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2019-2020 ANNUAL REPORT OF GROUNDWATER MONITORING AT 38 TABBITA ROAD, DUNMORE NSW

DUNMORE SAND & SOIL PTY LTD

8 SEPTEMBER 2020

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VERSION 1

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8 September 2020

Dunmore Sand & Soil Pty Ltd
C/- Boral Quarries
38 Tabbitta Road
Dunmore NSW 2529

Attention: **Ben Williams**
Environmental Coordinator

Dear Ben

Annual report on groundwater monitoring at 38 Tabbitta Road, Dunmore, NSW: 2019 - 2020

Please find enclosed a copy of our report entitled as above. Thank you for the opportunity to undertake this work.

Should you have any queries, please do not hesitate to contact us on (02) 9922 1777.

For and on behalf of
Environmental Earth Sciences NSW

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1 INTRODUCTION

Environmental Earth Sciences NSW was engaged by Dunmore Sand & Soil Pty Ltd (DSS) to monitor groundwater levels and quality at the Dunmore Lakes Sand Project (Stages 2 – 4) at 38 Tabbita Road, Dunmore, NSW (the 'site') between May 2019 and May 2020. Refer to **Figure 1** for the site's locality.

The Dunmore Lakes Sand Project (Stages 2 – 4) has been approved for the extraction and processing of approximately eight million tonnes of sand under Development Consent 195-8-2004 (2004), issued on 29 June 2005 per the Environmental Planning and Assessment (EP&A) Act 1979. It is recognised that the operation of the Dunmore Lakes Sand Project has the potential to influence groundwater beneath the site.

To manage the potential impact on groundwater, DSS has implemented a groundwater monitoring and management program in line with the Development Consents for Stage 2 – 4 as per the following plans:

- Environmental Management Plan (EMP) (DS&S, 2006);
- Water Management Plan (WMP) (Arcadis, 2016); and
- Groundwater Monitoring and Management Plan (GMMP) (Environmental Earth Sciences NSW, 2018b).

In addition, DSS is seeking to modify the current Project Approval (DA 195-8-2004) under Section 75W of the EP&A Act 1979 to provide for an additional extraction area (Stage 5) on adjoining private land, encompassing two separate extraction areas; Stage 5A located at 471 Riverside Drive, and Stage 5B located at 69 Fig Hill Lane, Dunmore. An Environmental Assessment (EA) was submitted to NSW Department of Planning, Industry & Environment (DPIE) in support of the modification proposal, for review and public exhibition in February 2019.

Quarterly monitoring of the Stage 5 area has also been undertaken since May 2019, in order to provide further background information prior to development and is included within this report.

2 OBJECTIVES AND SCOPE OF WORK

The objective of this report is to assess whether former and on-going sand extraction activities are impacting groundwater levels and quality in accordance with the aforementioned Development Consents and management plans pertaining to the site.

The scope of works undertaken to achieve this objective included:

- Downloading data from water level loggers;
- Manual water level measurement to calibrate water levels;

- Review water level data from data loggers in the vicinity of Swamp Road Quarry, the Stage 3 sand dredging area and the proposed Stage 5 sand dredging area; and

- Review the groundwater quality data collected by Environmental Earth Sciences NSW and Boral during the monitoring period.

3 FIELDWORKS AND DATA DOWNLOAD

The groundwater monitoring network established for the site is illustrated in **Figures 2** and **3**, with details summarised in **Table 1**.

Water level data from each active monitoring location was downloaded from pressure transducer data loggers ('divers') at quarterly intervals by Environmental Earth Sciences NSW personnel in August 2019, November 2019 and May 2020. The current active monitoring locations with divers are:

- Stage 2 – 4: bores DG1, DG5d, DG6s, DG17, DG21, DG31 and DG36;

- Stage 5: bores MW5A1, MW5A3, MW5B2s and MW5B2d;

- bores Lower Dam and Rocklow Creek

During the May 2019 monitoring event, the diver in bore DG59 was removed as it was close to the Stage 3 dredge pond. By the August 2019 monitoring round, both bores DG59 and DG60 had been destroyed as a result of the expansion of Stage 3. In order to ensure full coverage of the monitoring network, bore DG1 with diver was re-added to the active network.

Water level data from May 2019 to May 2020 for all bores in the active network have been compared to rainfall totals in **Appendix A**, **Chart 1a-1c** and to tidal data in **Appendix A**, **Chart 2a-2c**.

Water quality monitoring of the active groundwater network was undertaken at quarterly intervals by Environmental Earth Sciences NSW personnel in August 2019 and November 2019, and by Boral personnel in February 2020 and May 2020. Field parameter measurements recorded at each location including standing water level (shown in **Table 2**), temperature, pH, EC and ORP. Refer to **Appendix E** for water quality meter calibration certificates. Data was compared against trigger levels outlined in the GMMP (Environmental Earth Sciences NSW, 2018b) for the purposes of this Annual Report.

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Table 1: Monitoring bore network

Bore ID	Easting	Northing	Elevation (mAHD[1])	Depth (m)	Screen interval (mBGL[2])	Status[3]	Diver installed[3]	Comments
BHA	301383	616892	2.225	5.2	2.2-5.2	Decommissioned	-[4]	-
BHB	301450	6167890	-	5.1	2.1-5.1	Decommissioned	-	Decommissioned in November 2016 due to Stage 3 dredge pond expansion.
BHC	301531	6167902	-	5.2	2.2-5.2	Decommissioned	-	Decommissioned in November 2016 due to Stage 3 dredge pond expansion.
BHD	301620	6167901	1.760	5.1	2.1-5.1	Decommissioned	-	Decommissioned in May 2018.
BHE	301595	6167932	-	5.1	2.1-5.1	Decommissioned	-	Decommissioned in November 2016 due to Stage 3 dredge pond expansion.
BHF	301505	6167931	2.225	5.2	2.2-5.2	Decommissioned	-	Decommissioned in February 2018.
DG1	301665	6167434	2.225	-	-	**Active**	Yes	DG1-s included within active bore network in August 2019
DG2	301665	6167434	2.598	-	-	Inactive		Monitoring ceased due to completion of Stage 1 area.
DG3	302005	6167259	1.866	-	-	Inactive	-	2015-16 Annual review recommended that monitoring cease due to completion of Stage

Bore ID	Easting	Northing	Elevation (mAHD[1])	Depth (m)	Screen interval (mBGL[2])	Status[3]	Diver installed[3]	Comments
								1 (Environmental Earth Sciences, 2016)
DG4	301966	6167408	2.083	-	-	Inaccessible	-	No longer accessible Removed from monitoring network
DG5s	301883	6167521	1.717	7.00	4.0 – 7.0	**Active**	-	Nested wells (DG5s and DG5d)
DG5d	301883	6167521	1.717	15.00	11.0 – 15.0	**Active**	Yes	Nested wells (DG5s and DG5d)
DG6s	301844	6167628	1.647	6.70	4.0 – 6.7	**Active**	Yes	Nested wells (DG6s and DG6d).
DG6d	301844	6167628	1.647	14.30	10.0 – 14.3	**Active**	-	Nested wells (DG6s and DG6d)
DG7	276637	6203886	3.17	5.00	2.0 – 5.0	**Active**	Yes	Installed November 2018
DG17	275757	6203448	3.49	6.00	2.8 – 6.0	**Active**	Yes	Installed November 2018
DG21	276480	6203877	2.12	5.00	2.0 – 5.0	**Active**	Yes	Re-installed in November 2018 as bore had been damaged (June 2017)
DG31	276186	6203803	3.05	5.50	2.5 – 5.5	**Active**	Yes	Re-installed in November 2018 as bore had been damaged (June 2017). Diver replaced in August 2018 as faulty.
DG35	276088	6204430	3.84	8.0	4.0 – 8.0	**Active**	-	Bore installed August 2018. No diver

Bore ID	Easting	Northing	Elevation (mAHD[1])	Depth (m)	Screen interval (mBGL[2])	Status[3]	Diver installed[3]	Comments
DG36	275982	6204182	2.31	8.0	5.0 – 8.0	**Active**	-	Bore installed August 2018. Diver installed November 2018
DG54	301403	6167969	2.311	11.5	-	Decommissioned	-	Decommissioned in 2017 / 2018 due to Stage 3 dredge pond expansion.
DG56	301639	6168017	1.369	10.5	-	Decommissioned	-	Decommissioned in 2017 /2018 due to Stage 3 dredge pond expansion.
DG59	301125	6167718	1.763	8.69	-	Decommissioned	-	Decommissioned in August 2019 due to Stage 3 dredge pond expansion
DG60	301275	6167683	1.501	1.9	-	Decommissioned	-	Decommissioned in August 2019 due to Stage 3 dredge pond expansion
Lower Dam	300801	6167833		-	-	**Active**	Yes	-
Rocklow Creek	300546	6167880		-	-	**Active**	Yes	-
Middle Dam	-	-		-	-	Inactive	-	Recommend reinstallation as diver had been removed and location damaged.
MW5A1	302269	6166996	4.31	7.25	3.25 - 7.25	**Active**	Yes	Installed October 2018. Provides background data

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Bore ID	Easting	Northing	Elevation (mAHD[1])	Depth (m)	Screen interval (mBGL[2])	Status[3]	Diver Installed[3]	Comments
MW5A2	302103	6166973	3.24	6.00	2.0 - 6.0	**Active**	-	Installed October 2018. Provides background data
MW5A3	302054	6167198	1.74	12.00	3.0 - 6.0/ 9.0 – 12.0	**Active**	Yes	Installed October 2018. Provides background data
MW5B1	301887	6166442	4.07	6.00	2.0 - 6.0	**Active**	-	Installed October 2018. Provides background data
MW5B2s	302004	6066039	3.93	6.69	2.0 - 6.0	**Active**	Yes	Installed October 2018. Provides background data
MW5B2d	302004	6066038	4.12	10.25	6.5 – 10.25	**Active**	Yes	Installed October 2018 Provides background data
MW5B3	302247	6066272	2.06	11.20	3.0 – 6.0/ 8.5 - 11.2	**Active**		Installed October 2018. Provides background data
MW5B4	302157	6166438	2.56	6.33	2.0 - 6.0	**Active**	-	Installed October 2018. Provides background data
MW5B5	302131	6165707	4.63	12.0	3.0 – 6.0/ 9.0 - 12.0	**Active**	-	Installed October 2018. Provides background data. Often dry

Notes:
1. mAHD – metres above Australian Height Datum
2. mBGL – metres Below Ground Level
3. Correct as of May 2020 round
4. - : no information available

3.1 Water level calibration

Standing water levels (SWL) are manually measured from the top of casing (TOC) of each monitoring bore with the TOCs surveyed to Australian Height Datum (mAHD). To assess groundwater levels, these measurements from TOC are converted into relative levels to calibrate datalogger measurements. Subtracting the bore dip from the surveyed TOC level provides a water level in mAHD that can be used to calibrate the datalogger pressure reading. **Table 2** below summarises the SWL for bores generally obtained during the August 2019 to May 2020 monitoring period.

