Appendix B – CETCO – Design and Installation Guide for Drain Cel™ Passive Ventilation Systems & VI-20 Using Liquid Boot Membrane

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GAS BARRIER AND MITIGATION SYSTEM

Technical Specification

LOT 9002 Longford Rd, Beaconsfield WA

REPORT DATE: 29th February 2016

COMPLETED BY: Michael Novak

DOCUMENT CONTROL

DOCUMENT VERSION: FINAL

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DATE	29th February 2016	1st March 2016
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FOREWORD

The content of this specification has been produced based on the data and information provided for the project at Longford Rd, Beaconsfield. It provides site specific requirements and installation procedures for the practical implementation of the strategy in a construction environment. The entire content of this specification is subject to change based on any new information which could influence the outcomes of the overall goals. This specification should not be used for any purposes other than for this specific project. For any specific details, please contact CETCO.

1. INTRODUCTION

The following specification of the Gas Barrier and Mitigation System (GBMS) has been completed for use on the project located at Lot 9002 Longford Rd, Beaconsfield (the site). The content of the GBMS specification is aimed to achieve the following:

- Demonstrate the suitability of the proposed system as meeting or exceeding the adopted criteria (CIRIA R149 CS3)
- Outline construction protocol and installation methodology of the GBMS
- Provide adequate construction quality assurance (CQA) methods to validate system integrity

The site is impacted by landfill gas (LFG), as well as other hazardous volatiles and gases (inc. hydrogen sulphide), generated by the activities of filling a former limestone quarry. The site has undergone significant assessment to identify these impacts which has to shown to cause risk to future occupants. MDW Environmental Services (MDW) completed a site investigation and management plan to determine the level of protection (CIRIA R149 CS3), with an approved solution to mitigate risks (traditional gravel and pipe network with a gas membrane). CETCO were provided with MDW assessment work to review and propose an alternative solution to achieve a more practical and economical solution for landowners.

Using the above mentioned information, a GBMS comprising of a VI-20 vapour barrier with Liquid Boot sprayed seams underlain by a continuous geocomposite subfloor ventilation system has been proposed across the entire building footprint.

A Construction Quality Assurance (CQA) plan has been prepared to outline appropriate site procedures, roles and responsibilities of related parties, identify milestone events and inspection and validation regime which will be completed by CETCO or its approved applicator. Whilst the data may be collected on the provided CETCO CQA forms, alternative methods of documentation may be submitted to fulfil validation requirements for record keeping.

Based on the information provided by the client and its representatives, the following expected certification requirements to the GBMS are described in this report.

2. BACKGROUND INFORMATION

2.1. REFERENCE MATERIAL

CETCO have been provided with the following reference material in consideration of an appropriate solution and execution of the VBMS:

- MDW Environmental Services, Environmental Site Investigation Ground Gas Monitoring (Visits 1-6), Lot 9002 Longford Rd, Beaconsfield, WA, dated 16th February 2015

- MDW Environmental Services, Environmental Site Investigation Ground Gas Monitoring (Visits 7-9), Lot 9002 Longford Rd, Beaconsfield, WA, dated 16th February 2015

The information provided within the above mentioned documents has been interpreted to be the most updated, and accurate information pertaining to the site. It is expected that future changes to any of the above documents are reviewed and considered within the technical specification to validate the significance of any amendments and make changes, if required.

2.2. PROPOSED DEVELOPMENT

The development is to consist of 33 individual lots, each of one or two storeys, which will be constructed by individual land owners. The total footprint of land is approximately 10,000sqm, where all occupied hard standing will be considered for gas mitigation measures. The method of construction is understood to be ground bearing with limited internal foundations to accommodate the current approved mitigation strategy.

2.3. SUPPORTING DOCUMENTATION

As part of developing the herein technical specification, Zoic Environmental (Zoic), were engaged to review the proposed alternative solution and provide commentary (including justification) to the performance of the selected venting network. Appendix A will outline the rationale behind the proposed solution, demonstrating the performance as meeting the CIRIA R149 CS3 criteria, and providing some comparison to the current strategy. Per provided reference material, MDW have concluded that hydrogen sulphide odours will be mitigated effectively by the adoption of the CIRIA criteria for managing LFG. As such, it is expected that any updates within the management plan adopting the herein solution will draw similar conclusion.

3. PERFORMANCE AND SELECTION

Considering the aforementioned background information, the following components have been selected as part of the GBMS solution.

3.1. MEMBRANE SELECTION

The selection of VI-20 with Liquid Boot sprayed seams as the vapour barrier was considered based on precedence and experience with respect to LFG affected sites.

The VI-20 geomembrane consists of a 7 layer co-extruded geomembrane comprised of interleaving layers of ethylene - vinyl alcohol copolymer (EVOH) and virgin-grade polyethylene. This provides the barrier properties of EVOH to mitigate human health risk within the specific site.

The Hildebrand solubility parameter is based on the principle of “like dissolves like” and is a predictor of chemical resistance and barrier properties. A comparable value for the solubility parameter suggests strong interaction and mutual solubility, whereas non-comparable values suggest low interaction, strong chemical resistance and barrier properties. In the case of EVOH and hydrocarbon compounds, the solubility parameters are much different from one another, whereas e.g. HDPE is very similar to most hydrocarbon compounds. This prediction lies with observation in that EVOH possesses a much lower diffusion coefficient for hydrocarbons and gases as compared to HDPE. The data supporting this contention is shown in tables 1-3:

TABLE 1. SOLVENT SOLUBILITY PARAMETERS

SOLVENT	SOLUBILITY PARAMETER Δ(SI) [MPA]
Dichloromethane	20.3
1,2-Dichloroethane	20.0
Trichloroethylene	19.0
Benzene	18.7
Toluene	18.2
Ethylbenzene	18.0
m-Xylene	18.0
Water	47.9

TABLE 2. POYMER SOLUBILITY PARAMETERS

POLYMER	SOLUBILITY PARAMETER Δ(SI) [MPA]
Polypropylene	16.2
Polyethylene	16.4
Polyvinylchloride	19.6
Polyurethane	20.5
Nylon 6	26.0
Nylon 66	27.8
EVOH (32mol%)	38.9

TABLE 3. VI-20 DIFFUSION COEFFICIENTS

CHEMICAL	RESULT
Benzene	4.5×10^{-15} m^2/s
Ethylbenzene	4.0×10^{-15} m^2/s
m&p-Xylenes	3.7×10^{-15} m^2/s
Methane	$< 1.7 \times 10^{-10}$ $m^2/d \cdot atm$
o-Xylene	3.7×10^{-15} m^2/s
Radon	$<0.25 \times 10^{-12}$ m^2/s
Toluene	4.2×10^{-15} m^2/s

The supporting information has been provided to show methane performance, as well as demonstrating that presence of VOC's will not affect long term performance of the system. Liquid Boot, another gas and vapour resistant barrier has been proposed as an alternative to welding, to allow for any potential complex detailing due to nature of geology, proposed venting type and residential construction. The spray applied method, will allow for detailing of construction foundations, penetration as well as membrane overlaps. The integrity of the entire surface area of GBMS will be checked by smoke testing.

3.2. VENTING SELECTION

The use of open void solutions such as geocomposites offer superior performance to most alternatives because of the much higher air and gas flows that can be achieved, as well as its lesser tendency to block via silt or water NSW EPA (2012).

The 50mm geocomposite (Appendix D) was considered given its large void area, >95%, producing a more efficient void space than other materials. Produced in panel form, the rigid nature of the material does not make it suitable on all sites, and requires some substrate preparation to prepare a relatively flat plane to accommodate the clip-type mechanism. Often, this is best achieved by use of a sand layer to level any depressions in base material.

The composite layer will extend over the majority of footprint and will terminate not more than 1m from perimeter of building. The layer will be encapsulated in geotextile to protect from potential silting, and will be connected to external vents by use of a sump or vent box.

It should be noted that two methods of construction have been outlined in MDW management plan; low level stacks, or low and high level stacks on opposing ends of dwelling. Both options have been documented to allow for flexibility to the landowner.

Furthermore, it is recommended that CETCO are contacted during development of structural drawings and design to allow for review of incorporating stacks to the building design and providing option for value engineering where possible. This process is expected to manage any items outside of the herein specification and will be covered in the supply and installation cost. Where consultation is rejected, it will be the builders responsibility to incorporate the principles of the solution into construction and will require an inspection by a suitably qualified engineer or consultant.

3.3. SOLUTION SUMMARY

A summary of the adopted solution is provided below. An illustrated summary, as well as construction details, can be found in Appendix C.

TABLE 4. PROPOSED SOLUTION SUMMARY

ELEMENT	SUB-ELEMENT	NOTES
Sub Grade	Earth substrate Sand layer Silting layer	Straight and level cut to correct RL Used to level undulations for geocomposite (as required) Prevent silting/blockage (light gauge geotextile)
Ventilation Layer	50 mm thick interlocking Drain-Cel™ 2 x 100mm PVC Inlet pipes 2 x 100mm PVC Outlet pipes Ultrashield G-1000 geotextile	Placed over footprint and within 1 metre of internal face of edge footings SN6 sewer grade, with solvent cement joints (SCJ), Fabricated manifold sleeve and air inlet air brick/plate, bollard or vent box Outlets (if used) to extend to roof level with no more than two bends, and stand 0.5m above gutter or parapet level Placed over Drain-Cel™
Vapour Membrane	VI-20 with Liquid Boot sprayed seams	VI-20 Geomembrane (0.5mm) with Liquid Boot seams at 1.5mm
	UltraShield G-1000 geotextile	Placed over finished membrane Protection from oncoming trades
Concrete Slab	Reinforced concrete raft slab	Per structural specification

4. VAPOUR BARRIER AND MITIGATION SYSTEM INSTALLATION

The following outline represents site specific requirements upon site mobilisation. This information is to be used in conjunction with the attached Appendices.

4.1. PRECONSTRUCTION

A preconstruction meeting is fundamental prior to the implementation of the GBMS and is to be conducted prior to the implementation of the GBMS. The intention is to clearly outline responsibilities of related trades pertaining to the integrity and protection of the GBMS during construction. The meeting is structured such that each element of installation is described in detail including exclusion zones during installation and smoke testing. This process can be achieved by builder and installer, or may involve relevant trades.

To ensure that trade interference is minimised, a table of roles and responsibilities is provided to ensure that once the GBMS process commences, there are no changes to other building components.

TABLE 5. ROLES AND RESPONSIBILITIES OF SUBCONTRACTORS

ROLES	RESPONSIBILITES
Site Foreman	• Coordination and supervision of site trades • Coordination and inspections for purpose of VBMS CQA • Oversee and signoff plumbing, electrical and concreting components • Confirm acceptance and start date for CETCO • Complete site walk prior to concrete pour
Plumber	• Cross referencing services network with VBMS system to ensure no disturbances • Correct set out and placement of all services and signed off before handing to CETCO
Electrician	• Installation of electrical services with correct set out
Concreter	• Pouring structural elements 7 days prior to CETCO mobilisation • Ensure all structural elements are wood float finish where no voids/rough edges are present • All spoil material, excess steel, rocks and rubbish removed • Avoid machinery heavy/foot traffic post installation • Minimise steel wire clippings • Avoid cutting/grinding/torching on membrane. Produce designated area or use hand tools • Careful placement of steel, without vertical or abrupt dropping of material • Alerting CETCO of any accidents or identified defects in membrane • Careful placement of formwork • Minimising of star pickets, and strictly NO pickets inside pour area unless treated as penetration • Bar chairs and biscuit lids to be used

	• Care during concrete pour

4.2. SUBSTRATE PREPARATION

Prior to vapour barrier system implementation, it is important that substrate preparation has been completed to structural and environmental requirements. Care must be taken during installation to ensure that the substrate is clean and free of any foreign material (e.g., sharp or large rocks, building refuse, litter, fines, etc.) in order to minimise risk of membrane damage.

On any site requiring termite protection it is vital that it is installed prior to the membrane. **Liquid Boot or VI-20 are NOT termite barriers.**

The site is to be set out to allow for a thin sand blanket where required to allow for Drain-Cel to be placed on an even surface. Structural foundations including footings will require neat excavation to allow for membrane downturn and appropriate sealing to the top of footings. The services are not to have lagging installed until after vapour barrier installation and sign off.

4.3. VENTING INSTALLATION

Prior to placement of venting, a silting layer must be placed with minimum 50mm overlaps to prevent soil/silt blockage in the event of inundation.

The subfloor venting network will take the form of a Drain-Cel geocomposite layer. The installation process involves attaching each drainage cell to another via slots provided along edges. Where the drainage cell is to be placed alongside a wall or footing, a space no greater than 300mm will be left between the footing/pile cap and the drainage cell allowing for membrane height transition and detailing to structural elements. To avoid tearing of the membrane at the edge of a Drain-Cell panel, the end of the panel should be wrapped with G-1000 and crushed rock or similar used to chamfer a transition edge minimising point stresses on the membrane.

Cutting of the Drain-Cell to accommodate services and structural detail shall be done with care, ensuring that the cuts are smooth and do not have sharp points along the edge. It is preferred that any remaining voids are filled with the crushed rock to retain relative levels and minimise membrane puncture risk.

Termite protection should be applied after placement of Drain-Cel but before placement of vapour barrier.

4.3.1. INLETS

Two (2) Inlets are to be installed per dwelling if high level stacks are to be adopted (achieving 1050mm2/m). If low level stacks are considered, the number of stacks will increase from four (4) per lot to six (6). Inlets are to be placed at ground level, taking the form of an air brick/grate, or alternatively extending to a minimum height above flood level (if applicable) and completed with a “mushroom” cap. Illustrations and locations of the inlets have been documented in Appendix C. All inlets must have a clear venting area of 7850mm^2.

4.3.2. OUTLETS

Two (2) outlets are to be installed per dwelling unless low level stacks are adopted, in which case it will increase to three (3). Outlets are to take the form of PVC risers extending above roof level. Exact locations as well as illustrations of outlets are provided in Appendix C, however will generally be on the opposing building side to inlets. As with inlets, outlets must have a clear venting area of 7850mm^2.

The PVC pipe will bend from the horizontal venting layer by 90 degrees before extending vertically to roof with minimal bends to the extent practicable. Outlets will be completed at roof level with a 150mm Edmonds ‘Sewer’ turbine ventilator or similar, and must be placed at 500mm above parapet to achieve venting efficiency. The outlet must be located at least 500mm away from air intakes, accessible windows or balconies or as identified in the relevant Australian Standards.

4.3.3. PROTECTION AND COMPLETION

Inlets and outlets must be protected at all points after their installation to ensure their ongoing operation. Failure to ensure proper protection or care around inlets/outlets can lead to reduced performance or failure of the system as a result of water ingress or blockage.

Following the installation of inlet and outlet pipes, adequate protection will be considered by means of covers, shrouds or bollards to ensure long term protection of the GBMS. An inspection should be completed to verify the appropriate installation of the venting layer, implementation of inlets and outlets within nominated locations and to verify the suitability of selected protection measures. This may be done by the builder provided evidence is attached (photographs etc..) or a suitably qualified environmental consultant or engineer.

Inundation has been identified as a primary risk associated with subfloor venting performance during construction. The following table outlines potential receptors and actions to ensure the effects are minimised. The below table outlines risks associated with inundation, preventative actions and the persons responsible for protection of the system at that stage of construction.

