BUILDING DEWATERING IN THE BOTANY SANDS AND THE AQUIFER INTERFERENCE POLICY

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ABSTRACT

The Department of Primary Industries (DPI) Water is responsible for the management of groundwater across NSW. The management of groundwater extraction impacts including those associated with dewatering for building developments which predominate in Sydney within the Botany Sands Groundwater Source is one of the primary roles of the agency. There are an increasing number of residential and commercial developments that need to accommodate construction below the water table for basements and other functions. These have to be built in a way that mitigates adverse impacts on other building developments or other groundwater users, sensitive ecosystems or structures. Parts of Sydney's development are remarkably high-density and construction must be well planned to prevent such effects as unintentional groundwater mounding, obstruction of natural flows by the completed building, and potential basement inundation caused by periodic elevated water levels.

In order to demonstrate sustainable development principles, the Aquifer Interference Policy (AIP) requires the proponent to account for all groundwater take during both construction and occupation. This may include the proponent taking measures to avoid or prevent the take of groundwater where possible and include mitigation or avoidance strategies to reduce take of water. The proponent should demonstrate that adequate arrangements will be in place to ensure the minimal impact considerations of the AIP are met. The information needed for assessments of the groundwater impacts of proposed developments under the AIP requires a comprehensive evaluation of the hydrogeological environment. This information is required to allow DPI Water to balance the management of the groundwater resource with facilitating sustainable development.

In some instances, the use of secant piled cut-off walls to enclose an entire site may not be the optimum solution without other engineering measures because the walls effectively work like dams to groundwater flow. Alternate methods of construction might be more appropriate and facilitate flows both beneath and around structures. The dewatering considerations are not limited to individual properties as there are significant interferences from major infrastructure projects, as well as other nearby concurrent building developments, which need to be accommodated at the same time. This paper discusses requirements for proponents and their consultants that relate to the assessment of dewatering proposals in Sydney's Botany Sands Groundwater Source, which is part of the Greater Metropolitan Region Water Sharing Plan area.

1 INTRODUCTION

The NSW Department of Primary Industries - Water (DPI Water - formerly the "Office of Water") is responsible for managing all aspects of groundwater abstraction such as for water supply, dewatering abstraction for remediation, reinjection and incidental take of groundwater (seepage) in building and infrastructure. The NSW Environmental Protection Authority (EPA) has specific responsibility for contamination control and clean-up of groundwater. Groundwater quality issues are considered by DPI Water in respect of the abstraction of groundwater or undertaking other activities that are regulated under legislation administered by the agency.

Groundwater is currently managed under two Acts and one Regulation, cited as:

* *Water Act 1912* (WA 1912)
* *Water Management Act 2000* (WMA 2000)
* *Water Management (General) Regulation 2011* (Reg).

The transition from the WA 1912 to the WMA 2000 results in some complexity in the administration of the groundwater management framework is NSW. Until the WMA 2000 can be fully implemented these complexities with respect to the licensing and authorisation of abstraction within the construction and geotechnical applications, especially in terms of site dewatering and the ongoing take of groundwater, will continue.

2 LEGISLATED CONTROL

Section 91(3) of WMA 2000 relates to the licensing of "aquifer interference" activity approvals. An aquifer interference activity refers to the penetration of an aquifer, the taking of water from an aquifer in the course of carrying out mining or any other activity prescribed by the regulations, and the disposal of water taken from an aquifer in the course of carrying out mining or any other activity.

The pre-eminent aspects of concern for groundwater management are therefore that:

(1) all groundwater is managed in all circumstances, not just in the case of supply or flow of water in aquifers; that is, anywhere in the saturated zone of the subsurface as well as any intentional artificial recharge, interflow or perched water situations;

(2) groundwater volume has to be accounted for, and allocations are made to: (a) maintain the health of aquifers, (b) for the environment, and (c) for equitable distribution of the resource to non-environmental users.

Embracing all of the previous ideas is the Aquifer Interference Policy (NSW DPI, 2012). This Policy applies to all aquifer interference activities and has introduced a framework for assisting any activity involving groundwater. The AIP's core objectives are to:

(1) clarify the requirements for obtaining water licences for aquifer interference activities under NSW legislation; and
(2) establish and objectively define considerations for assessing and providing advice on whether more than minimal impacts might occur to a key water-dependent asset (NSW DPI, 2012).

The AIP applies to activities authorised under both the WA 1912 and the WMA 2000, although Section 91(3) of the WMA 2000 that provides for aquifer interference approval for an activity has not yet commenced. Consequently, dewatering groundwater take for building works is authorised by a licence under Part 5 of the WA 1912.

DPI Water's main concerns and which are brought to bear in operational assessment and approval decisions are:

* volume of water in aquifer systems;

* control and allocation of groundwater take;

* prevention of contamination and its spread (e.g. as a consequence of dewatering);

* aquifer health – in terms of hydraulics, yield and chemistry.

Thus, the management of many competing interests in respect of groundwater resources requires deliberate, well-informed judgements that not only require compliance with black-letter law, but also compliance with expectations of the community, considerations of equitable access to groundwater sources for the environment and other users, and considerations of cumulative and future impacts on the resource. Given that the resource has variable parameters to its definition (e.g. relating to recharge, flow, heterogeneity of distribution, abstraction yields and timing), this management is not amenable to a straight-forward, 'tick-a-box' or 'meet-a-criterion' assessment.

Under the WMA 2000 groundwater management decisions in NSW are made with special cognisance of community expectations. The need is spelt out in Section 3 of the WMA 2000 and includes clauses:

"(c) to recognise and foster the significant social and economic benefits to the State that result from the sustainable and efficient use of water,…

(d) to recognise the role of the community, as a partner with government, in resolving issues related to the management of water resources,

(f) to integrate the management of water sources with the management of other aspects of the environment, including the land, its soil, its native vegetation…" (WMA 2000).

3 BOTANY SANDS

The Botany Sands represent the principal water table aquifer system located generally south east of the Sydney CBD. They are the historic host of the State's second water supply and the foundation of much of Australia's diverse manufacturing enterprises since about the 1820s. They were considered for emergency water supply in 1942 and are presently the host for major urban renewal projects like Green Square, significant remnant manufacturing, transport infrastructure and thousands of residential and commercial developments from very dense multi-storey tower developments to the typical large lots (600 m^2 or more) of Australian cities. The groundwater is still actively exploited today, is highly contaminated in parts, quite fresh and clean in others, supports a limited number of groundwater dependent ecosystems and is effluent as a few lakes notably in Centennial Park and Mascot.