Table 2: Standing water levels across the monitoring network August 2019 – May 2020

Location	Trigger Value[1]		Aug 2019	Nov 2019	Feb 2020[4]	May 2020[4]
	Upper Limit (mAHD	Lower Limit (mAHD)				
DG-1	-	-	1.488	1.61	1.15	1.33
DG5 (shallow)	-	-	1.15	1.24	0.84	1.04
DG5 (deep)	1.91	0.17	1.22	1.31	0.88	1.04
DG6 (shallow)	-	-	1.07	1.18	0.87	1.03
DG6 (deep)	-	-	1.13	1.22	0.87	1.03
DG7			2.23	2.97	2.11	2.12
DG17			2.78	3.05	2.23	2.43
DG21			2.16	2.29	1.54	1.88
DG31	-	-	2.96	3.04	2.14	2.68
DG35			2.35	2.78	2.11	1.31
DG36			1.47	1.97	1.22	1.41
Rocklow Creek	-	-	0.36	0.63	-	-
Lower Dam	-	-	4.12	4.17	-	-
MW5A1	-	-	3.67	3.97	3.23	3.66
MW5A2	-	-	2.595	2.69	2.1	2.61
MW5A3	-	-	1.1	1.3	0.77	1.04
MW5B1	-	-	2.9	3.06	2.34	1.04
MW5B2s	-	-	3.03	3.1	2.61	3.08
MW5B2d	-	-	3.26	3.33	2.58	3.07

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Location	Trigger Value[1]		Aug 2019	Nov 2019	Feb 2020[4]	May 2020[4]
	Upper Limit (mAHD)	Lower Limit (mAHD)				
MW5B3	-	-	2.08	1.63	1.36	1.5
MW5B4	-	-	dry	2.16	1.95	2.4
MW5B5	-	-		dry	-	-

Notes:

1. Trigger values taken from Table 5: Physical Triggers – Groundwater Levels of the GMMP (Environmental Earth Sciences, 2018b) (mAHD).
2. – no information available or not applicable
3. All measurements in mBTOC – metres Below Top of Casing
4. Measurements taken by Boral

The data logging of the piezometric pressure (water pressure) in the monitoring bores containing divers was undertaken at 60-minute intervals, with readings compensated for barometric changes. The data from the loggers is downloaded quarterly at each location and used to compare the piezometric head with tidal influence and rainfall. No measurements obtained from the diver data or SWL readings exceeded the trigger values outlined in the GMMP (Environmental Earth Sciences, 2018b).

3.2 Rainfall data

Local daily rainfall data was obtained from the Bureau of Meteorology (BOM) weather station 068242 located at Kiama (Bombo Headland) approximately 4.6 km from site. The majority of rainfall during both 2019 and 2020 occurred over summer. Two significant summer rainfall events totalling 88 mm (4th to 6th June 2019) and 175 mm (6th to 13th February 2020) were recorded[1].

Rainfall during this monitoring period was higher compared to previous years, which historically has not exhibited any rainfall events in excess of 100 mm. Rainfall totals at stage 2-4 and stage 5 compared to water level data at DS&S are presented in **Appendix A**, **Chart 1a**, **Chart 1b** and **Chart 1c**.

3.3 Tidal data

Tidal data from the Minnamurra River tidal monitoring station (214442) was purchased from Manly Hydraulics Laboratory[2] for the period between 3 June 2019 and 3 June 2019, in addition to data from BOM for the purpose of comparing the water level data to tidal movements (**Appendix A**, **Chart 2a, Chart 2b** and **Chart 2c**).

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[1] Sourced from [illegible], Accessed on 16 July 2020;
[2] Sourced from [illegible] Accessed and purchased on 3 June 2020

3.4 Water quality data

Water samples collected by Environmental Earth Sciences NSW during August and November 2019 quarterly monitoring rounds were submitted to Sydney Analytical Laboratories (SAL), a NATA accredited laboratory for the following analyses:

- Ionic balance (Na, K, Mg, Cl, SO_4, HCO_3, Ca, F)
- Dissolved iron
- Total nitrogen
- Faecal coliforms and enterococci

Groundwater sample events in the February and May 2020 monitoring rounds was undertaken by Boral. Groundwater samples were submitted to Labpoint Pty Ltd (Labpoint), a NATA accredited laboratory for the following suites of analyses:

- pH
- Electrical conductivity
- Redox
- Dissolved oxygen
- Total phosphorous
- Total nitrogen
- Major cations and anions (Na, K, Mg, Cl, SO_4, HCO_3, Ca, F)
- Soluble iron
- Ammonium
- Nitrate
- Faecal coliforms and enterococci

The results for each location are illustrated in Schoeller Plots in **Appendix B** compared to its historical results. Full laboratory transcripts are included in **Appendix C**.

Bores west of the Princes Highway (ID: DG1, DG17, DG21, DG31, DG35 and DG36) and bores east of the Princes Highway (ID: DG5s, DG5d, DG6s and DG6d and DG7) are presented separately due to historic evidence of strong tidal influence on easterly bores. The results are compared to their site-specific trigger value derived in the GMMP (Environmental Earth Sciences, 2018b), not the DA criteria which is more generic and outlined under Development Consent 195-8-2004 (2004).

Table 4 of the **Tables Appendix** summarizes quarterly data for the western bores (ID: DG1, DG17, DG21, DG31, DG35 and DG36). The following were identified as exceeding GMMP Trigger Values:

- Elevated EC above the trigger value of 1500 µS/cm on two occasions at bores DG17 and DG21, on one occasion at bore DG31 in May 2020;
- Elevated sodium (Na) in February 2020 (563.1 mg/L) in bore DG17, August (695 mg/L) and September (695 mg/L) 2019 in bore DG31;
- Elevated potassium (K) was reported on only one occasion February 2020 at bore DG17;
- Bores DG17 and DG31 recorded in excess of magnesium (Mg) trigger values for at least two monitoring events;
- Elevated chloride (Cl) was only recorded on one occasion (May 2020) at bore DG31;
- Iron (Fe) above the trigger value of 3 mg/L was recorded in August and November 2019 at bore DG35 (upgradient bore) and February 2020 in bore DG17;
- Bore DG31 reported elevated concentrations of SO_4 on three occasions (August and November 2019 and May 2020), which in excess of GMMP trigger value (300 mg/L).
- Bores DG17 had bicarbonate (HCO_3) in excess of trigger values (400 mg/L) for all occasions; and
- Elevated ammonia (NH3-N) reported in November 2019 at Bore DG17 and November 2019 and February 2020 in DG35.

Table 5 of the **Tables Appendix** summarizes quarterly data for the eastern bores (ID: DG5s, DG5d, DG6s, DG6d and DG7). The following were identified as exceeding site-specific GMMP Trigger Values:

- Elevated sodium (Na) in February 2020 (563.1 mg/L) in bore DG6d;
- Elevated potassium (K) was reported on only one occasion in August 2019 at bore DG5d and May 2020 at bore DG6s, consistently between August 2019 and May 2020 at bore DG6d;
- Bores DG5d and DG6s recorded in excess of magnesium (Mg) trigger values for two consecutive monitoring events (August and November 2019), consistently between August 2019 and May 2020 at bore DG6d;
- Elevated chloride (Cl) was recorded on at least three occasions at bore DG5d and DG6d, an in two consecutive monitoring events at bore DG6s;
- Bore DG6d reported elevated concentrations of SO_4 on three occasions (August and November 2019 and May 2020), which was in excess of GMMP trigger value (1,170 mg/L). Bore DG6s reported elevated concentrations of SO_4 on one occasion in February 2020.

- Bores DG5d and DG6s had bicarbonate (HCO_3) in excess of trigger values (400 mg/L) for one occasion, bore DG6d reported elevated HCO_3 for two consecutive monitoring events in August and November 2019;
- Bore DG5d (May 2020), DG6s (May 2020) and DG6d (November 2019) reported elevated dissolved iron (Fe) concentrations on one occasion; and
- Elevated ammonia (NH3-N) was recorded on two occasions (August and November 2019) at bore DG5d.

Table 6 and **Table 7** of the **Tables Appendix** summarizes quarterly data for the Stage 5A (ID: MW5A1, MW5A2 and MW5A3) and Stage 5B (ID: MW5B1, MW5B2s, MW5B2d, MW5B3 and MW5B4). Concentrations of major ions and other analytes were considered comparable to those in the 2018- 2019 annual monitoring events. The following were identified as exceeding site-specific Trigger Values:

- Groundwater pH was recorded below the trigger value range at MW5A1 in August and November 2019 and May 2020;
- Elevated dissolved iron (Fe) was consistently recorded at MW5A3 between August 2019 and May 2020; and
- Bore MW5B2d reported elevated dissolved iron (Fe) concentrations on one occasion in May 2020.

These results are discussed in more detail in **Section 4.3**.

3.5 Procedures for quality control and quality assurance

For August 2019 and November 2019 groundwater monitoring events, quality control was achieved by using SAL which is a NATA registered laboratory using American Society for Testing and Materials (ASTM) standard methods supported by internal duplicates, the checking of high, abnormal or otherwise anomalous results against the background and other chemical results for the sample concerned.

Quality assurance is achieved by confirming that field results, or anticipated results based upon comparison with field observations, are consistent with laboratory results. Also, sampling methods are uniform, and decontamination is thorough. In addition, the laboratory undertakes additional duplicate analysis as part of their internal quality assurance program on the basis of one duplicate analysis for every 20 samples analysed.

Field observations are compared with laboratory results when they are not as expected. Confirmation, re-sampling and re-analysis of a sample are undertaken if the results are not consistent with field observations and/or measurements. In addition, field duplicate sample results must be within the acceptable range of reproducibility. The summary of the relative percentage differences (RPDs) of the collected intra duplicate samples is presented in **Appendix D**.

It is noted that the groundwater laboratory chemical results conducted by Boral for February and May 2020 groundwater monitoring rounds do not provide field duplicate samples.