TABLE 6. VENTING SYSTEM INUNDATION MANAGEMENT PLAN

STAGE	POTENTIAL RISK	RISK SCORE WITHOUT ACTION	PREVENTATIVE/CORRECTIVE ACTIONS	RESIDUAL RISK SCORE	RESPONSIBLE PERSONS
During Construction	Water from construction works – Concrete, mortar, high pressure cleaning	Moderate	Installation of temporary caps Installation of horizontal fitting Education of site workers via preconstruction meeting and regular toolbox meetings	Low	Builder
	Inclement weather and poor drainage/levels	High	Ensure pipes are at reasonable yet practical height above slab level Delay placement of Liquid Boot/VI-20 until ponding water has drained or has been pumped away	Low	Builder CETCO
	Workers disposing site wastes down pipework	Moderate	Clear labelling of vent piping Installation of temporary caps Education of site workers via preconstruction meeting and regular toolbox meetings	Low	ALL

Aesthetic completion of inlets and extension of risers to roof level (including any covers, acoustic or fire rating considerations) is the responsibility of the builder, and will not be performed by CETCO. The aforementioned table is aimed to assist the builder in management of such components until ready for installation and commissioning of final stacks and ventilators. A CQA inspection and sign off is necessary on completion of inlets and outlet stacks to demonstrate the 'system' is complete and conforms to the intent of design.

4.4. MEMBRANE INSTALLATION

Membrane installation is to be performed across the entirety of the building footprints, including any penetrations as detailed herein and Appendix B. The membrane is to be installed in a continuous manner beneath each of the dwellings.

VI-20 will be rolled out across the floor, with wrinkles, folds and stress points in the VI-20 to be reduced, laying the geomembrane tight in all corners or recesses, with all seam overlaps to be a minimum of 150mm before applying Liquid Boot.

Penetrations will be executed as described in Appendix C.

Where footings are present, VI-20 and Liquid Boot are to be overlapped and sealed a minimum 75mm over concrete. Once application is complete, and Liquid Boot seams have cured and tested in accordance with Section 5 and a G-1000 UltraShield protection layer is rolled out over the extent of the membrane to avoid any potential traffic damage.

It will be the responsibility of the applicator to validate procedures associated with membrane applications via the use of provided inspection forms. Forms have been provided within the Appendix E outlining checklists of key procedures.

4.5. SMOKE TEST AND SIGN OFF

To ensure the design intent of the GBMS is met, smoke testing will be completed as part of the validation process. The inspection will be performed following installation of the designated pour area, and will demonstrate monolithic installation prior to placement of protection layer and steel. The method of testing and pass criteria is presented within Section 5.

4.6. STEEL REINFORCEMENT

The placement of reinforced steel is to take place following smoke testing and handover by CETCO. Given the importance of the GBMS, additional care is required to prevent membrane puncture during steel work activity. Items assisting the appropriate installation include:

- Steel bar chairs with biscuit lids or plastic bar chairs with flat base to distribute loads
- Horizontal placement of steel on ground
- Minimising wire clippings on membrane
- Cutting reinforcement with pliers or bolt cutters
- Designating a grinding area away from membrane or employing a fireproof mat to the greater extent of work area
- Avoid oxy-torch within vicinity of completed membrane

It will be the builder's responsibility to manage these items in accordance with the provided 'preconstruction' guide; however an inspection will be completed by the approved applicator to allow for additional verification prior to placement of concrete.

4.7. CONCRETE

Whilst produced in generic form, it is expected that the concrete slab is placed according to the appropriate Australian Standards, best practice guidelines and completed in a quality workmanship like manner. It will be the responsibility of the builder to certify the performance of selected sub-contractors.

5. INSPECTION REQUIREMENTS

The CETCO quality assurance report focuses on critical detail pertaining to elements defined in this specification. The typical QA documentation is outlined in Appendix E. A description of each element is included below in sub-sections.

5.1. CONSTRUCTION QUALITY ASSURANCE PLAN

CETCO provides a Construction and Quality Assurance Plan (CQAP) for the vapour barrier system. The plan aims at collecting the appropriate data during construction, as well as identifying the testing and inspection regime for the GBMS. The following data will be collected during construction:

- Verification of silting layer, geocomposite layers and geotextiles (Form 1)
- Membrane application conformance to specification (Form 2)
- Smoke Testing and protection (Form 2.1)
- Final inspection on completion of building (builder or inspector)

If photographic evidence is sufficiently collected, the above verification process may be achieved without the need of completing the forms bearing in mind the process is completed by CETCO or its approved installer and will be providing the system warranty.

5.2. CQA INSPECTION DOCUMENTATION

The ITP forms described below may be used by CETCO or the approved applicator to support collection of data in demonstrating appropriate GBMS implementation. Each form consists of a series of checkbox items to ensure all requirements have been met to deliver a fit for purpose vapour barrier system.

5.2.1. FORM 1: SURFACE PREPARATION

Form 1 is intended to identify and document that surface preparation including substrate cleanliness (wall and floor), is appropriate and in accordance with the specifications. This includes reporting on any non-conformity within the sub grade and any deviations from the expected installation details.

5.2.2. FORM 2: MEMBRANE INSTALLATION INSPECTION & FORM 2.1: SMOKE TEST REPORT

Form 2 is intended to identify and document that membrane installation has proceeded according to the manufacturer directions and system specification and that the membrane has demonstrated integrity. This covers the general application of product, detailing around penetrations, the absence of membrane defects and the application of a protection course prior to steel and concrete or backfilling. Smoke testing outcomes are documented within the inspection.

5.2.3. FORM 3: POST-APPLICATION AND PRE-CONCRETE INSPECTION

Form 3 is intended to identify and document that the membrane was appropriately protected and free from damage during the continuation of other construction activity on the site. This may include the installation of additional service connections, steel reinforcing for concrete or preparations for backfilling.

5.3. SMOKE TESTING

A minimum of 24 hours should be allowed for complete membrane cure at above ambient conditions before official smoke testing. It is recommended that smoke tests occur in the morning, particularly during summer months to avoid membrane softening, in order to minimise risk of further damage. Membrane is to be inspected to ensure cure cycle is complete and anomalies should be repaired prior to set up of smoke machine.

Smoke testing occurs by destructively introducing an entry point at the centre of the membrane and pumping smoke for a period of time sufficient to ensure no pinholes remain and venting system depressurises as designed. While it is undesirable to destructively produce a test point for purpose of smoke testing, experience has suggested that the method allows for coverage of sufficient surface area with adequate smoke and pressure that detect even minor pinholes in membrane. The locations are best determined based on experience via expected performance and are made such that the smoke is emitted in multiple directions.

Although this specification outlines inspection areas and smoke coverage, it is the responsibility of the approved installer to increase these intervals if smoke does not travel the expected distance. Smoke testing is carried out in the presence of the site foreman and approved applicator and can include visits from the manufacturer, environmental consultant or auditor.

5.3.1. TEST FREQUENCY AND ACCEPTANCE CRITERIA

At a minimum, smoke testing is to be undertaken at intervals of 100 m^2. Where necessary, smoke testing intervals will be reduced to ensure smoke pervades all areas of the vapour barrier. The frequency is also very dependent on the conditions and layout of the site, which may impact the distance in which adequate smoke can travel.

A PASS or FAIL result of the smoke test is indicated by the extent of smoke detected from defect points and the ease at which rectification works can be undertaken. Whilst it is possible (and likely) that defects may be detected of all kinds, Liquid Boot's ability to patch and seal sequential sections of membrane allows for on-the-spot repairs without a FAIL result.

Criteria encountered which would lead to the designation of a FAIL result for the vapour barrier include:

- Significant detachment of the vapour barrier from detailing points (penetrations/strip footings/pile caps) or overlaps,
- Defects that require the significant removal and reapplication of the vapour barrier
- Other defects as identified by CETCO that require significant rectification beyond reasonable time allocated for smoke testing

5.3.2. REPAIRS

Excessive repairs will require re-testing following full cure cycle. The site foreman and manufacturer have authority to fail smoke test if not repaired to satisfaction of specification.

When approved, an 'oversize' patch is to be prepared for test hole and repaired by applying Liquid Boot at a thickness of 2mm.

5.4. SIGN OFF

Once completed to the satisfaction of all parties present, a hand over sheet is signed to pass responsibility to building contractor. Handover takes effect upon completion of G-1000 protection layer prior to reinforcing steel work.

6. CONTINGENCIES

Bearing in mind the quality assurance plan, the following have been considered potential issues which may require structured quality assurance:

- Substrate preparation and expectations
- Builder and site subcontractor obligations
- Membrane protection during staging
- Smoke testing and associated QA documentation
- Post construction performance

It has been identified that although most roles have been appropriately defined in the CQA plan, all parties are responsible for the success or failure of the system implementation. To assist in the success of application, an independent CQA regime will be adopted within the application and sign off of the selected system. The below is a guide to assist in management of potentially identified issues during installation.

6.1. DAMAGE

If damage occurs to the membrane during any stage of the concrete construction process, the item must be identified and repaired to CETCO approved standards with accompanied documentation. It is important that a preconstruction meeting and continual toolbox meetings are held to translate the importance of protecting the membrane, and any damage to be notified to a CETCO representative and/or site foreman immediately marked with bright marker for repair. A site walk is to occur after mesh placement by CETCO to confirm integrity however it is everyone's responsibility to identify defects.

Where an inspection or site walk identifies a defect, the inspector is to determine the extent of damage and establish whether the repair constitutes the need for further smoke testing following repair. A certificate of validation will be provided at the conclusion of the project, however if damage is found, a 'Corrective Action Report' is to be filled identifying the location of the damage. It is expected with a protection layer that damage is unlikely but will be detectable given the contrasting colours between G-1000 and the Liquid Boot membrane (white and black respectively). Where damage has remained un-detected/reported after smoke testing, it will be the responsibility of the builder to commission and determine secondary protection or remedial services.

Where pickets or other materials need to be inserted (formwork etc.), the areas must be highlighted in bright paint marker, be clearly visible and reported to the site foreman and approved installer for repairs. CETCO possess a series of repair methods (Figures 1 and 2) for when damage has occurred, and it is important that every sub-contractor be aware that damage must be repaired prior to slab pour. Typical repairs occurring during the construction process will not be documented if the related area has not been subject to a handover process taking effect post smoke test and placement of protection. Where damage has occurred during the construction phase post handover, a 'Site Observation Form' will be completed to document repairs carried out and their associated location (i.e. star picket or incidental). It is the responsibility of every contractor on site to ensure that adequate care is considered for the membrane and should be considered an integral component of the structure. Excessive negligence of site staff will result in implications on warranties granted by CETCO. In the event concrete areas are cut out during future construction, CETCO will need to be contacted to adopt the appropriate repair detail, document and submit to the appropriate authority.

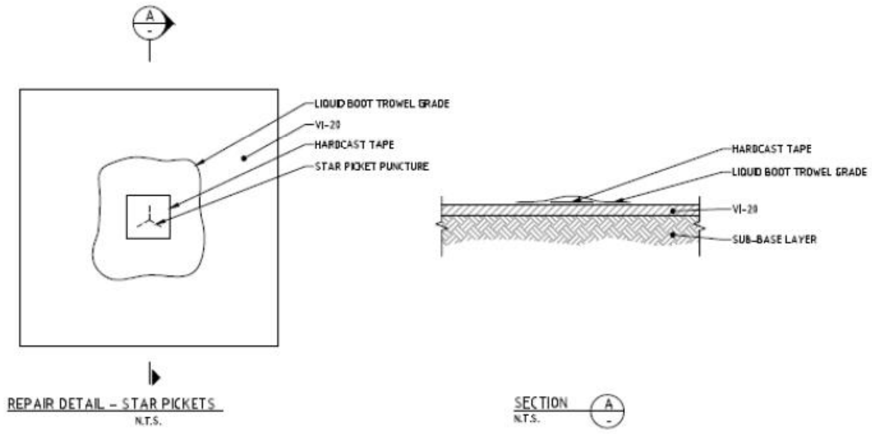

FIGURE 1. REPAIR METHOD FOR STAR PICKETS

Note: VI-20 detailing fabric may be used in lieu of Hardcast tape.

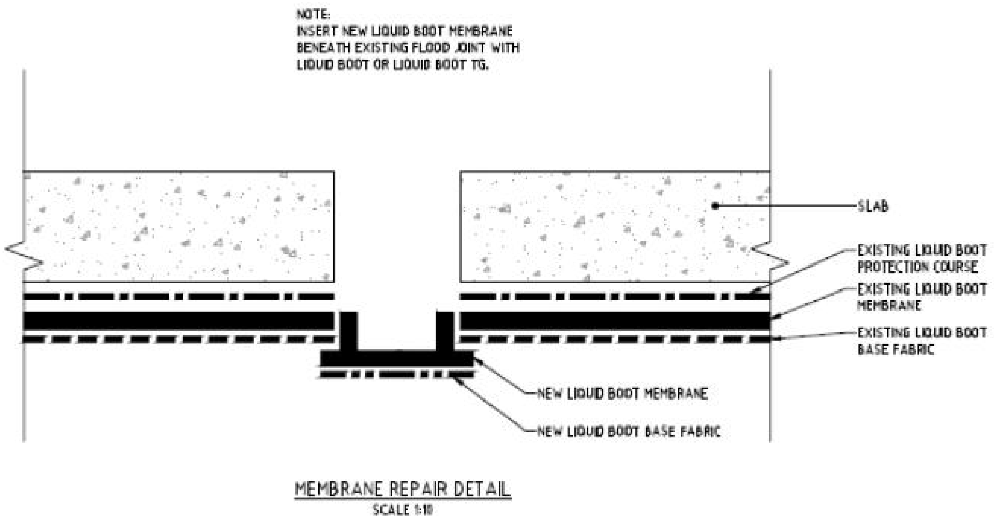

FIGURE 2. POST CONCRETE REPAIR METHOD

6.2. CONCRETE DRILLING AND CUTTING

All concrete drilling that occurs after concrete pour must be repaired using Liquid Boot Trowel Grade or Roller Grade. This can be achieved by applying the Liquid Boot over all holes and areas that come in to contact with the concrete (including around bolt heads and steel plates). For concrete cutting and core holing, see repair details provided in Section 6.2 or by contacting CETCO.

6.3. VAPOUR INTRUSION

In the event gas intrusion is found to occur, one of the following methods may be adopted as a means of rectification:

- Internal vapour caulking and associated validation
- Additional management measures, including retrospective membrane application
- Activation of subfloor ventilation system

6.4. ON GOING AND LONG TERM MAINTENANCE

The physical barriers once installed should not be tampered with for the life of the building. It is important that the manufacturer is contacted if one of the following occurs:

- Catastrophic fuel spill on floor of building causing risk of membrane degradation through construction joints
- Concrete cutting and removal due to service damage or repair

The site will need to be investigated and reported, and fuel spills will need to be contained as quickly as possible to a localised area. Where concrete requires removal, the building owner or similar must contact CETCO to notify the works, and arrange for a qualified membrane subcontractor to repair the membrane with details provided.

7. DISCLAIMER

Minerals Technologies (MTI), partners and its subsidiaries have completed this document under the assistance of third party consultants and engineers, and limit their liabilities to the documents provided by the client and its representatives. The system specification has been completed using data provided by the client and their representatives. Site conditions and assumptions have been produced based on assessment of reports. Conditions outside of these parameters are not the responsibility of MTI or its subsidiaries.

On successful completion of all identified system components, AMCOL Australia will offer a product warranty for a period of 15 years.

[END]

APPENDICES

A – SUPPORTING INFORMATION

ZOIC Environmental Pty Ltd
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Phone: +61 2 9231 1045
www.zoic.com.au

15121 Passive Venting Design Letter 26.02.16

26 February 2016

Michael Novak
MPN Projects Pty Limited
52 Tollhouse Road
Kings Park VIC 3021

Dear Michael,

Re: Lot 9002 Longford Road, Beaconsfield, WA

INTRODUCTION

Further to our recent discussions and correspondence, Zoic Environmental Pty Limited (Zoic) is pleased to provide MPN Projects Pty Limited (MPN), with the following comments regarding the gas protection measures required to facilitate the construction of 33 residential lots at the above site. Zoic understands that the protection measures are required to mitigate risks associated with gas from a former landfilled Limestone Quarry.

