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The Project Manager
Murlan Consulting Pty Ltd
Jones Bay Wharf
Sydney
2 October 2009
Attn: Mr. Ben MacGibbon

Dear Sir,

<u>RE: 35 WATER ST – WAHROONGA, FURTHER SUPPLEMENTARY HYDROGEOLOGY AND INFILTRATION REPORT.</u>

Further to your request we have installed additional high level piesometers following recommendations made by Ian Grey to Council.

- ” Installation of additional piezometers to allow monitoring of the perched groundwater system in the residual clay profile in the area(s) where construction will occur close to the BGHF. **These should be drilled to the base of the clay profile/top of bedrock or immediately below. Installation of at least two pairs of piezometers is recommended, with one located a few metres down slope of the other in each pair** to allow accurate assessment of local hydraulic gradients;”

We have advised in two previous reports, that the perched groundwater table noted by Grey does not exist and, that the soil type was such that it is in fact an aquiclude and the piesometers would not provide any further usefull information for either hydraulic gradient or transmiscivity. For a hydraulic gradient to be measured in piesometers, it is necessary to have a free water surface to be measured, which was not expected nor encountered. The expected permeability being very low and to be in the area recommended by Mr Grey, the bores would need to be within the area of the BGHF and would therefore be installed without the use of heavy drilling equipment to avoid damage to the assemblage. The installation was completed using hand methods which proved to be very difficult and time consuming due to the nature of the clay soils (very stiff to very hard clay Cu> 200kPa) and weathered shale.

During the installation of the bore holes for the piesometers it was found that very hard clay was encountered from a depth of 20mm and refusal of the 100mm continuous flight auger with tungsten carbide drill bit occurred on weathered shale at a depth of 2.6 to 2.8m. The drilling was conducted using a 5hp two man auger drill and the cuttings examined and logged as they were cleared from the augers. The clays were dry from the surface and no free water or excess moisture was encountered, the weathered shale was also dry. Pocket penetrometer readings were not obtained from the cuttings due to the fine dry and often powdery nature of the cuttings. Penetrometer readings were taken within the bored 250mm concreting hole at a depth of 350mm from the surface ranging from 350kPa – 450kPa.