4 DATA INTERPRETATION AND DISCUSSION

4.1 Temporal water levels

Chart 1a, **1b** and **1c** in **Appendix A** display the latest rainfall and groundwater levels (mAHD) at:

- Current (bores DG1S, DG5, DG6, DG17, DG21, DG31 and DG36) and historical (bores DG59) monitoring locations at DS&S since May 2018 (**Chart 1a**); and
- Rocklow Creek and Lower Dam at the Dunmore Quarry since October 2018 (**Chart 1b**).
- Stage 5 area (MW5A1, MW5A3, MW5B2s and MW5B2d) since October 2018 (**Chart 1c**)

4.1.1 Dunmore Sand & Soil (Stage 2-4)

Based on the data collected during the monitoring period May 2019 – May 2020, the following comments can be made in reference to **Chart 1a**, and the water level monitoring at DS&S

- All bores continue to display a strong relationship to large (> 20 mm) rainfall events with a slight lag time. Groundwater levels were anomalous compared to previous years' fluctuations mid -February, considered to be associated with the significant rainfall events (June 2019 and February 2020).
- Remaining fluctuations in groundwater are attributed to rainfall or tidal influences.
- Background bore DG5 (deep) reported a standing water level (SWL) of 1.04 m below top of casing (mBTOC). This is within the normal SWL range (2.15 – 0.9 mBTOC) measured for this location between August 2019 – May 2020.

The inferred groundwater flow directions are similar to previous annual groundwater monitoring events, indicated in **Figure 4** and **Figure 5** which showed a consistent south easterly pressure gradient towards Rocklow Creek, the Minnamurra River and the coast.

4.1.2 Dunmore Quarry

The data from Rocklow Creek showed good responsiveness to rainfall events >20 mm and a relatively stable level of groundwater. Refer to **Chart 1b** attached. Temporal data from the November 2018 to May 2020 period has been included.

4.1.3 Stage 5

The response to rainfall is rapid, confirming that recharge to the aquifer is primarily via direct infiltration from the surface, with potential local run-on from outcropping bedrock. Refer to **Chart 1c** attached. **Table 2** provides manual dip SWL data for all bores for the same period and confirms the relative consistency of groundwater elevations over time, with bore MW5B1 being hydraulically up-gradient of Stage 5B and bore MW5A2 up-hydraulic gradient of Stage 5A. Groundwater flow directions are to the north-east at Stage 5A in both November 2019 and February 2020, and the groundwater flow directions towards from north-east in

November 2019 to east in February 2020 at Stage 5B as indicated in **Figures 6 - 7**. respectively.

4.1.4 Groundwater level response to rainfall

The aquifer beneath site has historically responded rapidly to local rainfall events (Environmental Earth Sciences 2009-2019), a trend which was repeated during 2019-2020 monitoring period at all locations (**Appendix A**, **Chart 1a**, **1b** and **1c**).

Two rainfall events were recorded during the May 2019 – May 2020 monitoring period that exceeded 80 mm. Historically, several rainfall events >150 mm were generally recorded across the monitoring period. The increased recharge of the aquifer via rainfall was evidenced in the upward trend in groundwater levels across the site.

Water levels up-gradient (DG36) reported a downward trend over the winter of 2019, which recovered from February 2020 onwards, indicative of background aquifer behaviour, which is less influenced by tidal impacts and direct rainfall recharge.

Water levels at bores DG31 report a slight downward trend (refer **Chart 1a**), which is considered to be more closely associated with lower rainfall in the region than site activities.

The groundwater in bores DG21 and DG31, although affected by rainfall, appear to have a dampened response (lower overall fluctuations) during 2019-20 when compared to the other bores on site. This is likely as a result of reduced sensitivity to rainfall totals <20 mm, reduced tidal influences, and being located further up the catchment and closer to the edge of the aquifer/ unconsolidated sediments.

Bores DG17 and DG7 appear to be influenced both by rainwater recharge, and upstream tidal influences of Rocklow Creek and Dunmore Creek, respectively (**Chart 1a** and **Chart 1b**).

Bores down-gradient (DG5 and DG6) have generally remained consistent as these are more influenced by tidal fluctuations (**Appendix A**, **Chart 2a**).

Monitoring bores within Stage 5 exhibited a rapid rainfall response pattern and appeared to be more easily influenced by rainfall events (**Appendix A**, **Chart 1c**). Fluctuations in the water-table level up to 0.5m can be seen during significant rainfall events or periods of extended rainfall over several days, confirming that recharge to the aquifer is primarily via direct infiltration from the surface, with potential local run-on from outcropping bedrock. **Table 2** provides manual dip SWL data for all bores for the same period and confirms the relative consistency of groundwater elevations over time, with bore MW5B1 being hydraulically up-gradient of Stage 5B and bore MW5A2 up-hydraulic gradient of Stage 5A.

4.1.5 Groundwater level response and tide analysis

The unconfined aquifer which is intercepted by all bore locations is susceptible to tidal influences, however at relatively low amplitudes. Tidal characteristics of the aquifer are shown in **Appendix A**, **Chart 2a**, **Chart 2b** and **Chart 2c**.

Groundwater fluctuations in response to tidal influxes in bores DG5 and DG6 have historically been larger, while the tidal amplitudes at bores DG31 and DG21 exhibit dampened responses. Bores DG7 and DG17 also show dampened responses but appear to be impacted by fluctuations in Rocklow Creek and Dunmore Creek, respectively. This indicates a reduced tidal impact on groundwater levels further up the Rocklow Creek catchment.

Chart 2c shows groundwater fluctuations in bores (MW5A1 and MW5A3) at Stage 5A in response to tidal influxes are relatively larger than those bores (MW5B2d and MW5B2s) in Stage 5B, which showed dampened responses. This is to be expected given the proximity of Rocklow Creek to the north of Stage 5A.

4.2 Hydraulic gradient and groundwater flow direction

The groundwater hydraulic gradient at each location is determined by comparing the average standing water level (SWL, converted to mAHD) in the unconfined aquifer at each location to down-gradient bore DG5.

The inferred groundwater contours for Stage 2-4 (**Figure 4** and **Figure 5**) indicate that groundwater flow is influenced by both tidal movements and localised dredging activities in Stage 3, although overall there is a consistent south-easterly gradient towards Rocklow Creek, the Minnamurra River and the coast.

Beneath Stage 5, groundwater flow is towards the Minnamurra River which in turn flows around the south and east of the Site in a north-easterly direction. Groundwater flow is influenced by topography and regional recharge/ discharge zones. Hence, the hydraulic gradient is typical to the north east and east for both Stage 5A and Stage 5B areas towards the Minnamurra River feeding into the Pacific Ocean. It is anticipated that the outcrop of latite to the north of Stage 5B is likely to behave as a no-flow boundary (**Figure 6** and **Figure 7**).

4.3 Groundwater quality

4.3.1 Stage 2 - 4

Table 4 and **Table 5** summarise the chemical data collected in the August 2019 to May 2020 monitoring period at bores west and east of Princes Highway in Stage 2 -4, respectively. Bores west of the Princes Highway (ID: DG1, DG17, DG21, DG31, DG35 and DG36) and bores east of the Princes Highway (ID: DG5s, DG5d, DG6s and DG6d and DG7) are presented separately due the strong tidal influence on easterly bores. The results are compared to their site-specific trigger value, not the DA Criteria, which is more generic.

Due to tidal/ estuarine influences, bores east of the Princes Highway consistently reported greater salinity levels (as TDS in mg/L) than those west of the Princes Highway. The bores screened in the deeper portion of the aquifer (DG5d and DG6d) exhibited greater salinity concentrations than those screened in the shallow aquifer (DG5s and DG5s and DG7).

Ammonia (NH4-N) concentrations at bores west and the east of the site were reported as elevated compared to the trigger levels at various times. As the natural environment surrounding the site contains numerous wetlands and swamps, the presence of elevated concentrations of ammonia and other nitrogenous compounds is not unexpected and considered to be due to the natural breakdown of organic material.

Electrical conductivity (EC) above trigger values in the bores west of the Princes Highway will continue to be monitored. Analytes reported above the trigger values will continue to be monitored as per the contingency plan in the GMMP (Environmental Earth Sciences, 2018b), with consideration to current site operations and climate.

4.3.2 Stage 5

As works at Stage 5 have yet to commence, chemical data is provided for baseline information only and is subsequently presented in **Table 6** and **Table 7** for Stage 5a and Stage 5b, respectively. This area does not have site-specific values derived, the results have been compared to the DA Criteria currently in place for Stages 2-4, which is more generic. However, the more conservative values from the GMMP have also been included, for reference.

Based on the data collected to date, the following comments can be made in reference to the groundwater chemical monitoring at Stage 5:

- The dissolved iron concentrations were reported consistently exceeding trigger values at bore MW5A3.
- No elevated concentrations exceeding trigger values were recorded at Stage 5B from August 2019 to May 2020 groundwater monitoring events; except one exceedance was recorded for dissolved iron (Fe) at bore MW5B2d in May 2020 monitoring round.

However due to their proximity to the river, the elevated iron concentrations are considered representative of background levels.

5 RECOMMENDATIONS FOR FUTURE MONITORING

Quarterly groundwater level and quality monitoring should continue in line with the Development Consents for Stage 2 – 4 as well as the EMP (DSS, 2006), WMP (Arcadis, 2016) and GMMP (Environmental Earth Sciences, 2018b). It is understood that DSS ceased Stage 1 dredging activities at the Swamp Road site in March 2009, and the site is currently a rehabilitated pond. DSS is also in the process of seeking to modify the current project approval to include an additional extraction on the adjacent area (Stage 5). Sand dredging of Stage 2 is complete and dredging operations within Stage 3 are approaching capacity.

Based on a review of 2019/ 2020 monitoring data the following adjustments are recommended to the program:

- monitoring of representative onsite diver locations for both Stage 2 -4 and Stage 5 should continue at quarterly intervals as indicated on **Figure 2** and **Figure 3** by the active monitoring network;
- bore DG1 should be included as a replacement of historical bore DG59 within the active monitoring network, and monitored at quarterly intervals for the Stage 3 dredging area; and

- As there is proposed further dredging at Stage 5 area, it is anticipated that bores MW5A1 to MW5A3, MW5B1, MW5B2s and MW5B2d may be compromised. Should this occur, it is recommended that three additional bores be installed around the proposed pond in the Stage 5A extraction area: one to the north; one to the east; and one to the south of the pond. It is also recommended that a further bore be installed to the north of the Stage 5B dredging ponds. It is recommended that all new bores be installed to a depth of at least six meters below ground level (mBGL); and

- Site-specific groundwater trigger values should be developed for Stage 5 to be amended in the GMMP (Environmental Earth Sciences, 2018b).