The groundwater source is defined in the Greater Metropolitan Water Sharing Plan (WSP, 2011) as the “Botany Sands Groundwater Source” and is administered through statutory rules for using and protecting the resource across two groundwater management zones. Three physiographic ‘sectors’ are recognised – Northern, Western and Southern - that are frequently referred to in discussions concerning the Botany Sands’ hydrogeological behaviour. The Northern Sector, which is also the largest both spatially and volumetrically, is identified as all that part of the Beds north of the Cooks River and Botany Bay, and is the location of the most intense urban and industrial history; flows here are generally to the southwest and south ultimately discharging into Botany Bay. DPI Water maintains a small network of monitoring bores across the Botany Sands with the majority in the Northern Sector.

Much has been written about the geology and hydrogeology of the Botany Sands so the detail is not recounted here and the reader is referred to Hatley (2004), Albani and Rickwood (1998) and Albani (1981) for informative background information. The substantial matters of concern in the current context are twofold:

* the unevenness of the bedrock topography which defines an underlying structural depression (the Botany Basin); and,

* the presence of heterogeneity in the aquifer matrix as clay lenses, peat seams and layers, as well as sands of various coarseness and density.

In the first instance, the bedrock topography has been primarily shaped by the palaeodrainage in the Botany Basin about 100000 years ago (Albani,1981), followed by pro-grading (re-inundation) of the land as sea level rose to the approximate present level.

In the most recent erosive phase what has been left comprises a bedrock topography developed on the Ashfield Shale, Mittagong Formation and the Hawkesbury Sandstone units. This produced a variable topography of gently sloping terrain with typical clayey residual soils in the north western margin grading to more steeply defined gully and depression systems in the east and south - typical of what’s seen in the Hawkesbury Sandstone landscapes of today. The basin edges, for example around Wolli Creek, Moore Park, Matraville, and Matraville are typically steep and blocky, while the more flattened areas contain some significant palaeochannels and substantially deeper sub-linear features.

As the sea trangressed back onto the land, swampy conditions developed in many areas – initially around the basin edges. Thus marine clays and peaty beds are found in the sequence near much of the edges, but they are not confined to these margins because as the basin refilled with fluvio-marine sediments, resorting and redistribution of the material also occurred. Thus the nature of the Botany Sands is significantly heterogeneous in parts, yet sharing a great deal of homogeneity in others parts and at certain depths.

The heterogeneity of the clayey and peaty deposits has further implications. The presence of these materials interrupts the hydraulics of the Botany Sands primarily retarding, but also redirecting groundwater flows; as well as producing semi-confined conditions in some areas. These materials can also effectively concentrate contaminants by trapping and retarding them – everything from heavy metals to organic compounds. These effects are apparent around the Green Square and other nearby areas.

The micro-hydrogeological pattern influences the management of this groundwater source. Firstly in terms of the maintenance of flows and prevention of retardation; and secondly, in terms of concern for contaminant outputs in dewatering operations or induced flows to bores. Consequently, these matters have to be assessed, provided for, and mitigated where possible.

In terms of contamination – legislation is brought to bear through the operation of the *Protection of the Environment Operations Act 1997* (POEO Act) which is administered by the EPA, the NSW Groundwater Quality Protection Policy (NSW DLWC, 1998), the AIP and the WA 1912.

During dewatering operations this management regime requires:

1) determination of the contaminant potential of the groundwater;

2) treatment of output waters to at least a specified level of pH and otherwise consistent with sewer and/or stormwater disposal requirements imposed by other authorities;

3) prevention of direct reinjection without assessment.

4 CONSTRUCTION CONCERNS

In terms of the actual operation of the groundwater systems influenced by construction dewatering activities, DPI Water has three principal concerns that it seeks to manage. These concerns are the impacts on **recharge, flow and mounding.**

4.1 RECHARGE

Recharge in the Botany Sands is primarily by direct rainfall with an as yet unquantified contribution from spring systems and surface run-on in the surrounding more elevated areas of Hawkesbury Sandstone. The recharge appears to be uneven across the Basin and has itself not been adequately quantified but is primarily back-calculated from numerical groundwater flow models. Various authors and researchers have commented on this, but actual data determinations remain for further investigation. Merrick (1994) for example, has used recharge estimates varying between 6% and 37% of rainfall in models, and even higher proportions (up to 96%) are suggested in conjunction with irrigation (Benker *et al*., 2008).

The management difficulty in relation to recharge is that the ever increasing impermeable areas being constructed are going to change the recharge pattern in certain locations. This change will be twofold: firstly to decrease total recharge and increase runoff; and secondly, to concentrate recharge in the remaining natural open areas, or deep planting areas reserved in development lots. The effect of the second aspect is potentially going to influence flow directions and mounding; the effects may be cumulative and unpredictable. The reduction in recharge may itself be a mechanism for flow path redistribution and may also lead to unintended concentration of groundwater contamination in some locations. A further recharge source is leaking pipework, the amount of which can increase with increasing urbanisation.

It needs to be borne in mind that groundwater contamination can easily change from what initial site investigations reveal and any change may have deleterious impacts on the structural integrity of buildings (e.g. with pH, salinity or organics concentrations), or lead to unintended consequences due to seepage water in basements.

4.2 FLOW PATHS AND LEVELS

The baseline hydrogeological data for the Botany Sands essentially comprises the level data developed in respect of the city's emergency water supply concerns of 1942. There have been a number of studies of contamination, general groundwater quality and hydrogeochemical characterisation since 1937 until the present. In addition, a limited number of pump tests, hydraulic conductivity and transmissibility studies are reported, and historical evaluations have been made, but these are not further amplified in the present discussion: for further information see, for example, Hatley (2004) and Russell (2005).

DPI Water as a consequence of its review role, has reviewed a large amount of geotechnically- and hydrogeologically-based data derived from individual site assessments or larger studies of community importance. In order to better understand the historical and more recent data sets, these data have been placed into the contextual rainfall setting (Figure 1) in terms of the annual residual rainfall mass (RRM). An examination of Figure 1 shows that the RRM curve prior to 1942 and 2014 has remarkably similar characteristics. Both parts of the curve reflect a drying period where rainfall has been consistently or generally below or around average for a number of years.

