APPENDIX J

Odour Impact Assessment report
Defence Housing Australia
Odour Impact Assessment

Field Odour Inspection of
Leanyer-Sanderson WWTP, Darwin NT

Final Report
March 2017
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EXECUTIVE SUMMARY

The Odour Unit WA Pty Limited (TOU) was commissioned by Defence Housing Australia (DHA) to undertake an odour impact assessment (OIA) of the Leanyer-Sanderson Wastewater Treatment Plant (WWTP) in Darwin, NT and determine if odour emissions from the WWTP would impact on DHA’s land holdings to the north-west which reside at a minimal distance of 1.3kms downwind. The OIA involved the field odour inspection of the downwind surrounds between the land holdings and the WWTP to determine the extent (length and width) of the odour plume (if any) from the WWTP whilst also collecting statistical data for the presence, intensity and frequency of odour observations within those downwind surrounds.

TOU found that the odour emanating from the WWTP resembled typically well maintained WWTP pond configurations. Early morning field odour inspections attempted to observe odour during peak inflow periods at the WWTP. TOU believes it observed inflow peaks during those field inspections where odour was observed. TOU found that odour impacts were observable up to a distance of approximately 600m downwind and that those odours were of a low frequency, low intensity and would therefore not be considered a nuisance. Spot odour was observed along Barratt Road; however, the incidence of up, or downwind odours around that spot location failed to find any contributing odour suggesting the odour observations at that location may be a localised and not necessarily from the WWTP.

TOU further considered the assessment and findings of the Masterplan NT report (2015), specifically the contribution by GHD where a site-specific odour sampling and testing assessment was undertaken at the WWTP. GHD found that the risk of odour impacts beyond typically 500m was Low. TOU supported this conclusion based on its own inspection and assessment.

It is the opinion of TOU that the findings of the odour impact field inspection within the north-west assessment area surrounding the Leanyer-Sanderson WWTP support the judgement that odour impacts on the DHA land holdings, Muirhead North and 2CRU, would be negligible and in all likelihood nil. This conclusion is based on the standard daily operations of the WWTP without upset/breakdown conditions.
1 PROJECT BACKGROUND

The Odour Unit WA Pty Limited (TOU) was commissioned by Defence Housing Australia (DHA) in February 2017 to undertake a field-based odour impact assessment (OIA) of the Leanyer-Sander Waste Water Treatment plant (WWTP), Darwin NT, specifically DHA land holdings downwind of the WWTP in a north-westerly direction.

The purpose of this assessment was two-fold; the first being an attempt to determine the length and width of the odour plume (if any) from the WWTP whilst also making observations of odour intensity and frequency downwind, and the second being a review and consideration of the findings and recommendations of the Planning Report: “Proposal to Amend the NT Planning Scheme - Lots 6959, 6960 and 6961 Town of Sanderson (54 Fitzmaurice Drive, 4 Timor Court and, 7 Glyde Court, Leanyer)” prepared by Masterplan NT, February 2015, specifically Attachment C of the Masterplan report where an odour impact assessment of the WWTP was undertaken by GHD in 2015.

DHA has two land holdings (the “land holdings”) to the north-west of the WWTP, designated as 2CRU and Muirhead North. Muirhead North is the closest to the WWTP at a nominal distance of 1.3kms, with 2CRU residing at approximately 1.9kms north-west of the WWTP.

Between the DHA land holdings is an existing development currently under construction (Stage 7) as well as completed and occupied residential areas.

TOU undertook the assessment by the undertaking of an offsite field inspection methodology that determines the extent of the odour plume emitted, and its perceived impact from the WWTP using field methods based on the standard known as “Measurement of Odour Impact by Field Inspection” defined by the German Standard VDI 3940, and where the system by which those observed odours are ranked according to the strength of the odour sensation experienced is based on the German Standard VDI 3882 Part 1; and, the most recent European Methodology (BS EN 16841-2:2016) “Ambient air – Determination of odour in ambient air by using field inspection”.

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Reference to these methods hereinafter is referred to as the **field inspection method**. The field inspection method assessed odour impacts offsite from the WWTP under preferential weather conditions directly affecting the landholdings locale as well as other wind conditions during each day of inspection.