6 CONCLUSIONS

The data obtained from the data loggers installed in bores DG1, DG5, DG6, DG7, DG17, DG21, DG31, DG35, and DG36 indicates that over the past monitoring year natural fluctuations in water levels were occurring in response to rainfall and tide as illustrated in **Appendix A**. This is consistent with previous findings dating back to 2003 (Environmental Earth Sciences 2009, 2010, 2011, 2012, 2013a, 2014, 2015, 2016a, 2017 and 2018a, 2019).

All data obtained from the bores monitored strongly indicates the following:

- that influences on groundwater levels are related to recharge from rainfall and minor tidal influx (this finding is supported by chemical monitoring of tidal seawater intrusion from Rocklow Creek);

- reductions in groundwater levels are related to periods of low rainfall where the aquifer is slowly draining from Rocklow Creek and the south-east aquifer boundary; and

- water-table fluctuations are therefore naturally occurring and cannot be seen to be impacted by dredging activities in the area, except in immediate proximity to the dredge pond.

Based on the data collected to date, it is recommended to:

- continue to monitor SWL in all bores with downloads and manual measurements at quarterly intervals;

- exceedances of K, Mg and Cl in the deep aquifer to the east of the highway, and Mg in bores DG17 and DG31 are considered natural occurrences, and the GMMP should be revised to reflect this occurrence;

- continue to monitor groundwater quality in all active bores at quarterly intervals.

7 LIMITATIONS

This report has been prepared by Environmental Earth Sciences NSW ACN 109 404 006 in response to and subject to the following limitations:

1. The specific instructions received from Dunmore Sand & Soil Pty Ltd;

2. The specific scope of works set out in PO119078 dated 12 April 2019;

3. May not be relied upon by any third party not named in this report for any purpose except with the prior written consent of Environmental Earth Sciences NSW (which consent may or may not be given at the discretion of Environmental Earth Sciences NSW);

4. This report comprises the formal report, documentation sections, tables, figures and appendices as referred to in the index to this report and must not be released to any third party or copied in part without all the material included in this report for any reason;

5. The report only relates to the site referred to in the scope of works being located at 38 Tabbita Road, Dunmore, NSW, 2529 ("the site");

6. The report relates to the site as at the date of the report as conditions may change thereafter due to natural processes and/or site activities;

7. No warranty or guarantee is made in regard to any other use than as specified in the scope of works and only applies to the depth tested and reported in this report;

8. Our General Limitations set out at the back of the body of this report.

8 REFERENCES

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9 GLOSSARY OF TERMS

The following descriptions are of terms used in the text of this report.

Acid Sulfate Soil (ASS). A soil containing iron sulfides deposited during either the Pleistocene or Holocene geological epochs (Quaternary aged) as sea levels rose and fell.

Alluvial. Describes material deposited by, or in transit in, flowing water.

Anaerobic. Reducing or without oxygen.

Aquifer. A rock or sediment in a formation, group of formations, or part of a formation which is saturated and sufficiently permeable to transmit economic quantities of water to wells and springs.

Aquifer, confined. An aquifer that is overlain by a confining bed with significantly lower hydraulic conductivity than the aquifer.

Aquifer, perched. A region in the unsaturated zone where the soil is locally saturated because it overlies soil or rock of low permeability.

Background. The natural level of a property.

Baseline. An initial value of a measure.

Biodegradation. A biochemical process of microbial oxidation of complex organic compounds, to simpler chemical products. Micro-organisms derive the energy and cell carbon for growth from oxidation of organic compounds.

Bore. A hydraulic structure that facilitates the monitoring of groundwater level, collection of groundwater samples, or the extraction (or injection) of groundwater. Also known as a well, monitoring well or piezometer, although piezometers are typically of small diameter and only used for measuring the groundwater elevation or potentiometric surface.

Borehole. An uncased well drill hole.

Cation Exchange Capacity (CEC). The maximum positive charge required to balance the negative charge on colloids (clays and other charged particles). The units are milli-equivalents per 100 grams of material or centimoles of charge per kilogram of exchanger.

Clay. A soil material composed of particles finer than 0.002 mm. When used as a soil texture group such soils contain at least 35% clay.

Colluvial. Unconsolidated soil and rock material moved down-slope by gravity.

Confined Aquifer. An aquifer that is confined between two low-permeability aquitards. The groundwater in these aquifers is usually under hydraulic pressure, i.e. its hydraulic head is above the top of the aquifer.

Confining layer. A layer with low vertical hydraulic conductivity that is stratigraphically adjacent to one or more aquifers. A confining layer is an aquitard. It may lie above or below the aquifer.

Contaminant. Generally, any chemical species introduced into the soil or water. More particularly relates to those species that render soil or water unfit for beneficial use.

Contamination. Is considered to have occurred when the concentration of a specific element or compound is established as being greater than the normally expected (or actually quantified) background concentration.

Diffusion. A process by which species in solution move, driven by concentration gradients (from high to low).

Dilution. The mixing of a small volume of contaminated leachate with a large volume of uncontaminated water. The concentration of contaminants is reduced by the volume of the lower concentrated water. However the physical process of dilution often causes chemical disequilibria resulting in the destruction of ligand bonds, the alteration of solubility products and the alteration of water pH. This usually causes precipitation by different chemical means of various species.

Discrete sample. Samples collected from different locations and depths that will not be composited but analysed individually.

Dispersion. A process by which species in solution mix with a second solution, thus reducing in concentration. In particular, relates to the reduction in concentration resulting from the movement of flowing groundwater.

Dissolved Oxygen (DO). Oxygen in the gaseous phase dissolved in water. Measured either as a concentration in mg/L or as a percentage of the theoretical saturation point, which is inversely related to temperature. At 19, 20 and 21 degrees Celsius, the oxygen concentrations in mg/L corresponding to 100% saturation are 9.4, 9.2 and 9.0 respectively.

Electrical Conductivity (EC). The EC of water is a measure of its ability to conduct an electric current. This property is related to the ionic content of the sample, which is in turn a function of the total dissolved (ionisable) solids (TDS) concentration. An estimate of TDS in fresh water can be obtained by multiplying EC by 0.65.

Flow path. The direction in which groundwater is moving.

Fluvial. A material deposited by, or in transit, in streams or watercourses.

Fracture. A break in the geological formation, e.g. a shear or a fault.

Gradational. The lower boundary between soil layers (horizons) has a gradual transition to the next layer. The solum (soil horizon) becomes gradually more clayey with depth.

Gradient. The rate of inclination of a slope. The degree of deviation from the horizontal; also refers to pressure.

Groundwater. The water held in the pores in the ground below the water table.

Groundwater Elevation. The elevation of the groundwater surface measured relative to a specified datum such as the Australian Height Datum (mAHD) or an arbitrary survey datum onsite, or "reduced level" (mRL).

Head space. The air space at the top of a soil or water sample.

Heavy Metals. All metallic elements whose atomic mass exceeds that of calcium (20) and includes lead (Pb), copper (Cu), Zinc (Zn), cadmium (Cd), and tin (Sn).

Heterogeneous. A condition of having different characteristics in proximate locations. Non-uniform. (Opposite of homogeneous).

Horizon. An individual soil layer, based on texture and colour, which differs from those above and below.

Hydraulic Conductivity (K). A coefficient describing the rate at which water can move through a permeable medium. It has units of length per time. The units for hydraulic conductivity are typically m3/day/m2 or m/day.

Hydraulic Gradient (i). The rate of change in total head per unit of distance of flow in a given direction – the direction is that which yields a maximum rate of decrease in head. Hydraulic Gradient is unit less.

Hydraulic Head (h). The sum of the elevation head and the pressure head at a point in an aquifer. This is typically reported as an elevation above a fixed datum, such as sea level.

Hydrocarbon. A molecule consisting of carbon and hydrogen atoms only, such as found in petroleum.

Hydrocarbon, volatile. A hydrocarbon with a low boiling point (high vapour pressure). Normally taken to mean those with ten (or less) carbon atoms per molecule.

Infiltration. The passage of water, under the influence of gravity, from the land surface into the subsurface.

Ionic Exchange. Adsorption occurs when a particle with a charge imbalance, neutralises this charge by the attraction (and subsequent adherence of) ions of opposite charge from solution. There are two types of such a charge: pH dependent; and pH independent or crystalline charge. Metal hydroxides and oxy-hydroxides represent examples of the former type, whilst clay minerals are representative of the latter and are normally associated with cation exchange.

Ions. An ion is a charged element or compound as a result of an excess or deficit of electrons. Positively charged ions are called cations, whilst negatively charged ions are called anions. Cations are written with superscript +, whilst anions use - as the superscript. The major aqueous ions are those that dominate total dissolved solids (TDS). These ions include: Cl-, SO42-, HCO3-, Na+, Ca2+, Mg2+, K+, NH4+, NO3-, NO2-, F-, PO43- and the heavy metals.

Lithic. Containing large amounts of fragments derived from previously formed rocks.

Mottled. Masses, blobs or blotches of sub-dominant, varying colours in the soil matrix.

Nodulation. Are hard, usually small, accumulation of precipitated iron and/or manganese in the soil profile, usually a result of past alternating periods of oxidation/reduction.

Nodule. A small, concretionary (hard) deposit, usually of iron and/or manganese.

Organics. Chemical compounds comprising atoms of carbon, hydrogen and others (commonly oxygen, nitrogen, phosphorous, sulfur). Opposite is inorganic, referring to chemical species not containing carbon.

Oxidation. Was originally referred only to the addition of oxygen to elements. However oxidation now encompasses the broader concept of the loss of electrons by electron transfer to other ions.

Perched Groundwater. Unconfined groundwater separated from an underlying main body of groundwater by an unsaturated zone. Perched groundwater typically occurs in discontinuous, often ephemeral, lenses, with unsaturated conditions both above and below.

Permeability (k). Property of porous medium relating to its ability to transmit or conduct liquid (usually water) under the influence of a driving force. Where water is the fluid, this is effectively the hydraulic conductivity. A function of the connectivity of pore spaces.

Piezometric or Potentiometric Surface. A surface that represents the level to which water will rise in cased bores. The water table is the potentiometric surface in an unconfined aquifer.

pH. A logarithmic index for the concentration of hydrogen ions in an aqueous solution, which is used as a measure of acidity.

Polycyclic aromatic Hydrocarbons (PAHs). Complex organic molecules which originate typically in the combustion of organic compounds.

Potential Acid Sulfate Soil (PASS). A soil that has the potential to become acidic if it is exposed to the atmosphere.