The baseline 1942, and more recent data – June 2014, have been re-interpreted here (Figures 2A and 2B) in order to provide background information for the dewatering context. The water table patterns are remarkably similar, the 2014 map indicating that groundwater levels were slightly higher than in 1942 for the Green Square redevelopment area, together with some minor re-distribution of levels in the central Northern Sector associated with a lower number of extracting bores. Consequently the two water table maps (Figures 2A and B) are useful as direct comparisons for dry times and maybe represent the base situation from which groundwater levels will likely rise rather than fall.

In developing these models, certain modifications have been made to previous similar presentations including the conversion of all data to MGA coordinates, and the development of boundary water table levels developed on application of an estimated depth to water table at the boundaries where salient (10m) topographic contours cross. The water table map is also referenced to AHD as it provides a satisfactory universal reference frame which eliminates the effects of surface topographic modifications. Further, the boundary of the Botany Sands used for the aquifer modelling herein, conforms to the WSP except in the southeast - revised Port Botany construction, and where the area of coastal sands defined as the Yarra Aquifer (Dent, 1995 and 1996) has been omitted on the basis that it is hydraulically isolated from the broader system. The contouring has been developed applying the 'Natural Neighbour' algorithm using Surfer© software (Golden Software Inc 2010).

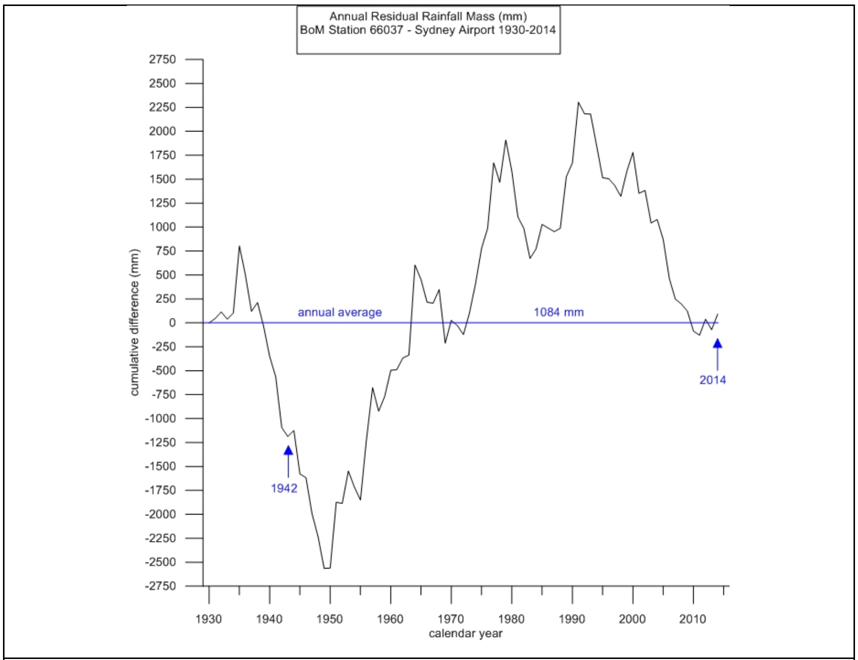


Figure 1: Annual Residual Rainfall Mass Curve for Botany Sands

(85 years of data 1930 -2014 at BoM Station 66037 – Sydney Airport)

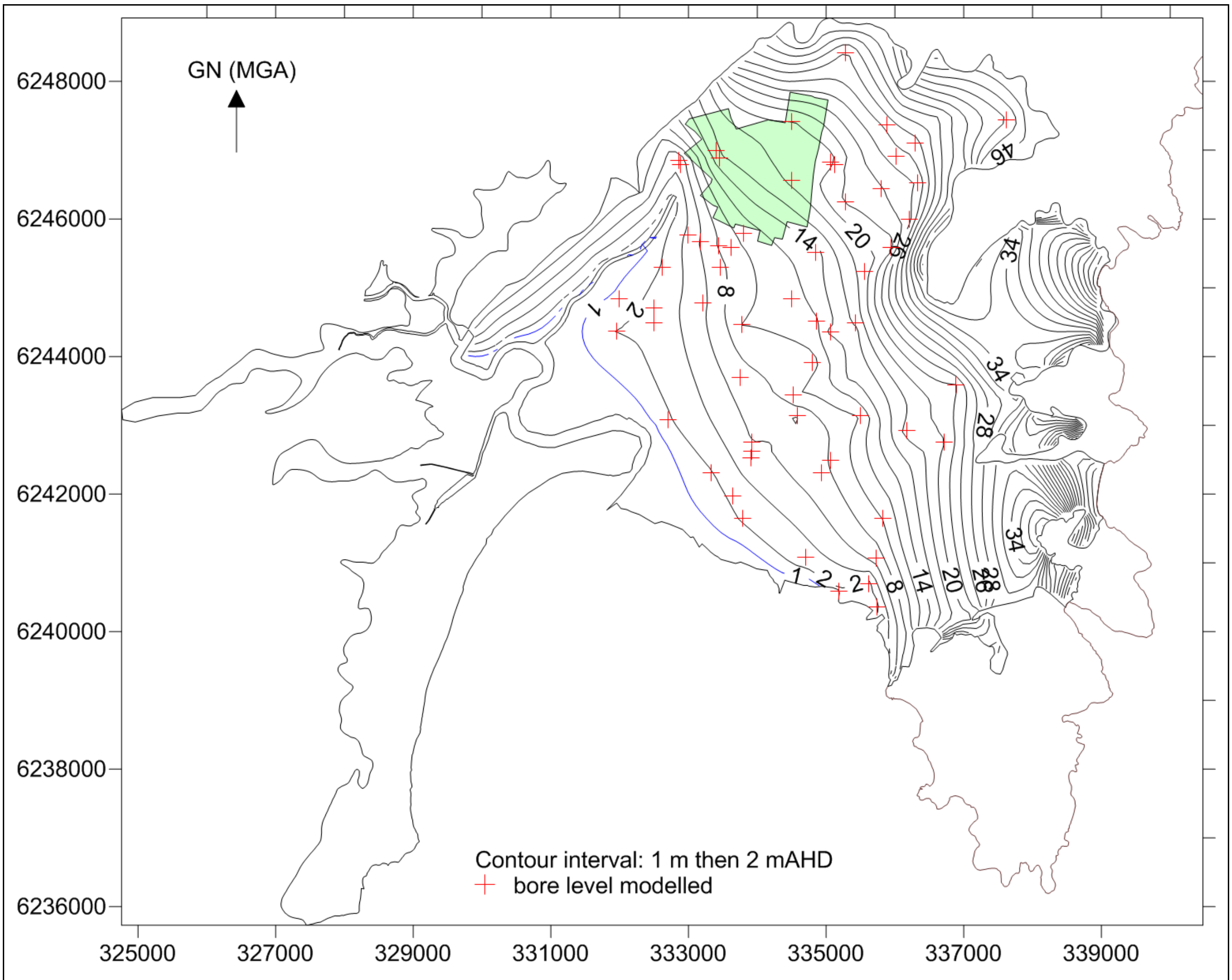


Figure 2A: Botany Sands Northern Sector_Water Table Map 1942 (composite data)

Data is that used by Merrick & Knight (1997) and Merrick (1998).