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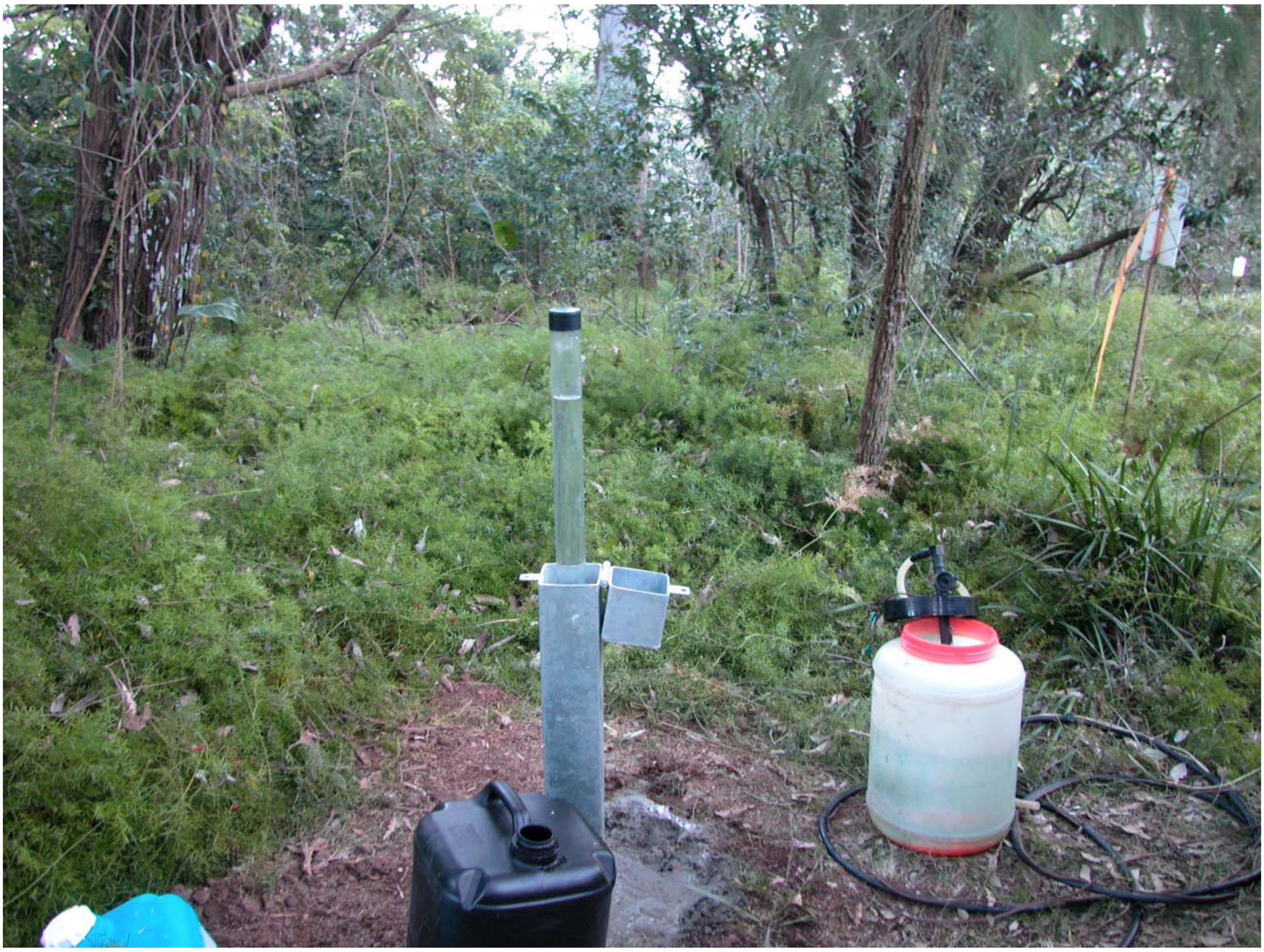
The above plate shows BH4 cuttings and installation of the piesometers tube. Note the dry clay cuttings (redish colour and grey dry shale cuttings.

On completion of BH4 in dry shale it was decided to install BH5 at a distance of 30m to see if there was a difference on the soil moisture state a reasonable distance in the area of concern. On completion of BH5 in dry shale it was concluded that the proposal for piesometers made by Mr Grey was unfounded and would be unworkable as there was no perched water table, nor would pairs of piesometers be of any use in gauging the permeability of the soils encountered, at best infiltration to some soil structures may be measurable. In the alternative it was determined that single piesometers should be used and tested. The method employed was to artificially wet the soils and perform Gelph permeameter or clear tube permeability testing within the boreholes as described below:



The above plate shows the permeameter in place during one test on BH5 the drums and electric pump are used for water storage and filling of the permeameter.

To this end the piesometers were constructed using micro slotted well screens 1.5m in length with a closed end. The screen length was backfilled with a graded filter of 2 and 3.5mm silica sand. The blank riser tube also 1.5m in length was packed externally with bentonite clay (Barroid – hole plug) and a 350mm deep concrete cap and riser cover fitted.

The riser was then fitted with a 50mm outside diameter clear polycarbonate measuring tube and flow damping cap. The bore holes were then filled with water until the filter and tube was full and left to allow the bentonite to swell and the surface of the soil to wet. Falling head tests were conducted on three occasions and the data analysed to provide a permeability for each bore.

LOCATION OF MONITORING STATIONS- PIESOMETER + SOIL MOISTURE STATIONS
PERMEAMETER AND FALLING HEAD TESTS AT MONITORING STATIONS 4 and 5.