These field inspection methods utilise field data observations by ‘ground-truthing’ detectable odours from a pre-defined odour source to assess the plume extent (and derived plume impact area), odour intensity of an observed odour at measurement points within the plume, and its frequency of observation at those measurement points. These odours are detected by field technicians (*panel members*) that have been calibrated for their olfactory sensitivity according to the Australian/New Zealand Standard AS/NZS4323.3:2001.

The odour impact assessment was undertaken during the period Thursday 23rd February – Tuesday 28th February inclusive. The weather conditions during the assessment were fine, clear skies with some overcast conditions.
2 TERMS & DEFINITIONS

“TOU” refers to The Odour Unit (WA) Pty Limited who are the commissioned consultant undertaking the method;

“sensory adaptation” temporary modification of the sensitivity of a sense organ due to continued and/or repeated stimulation. Note 1: Adaptation can also occur as a result of a gradually increasing stimulation;

“assessor” somebody who participates in odour testing;

“crossing” series of single measurements by a panel member starting at an odour absence point, crossing the plume direction more or less at a right angle towards an odour absence point on the other side of the plume direction. Note 1: The crossing shall cover similar distances at each side of the plume direction. Note 2: When a crossing does not yield odour presence points it shall start at a distance similar to the estimated maximum plume width;

“experienced panel member” panel member with the necessary experience to make valid observations for the dynamic method according to Australian Standard AS/NZS4323.3:2001 for Dynamic Olfactometry. Note 1: To become an experienced panel member a panel member shall participate at least five times in a measurement cycle with at least three different odour types;

“European odour unit” amount of odorant(s) that, when evaporated into 1 cubic metre of neutral gas at standard conditions, elicits a physiological response from a panel (detection threshold) equivalent to that elicited by one European Reference Odour Mass (EROM), evaporated in one cubic metre of neutral gas at standard conditions;

“field inspection” measuring odours in ambient air using panel members;

“field observations coordinator” individual responsible for the correct execution of the field measurement procedure;

“field survey” total of measurement sessions (cycles) required to characterize an exposure level (see part 1 grid method) or plume extent (see part 2 plume method) in an area under study affected by one or more sources or emitting facilities;

“intersection line” intersection line is a line perpendicular to the plume direction along which panel members are placed for the stationary plume method;
“method” refers to the methodology to be undertaken;

“methodology” means the system of all individual tasks, techniques, tools and measurements undertaken to collect the desired dataset of information or solve the problem;

“measurement day” refers to the day on which a measurement cycle, or cycles was undertaken;

“maximum plume reach” maximum distance downwind where an odour type can be perceived and recognized (under defined meteorological conditions);

“measurement cycle” procedure of consecutive field observations required to determine the odour plume extent once, conducted by a panel under defined meteorological conditions;

“measurement point” location where single measurement(s) are carried out;

“odorant” substance whose volatiles can be perceived by the olfactory organ (including nerves);

“odour” sensation perceived by means of the olfactory organ in sniffing certain volatile substances;

“odour absence point” measurement point at which the odour under study is not perceived and recognized as a result of a single measurement;

“odour detection” to become aware of the sensation resulting from adequate stimulation of the olfactory system;

“odour hour” odour hour is obtained by a single measurement when the percentage odour time reaches or exceeds 10 % by convention. Note 1: Only relevant for the stationary method. Note 2: A test result of one single measurement can be positive for more than one distinct odour type;

“odour presence point” measurement point at which the odour under study is perceived and recognized as a result of a single measurement;

“odour recognition (in ambient air)” odour sensation in ambient air that allows positive identification of the odour type;

“odour type” odour that can be recognized and assigned to a certain installation or source. Note 1: Odour types are defined specifically for one survey. One installation can emit more than one odour type. Several facilities can emit the same odour type;

“odour quality” means the comparative description of an odour with olfactory experience, e.g. “there is a smell of…”, “it smells burnt, rotten…” etc;

“panel member” assessor who is qualified to perform field inspections according to Section 6.2 of the Standard “Assessors and panel members”;
“panel selection” procedure to determine which assessors are qualified as panel members;