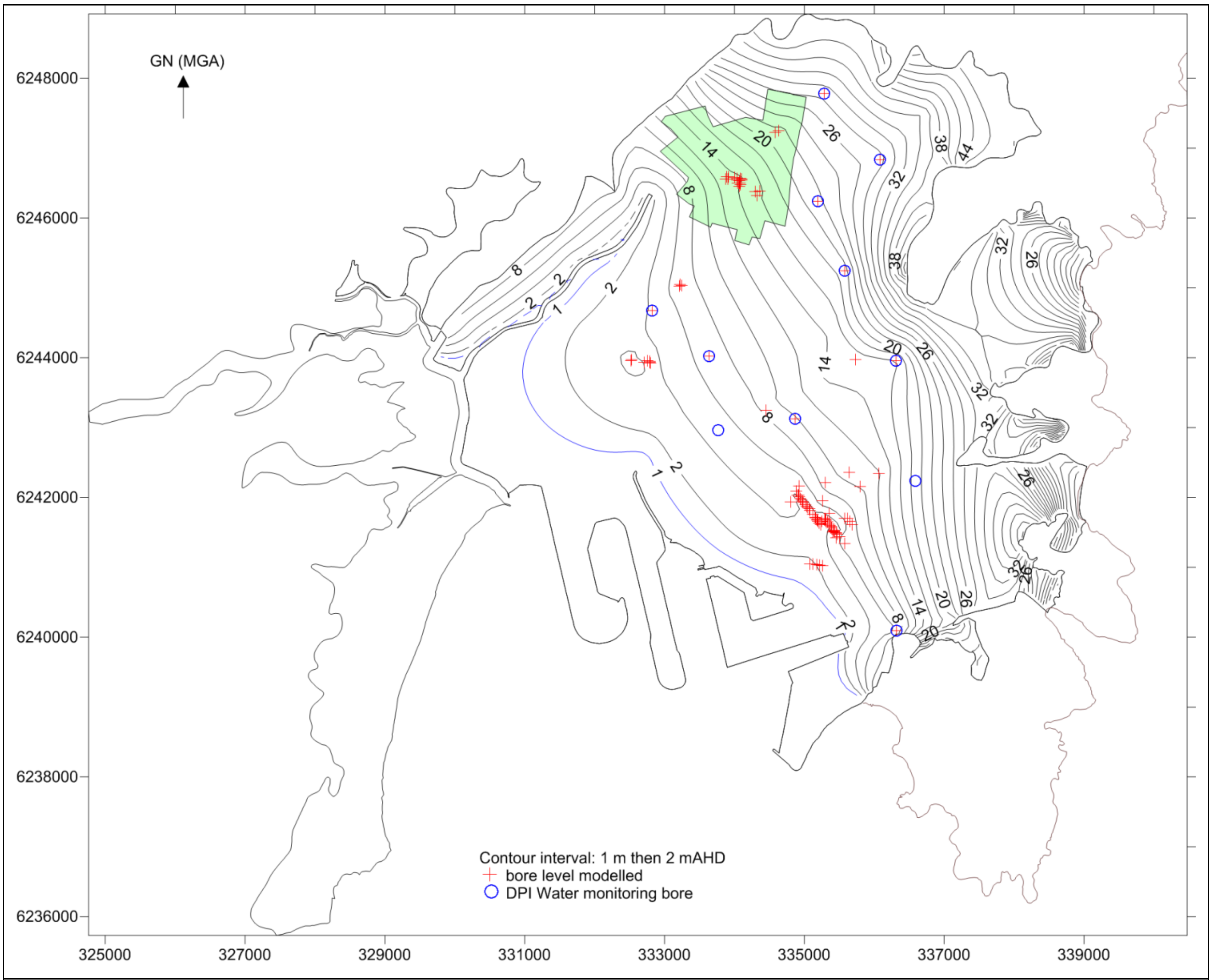


Figure 2B: Botany Sands Northern Sector_Water Table Map June 2014

The data are from a compilation of geotechnical and investigative reports available to DPI Water. The Green Square Development Area (shaded green) has been digitised from files available from Sydney City Council (2015).

4.3 MOUNDING

Mounding can occur when an excess of groundwater is impeded in its flow by a barrier, or a change of hydraulic conductivity, or a rapid increase in recharge. The primary concern in the construction dewatering context is that basement and infrastructure construction below the water table will present an excessive number of impenetrable barriers. These barriers will inevitably disrupt groundwater flow paths, especially when they are in close proximity to each other. Where the natural system can't accommodate the increased volume of water, mounding will occur with potential consequences of flooding basements or creating springs or seeps (i.e. a water-logging of the ground surface).

With the potential for mounding probably exacerbated by an increasing number of cut-off walls established in a small area; this matter is of particular concern in the Green Square precinct. Here sub-surface building proposals are plentiful and often have footprints extending as large basements beyond surface-demarked boundaries.