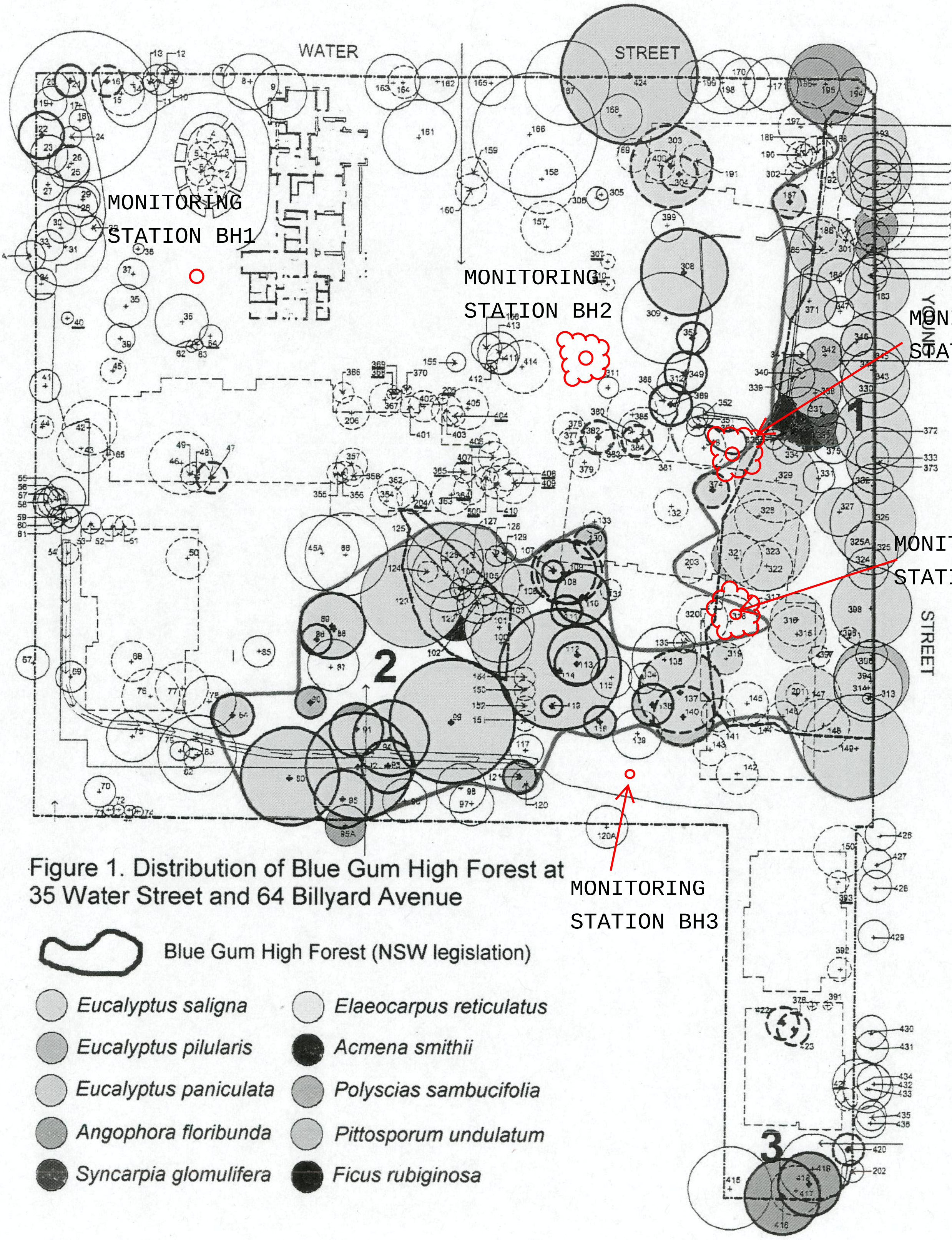


Figure 1. Distribution of Blue Gum High Forest at 35 Water Street and 64 Billyard Avenue (Figure 1 of Smith 2007a)

REVISED
6:22 pm, Oct 02, 2009

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BH4 provided consistent data on each of the three occasions tested and included times up to 15 hours between measurements.