To assist Zoic in the preparation of this letter report, MPN provided a project briefing on 4 February 2016 and supplied a copy the following documents:

- MDW Environmental Services (MDWES)(16.02.15) Environmental Site Investigation Ground Gas Monitoring (including Visits 1-6) Lot 9002 Longford Road, Beaconsfield, WA (Ref: E2014-004 Final);
- MDWES (19.02.15) Environmental Site Investigation Monitoring of Ground Gas (Visits 7, 8 and 9) Lot 9002 Longford Road, Beaconsfield, WA (Ref: E2014-004-ESI-R2 Final); and
- MDWES (22.07.15) Environmental Site Management Plan for Proposed Dwellings at Lot 9002 Longford Road, Beaconsfield, WA (Ref: E2014-004-ESMP-02 V8).

It is noted that a number of additional reports are referenced in the MDWES documents listed above but have not been provided to Zoic for review. It has been assumed that the documents provided are representative of the prevailing landfill gas conditions at the site.

SUMMARY OF AVAILABLE INFORMATION

Zoic has completed a review of the available information listed above and the following summarises the points considered relevant to the design of the proposed landfill gas protection measures:

- The site is located at Lot 9002, Longford Road, Beaconsfield (City of Fremantle), WA and comprises approximately 10,027m^2 in area. The site comprises a long thin strip of land parallel to Longford Road.

- The site is bounded to the west and north by residential land use. The eastern and southern boundary comprises vacant / undeveloped land (former Limestone Quarry and City of Freemantle's Landfill) beyond which lies South Freemantle Senior High School and residential land use. Some commercial land use is present to the south west.
- The site is grassed and slopes to the south. Topography ranges from approximately 28.5 to 23.1m AHD across the site.
- It is understood that the site will comprise a 33 Lot residential subdivision. Lot sizes range between 220 to 526m^2 in area. According to MPN, house footprints are likely to be in the range of 165 to 250m^2 in area.
- The site previously comprised part of a limestone quarry that was reportedly backfilled with "inert" construction material/rubble, concrete and sands. The material was compacted to ensure ground stability. The depth of the landfill was reportedly 20-25m below current surface levels.
- Perth Groundwater Atlas (DoE) indicates that groundwater is encountered at depths of 8 to 16m beneath the site with potential seasonal level variation of 0.5 to 3m.
- Prior to MDWES involvement, landfill gas monitoring had occurred on five occasions over an 18 month period in 2012 and 2013. Maximum concentrations were 21.8%v/v (methane), 14.7%v/v (carbon dioxide) and 1.5L/hr (flow). MDWES stated that flow rates remained low and possibly decreased (0-1.5L/hr) during the monitoring. In the shallow wells, methane and carbon dioxide reduced with time. In deeper wells, steady state concentrations decreased but peak concentrations were variable and the results were classified as CIRIA R149 Characteristic Situation (CS) 1 and 2. Further monitoring and extended data sets were recommended to characterise the deeper parts of the landfill and provide better site coverage.
- Fifteen gas monitoring wells comprised slotted 25mm PVC casing installed by MDWES to between 20-25m depth (i.e. base of the landfill). A 1.5m length of plain casing and bentonite seal with gas tap and lockable cover were installed at the surface.
- Nine visits over a period of 6 months were conducted in fifteen new (LFMW01 – LFMW15) and six existing (BHB01, BHA02, SB1, SB2, BHB03 and BHA06) landfill gas wells. The existing wells ranged from 4.75 to 14.25m deep but did not reach the base of the landfilled wastes.
- Ground conditions in new wells comprised up to 1.55m of "clean sand fill" capping beneath which sandy landfill material with clay lenses, gravel and stone was encountered to 24m bgl. Varying proportions of wood, glass, fabric, metal, concrete and plastic were noted throughout the landfill material. Wood shavings (LGMW3), 60% wood content (LGMW4), heavy wood content (LGMW9) and fibreboard (LGMW11) were noted from a brief review of the borehole logs conducted by Zoic. Corresponding total organic content tests in LGMW3 were generally <1% and it is noted that tests were not conducted at the same depths as the high wood content in LGMW4. LGMW9 and LGMW11 coincide with the highest total organic content of between 3.33 and 6.20%.
- The highest carbon dioxide concentration coincides with the highest organic matter concentrations recorded in LGMW11 but the highest flow rate was found in the centre of the site at LGMW05 and the highest methane was found in Area A Old Landfill in BHA02 in the northern part of the site.
- Natural limestone was encountered at depths between 17 to 24m bgl. Groundwater was identified at one location at 26m bgl.
- MDWES conducted gas monitoring on 27 February, 6 March, 13 March, 20 March, 3 April, 7 April, 20 May, 19/24 June and 22/23 July 2014.

- MDWES stated that gas monitoring was conducted in accordance with CIRIA (2007) guidelines for atmospheric pressure, gas flow, methane, carbon dioxide, carbon monoxide, oxygen, hydrogen sulphide and volatile organic compounds.
- The maximum concentrations recorded during the current monitoring period can be summarised as follows:
  - Flow: 13.7L/hr (LGMW5 visit 9)
  - Methane: 11.4% v/v (BHA02 visit 5)
  - Carbon dioxide: 21.5% v/v (LGMW11 visit 5)
  - Hydrogen sulphide: 7110ppm (LGMW14 visit 5)
  - VOC: 243ppm (LGMW14 visit 2)
- MDWES concluded that CIRIA R149 CS3 gas protection measures should be adopted.

The key requirements of the MDWES (22.07.15) Environmental Site Management Plan (ESMP) can be summarised as follows:

- A memorial on title was issued by DER under Contaminated Site Act (2003) that requires incorporation of gas protection measures as specified in the ESMP.
- Nine monitoring visits were conducted in 21 gas wells and the final visit was conducted during low pressure and high rainfall. The gas regime was classified as CIRIA R149 CS3 in landfill gas monitoring wells LGMW3 to 5 inclusive.
- MDWES stated that low concentrations of VOC and hydrogen sulphide were also present but CS3 measures were deemed sufficient to mitigate against these contaminants.
- Gas wells must be decommissioned before any development takes place.
- The ESMP details:
  - Puraflex welded membrane (0.45mm thick 2.1 x 50m rolls) installed by Merit Lining Systems to manufacturers recommendations.
  - Membrane will be thermally welded and covered with a sand blinding layer (2mm-6mm thick).
  - A compacted 300mm thick gravel layer comprising 5 to 20mm aggregate with a permeability of at least 0.16m/s is proposed.
  - Pipework will comprise 100mm diameter slotted (2-6mm) pipes and keyed into 0.5m x 0.5m gravel sumps located at the end of the slab. Gas drains are to be a minimum of 1.25m centres with inlet and outlets equivalent to a minimum of 1500mm^2 per metre length of wall. Pipework is to be interleaved.
  - Gas pipes will extent at least 250mm above ground level and can be extended to roof line and a cowl added to improve gas flow.

- Validation of the installation is to be by an independent inspector, noting that a Chartered Engineer from Merit Lining Systems is listed.
- Membrane has a lifespan of 100 years with a warranty of 15 years.
- The system must be protected and extended as appropriate when modifications are proposed. Further validation of any modification will be required.
- Section 7.10 and 7.15 of the ESMP states that the passive gas system and gas proof membrane are to be signed off by a professional person (e.g. Chartered Engineer) to ensure that they have been installed correctly.
- Section 7 of the ESMP acknowledges that alternative products may be used but compliance with the design would have to be demonstrated. Section 7.6 notes that use of other products or engineers needs to be approved by the Environmental Auditor, DER and DoH.

Zoic understands that this Passive Venting Design Letter is being prepared to satisfy the requirement outlined in the above bullet point.

LANDFILL GAS PROTECTION MEASURES DESIGN CONSIDERATIONS AND ASSUMPTIONS

No detailed information is available regarding the proposed housing layout and types as each lot will be developed by independent land purchasers. Given the anticipated lot sizes, the following assumptions have been made to represent a likely worst case private residential building:

- A review of Figure 4 in MDWES (22.07.15) ESMP indicates that the Longford Road frontage of each lot varies between 10-14m. The exception being No. 42, which is approximately 30m. The length of each of the lots is approximately 30m, with the exception of No. 56 and 57 (approximately 40-47m) and No. 42 (varies from 10m north to 30m south). It is considered that a likely worst case building dimension is 15m frontage with a 30m length. Whilst No. 42 is wider than this assumed dimension it is also notable that the building would also be shorter to accommodate the triangular nature of this block. Consequently, the overall building footprint at this location is likely to be similar to the assumed likely worst case.
- Given the dimensions of the lots and the future orientation of adjacent houses, the most practical venting direction is likely to be parallel to the length of each lot (i.e. approximately east to west). Although likely to be sheltered in nature, venting on the northern or southern sides of the buildings may also be possible depending on how close each house is constructed to the lot boundary. This may need to vary for No. 42, dependent on the final adopted building shape and orientation.
- The height of the proposed houses is unknown but is likely to be limited to one or two storeys. A single or double storey house with roof is likely to be approximately 3 to 4 or 6 to 8m high respectively. An assumed building height of 3m has been adopted. This is considered to be a likely worst case because more ventilation will occur beneath taller buildings and due to greater effective windspeeds at height and greater height differential between inlet and outlet.
- A review of Figure 5 in MDWES (22.07.15) ESMP indicates that a slab on grade construction was considered previously, thus providing a relatively simple / uninterrupted flow path for any proposed venting media beneath the slab.

The following key assumptions have been made in performing calculations to support the proposed passive landfill gas venting system for the likely worst case model house type described above:

- Building dimensions of 15m frontage and 30m length, a footprint of 450m^2 and a building height of 3m.
- The ground gas conditions presented in the reports provided are representative of all of the lot footprints to be protected. The gases being considered are methane and carbon dioxide only. Although, hydrogen sulphide and volatile vapours were detected, Zoic notes that MDWES stated that protection measures designed to satisfy CIRIA R149 CS3 requirements will also address these other contaminants.
- Methane has a lower explosive limit of 5%v/v and consideration of potential explosive risk is required. Carbon dioxide is not combustible. Although, hydrogen sulphide is present and has a lower explosive limit of 4.5%v/v, the maximum concentration recorded is 0.71%v/v and therefore unlikely to control potential explosive risks at the site.
- For the purposes of conservatism, the maximum recorded methane (11.5%v/v) and carbon dioxide (21.5%v/v) concentrations have been adopted.
- For the purposes of conservatism, the maximum recorded flow rate of 13.7L/hr has been adopted.
- *NSW EPA (March 2015) Draft Environmental Guidelines Solid Waste Landfills (Second edition 2015)* states that the threshold level for further investigation and corrective action for methane is 1.25%v/v when detected in subsoil monitoring or accumulation monitoring in enclosed structures. *NSW EPA (2015)* considers that landfill stabilisation criteria have been met when perimeter gas wells have fallen to concentrations of less than 1%/v/v methane and 1.5%v/v carbon dioxide for a specified period. These values are also presented in UK guidelines. An equilibrium concentration of 1%v/v methane and 1.5%v/v carbon dioxide will be adopted within the venting layer.
- The Bureau of Meteorology (BOM) collates wind roses for selected locations in Australia, the closest of which is in Perth. The wind roses for 9am and 3pm (refer to Appendix B) indicate that the predominant wind directions are easterly / north easterly (morning) and westerly / south westerly (afternoon). Given the orientation of the proposed lots, it is considered that air inlets and outlets would be best placed on the western and eastern faces of the buildings respectively. Flow direction within the model will be assessed as being parallel to building length.
- The BOM also provides annual average wind speeds for 9am and 3pm at selected weather stations across Australia, the closest of which is Swanbourne (refer to Appendix B). Wind speeds range between 19.2 and 23km/hr. For the purposes of the passive venting calculations, 19.3km/hr or 5m/s has been adopted.
- For the purposes of correcting mean windspeed to the site setting as detailed in BS5925:1991, the conservative terrain factors adopted are for a sheltered inland city location.

Zoic recommends that MPN, MDWES and the Site Auditor review the above assumptions and confirm that they are appropriate based on their knowledge of the site (e.g. all available investigation data) and understanding of the proposed development. If any uncertainty regarding the appropriateness of the assumptions exists then it is recommended that additional site specific data are obtained and the design calculations updated accordingly.

COMPARISON OF CURRENT AND PROPOSED PROTECTION DESIGN MEASURES

Puraflex is described as a 0.45mm thick extruded composite membrane comprising protective polymeric layers on both sides of an inner core consisting of polar and non polar polymers resistant to a wide range of industrial chemicals, harmful gases and hydrocarbons. The MDWES (22.07.15) ESMP stated that the joints will be welded.

The proposed alternative membrane is Liquid Boot VI20 with Liquid Boot sprayed seams. VI20 is described as a 0.5mm thick 7-layer co extruded EVOH membrane designed for methane, radon and volatile organic compounds.

The main difference between the two membranes is considered to be the jointing method. However, as QA/QC (including smoke testing) is proposed, it is considered that the integrity of the membrane and jointing will be proven post installation thus addressing this potential difference.

DETR (1997) Passive Venting of Soil Gases Beneath Building Research Report, Guide for Design, Volume 1 provides quantitative data on the relative performance of various ventilation media (including open voids, gravels, geocomposite blankets, void formers and pipes in gravel), building footprints (including 5x5m, 15m x 30 and 30 x 30m footprints), venting arrangements with different types of side ventilation on opposing sides of the building (including air bricks, gravel pits, low level and roof level risers) at specified spacings and guidance on design of passive gas protection measures.

DETR (1997) Model 5 is considered to most closely resemble the current protection measures design with interleaved pipes in gravel, air brick inlets and low level riser outlets in a 15m x 30m building footprint.

DETR (1997) Model 2 is considered to most closely resemble the protection measures design proposed in the following section. This comprises a continuous venting layer created by different media and venting types at opposing sides of the building.

Table 27 (reproduced in Appendix C) in DETR (1997) shows that the current protection measures provide Good venting performance for a 30m wide foundation for Gas Regime B (equivalent to CIRIA R149 CS3). The table also shows that the a clear venting void of between 22 and 100mm for a 30m wide foundation is likely to provide Good to Very Good venting performance for Gas Regime B. Consequently, Zoic considers that the proposed alternative venting solution incorporating an open void is likely to perform as well, if not slightly better, that the current venting solution.

MDWES (22.07.15) ESMP Figure 6 indicates that the current venting solution incorporates two inlets and two outlets on the eastern and western faces of the building connected to 100mm diameter pipework. For a 15m wide foundation, this equates to venting of approximately 1050mm^2/m run of wall.

DETR (1997) Model 5 indicates that side ventilation of between 525 to 590mm^2/m run of wall is sufficient to provide Good venting performance (maximum hazardous gas concentration of 2.22%v/v at 0.3m/s windspeed) for building dimensions up to 30m. It should be noted that DETR (1997) Model 5 used air brick inlets and low level risers and that increased venting performance can be achieved by use of roof level vent stacks.

DETR (1997) Model 2 indicates that 2210mm^2/m of side venting in a 60mm polystyrene void former (considered to be closest example to the proposed 50mm Drain-Cell void height), a maximum hazardous gas concentration of 0.54%v/v was predicted for 0.3m/s windspeed, which provides Very Good performance for building dimensions of up to 30m.