Porosity (n). The ratio of the volume of void spaces in a rock or sediment to the total volume of the rock or sediment. Typically given as a percentage.

Porosity, effective (ne). The volume of the void spaces through which water or other fluids can travel in a rock or sediment divided by the total volume of the rock or sediment.

Precipitation (chemical). There are two types of precipitation, pH dependent precipitation and solubility controlled precipitation. As the pH is raised beyond a threshold level the precipitation of metal cations such as oxy-hydroxides and hydroxides occur. As the pH is raised further precipitation continues until there are very few metal cations remaining in solution. This reaction is entirely reversible. Solubility controlled precipitation occurs between two ions when, at a given temperature and pressure, the concentration of one of the ions exceeds a certain level.

Profile. The solum. This includes the soil A and B horizons and is basically the depth of soil to weathered rock.

Purge (wells). The pumping out of well water to remove drilling debris or impurities; also conducted to bring fresh groundwater into the casing for sample collection. The later ensures that a more representative sample of an aquifer is taken.

QA/QC. Quality Assurance / Quality Control.

Recharge Area. Location of the replenishment of an aquifer by a natural process such as addition of water at the ground surface, or by an artificial system such as addition through a well

Recovery. The rate at which a water level in a well rises after pumping ceases.

Redox. REDuction-OXidation state of a chemical or solution.

Redox potential (Eh). The oxidation/reduction potential of the soil or water measured as milli-volt.

Reducing Conditions. Can be simply expressed as the absence of oxygen, though chemically the meaning is more complex. For more details refer to OXIDATION.

Remediation. The restoration of land or groundwater contaminated by pollutants, to a state suitable for other, beneficial uses.

Representative Sample. Assumed not to be significantly different than the population of samples available. In many investigations samples are often collected to represent the worst case situation.

Saturated Zone. A zone in which the rock or soil pores are filled (saturated) with water.

Shale. Fine-grained sedimentary rock formed by the compaction of silt, clay, or sand that accumulates in deltas and on lake and ocean bottoms. It is the most abundant of all sedimentary rocks.

Standing Water Level (SWL). The depth to the groundwater surface in a well or bore measured below a specific reference point – usually recorded as metres below the top of the well casing or below the ground surface.

Stratigraphy. A vertical sequence of geological units.

Subsoil. Subsurface material comprising the B and C horizons of soils with distinct profiles. They often have brighter colours and higher clay content than topsoils.

Texture. The size of particles in the soil. Texture is divided into six groups, depending on the amount of coarse sand, fine sand, silt and clay in the soil.

Topsoil. Part of the soil profile, typically the A1 horizon, containing material which is usually darker, more fertile and better structured than the underlying layers.

Total Dissolved Salts (TDS). The total dissolved salts comprise dissociated compounds and undissociated compounds, but not suspended material, colloids or dissolved gases.

Toxicity. The inherent potential or capacity of a material to cause adverse effects in a living organism.

Unsaturated Zone. The zone between the land surface and the water table, in which the rock or soil pores contain both air and water (water in the unsaturated zone is present at less than atmospheric pressure). It includes the root zone, intermediate zone and capillary fringe. Saturated bodies such as perched groundwater may exist in the unsaturated zone. Also referred to as the Vadose Zone.

Volatile. Having a low boiling or subliming pressure (a high vapour pressure).

Water table. Interface between the saturated zone and unsaturated zones. The surface in an aquifer at which pore water pressure is equal to atmospheric pressure.

Well. A hydraulic structure that facilitates the monitoring of groundwater level, collection of groundwater samples, or the extraction (or injection) of groundwater. Also known as a Bore.

ENVIRONMENTAL EARTH SCIENCES
CONTAMINATION RESOLVED

ENVIRONMENTAL EARTH SCIENCES GENERAL LIMITATIONS

Scope of services
The work presented in this report is Environmental Earth Sciences response to the specific scope of works requested by, planned with and approved by the client. It cannot be relied on by any other third party for any purpose except with our prior written consent. Client may distribute this report to other parties and in doing so warrants that the report is suitable for the purpose it was intended for. However, any party wishing to rely on this report should contact us to determine the suitability of this report for their specific purpose.

Data should not be separated from the report
A report is provided inclusive of all documentation sections, limitations, tables, figures and appendices and should not be provided or copied in part without all supporting documentation for any reason, because misinterpretation may occur.

Subsurface conditions change
Understanding an environmental study will reduce exposure to the risk of the presence of contaminated soil and or groundwater. However, contaminants may be present in areas that were not investigated, or may migrate to other areas. Analysis cannot cover every type of contaminant that could possibly be present. When combined with field observations, field measurements and professional judgement, this approach increases the probability of identifying contaminated soil and or groundwater. Under no circumstances can it be considered that these findings represent the actual condition of the site at all points.

Environmental studies identify actual sub-surface conditions only at those points where samples are taken, when they are taken. Actual conditions between sampling locations differ from those inferred because no professional, no matter how qualified, and no sub-surface exploration program, no matter how comprehensive, can reveal what is hidden below the ground surface. The actual interface between materials may be far more gradual or abrupt than an assessment indicates. Actual conditions in areas not sampled may differ from that predicted. Nothing can be done to prevent the unanticipated. However, steps can be taken to help minimize the impact. For this reason, site owners should retain our services.

Problems with interpretation by others
Advice and interpretation is provided on the basis that subsequent work will be undertaken by Environmental Earth Sciences NSW. This will identify variances, maintain consistency in how data is interpreted, conduct additional tests that may be necessary and recommend solutions to problems encountered on site. Other parties may misinterpret our work and we cannot be responsible for how the information in this report is used. If further data is collected or comes to light we reserve the right to alter their conclusions.

Obtain regulatory approval
The investigation and remediation of contaminated sites is a field in which legislation and interpretation of legislation is changing rapidly. Our interpretation of the investigation findings should not be taken to be that of any other party. When approval from a statutory authority is required for a project, that approval should be directly sought by the client.

Limit of liability
This study has been carried out to a particular scope of works at a specified site and should not be used for any other purpose. This report is provided on the condition that Environmental Earth Sciences NSW disclaims all liability to any person or entity other than the client in respect of anything done or omitted to be done and of the consequence of anything done or omitted to be done by any such person in reliance, whether in whole or in part, on the contents of this report. Furthermore, Environmental Earth Sciences NSW disclaims all liability in respect of anything done or omitted to be done and of the consequence of anything done or omitted to be done by the client, or any such person in reliance, whether in whole or any part of the contents of this report of all matters not stated in the brief outlined in Environmental Earth Sciences NSW's proposal number and according to Environmental Earth Sciences general terms and conditions and special terms and conditions for contaminated sites.

To the maximum extent permitted by law, we exclude all liability of whatever nature, whether in contract, tort or otherwise, for the acts, omissions or default, whether negligent or otherwise for any loss or damage whatsoever that may arise in any way in connection with the supply of services. Under circumstances where liability cannot be excluded, such liability is limited to the value of the purchased service.

FIGURES

Figure 1: Site locality map

Figure 2: Site layout and borehole locations – Stage 2-4

Figure 3: Site layout and borehole locations – Stage 5

Figure 4: Inferred Groundwater Contours, Stage 2-4 – Nov 2019

Figure 5: Inferred Groundwater Contours, Stage 2-4 – Feb 2020

Figure 6: Inferred Groundwater Contours, Stage 5 – Nov 2020

Figure 7: Inferred Groundwater Contours, Stage 5 – Feb 2020

Source: Google Maps

ENVIRONMENTAL EARTH SCIENCES

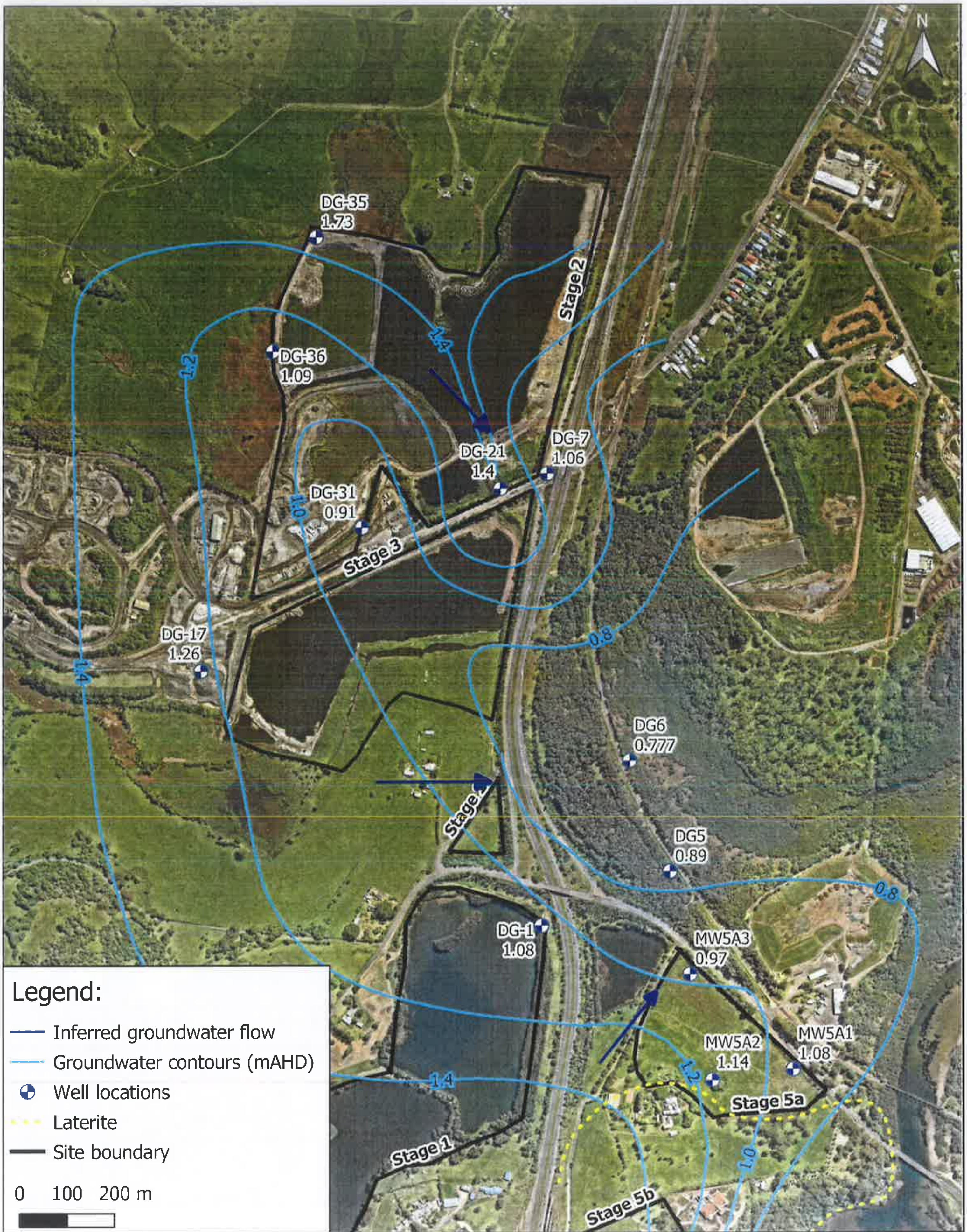
Title:	Site Locality Map		
Location:	Dunmore, NSW		
Client: Dunmore Sand and Soil Pty Ltd			Job No: 119037
Project Man: KS	Scale: As Shown		Figure 1
Drawn By: LB	Date: July 2020		