“plume extent” shape of the plume delineated by a smoothed interpolation polyline through the transition points, the source location and the location determined by the maximum plume reach estimate;

“plume extent area” surface area enclosed by a smoothed interpolation polyline through the transition points, the source location and the location determined by the maximum plume reach estimate;

“recognition threshold” as it relates to the German Standard VDI 3940 means the odorant concentration at which a detectable odour within a facility’s impact range can be clearly assigned to a facility for the first time;

“percentage odour time” refers to the total times/intervals which the odour is recognizable during a measurement cycle at a single measurement point;

“single measurement” procedure to obtain recorded observations at a given moment at a given measurement point necessary to determine absence or presence of recognizable odour. Note 1: For the stationary plume method one single measurement results in the test result ‘odour hour’ or ‘non-odour hour’. Note 2: For the stationary plume method the absence or presence is determined based on the observed percentage odour time over a defined single measurement duration. For the dynamic plume method the absence or presence is based on the direct and instantaneous observation of recognizable odour or the lack of it;

“single measurement duration” time required to conduct a single measurement. Note 1: The single measurement duration is 10 min (60 observations) for a stationary plume method. A single measurement duration of at least ten minutes is required in order to obtain a representative statement with at least 80% certainty on the odour situation within an hour. The single measurement duration for the dynamic plume method is the duration of one inhalation (one observation);

“sniffing unit” minimal amount of odorant(s), present into 1 cubic meter of air, that generates a response of recognition of a certain odour type by an experienced panel member, under field conditions;

“transition point” point halfway between the last absence point and the first presence point at the limit of the recognizable odour plume under investigation.
3 ODOUR ASSESSMENT METHODS

The European Standard (EN 16841-2:2016) process flow for determining the appropriate field inspection method follows as:

For the purpose of this assessment, the Plume Measurement method was chosen to determine the plume extent in the direction of the landholdings under preferential wind conditions. The Plume measurement allows the observers to move around in order to define the plume extents. Given the residential area, housing structures, local natural changes in topography and the dense bushland dividing the landholdings from the WWTP, a stationary method was not suited.
The plume method involves the determination of the presence or absence (YES/NO) of recognizable odours in and around the plume originating from a specific odorant emission source, for a specific emission situation and under specific meteorological conditions (specific wind direction, wind speed and boundary layer turbulence). The unit of measurement is the presence or absence of recognizable odours at a particular location downwind of a source.

The extent of the plume is assessed as the transition of absence to presence of recognizable odour. The results are typically used to determine a plausible extent of potential exposure to recognizable odours, or to estimate the total emission rate based on the plume extent, using reverse dispersion modelling. The plume extent measurement is particularly useful as a starting point for estimating emission rates for diffuse odorant sources where sampling at source is impracticable.

Further assessment of the plumes’ odour impact was undertaken by reference to the VDI Standard where the intensity and frequency of odour observations was determined at the plume extents (length and width). This provided further insight as to the plumes’ potential for odour decay as assessors move further away from the odour source.

3.1 Determination of Plume Extent (European Standard: EN 16841-2:2016)

Panel members are used to determine the presence or absence of the specific odour under investigation at different points downwind of a source under well-defined meteorological conditions. These conditions are chosen to ensure that the extent of the plume is well defined. The meteorological conditions during the field observations are measured and recorded.

Typically, the measurement is repeated to reduce uncertainty to an acceptable level. In this way variability due to random variations in meteorological conditions, panel member performance and odorant emission is averaged out. There are two versions of observation methods for plume extent measurement; stationary plume measurement, and dynamic plume measurement.
Using the dynamic method, the panel members cross the plume, while conducting single measurements at frequent intervals. By successively entering and exiting the plume and in this way determining the transition between absence and presence of recognizable odour, the extent of the plume is defined. This approach helps to avoid adaptation.

The plume direction is crossed at different distances from the source. This includes crossings at distances where no recognizable odour is detected. The maximum plume reach estimate is defined as the distance along the plume direction between the source and the point halfway from the furthest intersection line or crossing where odour presence points were recorded, and the first intersection line or crossing where only odour absence points were recorded. This equal distance between the two intersection lines/crossings is indicated as point 5 on the schematic Figure 1 below.