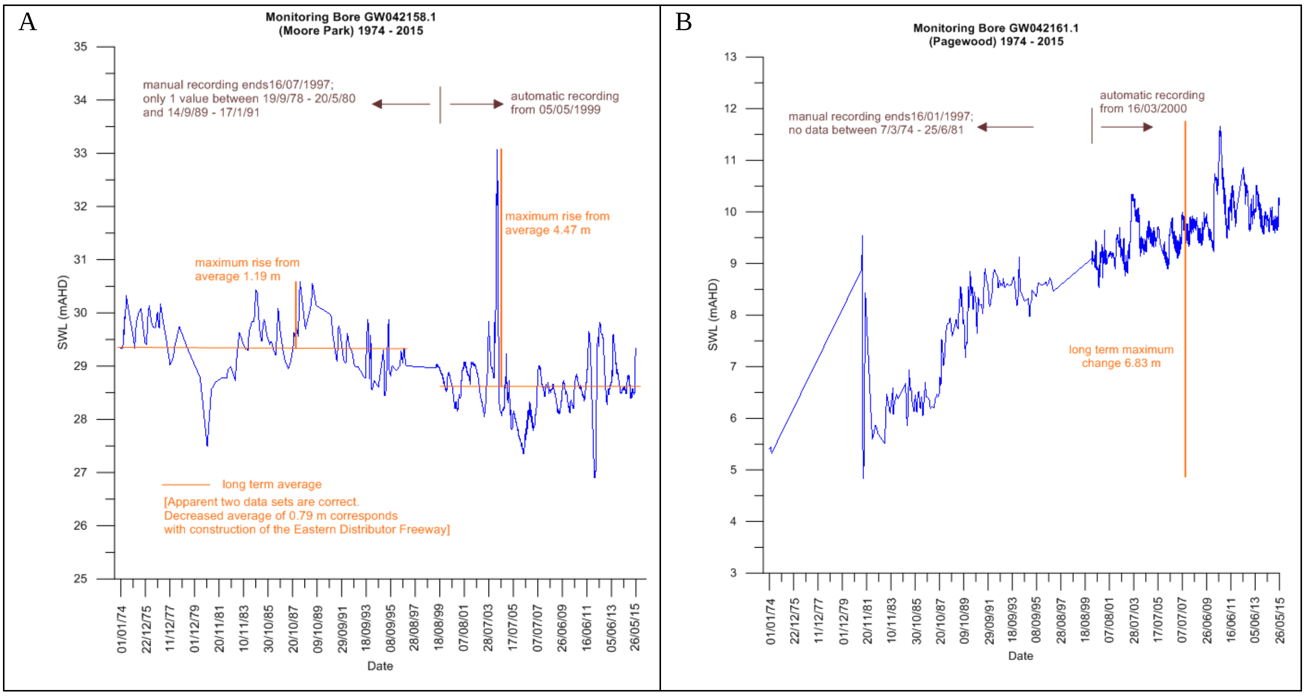
The potential difficulties are primarily being managed by DPI Water with conditions in development consents or state significant development approvals that provide for maintenance flows in and around and beneath tanked construction. To assist in the assessment of each site, details of any proposed permanent or temporary dewatering cut-off walls or systems are required. The currently common application of deep secant piled cut-off walls founded in bedrock can act as a major impediments to groundwater flow paths, effectively being a sub-surface dam with little prospect - because of their intended function - of maintaining any significant percentage of the natural flow system.

Additional issues can arise from the reliance on natural materials to provide pathways around and beneath constructed elements. In some cases the natural materials have been assessed for hydraulic conductivity by on-site testing, typically slug tests, which can be of limited value. Where construction is through fill materials, which are common in certain locations for example parts of the Green Square redevelopment, slug testing is potentially of no value because the aquifer matrix may frequently change and can be extremely heterogeneous. Ideally the situation needs to be reached where a blanket of highly permeable material is used as filling and lining in all disturbed construction areas, immediately adjacent to the new structure. In a sense this may act as a wick, but the effect is expected to assist overall aquifer function and reduce mounding.

General Terms of Approval issued by DPI Water for relevant projects now frequently incorporate terms to facilitate these arrangements.

The potential natural mounding due simply to groundwater level rise is a little difficult to estimate and requires a degree of professional judgement. In this regard Figures 3 and Table 1 have been prepared to provide some indicative information on potential variations in selected localities of the Northern Sector.

Figure 3 presents annotated hydrographs from four of DPI Water's monitoring bores in the Northern Sector; of special relevance is the potential water table rise above the medium term average. Typically, continuous monitoring data has now been available for 15 years, and with reference to Figure 1 this shows that the groundwater regime has been generally drying during this timeframe. Consequently the data analysis may understate the potential future situation. However, balancing the trends seen is the evidence that the variations across the Northern Sector are far from uniform, and it also seems that in many cases that sharp water table level rises can be accompanied by equally sharp falls. The situation is at best variable in all locations and at all times, and a cautious approach to provision for water table rise and its consequences is required.



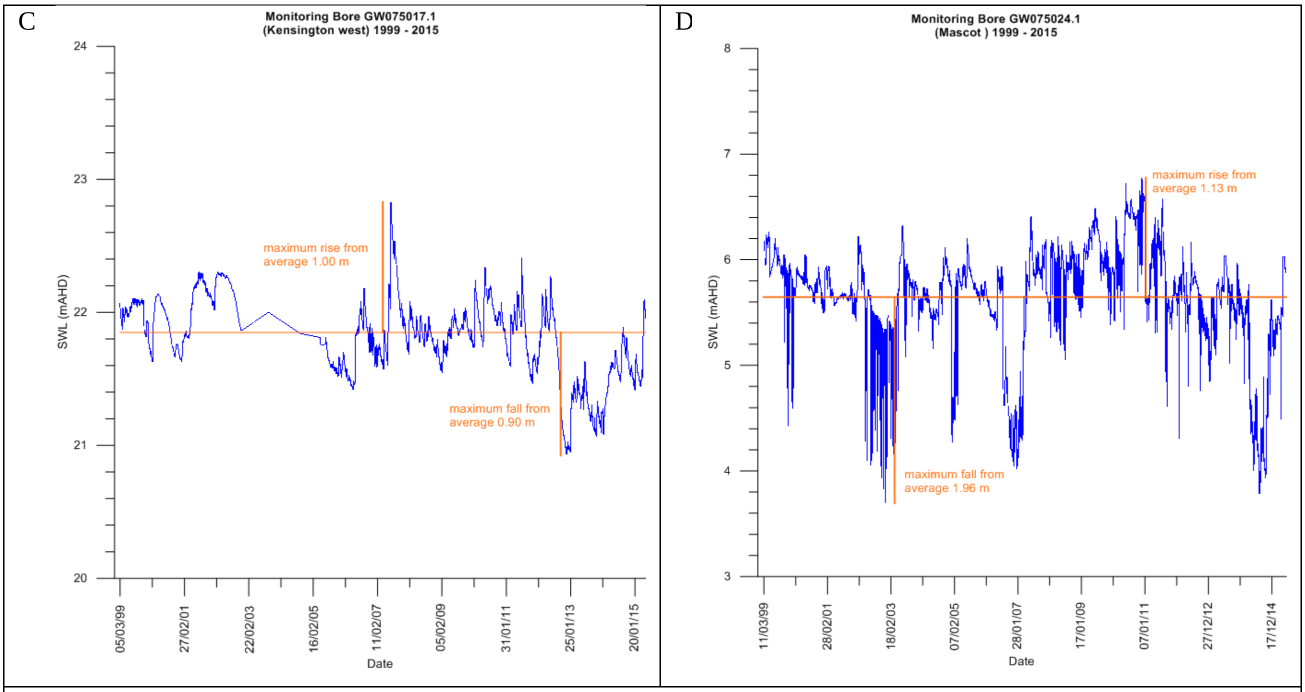


Figure 3: Hydrographs for Selected DPI Water Monitoring Bores – Northern Sector (indicating potential rises)

A. GW042158.1; B. GW042161.1; C. GW075017.1; D. GW075024.1

Data has been continuously recorded in these bores since March 1999; manual measurements in GW042158 and GW042161 are available since 1974.