DETR (1997) Section 8.2 stated that doubling of side ventilation produced a 45% decrease in the maximum steady state hazardous concentration. Consequently, adopting 1050mm^2/mm for a 60mm high void space is likely to double the maximum hazardous gas concentration described in Model 2 above (i.e. approximately 1.1%v/v methane), which equates to Good venting performance for building dimensions of up to 30m. This performance is considered to be comparable, if not slightly better, than that described in Model 5 above.

VAPOUR PROTECTION MEASURES DESIGN

In consideration of the adopted likely worst case house type, the assumptions stated herein and the MDWES (22.07.15) ESMP requirements, Zoic recommends the installation of the following landfill gas protection measures, which are supported by the calculations / associated notes and should be read in conjunction with this letter (Refer Appendix A).

- Construction of a reinforced concrete ground bearing floor slab with all joints and penetrations sealed with an appropriate gas resistant product. The number of floor slab penetrations should be minimised wherever possible.
- Underlying protection measures to comprise a VI20 Liquid Boot membrane with Liquid Boot sprayed seams and underlying 50mm high ventilated void comprising Polyfabrics Australia Drain-Cel 50mm or similar.
- An appropriate geotextile (e.g. CETCO Liquid Boot Ultrashield G1000 or similar) must be used above and below the membrane to protect it from damage. A layer or geotextile should also be placed beneath the Drain-Cel 50mm or similar to prevent future silting.
- Utility excavations must be sympathetically designed to ensure that they do not provide a conduit for gas migration (e.g. clay plug) and / or allow gases to accumulate to potentially harmful levels (e.g. vented covers).
- Care must be taken to ensure adequate venting of all subfloor compartments (i.e. formed by ground beam downstands, if present) and that the creation of venting deadspots is avoided. The Drain-Cel 50mm should be placed as close to the internal faces of the foundations as possible and no greater than 1m away.
- The sizes and locations of the inlets and outlets will need to be agreed with the Architect to ensure that the appearance of the proposed structure is not unduly compromised whilst ensuring the most direct venting path with minimal bends.
- To provide a preferential path of escape to atmosphere, the Drain-Cel 50mm must be connected to a collector pipe, vent box or similar (100mm diameter or clear venting area of at least 7850mm^2) to allow for inlets and outlets to be attached to the venting void.
- The attached calculations indicate that 2no. inlets are required per lot (noting that this is controlled by the adopted 1050mm^2/m minimum venting requirement) and should comprise air bricks with a minimum clear venting area of at least 7,850mm^2..
- The attached calculations indicate that 2no. outlets are required per lot (noting that this is controlled by the adopted 1050mm^2/m minimum venting requirement) and should comprise a high level vent stack and a wind driven ventilator (e.g. "Edmonds" sewer vent) with a minimum clear venting area of at least 7,850mm^2. Care must be taken to ensure that parapets or other building features do not shield the ventilators, thereby reducing their efficiency.

- If low level inlets and outlets are used then a minimum venting requirement of 1500mm2/m run of wall is recommended.
- Venting layer connection to inlets and outlets must remain as short and direct as is possible; with the minimum number of bends (e.g. preferably less than 2); and, designed as sympathetically as possible to facilitate efficient gas venting (e.g. shallow bends less than 45° from vertical).
- If internal high level vent stacks are used they must be sleeved in larger diameter pipe work and fully sealed to the floor slab and ceiling / roof penetration to prevent leakage occurring within the building. Alternatively, the pipework must be smoke tested and warranted against leaks.
- The products described above must be suitable for use, installed in accordance with the manufacturers' instructions / specifications by an approved contractor working under recognised QA/QC procedures (including smoke testing). The installer must provide a warranty to demonstrate that the landfill gas protection measures have been appropriately installed.
- Prior to commencement, a Work Health & Safety Plan must be prepared and all key stakeholders (e.g. MPN, the Auditor and the Environmental Consultant) must meet and establish the appropriate working practices and hold points to ensure that the landfill gas membrane and venting components are adequately protected from all trades during construction and to allow inspection and documentation of the installation works as they progress.
- Where applicable to this alternative design, the requirements of the MDWES (22.07.15) ESMP must also be met.

To ensure the on-going integrity of the landfill gas protection system, it is recommended that a mechanism is established (e.g. notation is placed on the property title and / or Environmental Management Plan) which highlights the requirement for occupants / tenants / maintenance workers not to damage or interfere with any components of landfill gas protection measures.

SENSITIVITY ANALYSIS

Passive venting calculations are generally considered to be conservative in nature and are likely to over rather than underestimate the actual amount of venting required to achieve adopted equilibrium concentration for the following reasons:

- The Pecksen method (1991) is used to estimate surface emission rates from a 50mm borehole. Flux box testing has shown that this method is generally conservative by a factor of at least 10.
- The maximum recorded methane, carbon dioxide concentrations and flow rates were adopted.
- Conservative sheltered city, rather than urban, terrain factors were adopted.
- A pressure coefficient was selected from the lower end of the range to reflect restriction of air flow through small openings.

LIMITATIONS

This letter report has been prepared for use by the Client who commissioned the works in accordance with the project brief only, and has been based in part on information obtained from the Client and other parties. The findings of this report are based on the scope of work outlined our proposal dated 19 November 2015. This letter report has been prepared specifically for the Client for the purposes of the commission, and use by any nominated third party in the agreement between Zoic and the Client. No warranties, express or implied, are offered to any third parties and no liability will be accepted for use or interpretation of this report by any third party (other than where specifically nominated in an agreement with the Client).

This letter report relates to only this project and all results, conclusions and recommendations made should be reviewed by a competent person with experience in environmental investigations and design of landfill gas protection measures, before being used for any other purpose. This letter report should not be reproduced without prior approval by the Client, or amended in any way without prior approval by Zoic.

Subject to the scope of work, Zoic's gas venting calculations rely on third party information of typical environmental conditions associated with the subject property area and does not include evaluation of any other issues.

Changes to the subsurface conditions may occur subsequent to the investigations conducted by third parties and described herein, through natural processes or through the intentional or accidental addition of contaminants. The conclusions and recommendations reached in this letter report are based on the information obtained at the time of the investigation.

This letter report does not comment on any regulatory obligations based on the findings. This letter report relates only to the objectives stated and does not relate to any other work conducted for the Client. The absence of any identified hazardous or toxic materials on the site should not be interpreted as a guarantee that such materials do not exist on the site.

All conclusions regarding the site are the professional opinions of the Zoic personnel involved with the project, subject to the qualifications made above. While normal assessments of data reliability have been made, Zoic assumes no responsibility or liability for errors in any data obtained from regulatory agencies, statements from sources outside of Zoic, or developments resulting from situations outside the scope of this project.

Zoic is not engaged in environmental assessment and reporting for the purpose of advertising sales promoting, or endorsement of any client interests, including raising investment capital, recommending investment decisions, or other publicity purposes. The Client acknowledges that this report is for its exclusive use.

CLOSURE

Zoic reserve the right to amend the supporting calculations and associated comments should additional or more detailed information be made available in the future.

We trust that the foregoing meets your requirements. However, should you have any queries or wish to discuss any points in greater detail please do not hesitate to contact us.

Yours sincerely,

Graeme Malpass
Principal Environmental Scientist

Appendix A: Standard Notes and Comments Sheet and Passive Landfill Gas Venting Calculation Sheets

Appendix B: Bureau of Meteorology 9am and 3pm Windroses and Mean Wind Speeds

Appendix C: Table 27 DETR (1997)

References:

- G. N. Peckson : 1985 Methane and the Development of Derelict Land.
- BS5925 : 1991 Ventilation Principles and Designing for Natural Ventilation.
- CIRIA 130 : 1993 Methane : Its Occurrence and Hazards in Construction.
- CIRIA 149 : 1995 Protecting Development from Methane.
- Wilson and Card : 1999 Reliability and Risk in Gas Protection Design.
- CIRIA 150 : 1995 Methane Investigation Strategies.
- CIRIA 151 : 1995 Interpreting Measurements of Gas in the Ground.
- CIRIA 152 : 1995 Risk Assessment for Methane and other Gases from the Ground.
- DETR : 1997 Passive Venting of Soil Gases Beneath Buildings Research Report Guide for Design Volume 1.
- BRE BR414 : 2001 Protective Measures for Housing on Gas Contaminated Land.
- CIRIA C665 : 2007 Assessing Risks Posed by Hazardous Ground Gases to Buildings
- Wilson, Card & Haines : 2009 Ground Gas Handbook
- NSW EPA : 2012 Guidelines for the Assessment and Management of Sites Impacted by Hazardous Ground Gases

Appendix A: Standard Notes and Comments Sheet and Passive Landfill Gas Venting Calculation Sheets

1. Denotes gas regime classifications from left to right for methane (as per Ref: 3), methane (as per Ref: 4) and carbon dioxide (as per Ref: 4).
2. Approximate height of building or in the case of standalone venting (e.g. in parking areas) the difference in height above ground of the inlet and outlet vents.
3. Calculated to aid determination of Cp (see note 20) in accordance with Ref: 1.
4. Calculated to aid determination of Cp (see note 20) in accordance with Ref: 1.
5. Concentration of methane typical of gas regime at the site in question.
6. Concentration of carbon dioxide typical of gas regime at the site in question.
7. Gas flow rate typical of gas regime at the site in question.
8. Gas flow rate used for calculation, which includes the factor of safety (F.o.S) defined by note 10.
9. Denotes the status of the gas concentrations and flows used in the calculation.
10. F.o.S defined by the confidence / adequacy of the desk study / ground investigation / gas monitoring data (range and frequency). Low (F.o.S = 3), Medium (F.o.S = 2) and High (F.o.S = 1).
11. Equilibrium concentration used for methane is Tier 1 screening value of 1%v/v, which is 5 times less than the L.E.L (Ref: 3)
12. Equilibrium concentration used for carbon dioxide is Tier 1 screening value of 1.5%v/v.
13. Terrain correction factors for wind speed as detailed in Ref: 1.
14. Exposure / shelter correction factor for wind speed as detailed in Ref: 1.
15. Assumed time that wind speed exceeds 50% of mean wind speed (see note 17) as defined in Ref: 1.
16. Assumed prevailing wind direction. In the absence of detailed information (e.g. windrose diagrams), this is usually from the west in NSW
17. Hourly mean wind speed exceeded for 50% of the time at a height of 10m above ground level. Taken from Figure 5 in Ref: 2. In Australia, local weather data is used fron nearest weather station or web based information sources.
18. Height, terrain and shelter corrected wind speed used in the calculation, as defined in Ref: 1.
19. Standard coefficient for sharp edged openings, as obtained from Ref: 1.
20. Coefficient obtained from Ref: 1.
21. Calculation based on Ref: 5, which assumes that the radius of influence (ROI) from a 50mm borehole is 1.78m radius or 10 square metres.
22. As detailed in Ref: 4.
23. As detailed in Ref: 4.
24. Based on the formula from Ref: 1.
25. Based on the formula from Ref: 1.
26a. Based on the formula from Ref: 1. If venting requirements are governed by default guidance then this will read NA (i.e. not applicable).
26b. Gives F.0.S of actual venting requirements. If venting requirements are governed by site emmission rates rather than default guidance then this will read NA.
27. F.o.S defined by the complexity of the proposed pipe routings, as discussed in Ref: 3 . Low (F.o.S = 1), Medium (F.o.S = 2) and High (F.o.S = 4).
28. Based on the formula from Ref: 1.
29. Divides the required area of ventilation given in note 28 by the width or length of the proposed structure.
30. Minimum venting requirement per metre based on current guidance or professional judgement to provide a suitable factor of safety.
31. Clear venting area of proposed inlet / outlet vent.
32. Based upon notes 29 and 31, the number of required vents can be calculated.
33. Based upon the proposed length / width of the building the spacings of the required number of vents can be calculated.

Consideration for Gas Protection Design Measures (based upon information provided in Refs : 2 and 3)

a. Maximum vent size used in DETR modelling was 4420mm^2/m.
b. When using gravel blanket the minimum inlet / outlet vent size should be 2000mm^2/m.
c. When using gravel blanket and pipework in isolation of geocomposite venting blanket the gravel layer should be a minimum of 300mm thick.
d. Gas flow through a gravel blanket is controlled more by grading (i.e. >20mm is best) rather than layer thickness. MoT Type 1 sub-base is not suitable for use in passive venting layers.
e. When using a gravel blanket any geocomposite venting strips should be interleaved to promote gas flow and prevent short circuiting of air flow. For greatest efficency the layout should be as symmetrical as possible with equal distances between the inlet and discharge network. Drains should be parallel and spacing should be based on manufacturers specifications or professional judgement.
f. Where high level vent stacks are proposed allowance for head loss due to riser pipe height should be made.
g. For maximum efficiency high level vent stacks should be placed at least 0.50m above eaves level and away from windows.
h. The minimum depth of an open void for a ventilation layer should be 100mm.
i. Where internal void space is interrupted by downstand beams etc, the area of openings in these beams should be a minimum of double, and preferably 4 to 5 times, the external venting area per metre run.
j. Minimum size of pipework used in venting systems should be 100mm. Where slotted pipework is requred the slots should exceed 10% of surface area.
k. Membranes should be installed in accordance with manufacturers instructions to ensure that appropriate vapour protection is provided.
l. Penetrations of the membrane should be kept to a minimum and should be appropriately sealed in accordance with the manufacturers
m. Services through the slab should also be sealed using a bituminous mastic sealant.
n. Prior to and post membrane installation appropriate care must be taken to ensure that the integrity of the membrane is not comprimised.
o. All products used for gas protection measures must be recognised products, installed under an appropriate quality assurance system by a qualified subcontractor. An installation warranty should be provided.
p. Care should be taken to ensure that the formation level for gas protection venting / membrane is not likely to be affected by settlement.

Passive LFG Venting Calculations

Project Information

Job Name	Lot 9002, Longford Road, Beaconsfield
Job Number	15121
Location	Western Australia
Client	MPN Projects Pty Limited
Structure (e.g. house)	House

References

1. BS5925 : 1991 Ventilation Principles and Designing For Natural Ventilation
2. CIRIA 149 : 1995 Protecting Development from Methane
3. DETR : 1997 Partners in Technology Guide for Design
4. Wilson and Card : 1999 Reliability and Risk in Gas Protection Design
5. G. N. Peckson : 1985 Methane and the Development of Derelict Land
6. Wilson, Card, Haines : 2009 Ground Gas Handbook

Gas Regime Information

Likely Source (s)	Landfilled Limestone Quarry			
Generation Potential (very low to high)	Refer to Zoic letter dated 10.02.16			
Range of Results (time)				
Number of Results				
Data Consistency vs Source (Y/N?)				
Adequacy of Data (low, medium, high)				
Comments (e.g. flooding / hydrocarbons)				
Characteristic Regime 3 (CH4), 4 (CH4), 4(CO2)	D	3	3	(note 1)

Gas Calculation Parameters

CH_4 Conc.	(% v/v)		11.5	(note 5)
CO_2 Conc.	(% v/v)		21.5	(note 6)
Recorded Flow Rate	(l/hr)		13.7	(note 7)
Standpipe Diameter	(m)		0.025	
Area of BH Influence	(m2)		10	
Calculation Flow Rate	(l/hr)		13.7	(note 8)
Status of Parameters	(ave / max)		max	(note 9)
F.o.S. Gas Flow Rate	(factor)		1	(note 10)
CH_4 Equilibrium Conc.[3]	(% v/v)	(fraction)	0.01	(note 11)
CO_2 Equilibrium Conc.[3]	(% v/v)	(fraction)	0.015	(note 12)

Building Details

Building / Source Length	(m)	30	
Building / Source Width	(m)	15	
Height of Building (enter "0" for source)	(m)	3	
Front Orientation	(direction)	various	
Height of Inlet	(m)	0.1	
Height of Outlet	(m)	3	
Area of Building / Source Footprint	(m^2)	450	
Height of Building / Eff. Vent Height	(m)	3	(note 2)
Sensitivity of End Use	(low, medium, high)	high	
Length / Width Factor[1]	(factor)	2.00	(note 3)
Height / Width Factor[1]	(factor)	0.20	(note 4)

Wind / Ventilation Details[1]

Terrain Type (city)	(k) / (a)	0.21	0.33	(note 13)
Exposure (sheltered)	(ratio)	0.46		(note 14)
% Time Wind Speed Exceeded		80		(note 15)
Wind Direction		various		(note 16)
Mean Wind Speed	(U_{50})	5		(note 17)
Mean Ref. Wind Speed	(m/s)	0.69		(note 18)
Sharp Edge Coeff.	(Cd)	0.61		(note 19)
Pressure Coeff.	(Cp)	0.4		(note 20)

Note : These caculations are subject to the attached notes and should only be used in conjunction with the comments presented in Zoic Environmental Pty Limited' letter of the same date.