The value of “k” or permeability measured using falling head data was calculated from the following equation for an open filter.

$$km = \frac{d^2 * \ln\left(\frac{2mL}{D}\right).}{8.L.(t2 - t1)}.\ln\frac{H_1}{H_2}\ for - \frac{mL}{D} > 4$$

In this case the transform ratio m (square root of $k_{horizontal}/k_{vertical}$)was taken as 1 however the vertical permeability may be several orders of magnitude greater than the horizontal due to tension crack formation, which would lower k markedly.

The most consistent value for K was obtained from BH4 - km = 9.23 x 10^{-9}m/sec

At BH 5 some difficulty with losses along the bore casing to the surface were experienced as the bentonite did not swell sufficiently to seal the bore in the first instance, additionally several tree roots were intersected during the installation of the bore and there appeared to be some structures within the upper soil around the roots which also contributed. The soil structures are tension cracks due to dessication, residual structure from the clay shale bedding planes and soil biology (worm tracks, spider and ant holes and the like). Even with these issues, the permeability was only marginally lower at km= 2.35 x 10^{-8}m/sec.

Given the above permeabilities it is likely that to measure a change in an adjoining piesometers only 2m from the initial borehole (about the minimum distance practical to install two borehole piesometers without causing interference problems due to the installation) as recommended by Mr Grey would require a time interval of 2.7 years based on the upper bound measurement of permeability. Over this amount of time, the water level in the relevant piesometers would have changed for many reasons unrelated to permeability, including evaporation and transpiration, interference, biological activity and the like. This further illustrates the flawed nature of an assumption of mass transmission of water laterally through the soils. Placing onerous restrictions on the basement design and construction methodology based on this flawed assumption would be unjustifiable in these circumstances.
Given the proposed excavation depth, the only reason for which a restriction or covenant on the methods of construction could be justified, would be if the restriction were framed to prevent or minimise the effects of drying and desiccation of the clays soils adjoining the excavation, during the period of open excavation prior to construction of the basement walls. This drying can be alleviated using several methods available to the constructors, including, jute covers and spray irrigation over the open batters, embedded retaining wall construction methods, short term excavation or shotcrete covering of the batters.

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As noted in our previous reports, the volume or percentage of available water to the ecosystem from the clays can be accurately measured and logged using soil moisture monitoring techniques. This information may also be used during and post construction to monitor and maintain the soil moisture required for the health of the BGHF.

The water available to the ecosystem is for the most part provided by direct vertical infiltration during rainfall events whereby the high shear strength of the clay, allows vertical tension cracking to form, which acts as individual reservoirs wetting and swelling the clays locally which then swell and "heal" the tension cracks formed during the dry. It is highly improbable from the test work performed and our observations of the site and general area, that any significant horizontal flow of groundwater could occur in the clay soil horizon directly, without significant interconnecting vertical structure, which to date has not been observed.
The lack of structure can be due in part to the way in which the site has been modified by the landscaping, gardens, hard surfaces and walls. Rainfall events have also maintained soil moistures to date, however, as the climate varies, the soil structure will also vary.

The existing infiltration areas to be taken up by the proposed development can be replaced with a passive infiltration system utilising rainwater collected from the roof and directed to the areas most in need. The system is passive and self regulating due to the nature of the clay soils. A sketch and flow sheet of the proposed system is attached and, it is possible to measure the effectiveness of the system using the a soil moisture monitoring system such as the type described previously in our report of 16 February 2009.

Soil Moisture and water Infiltration Model.

- Rainfall in general infiltrates very slowly into saturated clay and in particular where now measured permeability may be as low as 10^{-9} m/sec/m^2 (during prolonged rainfall events or over winter and when there is sufficient residual soil moisture to prevent tension cracking occurring within the clay soils). Where the clays can dry out, during the summer months, drought or prolonged exposure to the atmosphere without sufficient wetting, the clay may develop deep vertical tension cracks and surface water will infiltrate vertically very quickly through these tension cracks to depth. As the clays take on sufficient moisture to swell the tension cracks close preventing further infiltration and runoff occurs.
- Based on the measured infiltration rates from BH4 and BH5 for the soil horizon, a moisture infiltration rate of 0.0021 Litres/m2/sec is to be expected and based on a 50m length of permeable paved infiltration zone 2m in width and 200mm deep, a total of 15,200 litres can be stored and 13,934 litres will be infiltrated in 24 hours.
- This infiltration system is proposed to be located along the southern sides of the development underneath the existing and new trafficable areas. This provides the infiltration necessary without sterilising any additional area available for landscape use.