The plume extent is defined by the transition points. A transition point is the point halfway between adjacent odour absence point and odour presence point for the odour type under study. In order to prevent possible adaptation effects causing incorrect observations, the transition points in the dynamic plume method are only determined whilst entering the plume, and not while exiting.
Figure 1: Schematic diagrams of an example of dynamic plume measurement; in the first drawing the measurement commences moving towards the source; in the second drawing the measurement commences from the source.
3.1.1 Dynamic Plume Method

A measurement cycle consists of at least 20 single measurements at different distances from the source by at least two experienced panel members in order to define at least 6 transition points and finally the odour plume extent. These observations (single measurements) are to be done on foot or by bike.

It is advisable to estimate the plume direction and the rough plume extent beforehand, e.g. by car, as a guide for the measurement. Before starting the observations, timing devices shall be synchronized.

The experienced panel members begin a measurement cycle by starting observations either close to the source or at a certain distance downwind. In case of a complex source situation emitting different odour types, it is advisable to start at a distance downwind where the different odours can be clearly discerned. The objective of these initial observations is to familiarize the experienced panel members with the odour type(s) under investigation. The decision of where to start and which direction to go is to be made by the field observations coordinator.

In order to prevent adaptation to the odour under investigation, panel members regularly go in and out the plume preferably by crossing the plume axis in a zigzag pattern as shown in Figure 1. In certain circumstances it is however allowed to cross only the edge of the plume in a zigzag way, e.g. when the complete crossing of the plume is not possible due to geographical restrictions.

The plume is then repeatedly crossed at different distances from the source in order to cover the whole estimated plume extent. The observations should include crossings at distances downwind where no odour is recognized, in order to ensure that the maximum odour plume reach can be determined.

Each measurement point is chosen by the experienced panel member and is indicated on a topographical map or on a portable GPS-system by adding a waypoint. For each measurement point, the exact time is registered, and also whether or not the odour under
investigation is recognized. Information about other odour types should also be registered.

3.2 Determination of Odour Intensity (German Standard: VDI 3940; 3882 Part 1)

Following the determination of the Plume extent, the assessors then refer to VDI for determining odour intensity at incremental plume extents downwind of the odour source.

With this method, a panel of calibrated and experienced panel members conduct a single measurement(s) at discrete measurement points (defined within the determined odour plume) downwind of the site. Each measurement cycle comprises 60 grab measurements every 10 seconds for a single measurement cycle of 10 minutes. Each grab measurement results in a single Odour Sample. For every single measurement the panel assesses the presence, character and intensity of any observed odours.

The measurement cycle is often reflective of worst-case meteorological conditions. The result of each measurement cycle determines the odour intensity at each measurement point, incremental spaced along the plume extents, and thus determines the resultant odour intensity decay of the plume downwind of the odour source. In general, the objective of a survey is to determine the decay of odours observed downwind of the odour source/s thus defining the odour impact and impact range.

Within the impact range the magnitude of the odour impact can be defined by determining the maximum distance to which the clearly recognizable odour is considered problematic. This is done by firstly assigning a level of odour intensity (the quantitative scale) considered problematic for a given odour source, which would be considered equal to or greater than a nuisance odour intensity. For example; an intensity of 3 (distinct) may be considered the upper limit to which an observed odour is acceptable in the community. Once a 3 is observed, or greater, the odour is clearly recognizable at that measurement point and hence the observed odour can be assigned to the facility being assessed (the recognition threshold). Multiple measurement points within the assessment area impacted by an observed odour intensity of 3 or greater would then make up the impact range. However, the frequency of the odour observations must also be considered.
The observed odour intensities are quantified according to the German Standard VDI 3882 Part 1. The category scale for judging odour intensity in the field is a quantitative reference scale where panel members award one of the attributes in the Table 1 (below) to his or her odour impression.