Passive LFG Venting Calculations

Flow Results[1,2,4,5]

Surface Emission Rate[5,6]	($m^3/s/m^2$)	3.81E-07	(note 21)
Height of Subfloor Void (v)/Geocomposite & Gravel (g)	(m)	0.05	v
CH_4 Limiting Borehole Volume Flow Rate	(l/hr)	1.5755	(note 22)
CO_2 Limiting Borehole Volume Flow Rate	(l/hr)	2.9455	(note 23)
Air Through Void CH_4 (for equilibrium)	($m^3/s/m^2$)	4.33E-06	(note 24)
Air Flow Through Void CO_2 (for equilibrium)	($m^3/s/m^2$)	5.37E-06	(note 25)
Air Flow Parallel to (length / width?)		length	
Time to Fill Void CH_4 to 5% (No dilution)[6]	(hours)	16	footprint
No. Air Changes per Hour (to maintain equilibrium)	(no.)	NA	(note 26a)
Width of Geocomposite: Drain-Cel 50mm	(m)	void	
Proposed Spacing of Geocomposite Strips	(m)	NA	
Required Air Flow Beneath Building	(m^3/s)	2.42E-03	
Cross Sectional Air Flow Beneath Building	($m^3/s/m$)	1.61E-04	
Air Flow Through Geocomposite Strips Acceptable ?		NA	
Air Flow Through Gravel Acceptable ?		NA	

Ventilation Requirements[1]

F.o.S. Overall Venting Requirements	(fos)	1	(note 27)
Total Area of Ventilation (Aw)	(mm^2)	9029	(note 28)
Required Ventilation	(mm^2/m)	602	(note 29)
Minimum Venting Requirement	(mm^2/m)	1050	(note 30)
Pipework Complexity (low, medium, high)		low	
Preferred Size of Inlet Vent	(mm^2)	7850	(note 31)
Preferred Size of Outlet Vent	(mm^2)	7850	(note 31)
Number of Inlets Required	(no.)	2	(note 32)
Number of Outlets Required	(no.)	2	(note 32)
F.o.S of Default System	(fos)	1.7	(note 26b)
Air Transmissivity - 20mm gravel	($m^3/s/m$)	NA	(Ref: 6)
Air Transmissivity - GeoVent	($m^3/s/width$)	NA	(CETCO)

Outlet Spacing (m) 7.5 Inlet Spacing (m) 7.5 (note 33)

Additional Information

PITR / DETR	CH_4	ER	ER	Void (100mm)		Geocomposite (36mm)	
Gas Regime		(m/s)	($m^3/s/m^2$)	5m	30m	5m	30m
A	1	0.005	9.80E-06	A	A	A	A
B	5	0.005	9.80E-06	VG	VG	VG	G
C	5	0.01	1.96E-05	VG	VG	VG	F
D	20	0.005	9.80E-06	VG	VG	G	P
E	20	0.01	1.96E-05	VG	G	G	U
F	20	0.05	9.80E-05	G	P	F	U

Windspeed to Maintain Equilibrium		
	CH_4(1%)	CO_2(1.5%)
VG	0.3	0.3
G	1	1
F	2	2
P	3	3
A	adequate	adequate
U	unsuitable	unsuitable

Max Limiting Flow Rate (l/hr)	CIRIA 149	PITR	Additional Factors
<0.07	1	A	methane and carbon dioxide not to exceed 1% and 1.5% v/v
<0.7	2	B	flow rate < 70l/hr otherwise increase to Characteristic Situation 3
<3.5	3	C	None
<15	4	D	QRA required to evaluate appropriateness of protection measures
<70	5	E	QRA required to evaluate appropriateness of protection measures
<70	6	F	QRA required to evaluate appropriateness of protection measures

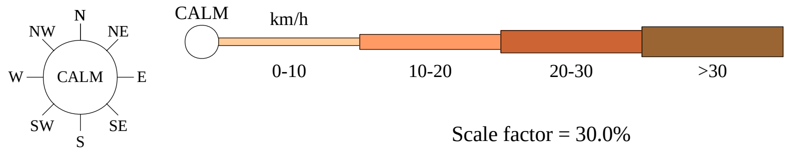
Note : These caculations are subject to the attached notes and should only be used in conjunction with the comments presented in Zoic Environmental Pty Limited' letter of the same date.

Appendix B: Bureau of Meteorology 9am and 3pm Windroses and Mean Wind Speeds

WIND FREQUENCY ANALYSIS (in km/h)

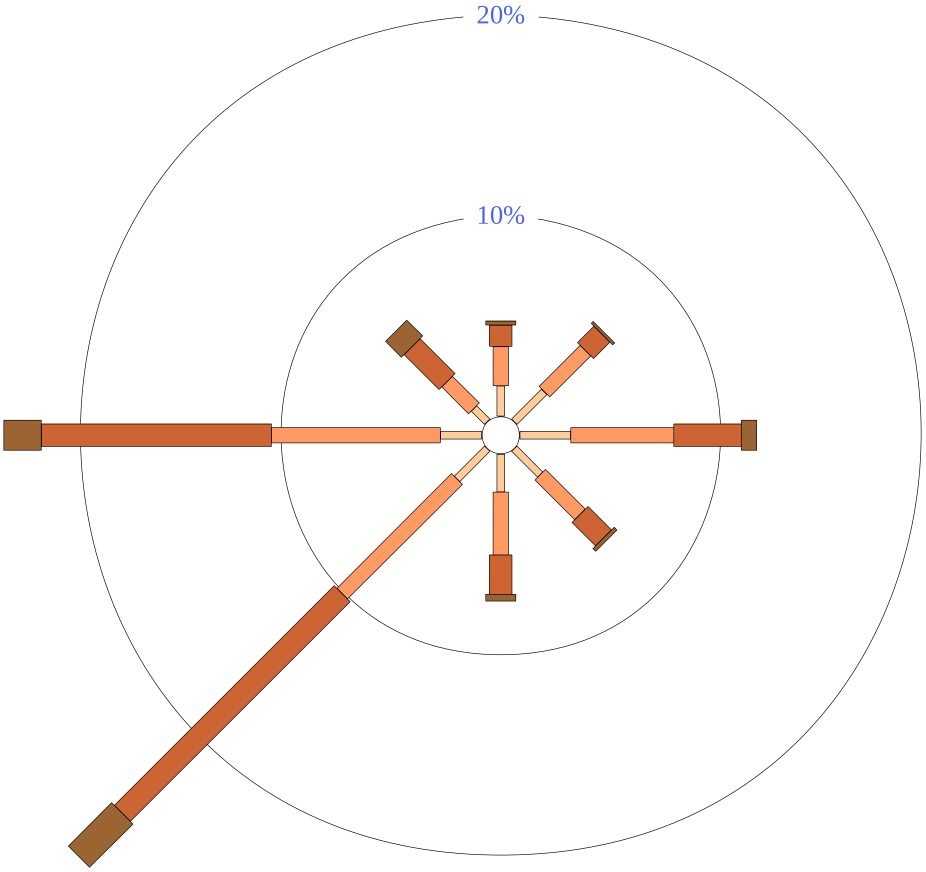
PERTH AIRPORT STATION NUMBER 009021

Latitude: -31.93 ° Longitude: 115.98 °



3 pm
21917 Total Observations (1944 to 2004)

Calm 5%



Wind directions are divided into eight compass directions. Calm has no direction.
An asterisk (*) indicates that calm is less than 1% .
An observed wind speed which falls precisely on the boundary between two divisions (eg 10km/h) will be included in the lower range (eg 1-10 km/h). Only quality controlled data have been used.

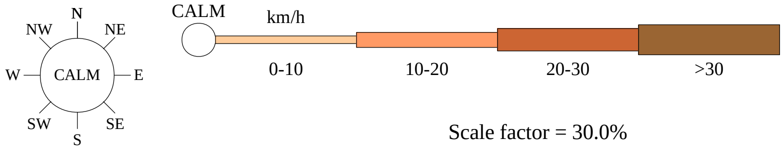
Australian Government
Bureau of Meteorology

Prepared by the National Climate Centre of the Bureau of Meteorology.
Contact us by phone on (03) 9669 4082, by fax on (03) 9669 4515, or by email at webclim@bom.gov.au . We have taken all due care but cannot provide any warranty nor accept any liability for this information.

WIND FREQUENCY ANALYSIS (in km/h)

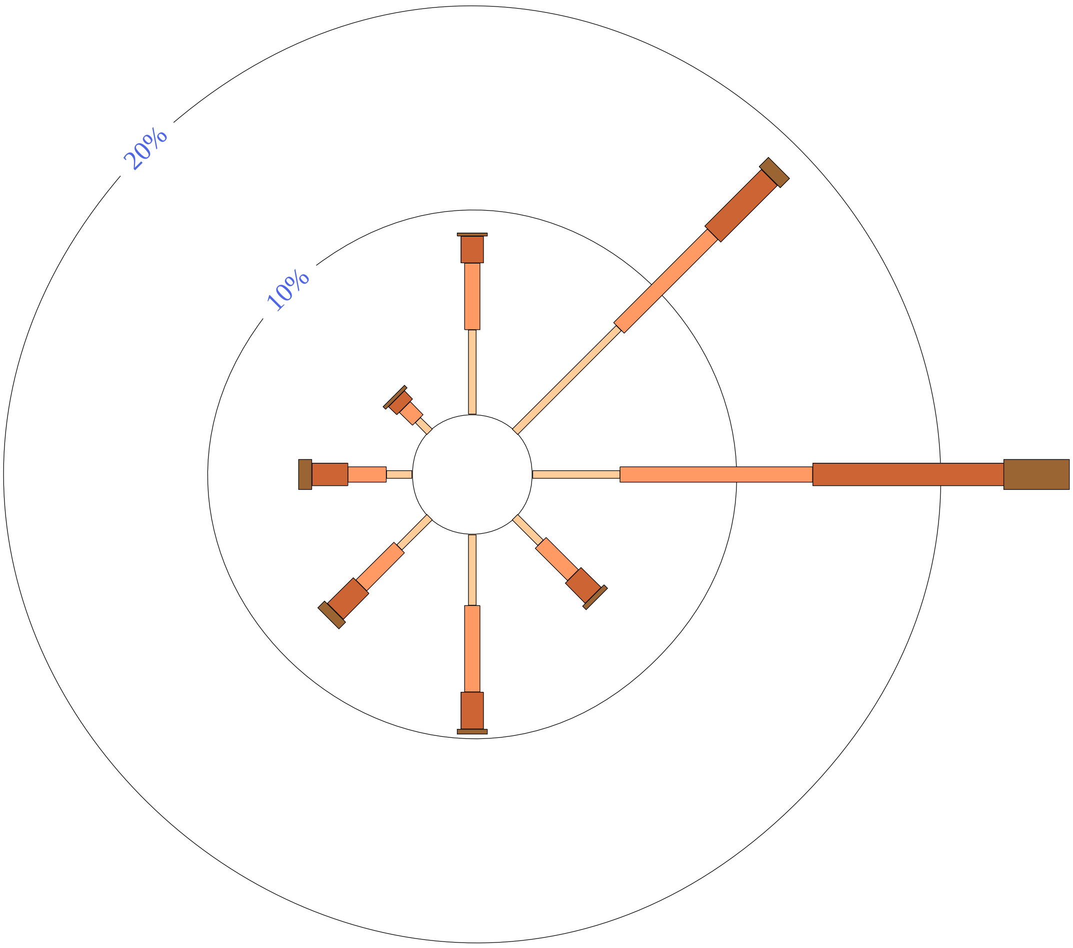
PERTH AIRPORT   STATION NUMBER 009021

Latitude: -31.93 ° Longitude: 115.98 °



9 am
21932 Total Observations (1944 to 2004)

Calm 15%



Wind directions are divided into eight compass directions. Calm has no direction.
An asterisk (*) indicates that calm is less than 1% .
An observed wind speed which falls precisely on the boundary between two divisions (eg 10km/h) will be included in the lower range (eg 1-10 km/h). Only quality controlled data have been used.

Australian Government
Bureau of Meteorology

Prepared by the National Climate Centre of the Bureau of Meteorology.
Contact us by phone on (03) 9669 4082, by fax on (03) 9669 4515, or by email at webclim@bom.gov.au . We have taken all due care but cannot provide any warranty nor accept any liability for this information.

html

Search

- Weather & climate data
- Maps - recent conditions
- Maps - average conditions
- Climate change
- Extremes of climate
- About Australian climate

Site information

Site name: SWANBOURNE
Site number: 009215
Latitude: 31.96 °S **Longitude:** 115.76 °E
Elevation: 41 m
Commenced: 1985 **Status:** Open
Latest available data: 02 Dec 2015

Additional information

Additional site information

Nearest alternative sites

1. 009151 SUBIACO TREATMENT PLANT (2.9km)
2. 009035 NEDLANDS UWA (6.3km)
3. 009097 PERTH GARDENS (8.3km)

View: Main statistics All available Period: 30 year period not available Text size: Normal Large

Statistics	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Years		Plot	Map
Temperature																	
Mean maximum temperature (°C)	29.9	30.7	29.0	25.5	22.2	19.5	18.4	19.0	20.0	22.4	25.4	28.0	24.2	22	1993 2015		
Mean minimum temperature (°C)	18.2	18.7	17.3	15.2	12.6	10.6	9.6	10.1	11.0	12.4	14.7	16.5	13.9	22	1993 2015		
Rainfall																	
Mean rainfall (mm)	14.6	7.2	21.4	39.2	91.6	124.2	147.8	115.1	82.2	43.5	24.9	11.8	723.5	22	1993 2015		
Decile 5 (median) rainfall (mm)	1.4	1.9	12.2	31.4	90.2	126.2	150.2	119.4	80.5	38.9	23.0	5.6	744.6	22	1993 2015		
Mean number of days of rain ≥ 1 mm	1.1	0.8	2.3	4.6	9.0	12.5	15.2	12.8	10.9	5.6	3.9	2.0	80.7	22	1993 2015		
Other daily elements																	
Mean daily sunshine (hours)																	
Mean number of clear days																	
Mean number of cloudy days																	
9 am conditions																	
Mean 9am temperature (°C)	23.8	23.9	22.1	19.5	16.4	13.7	12.9	13.6	15.6	17.8	20.8	22.7	18.6	17	1993 2010		
Mean 9am relative humidity (%)	53	55	58	65	72	77	78	76	69	62	57	53	65	16	1993 2010		
Mean 9am wind speed (km/h)	19.5	19.7	19.3	17.3	18.0	19.6	20.0	18.5	19.5	19.1	19.5	19.8	19.2	17	1993 2010		
9am wind speed vs direction plot	PDF	PDF	PDF	PDF	PDF	PDF	PDF	PDF	PDF	PDF	PDF	PDF	PDF				
3 pm conditions																	
Mean 3pm temperature (°C)	26.3	27.2	26.3	23.3	20.8	18.0	17.0	17.3	18.1	19.9	22.4	24.9	21.8	17	1993 2010		
Mean 3pm relative humidity (%)	55	54	52	57	59	62	63	63	62	59	58	54	58	16	1993 2010		
Mean 3pm wind speed (km/h)	27.7	25.8	23.0	19.9	18.4	19.3	20.2	20.8	23.0	24.9	26.1	27.2	23.0	17	1993 2010		
3pm wind speed vs direction plot	PDF	PDF	PDF	PDF	PDF	PDF	PDF	PDF	PDF	PDF	PDF	PDF	PDF				

red = highest value blue = lowest value

Product IDCJCM0030 Prepared at Thu 03 Dec 2015 01:59:41 AM EST

Related information

Maps

- Long term climatology maps for selected elements

Appendix C: Table 27 DETR (1997)