ENVIRONMENTAL EARTH SCIENCES

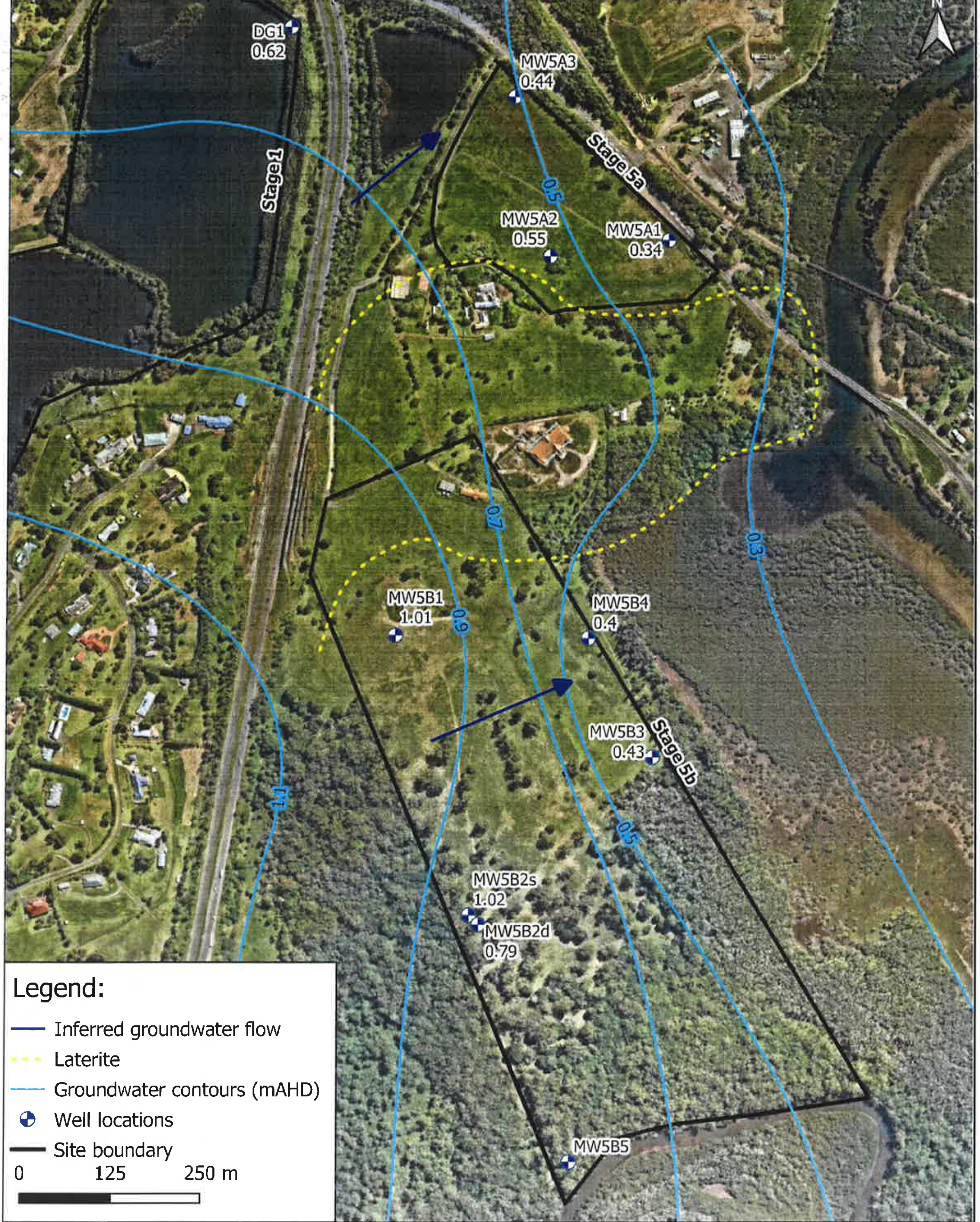
Drawn by: EG	Date: July 2020	**Dunmore Sand & Soil Pty Ltd**	Site Layout and Borehole Locations - Stage 2-4	Figure No. 2
Proj. Manager: KS	Scale: As shown	Dunmore, NSW		
Job No: 119037	Source: NearMaps (c)			

ENVIRONMENTAL EARTH SCIENCES	Drawn by: EG	Date: July 2020	**Dunmore Sand & Soil Pty Ltd**	Site Layout and Borehole Locations - Stage 5	Figure No. 3
	Proj. Manager: KS	Scale: As shown	Dunmore, NSW		
	Job No: 119037	Source: NearMaps (c)			

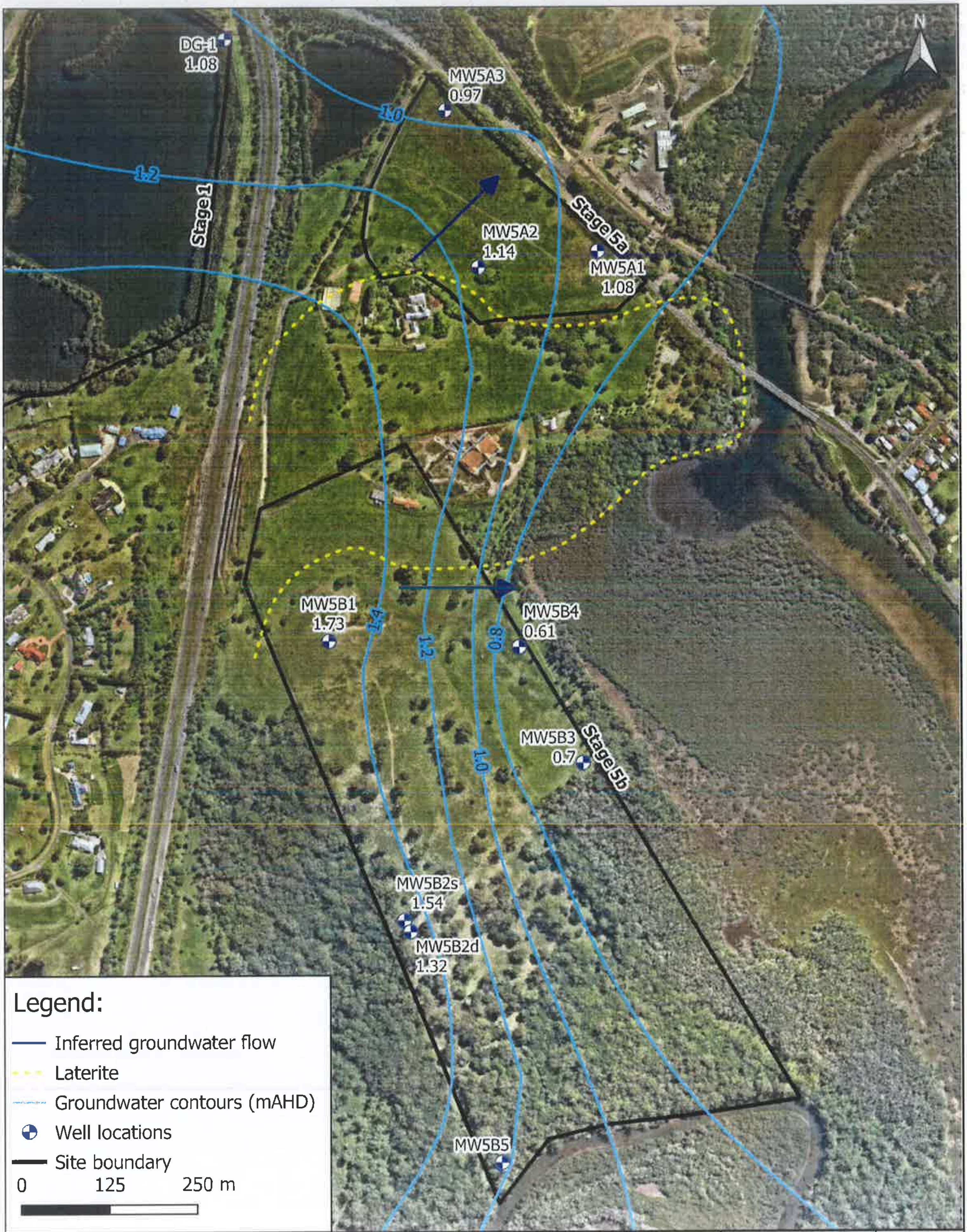
ENVIRONMENTAL EARTH SCIENCES	Drawn by: NE	Date: July 2020	**Dunmore Sand & Soil**	Inferred Groundwater Contours Stages 2-4 - Nov 2019	Figure No. 4
	Proj. Manager: KS	Scale: As shown	Dunmore, NSW		
	Job No: 119037	Source: Nearmaps			



ENVIRONMENTAL EARTH SCIENCES	Drawn by: NE	Date: July 2020	Dunmore Sand & Soil	Inferred Groundwater Contours Stages 2-4 - Feb 2020	Figure No. 5
	Proj. Manager: KS	Scale: As shown	Dunmore, NSW		
	Job No: 119037	Source: Nearmaps			



ENVIRONMENTAL EARTH SCIENCES	Drawn by: NE	Date: July 2020	Dunmore Sand & Soil	Inferred Groundwater Contours Stage 5 - Nov 2019	Figure No.
	Proj. Manager: KS	Scale: As shown			6
	Job No: 119037	Source: Nearmaps	Dunmore, NSW		



ENVIRONMENTAL EARTH SCIENCES	Drawn by: NE	Date: July 2020	Dunmore Sand & Soil	Inferred Groundwater Contours Stage 5 - Feb 2020	Figure No. 7
	Proj. Manager: KS	Scale: As shown	Dunmore, NSW		
	Job No: 119037	Source: Nearmaps			

