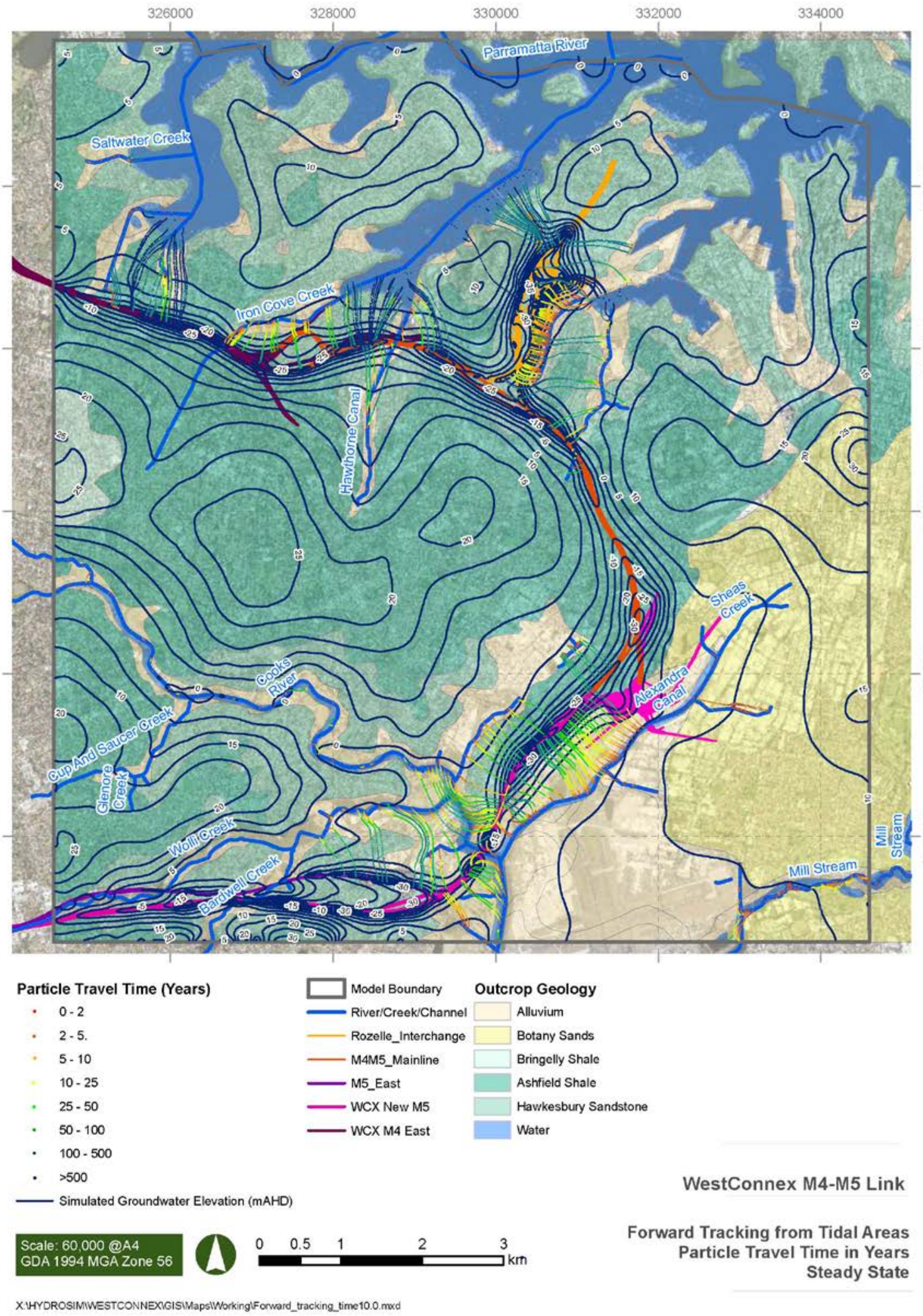

Figure 6-19 Forward tracking from tidal areas showing particle travel time in years