				Open Void Space[6]		Polystyrene Shuttering[6]				Geocomposite Drainage Blanket		20mm Single Size Gravel Blanket		20mm Single Size Gravel Blanket with Interleaved Pipes at 3m Centres[3]
						Equivalent Clear Void Depth 22mm		Equivalent Clear Void Depth 100mm		Equivalent Clear Void Depth 36mm				
Foundation Width[4]				5m	30m	5m	30m	5m	30m	5m	30m	5m	30m	30m
Gas Regime				Gas Dispersal Characteristics of Media for Methane Hazards										
Gas Regime	Methane Conc. (%v/v)	Emission Rate[1] (m/s)	Char Situ[2]											
A[5]	1	0.005	2	Adequate	Adequate	Adequate	Adequate	Adequate	Adequate	Adequate	Adequate	Adequate	Adequate	Adequate
B	5	0.005	3	Very Good	Very Good	Very Good	Good	Very Good	Very Good	Very Good	Good	Good	Poor	Good
C	5	0.01	4	Very Good	Very Good	Very Good	Good	Very Good	Very Good	Very Good	Fair	Fair	Unsuit	Fair
D	20	0.005	4	Very Good	Very Good	Very Good	Fair	Very Good	Good	Good	Poor	Poor	Unsuit	Poor
E	20	0.01	4	Very Good	Good	Good	Poor	Very Good	Good	Good	Unsuit	Poor	Unsuit	Unsuit
F	20	0.05	5	Good	Poor	Fair	Unsuit	Fair	Poor	Fair	Unsuit	Unsuit	Unsuit	Unsuit

1 Emission rate values refer to equivalent total gas flow velocity from 50mm diameter borehole and Peckson(12) assumption
2 Characteristic situation after CIRIA Report 149(3)
3 Gas Dispersal Characteristics based on maximum steady state concentration over 80% area of foundation, pipes at interleaved 3m centres
4 Assumes sympathetically detailed underside of foundation
5 Gas dispersal characteristics have not been assessed using Figure 3, since maximum concentration entering the ventilation layer is equivalent to the target concentration
6 For open void space and polystyrene shuttered ventilation layers additional side ventilation provision can improve the gas dispersal characteristics

Table 27 Summary of Gas Dispersal Characteristics of Different Ventilation Media on Idealised Foundations

B – VI-20 SPECIFICATION

VI-20 Geomembrane - Brownfield Membrane and Vent Systems Specifications

Section 07 2623.19 – August 2010 (Supersedes All Previous Versions)

Version 5.0

> This guide specification has been prepared according to the principles established in the Manual of Practice published by the Construction Specification Institute and may have changed. Therefore, please confirm that this specification is still current and has not been superseded by checking at www.cetco.com or by calling 1-714-384-0111 for the most recent version.

PART 1 - GENERAL

1.01 RELATED DOCUMENTS

A. General and Supplementary Conditions and Division 1- General Requirements applies to this section. Provide gas vapor barrier as indicated, specified and required.

1.02 WORK SUMMARY

A. Work in this section - principal items include:
1. VI-20 geomembrane provides protection from the following gases: Methane, Hydrocarbon vapors in concentrations up to 20,000ppm, Hydrogen Sulfide, Radon.
2. Soil vapor extraction piping and low profile venting system beneath the gas vapor membrane.

1.03 RELATED REQUIREMENTS:

A. Other specification Sections which directly relate to the work of this section include, but are not limited to, the following:
1. Division 03 Section "Cast-In-Place Concrete" for concrete slabs.
2. Division 07 Section "Self-Adhering Sheet Waterproofing."
3. Division 07 Section "Cold Fluid-Applied Waterproofing."
4. Division 07 Section "Crystalline Waterproofing."
5. Division 26 Section "Conduit and other Electrical Penetrations."
6. Division 31 Section "Earthwork, Excavation and Fill, Shoring."
7. Division 33 Section "Geocomposite Foundation Drainage."

1.04 SYSTEM DESCRIPTION

A. Provide gas/vapor barrier system with prefabricated composite venting system to mitigate the passage of gas or vapor and install without defects, damage or failure. Gas vapor barrier shall be high performance VI-20 Geomembrane with EVOH core technology, Liquid Boot® at overlap seams/penetrations, UltraShield protection course and applicable accessory products

1.05 SUBMITTALS

A. General: Prepare and submit specified submittals in accordance with "Conditions of the Contract" and Division 1 Submittals Sections.

B. Product Data: Submit manufacturer's product data, with complete general and specific installation instructions, recommendations, and limitations.

C. Product Samples: Submit representative samples of the following for approval:
1. GeoVent – low profile vapor extraction system.
2. VI-20 – high density polyethylene (HDPE) and ethylene vinyl alcohol (EVOH) composite membrane.
3. VI-20 Detailing Fabric – ethylene vinyl alcohol (EVOH) and polypropylene composite membrane.
4. Liquid Boot® - asphalt latex overlap seams/penetrations sealer.
5. UltraShield G-1000 – polypropylene needle punched protection course.

D. Contractor Certificate: At time of bid, submit written certification that installer has current Approved Applicator status with gas vapor membrane manufacturer.

1.06 QUALITY ASSURANCE

A. Manufacturer Qualifications: Gas vapor membranes and all accessory products shall be provided by a single manufacturer with a minimum of 25 years experience in the direct production and sales of gas vapor systems. Manufacturer shall be approving an acceptable installer/applicator and recommending appropriate installation methods.

B. Installer Qualifications: A firm that is trained and approved by the gas vapor barrier system manufacturer for installation of the gas vapor barrier system required for this Project. The installing company should have at least three (3) years experience in work of the type required by this section, who can comply with manufacturer's warranty requirements.

C. Pre-installation Conference: A pre-installation conference shall be held at the site prior to commencement of field installation to establish procedures to maintain required working conditions and to coordinate this work with related and adjacent work. Verify that final gas vapor barrier components and system details comply with gas vapor barrier manufacturer's current installation requirements and recommendations. Pre-con meeting attendees should include representatives for the owner, architect, inspection firm, general contractor, gas vapor installer/applicator, concrete contractor, excavating/backfill contractor, and mechanical and electrical contractors if work penetrates the gas vapor membrane.

D. Independent Inspection: Owner shall make all arrangements and payments for an independent inspection service to monitor gas vapor membrane material installation compliance with the project contract documents and manufacturer's published literature and site specific details. Independent Inspection Firm shall be an approved company participating with the gas vapor membrane manufacturer's Certified Inspection Program. Inspection service shall produce reports and digital photographs documenting each inspection. Reports shall be made available to the Contractor, gas vapor membrane installer, gas vapor membrane material manufacturer, and Architect. Inspections should include substrate examination, beginning of gas vapor membrane installation, periodic intervals, and final inspection prior to concrete or backfill placement against the gas vapor barrier.

1.07 DELIVERY, STORAGE AND HANDLING

A. Delivery and Handling: Deliver materials in factory sealed and labeled packaging. Sequence deliveries to avoid delays, while minimizing on-site storage. Handle and store following manufacturer's instructions, recommendations and material safety data sheets. Protect from construction operation related damage, as well as, damage from weather, excessive temperatures and prolonged sunlight. Remove damaged material from site and dispose of in accordance with applicable regulations.

B. Do not allow material to freeze in containers

C. Remove and replace liquid materials that cannot be applied within their stated shelf life.

1.08 JOB CONDITIONS

A. Environmental Limitations: Install VI-20 geomembrane system within the range of ambient and substrate temperatures recommended by manufacturer. Do not apply VI-20 geomembrane system to a damp or wet substrate, when relative humidity exceeds 85 percent, or when temperatures are less than 5 deg F (3 deg C) above dew point.

B. Do not install VI-20 geomembrane system in snow, rain, fog or mist, or when such weather conditions are imminent during application and curing period of Liquid Boot® seams/penetration sealer.

C. Maintain adequate ventilation during application and curing Liquid Boot® seams/penetration sealer.

D. Surface preparation shall be per manufacturer's specification.

1.09 COORDINATION

A. Coordinate installation of VI-20 geomembrane with installation of other construction.

1. Positively secure plumbing, electrical, mechanical, and structural items to be under or passing through the gas vapor barrier in their proper positions and appropriately protected prior to membrane installation.

2. Install VI-20 geomembrane before placement of reinforcing steel. When not possible, mask all exposed reinforcing steel prior to membrane installation.

1.10 PRODUCT WARRANTY

A. Upon delivery and acceptance by the Owner of material specified by this Section, the materials manufacturer will provide a written one year standard material indicating the material conforms to its product specifications and is free of material defects. Factors affecting the results obtained from using this product including weather, equipment utilized, construction, workmanship and other variables are all beyond the manufacturer's control.

Under this product warranty, manufacturer will provide replacement material, at no charge, for any product proven not to meet the material properties listed in the published product literature This warranty is in lieu of any and all other warranties expressed or implied (including any implied warranty of merchantability or fitness for a particular use), and manufacturer shall have no further liability of any kind including liability for consequential or incidental damages resulting from any defects or delays caused by replacement or otherwise.

PART 2 - PRODUCTS

2.01 MANUFACTURER

A. Provide VI-20 geomembrane, venting system and applicable accessories as manufactured by Colloid Environmental Technologies Company (CETCO), 2870 Forbs Ave, Hoffman Estates, IL 60192,, USA. Phone: (847) 851-1800; Fax: (847) 851-1899; Web-site: http://www.sedimentremediation.com.

2.02 QUALIFICATIONS

A. The gas vapor barrier manufacturer must have produced at least 22 million square feet (2 million square meters) of gas vapor barrier, with at least 22 million square feet (2,000,000 square meters) installed.

2.03 MATERIALS

A. VI-20® is a seven-layer co-extruded membrane made from ethylene vinyl alcohol (EVOH) and polyethylene to provide strength as well as resistance to VOC vapor transmission. VI-20 membrane is an under-slab barrier when used in conjunction with Liquid Boot® at overlap seams and penetrations will inhibit volatile organic compound vapor migration through the concrete.

VI-20 geomembrane barrier physical properties:

PROPERTIES	TEST METHOD	VALUE
Thickness, nominal	ASTM D5199	0.51 mm
Weight	ASTM D5261	498 g/m^2
Tensile Strength	ASTM E154	258 N/cm (58 lb/in)
Methane Permeability	ASTM D 1434	< 5 x 10-10 m2/d•atm
Radon Diffusion Coefficient		< 0.25 x 10-12 m2/s

B. Fluid applied gas vapor barrier system - Liquid Boot®; single courses, high build, polymer modified asphaltic emulsion. Water borne and spray applied at ambient temperatures. A minimum thickness of 60 dry mils, unless specified otherwise as some cities and engineers may require a thicker membrane. Non-toxic and odorless. Liquid Boot® Trowel Grade has similar properties with greater viscosity and is trowel applied. Manufactured by CETCO in Santa Ana, CA and Cartersville, GA (714) 384-0111.

C. ACCESSORY GAS VAPOR BARRIER PRODUCTS: All accessory gas vapor barrier materials shall be provided by the manufacturer or shall have manufacturer's written approval for substitution.

1. GeoVent – low profile vapor extraction system.
   i. Liquid Boot® GeoVent end outlet.
   ii. Liquid Boot® GeoVent interior Footing Sleeves.
   iii. Liquid Boot® GeoVent Fabric Reinforced Tape.
2. Liquid Boot® Detailing Fabric – ethylene vinyl alcohol (EVOH) and polypropylene composite membrane.
3. UltraShield G-1000 – polypropylene needle punched protection mat.
4. Adhesive system for VI-20 geomembrane and UltraShield G-1000: Use Liquid Boot® UltraGrip.

PART 3 - EXECUTION

3.01 EXAMINATION

A. The installer, with the Owner's Independent Inspector present, shall examine conditions of substrates and other conditions under which this section work is to be performed and notify the contractor, in writing, of circumstances detrimental to the proper completion of the work. Do not proceed with work until unsatisfactory conditions are corrected and are acceptable for compliance with manufacturer requirements. General substrate conditions acceptable for the gas vapor barrier installation are listed below. For conditions not covered in this Section, contact the gas vapor barrier manufacturer for guidance.

B. SOIL SUBSTRATES:

1. Moisture condition and compact sub-grade to a minimum relative compaction of 90 percent or as specified by civil/geotechnical engineer with finished surface smooth, uniform, free of debris and standing water.
2. Stones or dirt clods greater than 1/4 inch to be removed. Aggregate sub-bases shall be rolled flat, free from any protruding sharp edges.
3. Penetrations must be prepared in accordance with manufacturer's specifications. All form stakes that penetrate the membrane shall be of rebar which shall be bent over and left in the slab.
4. Trenches oversizes are to be cut to accommodate gas vapor barrier membrane and protection course with perpendicular to sloped sides and maximum obtainable compaction. Finish grade and compact the adjoining grade.
5. Provide excavated walls vertical or sloped back, free of roots and protruding rocks.
6. Soil sterilant applications should at the sterilant manufacturer's recommended rate.

C. MECHANICAL OR OTHER PENETRATIONS: Mechanical, structural, or architectural materials that will pass through the plane of the gas vapor membrane shall be properly installed and secured in their final position prior to installation of VI-20 geomembrane system.

D CONCRETE: Concrete to be gas vapor proof shall be properly placed and consolidated. Reinforced structural slabs should be a minimum of 6" (150 mm) thick when placed on a working mud slab. Reinforced concrete slab(s) on compacted grade shall be a minimum of 4" (100 mm) thick.

1. At cast in place concrete surfaces, provide a light broom finish or smoother, free of any dirt, debris, loose material, release agents or curing compounds. Fill voids more than 1/4 inch deep and 1/4 inch wide.
2. At masonry joints, cold joints, and form joints, provide a struck smooth surface. Prepare penetrations in accordance with manufacturer's specifications.
3. Completely grout all cracks or cold joints greater than 1/16 inch with non-shrink grout. Install Hardcast reinforcing tape over all cold joints, cracks and form tie holes (after holes and cracks are grouted).

3.02 SURFACE PREPARATION

A. Provide 24 inch minimum clearance out from surfaces to install VI-20 geomembrane. The application surface shall be prepared and provided to the applicator in accordance with manufacturer's specifications listed below:

B. Remove dirt, debris, oil, grease, cement laitance, or other foreign matter which will impair or negatively affect the performance of VI-20 geomembrane and venting system.

C. Protect adjacent work areas and finish surfaces from damage or Liquid Boot® over spraying during overlap seams and penetrations application.