In Table 1 the data is broadly analysed for maxima, minima and the range of potential variations. The monitoring bores have shown that in the last 15 years a positive variation above average of up to 2 - 4 m could be quite commonly expected in some locations, and further analysis is warranted. These data should be interpreted as providing context for the general Northern Sector situation: they cannot be used as a substitute for site-specific groundwater investigation for the equivalent monitoring period.

Figure 4 has been prepared to represent the situation for considerations in mounding and to explain DPI Water's requirements now being incorporated into General Terms of Approval for proposed developments.

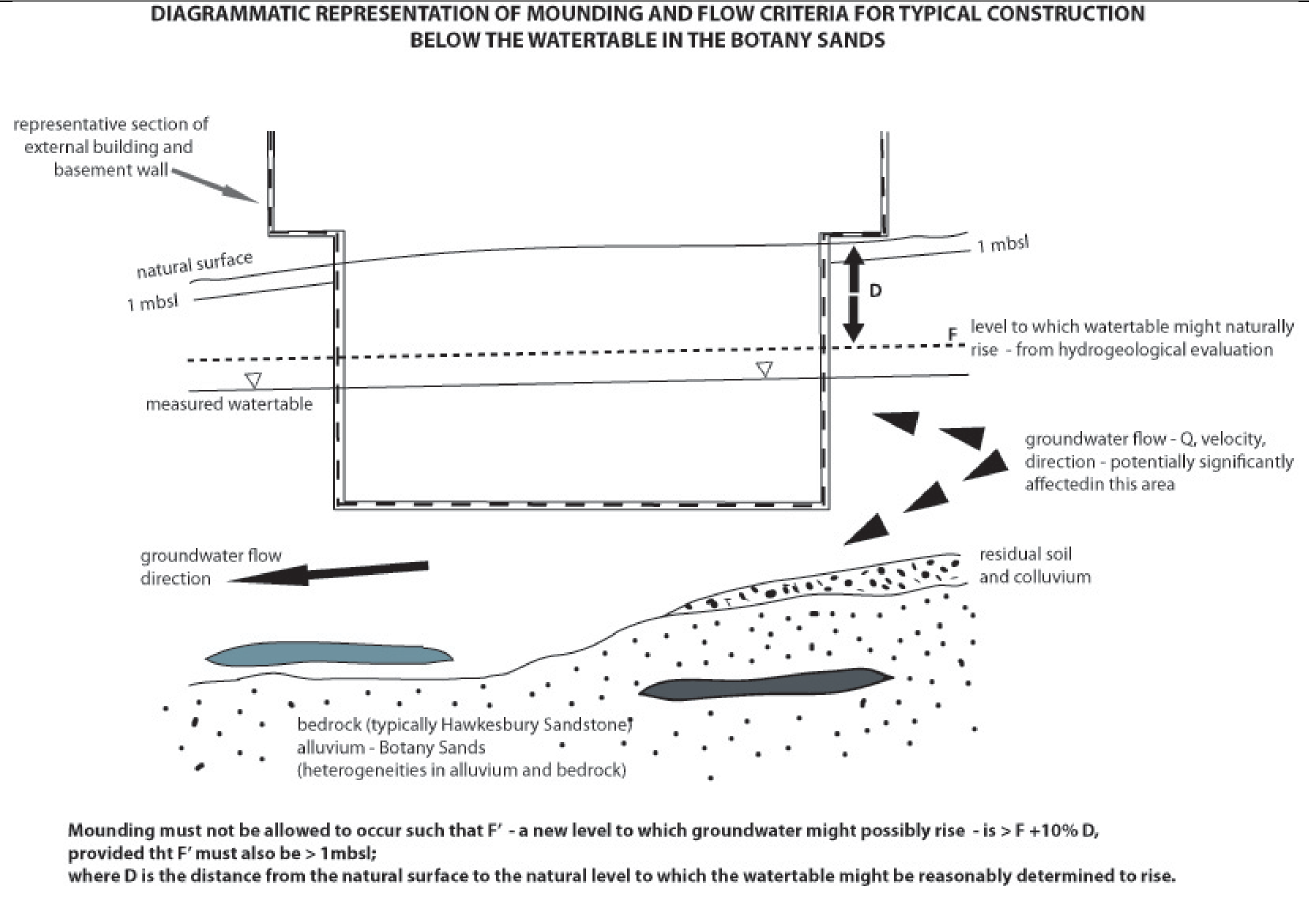


Figure 4: Explanation of Mounding Control Requirements and Reference Concepts

Table 1 DPI Water Monitoring Bore Data

Continuously Recorded SWLs – Botany Sands

Bore # (a)	Easting	Northing	Suburb	Start Date	End Date	Time Continuous Monitoring (years)	RL of Measuring Point (mAHD)	Average (mAHD)	Min (mAHD)	Max (mAHD)	Negative maximum variation below average (m)	Positive maximum variation above average (m)	Total maximum variation (m)
GW042158.1	335282.6	6247778.7	Moore Park	5/5/1999(b)	25/5/2015	16.1	35.11	28.61	26.89	33.07	1.71	4.47	6.18
GW042161.1	334867.2	6243125.3	Eastlakes	16/3/2000(c)	25/5/2015(d)	15.2	21.55	9.67	8.53	11.66	1.14	2.00	3.13(e)
GW075017.1	335196.7	6246242.7	Kensington	5/3/1999	25/5/2015	16.2	24.34	21.83	20.93	22.83	0.90	1.00	1.90
GW075018.1	336081.4	6246830.8	Randwick	5/3/1999	25/5/2015	16.2	28.29	27.05	26.31	28.04	0.74	1.00	1.74
GW075019.1	336317.2	6240096.2	Matraville	5/3/1999	25/5/2015	16.2	13.93	5.52	5.12	6.13	0.40	0.61	1.02
GW075020.1	336591.4	6242236.4	Maroubra	5/3/1999	3/10/2013(f)	14.6	20.07	9.62	6.14	15.46	3.48	5.85	9.32
GW075021.1	335577.8	6245245.4	Kensington	6/3/1999	25/5/2015	16.2	22.75	19.01	18.14	19.69	0.86	0.68	1.55
GW075022.1	333769.9	6242958.3	Botany	11/3/1999	6/3/2014	15.0	6.59	5.09	4.61	6.59	0.48	1.50	1.97
GW075023.1	333640.3	6244019.1	Mascot	13/5/2005	25/5/2015	10.0	7.52	6.99	6.51	7.65	0.48	0.66	1.14
GW075024.1	332822.8	6244670.3	Mascot	11/3/1999	25/5/2015	16.2	7.10	5.65	3.70	6.78	1.95	1.13	3.08
GW075025.1	336309	6243958.3	Daceyville	5/3/1999	25/5/2015	16.2	24.17	15.21	12.45	18.46	2.75	3.26	6.01

(a) bore number GWxxxxxx.1 refers to pipe #1 in a multi-level piezometer nest, targeting the water table
(b) manual data is available from 1/1/74 (nom) – 16/1/1997 (overall 41.4 years of recording available for this bore)
(c) manual data is available from 1/1/74 (nom) – 16/1/1997 (overall 41.4 years of recording available for this bore)
(d) bore GW042161.1 there is no data between 23/11/2011 and 18/6/2012 (0.6 yr)
(e) note this bore has shown a generally continuous rise in water level since 1974 (see Figure 3)
(f) At some time about October 2013 the recorder in bore GW075020.1 ceased to function reliably – data have been truncated

5 REINJECTION

The matter of reinjection is of great interest as a management tool. If abstracted groundwater from the dewatering process can be returned to the aquifer system, this can work as an effective management strategy both in respect of the dewatering project and for the broader resource.

In terms of a dewatering operation, however, this is not usually possible because dewatering in urban redevelopment blocks typically goes to the lot boundary. Without a neighbour's permission therefore, reinjection at the boundary becomes unworkable.

Reinjection brings both other benefits and difficulties. It is beneficial for maintaining volumes in the aquifer and preventing minor re-organisation of flow-paths. Reinjection is often a possible solution for subsidence effects induced by the dewatering operations. The process has not as yet been widely tried in the Botany Sands but is a matter that could be used if shown to have considerable benefits.

The process can be detrimental if the reinjection causes mounding either because of built restrictions or heterogeneity of aquifer materials, or the simple incapacity of the aquifer to absorb the volume.

Dewatering operations associated with reinjection require different licensing for both aspects. The AIP is an important tool brought to bear here for the assessment.

6 SITE ASSESSMENT – WHAT THE REGULATOR NEEDS