TABLES

ENVIRONMENTAL EARTH SCIENCES
CONTAMINATION RESOLVED

Table 3: Standing water levels: Feb 2017 – May 2020

Location	Feb-17	May-17	Aug-17	Nov-17	Feb-18	May-18	Aug-18	Nov-18	Feb-19	May-19	Aug-19	Nov-19	Feb-20	May-20
Units			mBGL				mBGL			mBGL			mBGL	
DG-1											1.488	1.61	1.15	1.33
DG5_S	-	-	-	-	-	1.18	1.005	-	-	1.12	1.15	1.24	0.84	1.04
DG5_D	2.85	0.96	1.03	-	1.1	1.23	1.07	1.25	1.11	1.12	1.22	1.31	0.88	1.04
DG6_S	-	-	0.89	-	1.025	1.13	0.97	0.99	1.03	0.97	1.07	1.18	0.87	1.03
DG6_D	-	-	-	-	-	1.19	1.03	-	-	1.04	1.13	1.22	0.87	1.03
DG7	-	-	-	-	-	-	-	2.255	2.215	2.115	2.23	2.97	2.11	2.12
DG17	-	-	-	-	-	-	-	2.48	2.53	2.665	2.78	3.05	2.23	2.43
DG21	-	-	-	-	-	-	-	2.24	2.2	2.034	2.16	2.29	1.54	1.88
DG31	2	2.12	2.48	2.48	2.785	2.9	Damaged	3.02	2.805	2.835	2.96	3.04	2.14	2.68
DG35	-	-	-	-	-	-	-	2.35	2.205	2.21	2.35	2.78	2.11	1.31
DG36	-	-	-	-	-	-	-	1.44	1.33	1.36	1.47	1.97	1.22	1.41
DG59	0.85	0.92	1.15	0.91	1.48	1.675	1.65	1.485	1.53	1.51	-	-	-	-
DG60			dry at 1.75	dry at 1.75	1.626	dry	dry at 1.75	1.56	1.58	dry at 1.75	-	-	-	-
Rocklow Creek	0.26	0.23	0.28	0.24	0.565	0.383	0.325	0.25	0.3	3.75	0.36	0.63		*
Lower Dam	2.91	2.76	3.41	2.79	4.361	4.832	4.47	3.44	2.92	0.3	4.12	4.17		*

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Location	Feb-17	May-17	Aug-17	Nov-17	Feb-18	May-18	Aug-18	Nov-18	Feb-19	May-19	Aug-19	Nov-19	Feb-20	May-20
MW5A1										4.03	3.67	3.97	3.23	3.66
MW5A2										2.59	2.595	2.69	2.1	2.61
MW5A3										1.13	1.1	1.3	0.77	1.04
MW5B1										-	2.9	3.06	2.34	2.8
MW5B2s										2.97	3.03	3.1	2.58	3.08
MW5B2d										3.2	3.26	3.33	2.61	3.07
MW5B3										1.49	1.532	1.63	1.36	1.5
MW5B4										2.31	2.08	2.16	1.95	2.4
MW5B5										dry	dry	dry	dry	dry

Table 4: Results for bores west of the Princes Highway (ID: DG1, DG17, DG21, DG31, DG35, DG36) between August 2019 - Present

Analyte[1]	Units	Trigger Value DA[2]	Trigger Value GMMP[3]	DG1[4] Aug-19	DG1[4] Nov-19	DG1[4] Feb-20	DG1[4] May-20	DG17 Aug-19	DG17 Nov-19	DG17 Feb-20	DG17 May-20
pH		[illegible]	**6.8 – 8.5**	7.5	7.2	[illegible]	[illegible]	7.1	7	7.2	7
EC	µS/cm	<1,500	**1,500**	-	-	600	691	-	-	**2,730**	**2,970**
TDS	mg/L		-	390	330	-	-	1,390	1,220	-	-
Total N	mg/L	100 – 500	-	2.5	1.5	3.81	0.64	1.4	0.33	1.65	0.12
Na	mg/L	400	**560**	44	12	50.77	13.05	310	295	**563.1**	149.7
K	mg/L	50	**50**	3.3	2.2	3.16	5.292	30	22	**115.6**	30.68
Mg	mg/L	50	**80**	15	14	12.28	16.52	**82**	65	**91.32**	**112.4**
Cl	mg/L	300	**1,400**	37	29	37.16	40	330	340	456.7	486
Ca	mg/L	-	-	67	62	53.04	36.67	86	81	143.7	72.78
F	mg/L	-	-	0.19	0.16	<0.5	<0.5	0.51	0.45	[illegible]	[illegible]
Fe	mg/L	[illegible]	**3**	0.29	0.07	1.48	2.816	0.12	0.47	**3.04**	0.58
NO_3	mg/L			0.31	<0.1	1.16	0.52	0.22	<0.1	0.24	0.08
SO_4	mg/L	250	**300**	8	10	1.23	4.1	25	55	41.57	7.8
PO_4^3	mg/L	5 – 50	**4**	<0.1	0.12	-	-	1.2	0.34	-	-
HCO_3	mg/L	750	**400**	335	295	281	259	**950**	**780**	**730**	**[illegible]**
NH_3N	mg/L	20	**1**	0.3	0.8	<0.01	<0.01	0.8	**1.8**	0.54	0.29

Analyte[1]	DG21 Aug-19	DG21 Nov-19	DG21 Feb-20	DG21 May-20	DG31[4] Aug-19	DG31[4] Nov-19	DG31[4] Feb-20	DG31[4] May-20
pH	6.5	6.1	6.6	6.2	7	6.6	7.1	7
EC	-	-	**2,120**	**1,974**	-	-	1,246	**6,380**
TDS	1,020	1,260	-	-	2,930	2,820	-	-
Total N	1.9	0.3	0.27	0.12	0.6	0.46	0.77	4.45
Na	260	290	342	102.4	**700**	**650**	129.3	283.6
K	10	26	10.14	3.77	29	23	11.45	21.44
Mg	44	59	42.29	37.3	**83**	76	19.2	**104.4**
Cl	450	555	485.7	482	1,230	1,260	218.1	**1667**
Ca	52	64	117.4	64.27	215	190	44.57	224.2
F	0.15	0.13	<0.5	<0.5	<0.1	<0.1	<0.5	<0.5
Fe	1.2	1.9	1.07	1.696	0.74	0.47	0.42	1.471
NO_3	<0.1	<0.1	0.2	0.12	<0.1	<0.1	0.18	[illegible]
SO_4	150	195	183.57	133	**670**	**490**	192.6	**451**
PO_4^3	0.12	0.1	-	-	<0.1	<0.1	-	-
HCO_3	90	[illegible]	120	[illegible]	[illegible]	135	[illegible]	170
NH_3N	0.2	0.3	<0.01	<0.01	<0.1	<0.1	<0.01	0.05

Analyte[1]	DG35 Aug-19	DG35 Nov-19	DG35 Feb-20	DG35 May-20	DG36 Aug-19	DG36 Nov-19	DG36 Feb-20	DG36 May-20
pH	6.9	6.7	6.8	7.3	[illegible]	6.8	7.1	7.8
EC	-	-	1,023	1,077	-	-	1,454	1,259
TDS	655	505	-	-	660	1,020	-	-
Total N	3.5	1.3	1.24	0.94	0.1	0.3	0.31	0.12
Na	90	74	65.62	30.94	120	**[illegible]**	**[illegible]**	40
K	3.5	7.9	9.83	6.781	15	15	19.44	10.78
Mg	36	35	29.18	43.75	38	44	35.99	40.14
Cl	58	58	63.26	70	110	175	159.8	127
Ca	73	55	39.92	105.6	66	**[illegible]**	**[illegible]**	31.27
F	0.15	0.15	<0.5	<0.5	0.33	0.29	<0.5	<0.5
Fe	**23**	**20**	<0.01	2.425	0.47	0.47	<0.01	0.682
NO_3	[illegible]	<0.1	[illegible]	0.08	0.16	<0.1	0.14	0.12
SO_4	230	140	212.8	253	155	230	**[illegible]**	149
PO_4^3	<0.1	<0.1	-	-	0.13	<0.1	-	-
HCO_3	270	[illegible]	107	223	336	360	311	313
NH_3N	0.2	**1.3**	**1.16**	0.82	<0.1	<0.1	0.03	<0.01

Notes:

1. EC = Electrical Conductivity, TDS = Total Dissolved Solids, PO4 = Phosphorous, Total N = Total Nitrogen, Na = Sodium, K = Potassium, Mg = Magnesium, Cl = Chloride, Ca = Calcium, F = Fluoride, SO4 = Sulfate, HCO3 = Bicarbonate, Fe = Dissolved Iron, NH3N = Ammonia
2. DA Criteria is not site specific and outlined under Development Consent 195-8-2004 (2004), issued on 23 June 2005 for The Dunmore Lakes Sand Project (Stages 2 – 4)
3. GMMP Criteria is a site specific criteria for groundwater quality and a in place in the GMMP (Arcadis, 2016)
4. Elevated concentrations to site-specific GMMP criteria are **shaded and bold**

Table 5: Results for bores east of the Princes Highway (ID: DG5-S, DG5-D, DG6-S, DG6-D and DG7) between August 2019 - Present