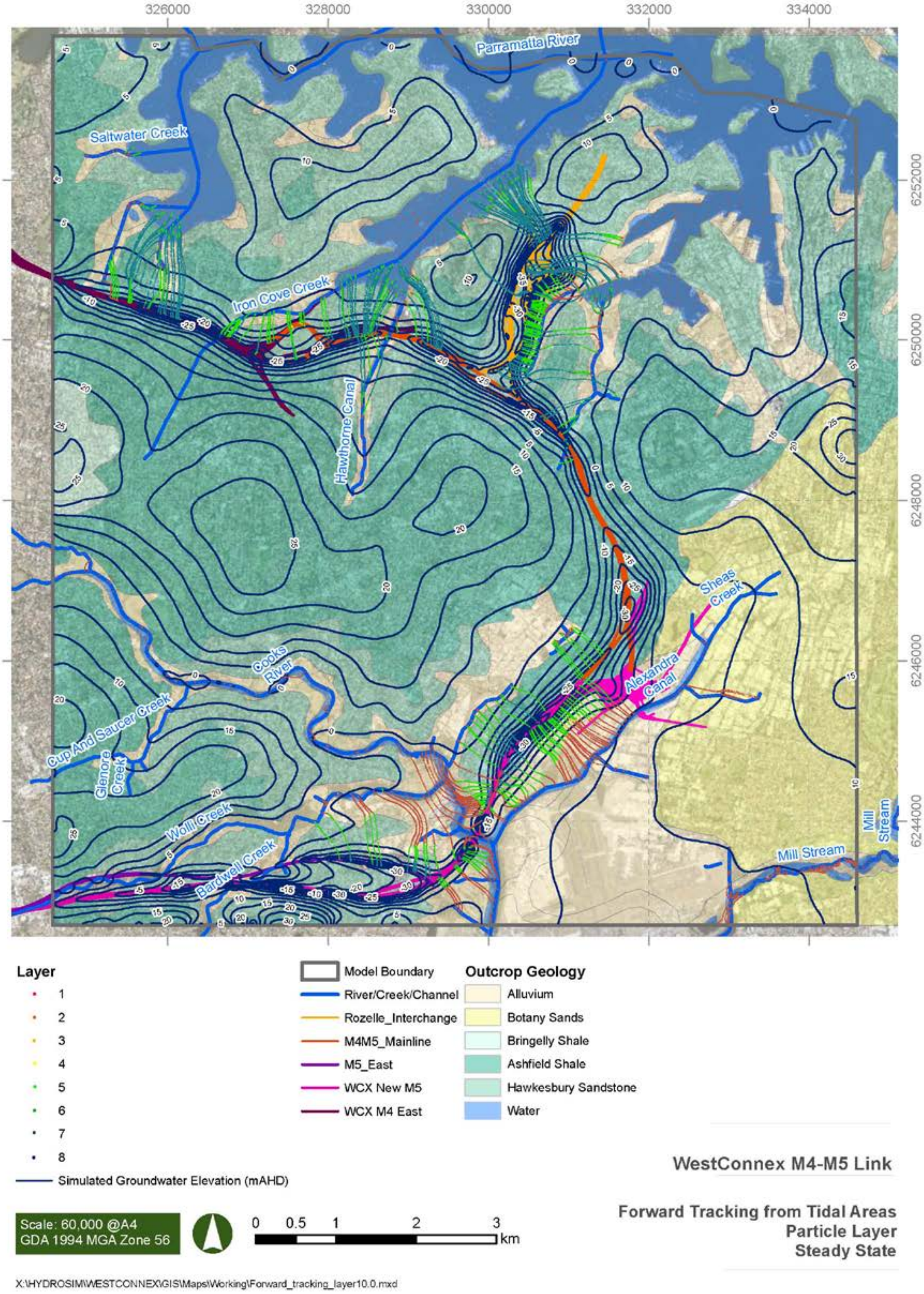

Figure 6-20 Forward tracking from tidal areas showing particle layer

Groundwater inflows to the tunnel should be tested and treated accordingly before disposal, as it is likely the concentration of salts and other contaminants will continue to increase over the operational life of the tunnels as a greater volume of saline water flows towards the tunnels. It is expected however that the contribution of saline water from tidal areas will be relatively small in comparison to overall tunnel inflow, therefore the combined tunnel seepage should not have excessively high salinities. As water entering the tunnels will be treated and then ultimately discharged to watercourses that drain to the tidal water bodies, the salt content of water entering the tunnels is less of an environmental issue and more of an operational/corrosivity issue. The tunnels adjoining St Peters Interchange are likely to see the most risk of saline water seepage due to its proximity to the Botany Sands and the large alluvial /paleochannel feature associated with Cooks River. The capture area and travel times also suggest that the Rozelle Interchange will receive saline water originating in White Bay and Rozelle Bay, and water from the Parramatta River will enter the M4 East tunnels and western extent of the M4-M5 Link Mainline.

7 CONCLUSIONS

A regional scale groundwater model has been prepared by HydroSimulations to provide input to the predicted effects of the M4-M5 Link project required as part of the Technical Groundwater Assessment (AECOM, 2017). The model was also required to consider the cumulative impacts of the earlier stages of WCX (M4 East and New M5).