Given the multiple interests to be considered and satisfied in the dewatering context, DPI Water has a substantial information need in order to assist its assessments of development proposals and later licensing. Broadly the information required falls under the following criteria:

1) adequate site description accompanied by survey plans that indicate the site setting, surface detail and ground levels to AHD;

2) description of the proposed works plus a footprint plan at the existing surface; basement levels and a representative section of basement and sub-basement (e.g. lift wells) construction – clearly marked with relative levels to AHD;

3) geological characterisation of the site including borelogs (with complete location information in 3 dimensions, MGA, AHD) and a geological section (corrected to AHD) also showing the water table; considered discussion of the geological setting;

4) hydrogeological characterisation of the site illustrating recent water table position (AHD) from at least 3 piezometers, a water table map for the site and its immediate surrounds to 20-50 m off-boundary; an assessment of the likely level to which the water table might rise;

5) a calculation of the amount of dewatering needed during construction (including the water volume of excavated soils) and during building occupation (ongoing take);

6) discussion of the likely means of dewatering on a temporary and/or ongoing basis consistent with DA condition, and being cognisant that conditions are increasingly going to require maintenance of flows beneath and around waterproof structures.

This information will need to be provided to DPI Water on two occasions. Initially at construction proposal assessment i.e. for DPI Water's assessment of a development application. In the case of council-controlled development applications IDAS is the preferable mechanism.

Secondly, the information must be refined and is re-presented and/or updated at the time of applying for a water licence. The re-presentation is necessary because there are often long delays between original conceptualisation at the time of site investigation and the commencement of construction. During this period, development designs frequently change especially in the amount and dimensions of basements, the methods of dewatering alter, and therefore the approval and licensing requirements may also change.

6.1 TEMPORARY CONSTRUCTION DEWATERING LICENCE

The licence which enables the construction is currently granted under Part 5 of WA 1912 (this will change). The licence is only valid for 12 months and confers absolutely no ongoing water take rights for the development.

The applicant for such a licence needs to demonstrate to DPI Water that the dewatering will be performed in a manner that imposes minimal impact beyond the site being developed. Accordingly, the application needs to include a site Dewatering Management Plan which includes the information required by the previous criteria, and in addition includes information for three additional criteria:

7) the relationship of the proposed construction to the current water table (architectural section);

8) the method of, and approval for, disposal of the dewatered groundwater, including the aspects of:

(a) an approval to dispose of the water to sewer, stormwater or surface water;

(b) metering of the volume of water abstracted or disposed;

(c) handling/treating of the extracted water to remove any contamination and adjust its parameters (e.g. pH, salinity, organic content), to a level suitable for disposal;

9) details of the monitoring of dewatering effects during the process and for a period afterwards. In this regard DPI Water prefers that continuous monitoring by waterlevel loggers be undertaken in observation bores adjacent to the site.

6.2 REPORTING

Since the early 1990s DPI Water and its predecessor agencies have required that dewatering volumes, water quality, and performance and management aspects of the dewatering system, be reported to them, upon completion of the process.

From the first half of 2015 a new operational paradigm was introduced in respect of this aspect of future developments. Accordingly, approval to occupy the finished buildings has now been tied to the provision of the appropriate reporting.

6.3 ONGOING TAKE

Not all buildings below the water table prevent the ongoing take of groundwater. Although the amount of seepage is ideally very low, in some situations including partial tanking and some marginal situations*, this is not the case.