Analyte[1]	Units	Trigger Value		DG5-S				DG5-D				DG6-S				DG6-D				DG7			
		DA[2]	GMMP[3]	Aug-19	Nov-19	Feb-20	May-20	Aug-19	Nov-19	Feb-20	May-20	Aug-19	Nov-19	Feb-20	May-20	Aug-19	Nov-19	Feb-20	May-20	Aug-19	Nov-19	Feb-20	May-20
pH	-	6.5 – 8.5	6.5 – 8.5	7.5	7.1	7.7	7.6	7.5	7.2	7.7	7.5	6.8	6.6	7.1	6.6	7.2	5.9	6.9	6.9	7.3	6.9	7	6.9
EC	µS/cm	<1,500	33,000	1,331	1,190	1,611	1,549		9,564	16,490	18,130	1,792	283	25,300	19,490	2,115	2,193	16,950	25,400	177	140	271	514
TDS	mg/L	-	-	770	810	-	-	14,400	13,600	-	-	12,100	11,100	-	-	15,900	17,100	-	-	92	215	-	-
Total N	mg/L	100 – 500	-	1.9	1.1	0.72	0.61	5.5	5.6	2.58	2.01	2.2	2.5	20.52	0.66	2.4	2.7	0.47	18.3	1.3	0.7	0.99	0.32
Na	mg/L	400	6,500	130	145	127	49.97	4220	4020	21.19	1354	3510	3190	41.01	1572	4470	4330	6114	1049	19	55	15.31	14.27
K	mg/L	50	170	8.2	7.9	12.62	6.656	190	140	9.65	141.2	160	130	13.13	182.8	210	176	253.3	192.1	2.8	3.7	0.31	2.966
Mg	mg/L	50	420	18	18	20.06	19.13	536	620	123.1	297.7	460	460	80.85	351.3	595	670	586.3	436.2	4.1	8.2	10.15	14.73
Cl	mg/L	300	6,900	210	245	310.1	306	8020	7300	5920.6	7271	6440	6090	9391.6	9606	8710	9220	6510	9889	19	49	26.65	63
Ca	Ca-	-	-	125	140	88.25	122.6	340	315	97.36	380.1	235	220	74.78	224.1	330	400	95.39	350.6	10	9.1	22.14	62.94
F	mg/L	-	-	0.16	0.19	<0.5	<0.5	0.29	0.3	0.6	0.5	0.36	0.34	<0.5	0.5	0.26	0.23	0.5	<0.5	0.38	0.34	<0.5	<0.5
PO_4	mg/L	5 – 50	0.7	0.12	0.12	-	-	0.2	0.12	-	-	0.1	<0.1	-	-	<0.1	<0.1	-	-	0.37	0.13	-	-
NO_3	mg/L	-	-	1.7	0.58	0.18	0.6	<0.1	<0.1	0.32	0.02	0.19	0.18	20.1	0.65	<0.1	<0.1	0.23	17.9	2.1	<0.1	0.23	0.19
SO_4	mg/L	250	1,170	96	100	75.32	89	1020	960	742.5	878	250	750	1336.9	959	1280	1420	903	1363	10	62	21.81	26
HCO_3[4]	mg/L	750	420	345	345	284	252	436	385	277	298	450	390	389	277	495	486	294	165	55	44	34	132
Fe	mg/L	6	4	9.2	0.14	0.09	1.693	0.11	0.1	3.04	5.649	1.9	0.52	0.59	4.059	0.06	12	1.66	1.382	0.31	0.24	1.12	2.171
NH_3N[5]	mg/L	20	3	<0.1	0.2	0.3	<0.01	4.9	6.3	1	1.99	0.8	1	1.2	0.03	0.7	4	0.34	0.96	<0.1	0.4	0.3	0.09

Notes:

1. EC = Electrical Conductivity, TDS = Total Dissolved Solids, PO4 = Phosphorous, Total N = Total Nitrogen, Na = Sodium, K = Potassium; Mg = Magnesium, Cl = Chloride, Ca = Calcium, F = Fluoride; SO4 = Sulfate, HCO3 = Bicarbonate, Fe = Dissolved Iron, NH3N = Ammonia
2. DA Criteria is not site specific and outlined under Development Consent 195-8-2004 (2004), issued on 29 June 2005 for The Dunmore Lakes Sand Project (Stages 2 – 4)
3. GMMP Criteria are site-specific criteria for groundwater quality and a sub-plan to the WMP (Arcadis, 2016)
4. Elevated concentrations to site-specific criteria are **shaded and bold**.

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Table 6: Results for bores in Stage 5A between August 2019 - Present

Analyte[1]	Units	Trigger Value DA[2]	Trigger Value GMMP[3]	MW5A1 Aug-19	MW5A1 Nov-19	MW5A1 Feb-20	MW5A1 May-20	MW5A2 Feb-20	MW5A2 May-20	MW5A3 Aug-19	MW5A3 Nov-19	MW5A3 Feb-20	MW5A3 May-20
pH	-	6.5 – 8.5	6.5 – 8.5	5.8	5.8	6.7	**5.8**	6.6	6.6	7.4	7.4	6.8	7.4
EC	µS/cm	<1,500	1,500	210	187	261	260	903	965	927	786	1,215	850
TDS	mg/L		-	115	140	-	-	-	-	475	516		
Total N	mg/L	100 – 500	-	3.1	3.7	2.25	6.37	1.2	0.35	2.1	1.8	1.59	0.32
Na	mg/L	400	560	13	25	150	5.167	80.72	29.9	100	125	161.8	32.82
K	mg/L	50	50	3.1	4.0	17.73	8.366	2.5	4.506	4.4	5.4	12.07	4.041
Mg	mg/L	50	90	4.5	5	15.5	6.18	26.15	34.06	12	11	14.63	11.11
Cl	mg/L	300	1,400	29	30	46.01	42	83.46	99	180	200	264.94	159
Ca	mg/L	-	-	17	10	34.07	19.54	66.78	65.02	49	43	66.03	35
F	mg/L	-	-	0.11	<0.1	<0.5	<0.5	<0.5	<0.5	0.15	0.13	<0.5	<0.5
Fe	mg/L	6	3	0.67	0.1	0.49	1.5	0.8	2.387	**4.6**	**3.5**	**5.33**	**4.108**
NO_3	mg/l	-	-	9.8	11	2.05	6.36	0.91	0.31	<0.1	<0.1	1.15	0.28
SO_4	mg/L	250	300	19	33	22.64	27	46.92	25	14	15	12.56	9.1
PO_4[5]	mg/L	5 – 50	4	<0.1	<0.1	-	-	-	-	0.23	<0.1	-	-
HCO_3[6]	mg/L	750	400	26	24	50.4	29	336	330	180	185	185	151
NH_3N[7]	mg/L	20	1	<0.1	<0.1	<0.01	<0.01	<0.1	<0.1	0.8	0.9	<0.01	<0.01

Notes:

1. EC = Electrical Conductivity; TDS = Total Dissolved Solids; PO4 = Phosphorous; Total N = Total Nitrogen; Na = Sodium; K = Potassiu
   Ca = Calcium; F = Fluoride; SO4 = Sulfate; HCO3 = Bicarbonate; Fe = Dissolved Iron; NH3N = Ammonia
2. DA Criteria is not site specific and outlined under Development Consent 195-8-2004 (2004), issued on 29 June 2005 for The Dunmore Lak
3. GMMP Criteria is not specific, but are the more conservative site-specific criteria derived for groundwater quality and a sub-plan to the WMI
4. Elevated concentrations to site-specific GMMP criteria are **shaded and bold.**
5. Reported as Total Phosphorous in Feb '20 and May '20 hence not included
6. Reported as mg/$CaCO_3$/L in Nov '17 and Feb '18 These results were converted to HCO_3 by multiplying mg/$CaCO_3$/L by 1.219
7. Divided by 1.2 when reported as Ammonia Total to get NH_3N
8. Feb 2020 and May 2020 laboratory analysis undertaken by Boral. Analysis did not include for TDS

Table 7: Results for bores in Stage 5B between August 2019 - Present

Analyte[1]	Units	Trigger Value		MW5B1		MW5B2-S				MW5B2-D				MW5B3		MW5B4		
		DA[2]	GMMP[3]	Feb-20	May-20	Aug-19	Nov-19	Feb-20	May-20	Aug-19	Nov-19	Feb-20	May-20	Feb-20	May-20	Aug-19	Feb-20	May-20
pH	-	6.5 – 8.5	6.5 – 8.5	7.7	7.7	7.4	7.1	7.4	7.4	7.6	7.3	7.5	8	7.7	7.8	7.6	7.6	7.4
EC	µS/cm	<1,500	1,500	417	397	742	633	724	724	658	588	676	680	563	620	-	603	592
TDS	mg/L	-	-	-	-	440	385	-	-	325	350	-	-	-	-	390	-	-
Total N	mg/L	100 – 500	-	3	3	1.1	0.9	0.7	0.69	1.3	0.6	0.86	0.18	0.72	0.15	1.1	0.4	0
Na	mg/L	400	560	27	7	48	50	74.31	12.79	41	44	63.76	11.38	43.27	10.43	36	53.76	10
K	mg/L	50	50	9	5	3.8	4.3	9.09	3.388	4.6	4.6	9.34	2.806	5.47	1.998	2.3	5.1	2
Mg	mg/L	50	90	7	7	14	12	15.47	13.47	14	12	16.03	12.4	11.69	12.01	11	8.33	5
Cl	mg/L	300	1,400	33	36	46	45	46.01	49	49	55	55.92	66	45.22	52	34	41.92	41
Ca	mg/L	-	-	50	42	92	86	93.25	80.72	75	75	82.5	63.99	84.47	65.4	100	115.4	52
F	mg/L	-	-	<0.5	<0.5	0.16	0.14	<0.5	<0.5	0.15	0.14	<0.5	<0.5	<0.5	<0.5	0.19	<0.5	<0.5
Fe	mg/L	6	3	0	1	1.2	0.16	0.84	1.178	0.55	0.05	0.61	**4.396**	0.21	0.888	0.09	0.32	1
NO_3	mg/L	-	-	3	3	<0.1	<0.1	0.53	0.56	0.35	<0.1	0.79	0.17	0.66	0.14	1.1	0.4	0
SO_4	mg/L	250	300	36	36	39	31	35.81	35	17	17	19.76	17	4.94	3.3	11	14.41	5
PO_4	mg/L	5 – 50	4	-	-	0.18	<0.1	-	-	<0.1	<0.1	-	-	-	-	<0.1	-	-
HCO_3	mg/L	750	400	166	107	365	340	294	288	300	290	263	242	246.0	239.0	375	250	248
NH_3N[5]	mg/L	20	1	<0.01	<0.01	<0.1	0.4	<0.01	<0.01	<0.1	0.6	<0.01	<0.01	<0.01	<0.01	<0.1	<0.01	<0.01

Notes:

1. EC = Electrical Conductivity; TDS = Total Dissolved Solids; PO4 = Phosphorous; Total N = Total Nitrogen; Na = Sodium; K = Potassium; Mg = Magnesium; Cl = Chloride; Ca = Calcium; F = Fluoride; SO4 = Sulf
2. DA Criteria is not site specific and outlined under Development Consent 195-8-2004 (2004), issued on 29 June 2005 for The Dunmore Lakes Sand Project (Stages 2 – 4).
3. GMMP Criteria are site-specific criteria for groundwater quality and a sub-plan to the WMP (Arcadis, 2016).
4. Elevated concentrations to site-specific criteria are **shaded and bold.**
5. Divided by 1.2 when reported as Ammonia Total to get NH_3N
6. Feb 2020 and May 2020 laboratory analysis undertaken by Boral. Analysis did not include for TDS.
7. Reported as Total Phosphorous in Feb '20 and May '20 by Boral, hence not included.