3.03 INSTALLATION OF GAS COLLECTION/VENT SYSTEM

A. Roll out Liquid Boot® GeoVent per approved layout
B. Provide prefabricated Liquid Boot® GeoVent Sleeves or GeoVent End Outlets where venting penetrates interior footing
C. At points of intersections, cut away geotextile to produce rectangular flaps. Interlock exposed dimple board in a Lego-like fashion. Fold flaps of geotextile in a manner so that the dimple board is covered completely. Secure geotextile folds with Liquid Boot® Fiber Reinforced Tape so that the geotextile is completely impermeable to sand fill
D. Use Liquid Boot® GeoVent End Outlet to attach to a solid (non-perforated 2" (inches) diameter PVC pipe at penetration through building foundation. Seal/grout piping at penetrations through foundation using approved methods.

3.04 INSTALLATION ON DIRT SURFACES AND MUDSLABS

3.04.10 OPTION 1

A. Roll out VI-20 geomembrane on sub-grade and overlap seams a minimum of 6 inches. Lay geomembrane tight at all inside corners. Apply a thin 60 mil Liquid Boot® spray applied within the seam overlap. Line trenches with geomembrane extending at least six inches (6") onto adjoining sub-grade if slab and footings are to be treated separately.

B Minimize the use of nails to secure the geomembrane to the dirt subgrade. Nails that cannot be removed from the dirt subgrade are to be patched with Liquid Boot® Detailing Fabric overlapping the nail head by a minimum of two inches (2"). Apply a 60 mil Liquid Boot® over the Detailing Fabric patch, when patching with geomembrane.

C. Sealing around penetrations.

D. Do not penetrate membrane. Keep membrane free of dirt, debris and traffic until a protective cover is in place. It is the responsibility of the General Contractor to insure that the membrane and the protection system are not penetrated.

E. After VI-20 geomembrane installation completed, check overlap and penetration seals for leaks/pin-holes, install protection material pursuant to manufacturer's instructions.
1. Perform all testing or inspection to be performed prior to placing protection course.

3.04.20 OPTION 2

A. Roll out VI-20 geomembrane on sub-grade and overlap seams a minimum of 6 inches. Lay geomembrane tight at all inside corners. Use Twinny T, Comet automatic welder or equivalent equipment as approved by manufacturer to weld overlapping areas. Line trenches with geomembrane extending at least six inches (6") onto adjoining sub-grade if slab and footings are to be treated separately

B. Minimize the use of nails to secure the geomembrane to the dirt sub-grade. Damaged areas or nails that cannot be removed from the dirt sub-grade are to be patched with VI-20 geomembrane using handheld welding equipment with minimum of 3" of VI-20 geomembrane overlapped.

C. Sealing around penetrations.

D. Do not penetrate membrane. Keep membrane free of dirt, debris and traffic until a protective cover is in place. It is the responsibility of the General Contractor to insure that the membrane and the protection system are not penetrated.

E. After VI-20 geomembrane installation completed, check overlap and penetration seals for leaks/pin-holes, install protection material pursuant to manufacturer's instructions
 1. Perform all testing or inspection to be performed prior to placing protection course

3.05 SEALING AROUND PENETRATIONS

A. Clean all penetrations. Sand metal penetrations clean with emery cloth.

B. Roll out VI-20 geomembrane on sub-grade, overlapping seams a minimum of six inches (6"). Cut the geomembrane around penetrations so that it lays flat on the sub-grade. Lay geotextile tight at all inside corners. Apply a thin (20 mil) LIQUID BOOT® within the seam overlap then lap VI-20 Detailing Fabric around penetrations extending 3 inches around the base of penetration.

C. At the base of penetration install a minimum ¾ inch thick membrane cant of Liquid Boot®, or other suitable material as approved by manufacturer. Extend Liquid Boot membrane at a 60 mil thickness three inches (3") around the base of penetration and up the penetration a minimum of three inches (3"). Allow to cure overnight before the application of Liquid Boot® membrane. (See manufacturer's standard detail.)

D. Allow Liquid Boot® to cure completely before proceeding to step "F".

E. Wrap penetration with polypropylene cable tie at a point 2 inches above the base of the penetration. Tighten the cable tie firmly so as to squeeze, but not cut, the cured membrane collar.

3.06 FIELD QUALITY CONTROL

A. The VI-20 geomembrane must be tested in the proper manner as described below. However, over-sampling defeats the intent of inspections. Inspectors should always use visual to identify damaged areas. Seams or penetrations areas suspected to have holes or leaks should be checked using welded air pressure chamber between the weld tracks and/or smoke test.

B. **PRESSURE CHAMBER TEST**

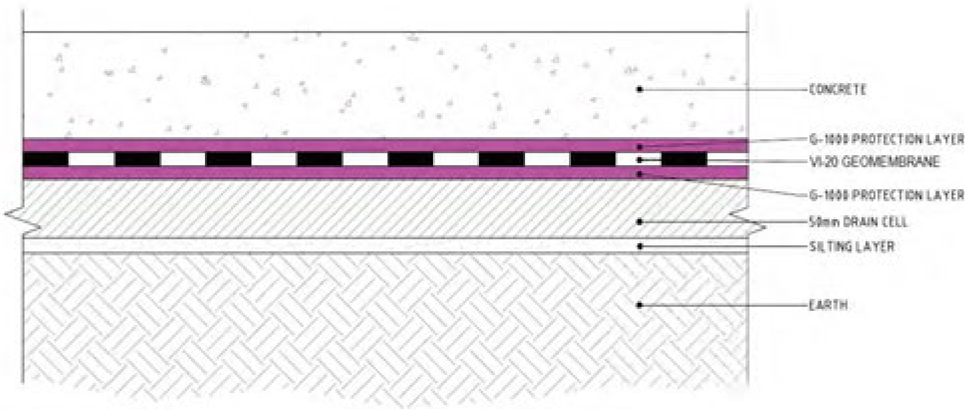
 1. Pressure chamber tests for welding breaches in accordance with the manufacturer's written instructions.

C. SMOKE TESTING FOR HOLES

 1. Smoke tests the membrane for holes and other breaches in accordance with the manufacturer's written instructions.

END OF SECTION

C – CONSTRUCTION DRAWINGS



TYPICAL CROSS SECTION
N.T.S

CONSTRUCTION ISSUE

REV	DATE	DESCRIPTION	BY	CHECK	DESIGN	VERIFY

SCALES

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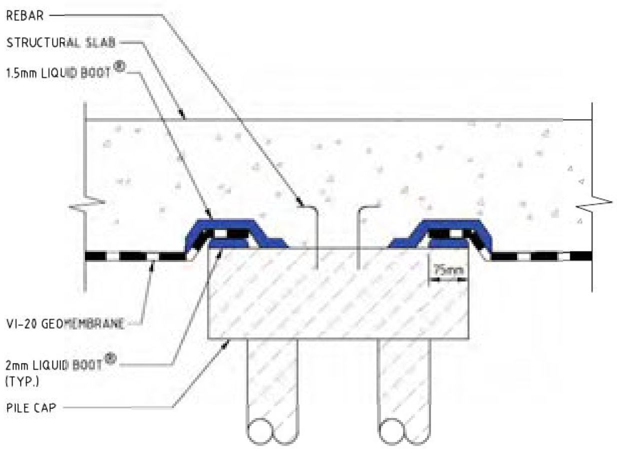
CLIENT

PROJECT LONGFORD ROAD, BEACONSFIELD

CROSS-SECTIONAL DETAIL

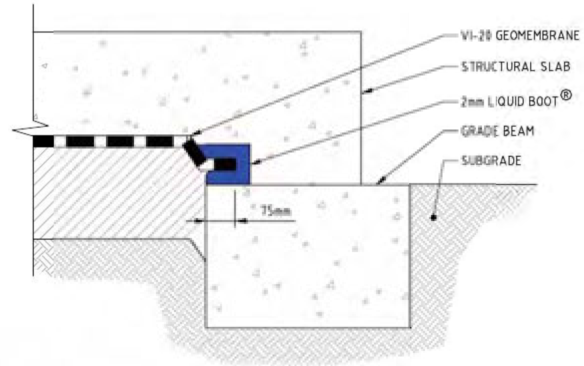
DRAWING NO. 0001

REVISION A



GAS VAPOR BARRIER
PILE CAP
N.T.S

NOTE:
BRING THE MEMBRANE 75mm ONTO THE PILE CAP, THE GEOTEXTILE IS THEN ENCAPSULATED IN THE MEMBRANE.



GAS VAPOR BARRIER
OVER FOOTING AND GRADE BEAMS
N.T.S

NOTE:
BRING THE MEMBRANE 75mm ONTO THE FOOTINGS, THE GEOTEXTILE IS THEN ENCAPSULATED IN THE MEMBRANE.

CONSTRUCTION ISSUE

REV	DATE	DESCRIPTION	BY	CHECK	DESIGN	VERIFY

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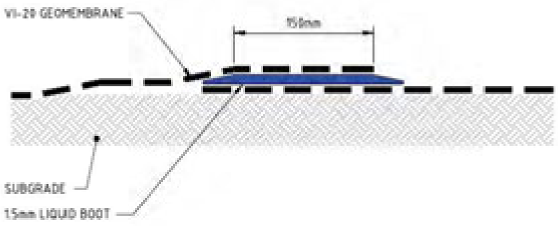
PROJECT: LONGFORD ROAD, BEACONSFIELD

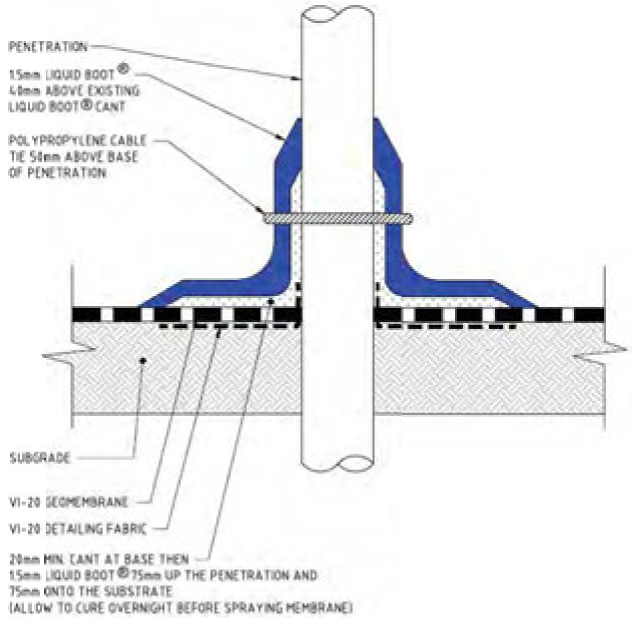
MEMBRANE DETAILS
SHEET 1

DRAWING NO. 0005

REVISION A

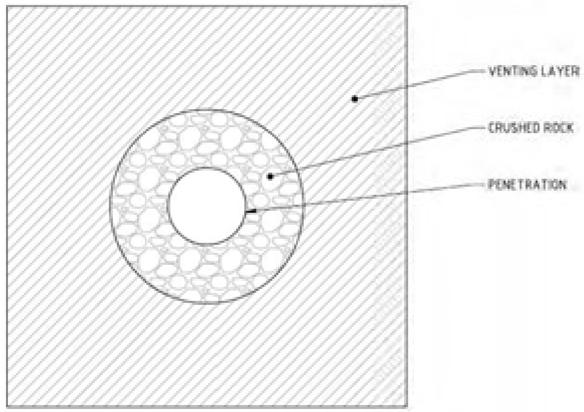


GAS VAPOR BARRIER
MEMBRANE LAP JOINTS
N.T.S



GAS VAPOR BARRIER PENETRATIONS
N.T.S

NOTE:
ALL PENETRATIONS SHALL BE CLEANED AS PER SPECIFICATIONS BEFORE LIQUID BOOT® IS APPLIED.



PENETRATIONS TYPICAL DETAIL
N.T.S

CONSTRUCTION ISSUE

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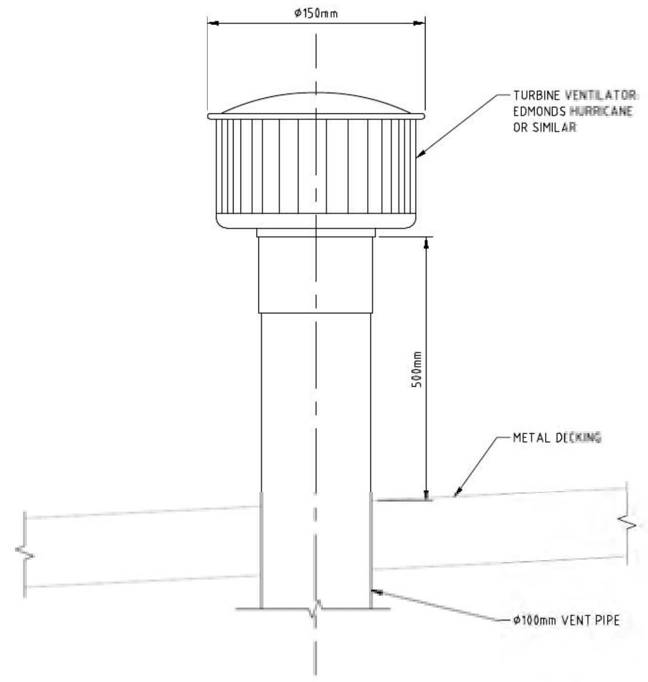
PROJECT
LONGFORD ROAD, BEACONSFIELD

MEMBRANE DETAILS
SHEET 2

DRAWING NO.
0006

REVISION
A



TURBINE VENTILATOR TYPICAL DETAIL
N.T.S

CONSTRUCTION ISSUE

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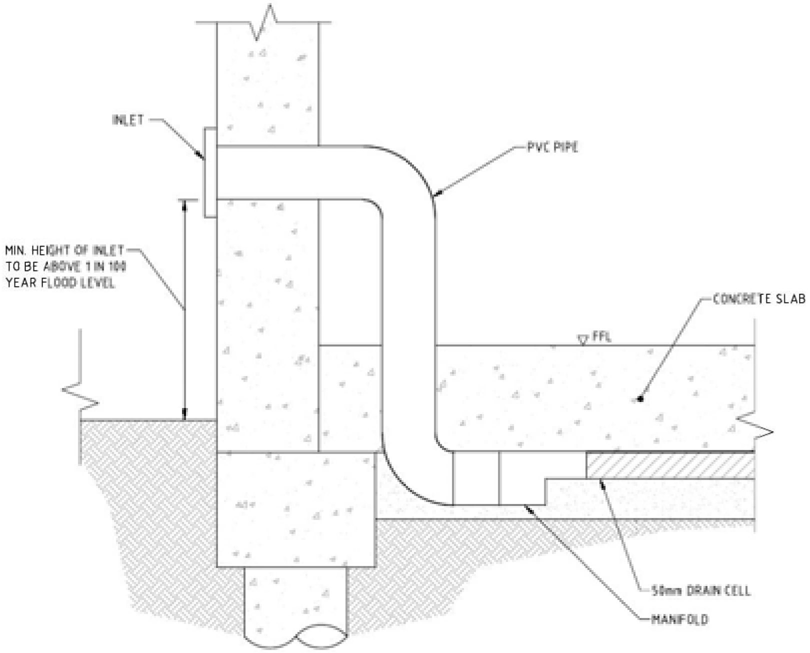
PROJECT: LONGFORD ROAD, BEACONSFIELD