<table>
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<th>Odour Strength</th>
<th>Intensity Rank (code)</th>
<th>TOU Interpretation (meaning)</th>
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<tr>
<td>Not detectable</td>
<td>0</td>
<td>No odour detected</td>
</tr>
<tr>
<td>Very Weak</td>
<td>1</td>
<td>Odour recognised and assigned to the odour source (recognition)</td>
</tr>
<tr>
<td>Weak</td>
<td>2</td>
<td>Odour is weak but not yet distinct</td>
</tr>
<tr>
<td>Distinct</td>
<td>3</td>
<td>Odour is clearly distinct</td>
</tr>
<tr>
<td>Strong</td>
<td>4</td>
<td>Strong odour detectable</td>
</tr>
<tr>
<td>Very Strong</td>
<td>5</td>
<td>If offensive, observer may consider moving from the area</td>
</tr>
<tr>
<td>Extremely Strong</td>
<td>6</td>
<td>Odour is sufficiently over-powering that assessor moves from area</td>
</tr>
</tbody>
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An odour is clearly recognised (category of intensity 1) when the odour quality and hence an origin of the odour source can be clearly assigned.

The use of VDI 3940 will allow additional interpretation of the odour plume to determine of the entire odour plume elicits an odour impact, or if the farthest downwind extents of the plume exhibit sufficiently low odour intensities and frequency of observations thus demonstrating that the entire plume is not necessarily constrained as an odour impact. In other words, the Plume method can be further refined using observations of odour intensity along the extents and within the plume.
3.3 Selection of Assessors and Odour Panel

- The initial selection of assessors is carried out according to AS/NZS4323.3:2001 Dynamic Olfactometry;
- The panel selection is carried out before the field observations are conducted. The assessment of compliance with the panel selection criteria shall not be dated more than 6 months before the date of field observations;
- Valid observations shall only be carried out by panel members;
- To become an experienced panel member for the dynamic method a panel member shall participate at least five times in a measurement cycle with at least three distinct odour types;
- The size of panel to be used in one measurement cycle shall be;
  - For the dynamic plume method a minimum of two experienced panel members is required, to make measurements simultaneously.

3.4 Accompanying Meteorological Measurements

Representative meteorological measurements of the area were carried out during the measurement cycle for the following parameters:

- Wind speed;
- Wind direction; and
- Temperature.

Additional visual observations should also be made for unusual features, e.g. precipitation, mist, snow, during each measurement cycle.
4 SCOPE OF WORKS SUMMARY & ASSESSMENT AREA

TOU deployed two personnel to Darwin to undertake the Plume Measurement field inspection method and supporting odour intensity and frequency method. The logistics and project steps are summarised as follows:

(i) Deploy to Darwin on Thursday 23rd February 2017;
(ii) Undertake a reconnaissance of the WWTP and surrounding primary assessment area and determine the odour type, plume extent and constraints to the assessment methods;
(iii) Starting around 5-6AM each day, undertake the first of multiple measurement cycles prescribed by the Dynamic Plume Method for one complete field survey, with an expectation that a minimum of two (2) cycles will be completed each day to determine the odour plume reach and width;
   a. each measurement cycle will consist of at least 20 single measurement points;
   b. the length of each measurement cycle will depend upon the clear observation of an odour plume; however, the expectation is that one measurement cycle will take up to 2 hours to complete including Odour Intensity determination;
   c. Depending on local weather conditions, TOU may undertake the method in the early AM and possibly in the PM hours to achieve a representative dataset;
(iv) During each measurement cycle assessors will undertake odour intensity determination at incremental locations along the plume extent, or at locations it deems of relevance during the measurement cycle;
(v) scrutiny of field observations and subsequent mapping of findings;
(vi) determination of plume reach, width and derived impact area for each measurement cycle;
(vii) overlay of all measurement cycles to determine the maximal plume reach, width and derived impact area; and
(viii) determination of overall plume odour impact by consideration of odour intensity observations along the plume extents.
4.1 Odour Assessment Area

The odour source that is the subject of this assessment is the Leanyer-Sanderson WWTP, Darwin NT. The odour assessment area is primarily focused within the north-west quadrant adjacent to the WWTP. Other assessment areas under differing wind conditions were decided upon at the time of each daily assessment.

The primary assessment area is designated by the two yellow-dashed polygons to the north-west of the WWTP (refer Figure 2 below). Also designated is the newly developed and under construction residential area (blue polygon). The WWTP itself consists of a Ponds system with inlet chambers and other infrastructure. It should be noted that the treated effluent is discharged into Buffalo Creek directly north of the WWTP ponds.