Infiltration and drainage

The landscape concept plan and the stormwater management plans LHO Group have compiled, has been studied in light of the hydrological aspects of drainage and water use on site and in particular with respect to applying a similar surface water load to the landscape from the finished works as could be expected from the current situation. The landscape plan and stormwater management plans envisage the re-use of collected rainwater for irrigation of the landscaped areas and other uses on site. The current plans utilise storage and a large on site detention tank at the bottom of the site (south east corner), prior to discharge to the stormwater network. LHO Group Drawing 0608-008 C03 and C04 Rev D which show the proximity of the existing paved areas, the new buildings and the areas

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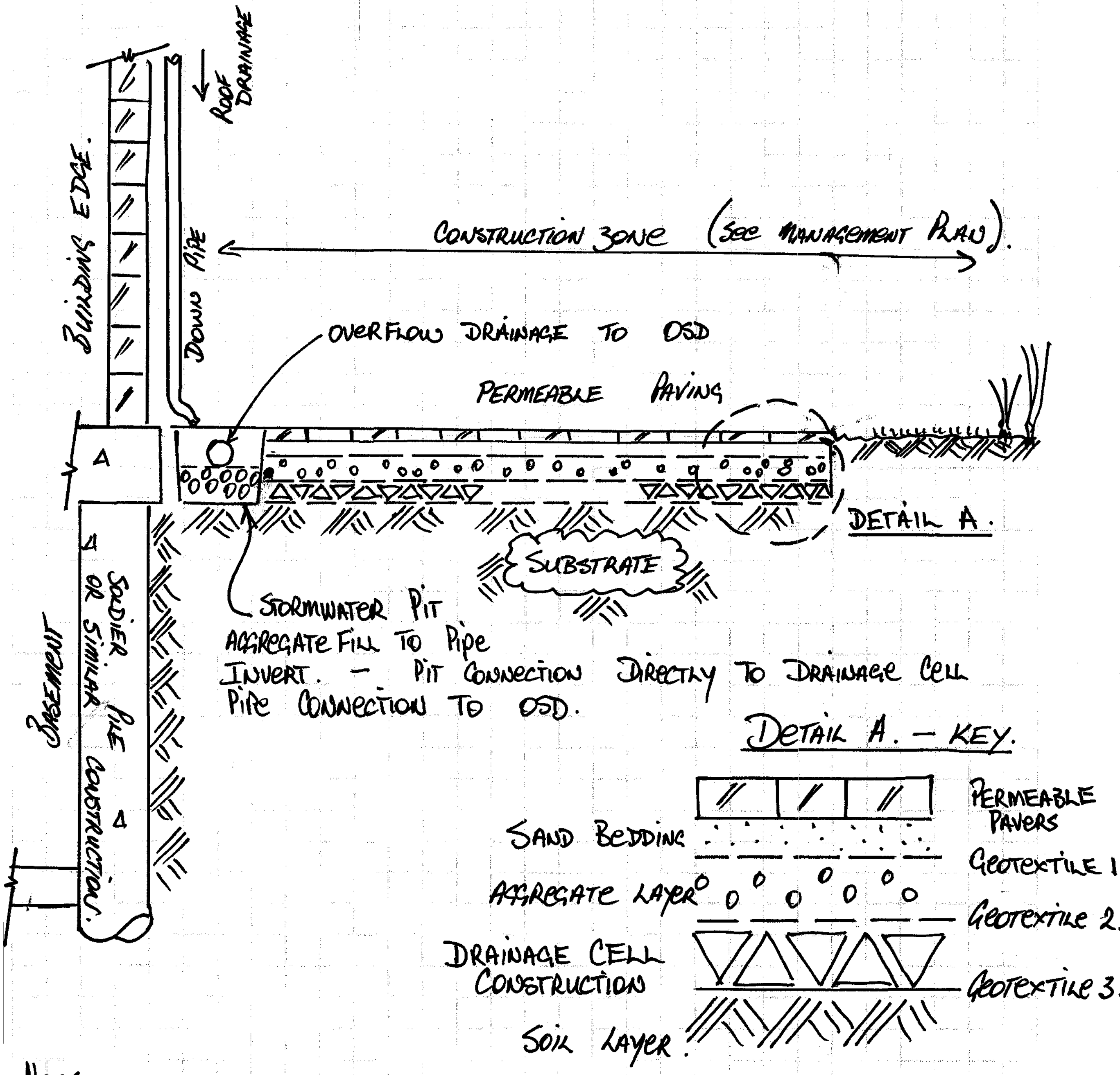
Job No 2719