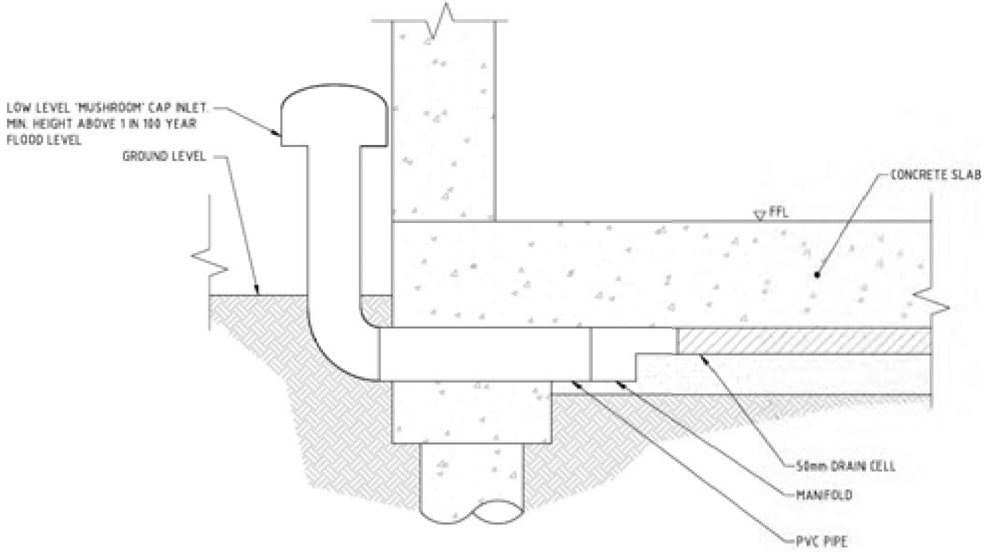
TYPICAL DETAILS
SHEET 1

DRAWING NO.: 0010

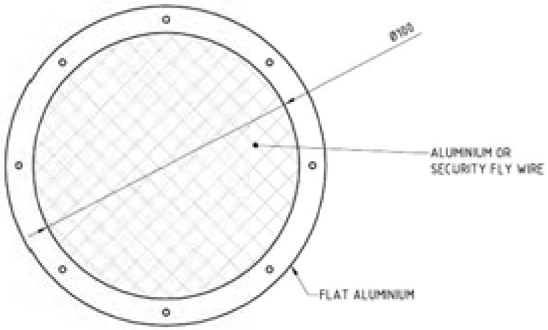
REVISION: A



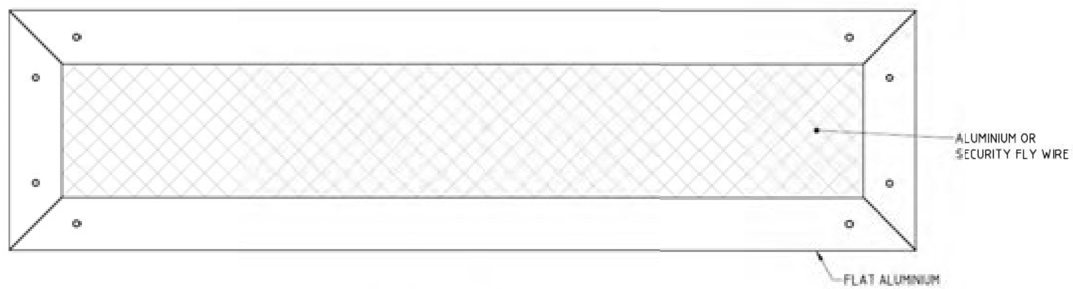
INLET DETAIL - Z TYPE
N.T.S



ALTERNATE INLET DETAIL - MUSHROOM
N.T.S



OPTION 1
VENT INLET DETAIL - FRONT VIEW
N.T.S



OPTION 2
VENT INLET DETAIL - FRONT VIEW
N.T.S

CONSTRUCTION ISSUE

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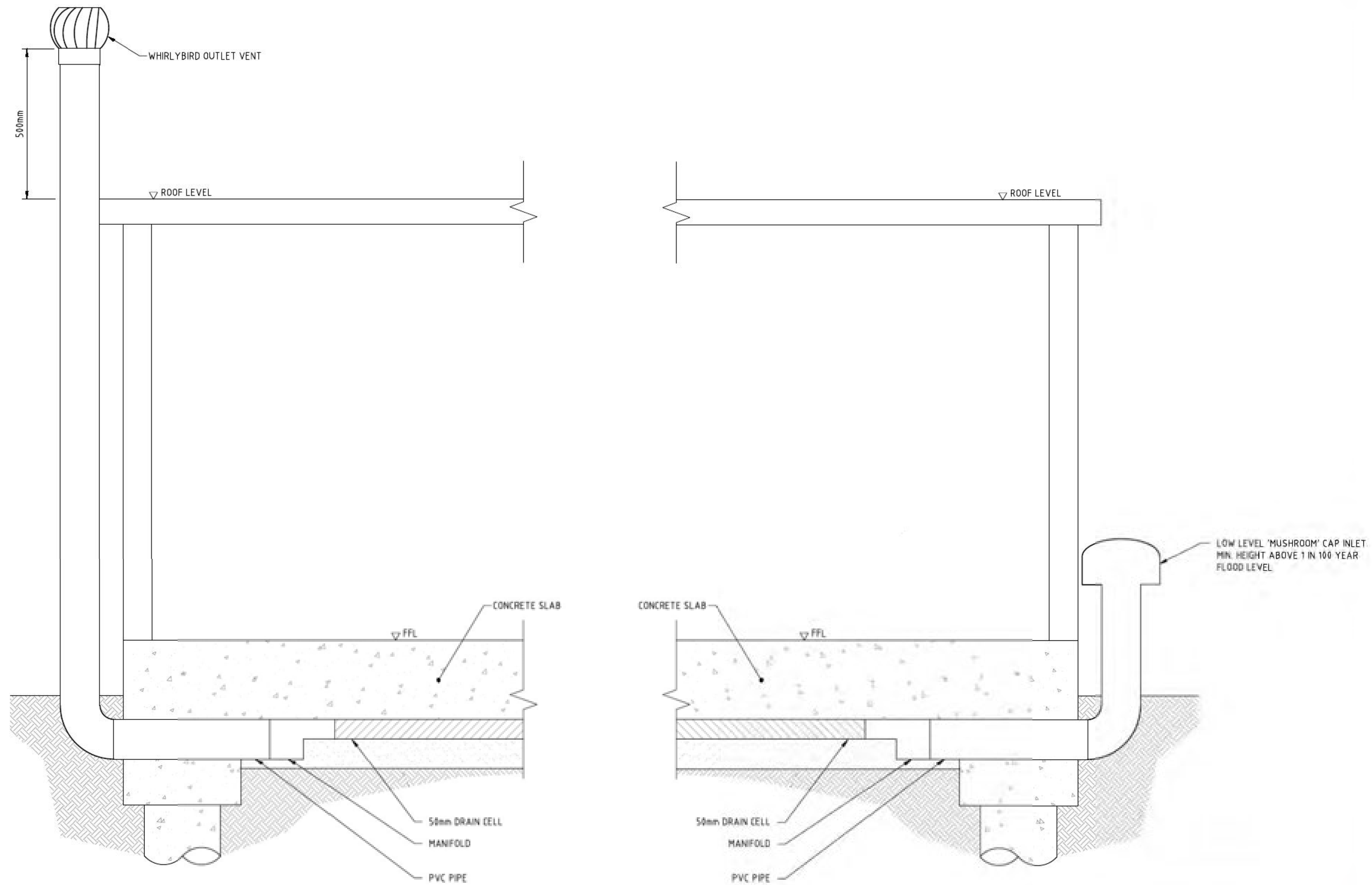
PROJECT
LONGFORD ROAD, BEACONSFIELD

TYPICAL DETAILS
SHEET 2

DRAWING NO. 0011
REVISION A



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PROJECT
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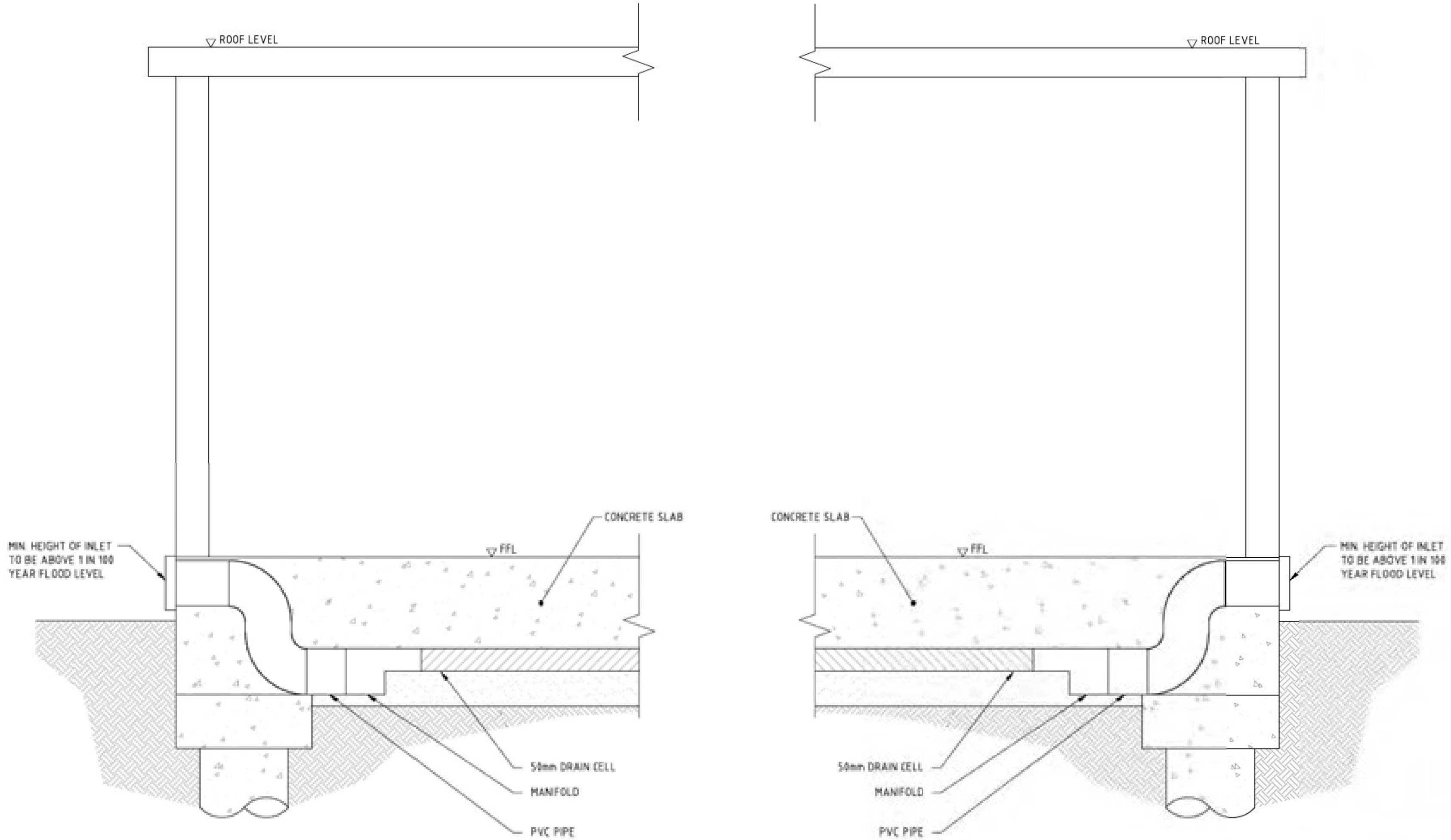
INLET/OUTLET DETAIL
SHEET 1

DRAWING NO. 0012

REVISION A



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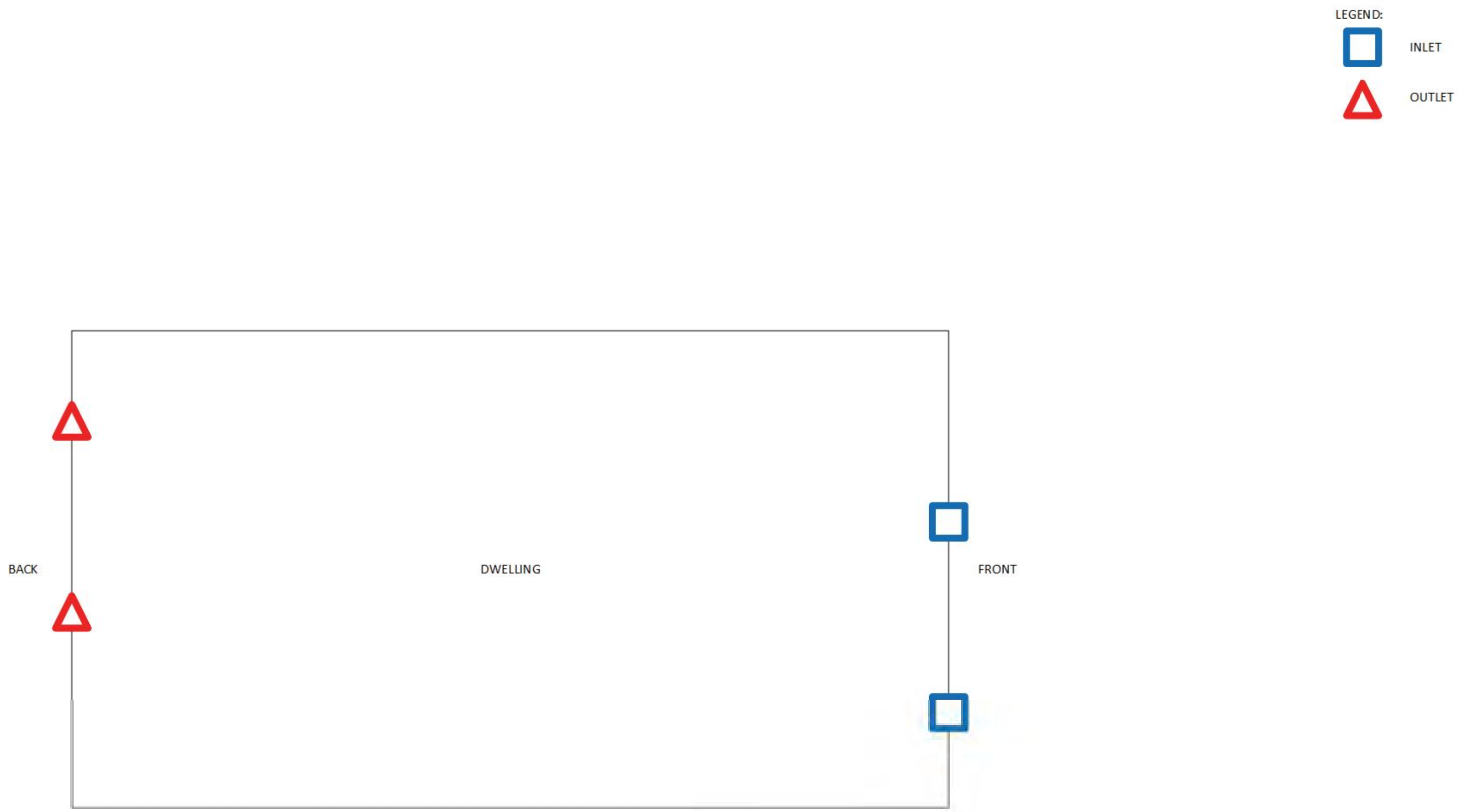
PROJECT LONGFORD ROAD, BEACONSFIELD

INLET/OUTLET DETAIL
SHEET 2

DRAWING NO. 0013

REVISION A



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INLET/OUTLET LAYOUT
SHEET 1

DRAWING NO.: 0014

REVISION: A

CONSTRUCTION ISSUE

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INLET/OUTLET LAYOUT
SHEET 2

DRAWING NO.: 0015

REVISION: A