The assessment area focused primarily on the residential area within the blue polygon. Line of sight to the ponds was only achieved along Fitzmaurice Drive (refer Figure 3). TOU undertook the dynamic plume method along Fitzmaurice Drive and within the residential area where odour was detectable.

During easterly wind conditions TOU observed the odour directly along the Fenceline of the WWTP and compared that odour character to the observable odour downwind of the WWTP. Under differing wind conditions TOU attempted to traverse the dense bushland as much as possible.
Figure 2: Layout of Leanyer-Sanderson WWTP (green polygon), adjacent Residential development (blue polygon) and primary Assessment Areas (yellow dashed polygons)
Figure 3: Layout of Existing and Under Construction adjacent Residential Area (Fitzmaurice Drive southern road and dotted line)
5 PRELIMINARY ODOUR PLUME DETERMINATION

TOU undertook a preliminary odour plume reconnaissance on Thursday, February 23\textsuperscript{rd} from approximately 3PM onward, unfortunately the winds were from the west and line of sight was not achievable on that day.

Traversing the southern downwind surrounds was possible only up to a distance of approximately 1.2kms via access off Vanderlin Drive. No odour was detected.

On Saturday, 25\textsuperscript{th} February the winds were originating from the east in the early AM periods. TOU was then able to better determine an odour plume determination following observations of the pond odours made from the ponds fenceline along the western boundary of the WWTP.

The odour plume was observable along Fitzmaurice Drive only, and during the observations was narrow and intermittent with low odour intensity. The plume barely extended beyond the Power and Water boundary with intermittent low intensity odours at the extent; moreover, the plume width was difficult to observe since local terrain effects provided buffering of the odour; however, TOU estimated the width to be approximately 150m. Figure 4 to follow shows the pre-determined odour plume length and width observations between 6AM – 9AM.

Replicating the odour plume proved difficult thereafter due primarily to wind conditions, but also due to local obstacles such as terrain and building structures. Spot odour observations were made further within the residential area. These observations along with all assessment observations are detailed in Section 8.
Figure 4: Preliminary Odour Plume Determination on Saturday, 25th February
6 LOCATIONS OF FIELD INSPECTION POINTS

The positions of the main field inspection locations are listed below. The numbering of the inspection points don’t reflect the order in which they were assessed, the numbering is purely for I.D purposes. The field inspection locations can be viewed on Figure 5.

Other locations were also inspected for the purposes of determining other odour sources and to establish areas where field inspections could take place. These locations are depicted as yellow dots on Figure 5.