PROJECT SK 15-9-02 INFILTRATION

DATE 20-9-09



NOTES:

DRAINAGE CELL VOLUME = 1:5 YEAR ARI VOLUME × PRE EXISTING DEVELOPEMENT NATURAL AREA LOSS × INFILTRATION RATE × STORM EVENT TIME (30MIN → 120MIN).

RAINFALL & INFILTRATION RATE WILL CONTROL THE VOLUME & THEREFORE THE LENGTH & WIDTH REQUIRED FOR THE CELLS WITHIN THE CONSTRUCTION ZONES.

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PREPARED [signature]

remaining as extensively un-touched. The paved area footprint has in the past been mostly undrained and has provided a catchment which supplies a passive irrigation system along its lower edge, to the landscaping and existing gardens as infiltration zones for soil moisture. The design proposed maintains and enhances these catchments. It is our opinion that these areas can be designed to replace the reduced natural infiltration areas resulting from land use by the development and, managed to form a permanent replacement of these infiltration areas both during construction and on completion using the storage and re-use systems planned. The amount of re-use through irrigation can be managed from the data provided by the soil moisture measurement network .

Conclusions and recommendations:

- Given the extremely slow rate of horizontal transmission through the clays and the underlying Ashfield Shale it is our opinion that the perceived edge effects can be managed by effectively providing a sealing layer to the excavation batters during excavation for the basement. Typically construction could be as soldier pile and infill panel design, shotcrete blinding of any exposed soil horizon, contiguous or secant pile or other continuous membrane type shoring or slope retention system which can effectively prevent moisture loss over a 6 to 12 month period.

- The construction management plan provides for a 3m construction zone which is adequate room for the construction equipment and, techniques required to be construct the basements without adversely impacting on the surrounding flora and environment. It has been our recent experience on many construction projects where a 1.2 to 2m construction zone provided adequate room for the building process, scaffolding and protection of adjoining properties. This zone will only be utilised for pedestrian and incidental use and serves as a buffer zone between the construction outline and the ecological outline. Its significance in part will be the for the location of the proposed primary infiltration zone will be take up part of the width in the areas identified by the horticulturalists, reducing any perceived edge effect and maintaining a moisture buffer as is demonstrated by the sketch below:

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- The water harvesting and management plan proposed by LHO Group, is best suited for controlled management of soil moisture after construction and the management of the gardens and BGHF soil moistures. The proposed system guarantees the soil moisture in a less hap hazard manner than at present and allows for the future management of the landscape.

For & on Behalf of
D.F.Dickson & Associates Pty Limited

D.F.Dickson BSc MS (q) MIEA CPEng (rtd) GSA NPER 2074820

Further documents and references used in preparation of this report are as follows:

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8. Leaf, tree and soil properties in a Eucalyptus saligna forest exhibiting canopy decline. Christine Stone and Jack Simpson. New South Wales Department of Primary Industries Science and Research, Beecroft, NSW 2119, AUSTRALIA.
9. Soil physical properties affecting root growth in rehabilitated gold mine tailings Selva Kumar Arunachalam, Christoph Hinz and Graham Aylmore School of Earth and Geographical Sciences, Faculty of Natural and Agricultural Sciences, The University of Western Australia.

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18. SCCG Groundwater Management Handbook - 2006