The ongoing take of groundwater is an *aquifer interference activity* and will typically need to be licensed because it is taking water from the groundwater source and consequently needs to be accounted for in the sharing of the resource. In relevant situations, the volume of water take needs to be recorded regularly (e.g. by a meter on a sump pump), and licensed accordingly. Very small takes, up to about 3 ML/yr will not normally require a licence provided that the amount can be substantiated. It is the building's developer in the first instance that must provide for this matter, followed by strata or building managers in an ongoing role.

* Around the edges of the Botany Basin for instance, some buildings completely intersect the Botany Sands and are founded in Ashfield Shale or Hawkesbury Sandstone bedrock which also requires excavation. The effect is also seen at the margins of other coastal alluvial deposits.

7 INFRASTRUCTURE

The present construction activity in the Botany Sands is not limited to new buildings. There are significant infrastructure projects scheduled for construction and currently in the planning phase. These include the Sydney CBD and South East Light Rail, the Green Square Stormwater Drain, the potential redevelopment of the Kurnell Peninsula as well as future road and rail tunnels. The AIP applies to all these projects, but additional evaluations are made and a variety of alternate conditions may be imposed by DPI Water depending on the project.

In addition, existing infrastructure like the Eastern Distributor, Sydney Airport Railway, the desalinated water pipeline, the Orica contamination remediation and further developments associated with Port Botany and Sydney Airport are contributors to a variety of impacts. Primarily the effect is to alter groundwater flow paths and these alterations need to be factored into other considerations for subsurface construction.

A consequence of some infrastructure development is the ongoing take of groundwater. The API requires the proponent to limit this take wherever possible as this impacts on the amount of groundwater available for long term average annual groundwater extraction managed under the WMA 2000. The AIP prescribes a hierarchical framework of avoiding take, limiting or mitigating effects on groundwater.

8 CONCLUSION

The AIP requires the take of groundwater to be accounted for and sets minimal impact considerations for impacts of development on groundwater. The aquifer and interference concepts are very broad so that effectively any intersection of groundwater by any activity is included. In intensely developed urban and industrial areas like the Botany Sands, DPI Water is seeking to manage the groundwater resource to minimise impacts from recharge depletion, changes in flow regimes, mounding, and to maintain the resource for all users including the environment.

9 REFERENCES

Albani, A.D. *Sedimentary environments and Pleistocene chronology of the Botany Basin, N.S.W., Australia*, Geo-Marine Letters, 1981, **1**, pp: 163-167

Albani, A.D. and Rickwood, P.C. *The Botany Basin: its bedrock topography and recent geological history*, in Environmental Geology of the Botany Basin: conference proceedings, McNally G.H. and Jankowski, J. eds, Environmental, Engineering and Hydrogeology Specialist Group of the Geological Society of Australia, 1998, pp: 190-196

Benker, E., Hart, M.W., Russell, G.N. and Yu, S.E. *Managing groundwater contamination in Sydney's Botany Sands Beds aquifer – a regulatory perspective*, in 6th IAHS International Groundwater Conference – "Securing Groundwater Quality in Urban and Industrial Environments: conference proceedings,2008, pp: 451-458

Dent, B.B. *Hydrogeological Studies at Botany Cemetery, New South Wales*, M.Sc. Proj. Rept., University of Technology, Sydney, 1995 unpub

Dent, B.B. *The "Yarra Aquifer" - a case of mixed urban interactions*, 13th Australian Geological Convention, Canberra, Geol. Soc. Aust., Abstracts, No 41, 1996, p110

Golden Software Inc, *Surfer ver 9*, modelling software, 2010

Hatley, R.K. *Hydrogeology of the Botany Basin*, Australian Geomechanics, 2004, **39** (3): pp 73-90

Merrick, N.P. *A groundwater flow model of the Botany Basin*, in Conference Proceedings IAH/IEA "Water Down Under", Adelaide, 1994, pp: 21-25

Merrick, N.P. *Glimpses of history: the evolution of groundwater levels and usage in the Botany Basin* in Environmental Geology of the Botany Basin: conference proceedings, McNally G.H. and Jankowski, J. eds, Environmental, Engineering and Hydrogeology Specialist Group of the Geological Society of Australia, 1998, pp 230-242

Merrick, N.P. and Knight M. J. *An overview of historical groundwater levels and chemistry in the Botany Basin*, unpublished research report, Project Number C96/44/014, Insearch Limited for Department of Land and Water Conservation, 1997, 94pp

NSW Department of Land & Property Information, SIX Imagery, http://maps.six.nsw.gov.au/, 1943

NSW Department of Land &Water Conservation, The NSW Groundwater Quality Protection Policy, 1998, 32pp

NSW Department of Primary Industries, *NSW Aquifer Interference Policy: NSW Government policy for the licensing and assessment of aquifer interference activities, State of New South Wales , Publication number 11445*, 2012, 31pp

POEO, *Protection of the Environment Operations Act 1997,* NSW Legislation as updated from time to time, www.legislation.nsw.gov.au, 2015

Russell, G.N. *Hydrogeology of the Botany Sand Beds (GWMA 018; Groundwater in an urbanised aquifer*, NSW Department of Infrastructure, Planning and Natural Resources, 2005, 115 pp

Sydney City Council, *Green Square,* http://www.cityofsydney.nsw.gov.au/vision/major-developments/green-square, 2015

WA 1912, *Water Act 1912 No 44*, NSW Legislation as updated from time to time, www.legislation.nsw.gov.au

WSP, *Water Sharing Plan for the Greater Metropolitan Groundwater Sources 2011*, NSW Legislation as updated from time to time, www.legislation.nsw.gov.au

WMA 2000, *Water Management Act 2000 No 92,* NSW Legislation as updated from time to time, www.legislation.nsw.gov.au, 2015

10 ABBREVIATIONS

AHD – Australian Height Datum

AIP – NSW Aquifer Interference Policy

BoM – Australian Bureau of Meteorology

CBD – Central Business District

DA – Development Application

DLWC – Department of Land & Water Conservation (now known as NSW DPI Water)

DPI – NSW Department of Primary Industry

EIS – Environmental Impact Statement

EPA – NSW Environmental Protection Authority

IDAS – Integrated Development Approval System

MGA – Map Grid of Australia coordinate system

ML/yr – Megalitres per year

POEO – *NSW Protection of the Environment Operations Act 1997*

RRM – residual rainfall mass

WA 1912 – *Water Act 1912*

WMA 2000 – *Water Management Act 2000*

WSP – Water Sharing Plan (as legislated)