The model has been built consistent with methods outlined in the *Australian Groundwater Modelling Guidelines* (Barnett *et al.*, 2012) as well as the MDBC Groundwater Flow Modelling Guideline (MDBC 2001), and provides a Class 2 confidence lLevel, which is suitable for its intended use of predicting the impacts of the proposed developments.

The key findings of this assessment are:

- The maximum annual inflow for the M4 East and New M5 components of WCX peaks at 806 ML/year in 2019, which is the final year of tunnel construction for these projects.
- The peak inflow to the M4-M5 Link project (inclusive of ventilation tunnels) does not occur until 2021, where a peak volume of 930 ML/year is obtained (again coinciding with the end of tunnel excavation).
- The cumulative inflow to WCX tunnels at the end of all phases of tunnel construction (end of 2021) is 5.6 GL, and 8.2 GL at project opening (2023).
- Long term tunnel inflow rates are 0.44 L/sec/km for combined M4 East and New M5 projects, and 0.24 L/sec/km for the M4-M5 Link project based on overall tunnel lengths of 32.5 km and 41.5 km respectively (inclusive of tunnels in two directions for the mainline and interchanges). This is well below the maximum allowable rate of 1 L/sec/km.
- Drawdown is expected to remain localised to the tunnel alignments, with a maximum modelled drawdown extent of less than 800 m either side of the alignment (near to Newtown) for all layers at project opening (2023), extending to 1.5 km at the end of the long-term model prediction (2100).
- The M4 East and New M5 projects reduce the baseflow input to Iron Cove Creek and Bardwell Creek by 38% and 21% respectively at the end of construction, with minimal to no impacts in any of the other streams. The M4-M5 phase of WCX adds a further 5% baseflow reduction to Iron Cove Creek, as well as reducing baseflow to Hawthorne Canal by 32%, Whites Creek by 75% and Johnstons Creek by 20%.
- The baseflow to the watercourses continues to reduce over time as the drawdown propagates away from the tunnels, with cumulative impacts of a 48% reduction in baseflow to Hawthorne Canal, 56% reduction to Iron Cove Creek, 28% to Johnstons Creek, 22% to Bardwell Creek and an 83% loss of baseflow to Whites Creek which is situated below the Rozelle Interchange. However it is important to note that the baseflow contribution to stream flow is expected to be very small due to the channels being concrete lined, with the majority of flow coming from tidal supplied water and surface runoff. Therefore the loss in baseflow is not expected to have a significant impact on overall flow.
- There are no high priority GDEs in the study area. Six locations identified by BoM as being potential GDEs would experience predicted drawdowns of greater than 2 m if they were in contact with the regional water table, however none of the GDEs are considered as having a high potential for groundwater interaction. All of the affected

GDEs are located in the vicinity of the New M5 and no predicted impacts to these locations are associated with the M4-M5 Link project.

- Drawdown due to the construction and operation of the overall WCX works is expected to have drawdown greater than 2 m at 11 registered groundwater abstraction bores (GW110247, GW02109, GW109965, GW108406, GW109966, GW108588, GW072161, GW109964, GW109963, GW107993 and GW109191) screened within the alluvium or Hawkesbury Sandstone. Only one of these bores (GW110247 located at Sydney University) is predicted to have drawdown directly attributable to the M4-M5 Link project, the other bores being impacted by the New M5.
- Capture zone analysis qualitatively suggests groundwater from tidal alluvium areas (assumed to have a high salinity due to direct connection with water bodies with concentrations at or approaching sea water) is likely to enter the tunnels. The first saline water would enter a tunnel within a few days to weeks in areas where a tunnel underlies alluvium (e.g. near Cooks River, Whites Creek and Iron Cove Creek). This would increase in volume (and therefore overall concentration) with time as water is increasingly drawn towards the tunnel from further afield. The drainage of groundwater from saline water bodies is expected to increasingly reduce the groundwater quality over time in the aquifers between the sources and the tunnels. However, the actual concentrations of water over time is not able to be quantified with this groundwater flow model.
- Due to time restrictions, minor changes to the project that were made after completion of groundwater modelling have been qualitatively assessed. These changes include a small increase in the length of tunneling for entry/exit ramps at Parramatta Road and bifurcation of tunnels at Haberfield, Leichhardt and St Peters to allow for smoother traffic flow between intersections. It is expected that there will be a small increase in groundwater inflow volume and the extent of drawdown local to the project alterations, however these increases are expected to be relatively minor. It is not anticipated that these changes would result in any additional impacts to groundwater users or GDEs due to the location of the changes relative to the potential receptors. Any changes in stream flow due to the changes would be negligible.

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