Table 2: Field Inspection Locations

<table>
<thead>
<tr>
<th>Location Address</th>
<th>Location Characteristics</th>
<th>Downwind Compass Bearing</th>
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<tr>
<td>1 Fitzmaurice Drive @ Power &amp; Water Gate</td>
<td>At the outer boundary of the WWTP</td>
<td>ENE</td>
</tr>
<tr>
<td>2 Fitzmaurice Drive adjacent to Withnall Circuit</td>
<td>Along Fitzmaurice Drive</td>
<td>ENE</td>
</tr>
<tr>
<td>3 Withnall Circuit</td>
<td>Adjacent to open space; No line of sight to WWTP</td>
<td>E</td>
</tr>
<tr>
<td>4 Withnall Circuit</td>
<td>Adjacent to open space; No line of sight to WWTP</td>
<td>E</td>
</tr>
<tr>
<td>5 Spargo Street</td>
<td>Middle of Street length; No line of sight to WWTP</td>
<td>E</td>
</tr>
<tr>
<td>6 Ward Crescent</td>
<td>Adjacent to open space; No line of sight to WWTP</td>
<td>E</td>
</tr>
<tr>
<td>7 Ward Crescent</td>
<td>Adjacent to open space; No line of sight to WWTP</td>
<td>E</td>
</tr>
<tr>
<td>I.D</td>
<td>Location Address</td>
<td>Location Characteristics</td>
</tr>
<tr>
<td>-----</td>
<td>----------------------------------------</td>
<td>--------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>8</td>
<td>Withnall Circuit / Barratt Street Corner</td>
<td>Within Residential area; No line of sight to WWTP</td>
</tr>
<tr>
<td>9</td>
<td>Mahoney Street</td>
<td>Adjacent to open space; No line of sight to WWTP</td>
</tr>
<tr>
<td>10</td>
<td>Mahoney Street / Hannan Street Corner</td>
<td>Adjacent to open space; No line of sight to WWTP</td>
</tr>
<tr>
<td>11</td>
<td>Mahoney Street / Lemke Street Corner</td>
<td>Adjacent to open space; No line of sight to WWTP</td>
</tr>
<tr>
<td>12</td>
<td>Mahoney Street / Hargrave Street Corner</td>
<td>Adjacent to open space; No line of sight to WWTP</td>
</tr>
<tr>
<td>13</td>
<td>Hargrave Street</td>
<td>Adjacent to open space; No line of sight to WWTP</td>
</tr>
<tr>
<td>14</td>
<td>Street Drainage Runoff</td>
<td>Adjacent to open space; No line of sight to WWTP</td>
</tr>
<tr>
<td>15</td>
<td>Newmarch Street Corner</td>
<td>Adjacent to Park within Residential area; No line of sight to WWTP</td>
</tr>
<tr>
<td>16</td>
<td>Lee Point Road / Asche Street Corner</td>
<td>Main Road &amp; within Residential area</td>
</tr>
<tr>
<td>17</td>
<td>Lee Point Road / Fitzmaurice Corner</td>
<td>Main Road &amp; within Residential area; general line of sight to WWTP ponds</td>
</tr>
<tr>
<td>18</td>
<td>Lemke Street / Coleman Street Intersect</td>
<td>Adjacent to Park within Residential area; No line of sight to WWTP</td>
</tr>
<tr>
<td>19</td>
<td>Fenceline of Power &amp; Water</td>
<td>Adjacent to Creek; No line of sight to WWTP</td>
</tr>
<tr>
<td>LD</td>
<td>Location Address</td>
<td>Location Characteristics</td>
</tr>
<tr>
<td>----</td>
<td>----------------------------------</td>
<td>------------------------------------------</td>
</tr>
<tr>
<td>20</td>
<td>Fenceline of WWTP Ponds</td>
<td>Clear line of sight to WWTP Ponds</td>
</tr>
<tr>
<td>21</td>
<td>Fenceline of WWTP Ponds</td>
<td>Clear line of sight to WWTP Ponds</td>
</tr>
<tr>
<td>22</td>
<td>Fenceline of WWTP Ponds</td>
<td>Clear line of sight to WWTP Ponds</td>
</tr>
<tr>
<td>23</td>
<td>Fenceline of WWTP Ponds</td>
<td>Clear line of sight to WWTP Ponds</td>
</tr>
<tr>
<td>24</td>
<td>Hodgson Drive</td>
<td>Adjacent to bushland; No line of sight to WWTP</td>
</tr>
<tr>
<td>25</td>
<td>Buffalo Creek Road</td>
<td>Adjacent to bushland &amp; Caravan Park waste ponds; No line of sight to WWTP</td>
</tr>
</tbody>
</table>
Figure 5: Position of Main Field Inspection Locations surrounding the WWTP (yellow numbers) as well as other locations for inspection (yellow dots)
## 7 FIELD INSPECTION MEASUREMENT DAYS & WEATHER CONDITIONS

<table>
<thead>
<tr>
<th>Date &amp; Day</th>
<th>Time of Field Inspections</th>
<th>Darwin AP AWS 0630hrs Observations</th>
<th>Darwin AP AWS 1400hrs Observations</th>
<th>Temp. (min)</th>
<th>Temp. (max)</th>
<th>Rain</th>
<th>Relative Humidity @ 0630hrs</th>
<th>Cloud @ 0900hrs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Wind Direction</td>
<td>Wind Speed</td>
<td>Temp.</td>
<td>Wind Direction</td>
<td>Wind Speed</td>
<td>Temp.</td>
<td>mm</td>
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<tr>
<td>Thursday, 23&lt;sup&gt;rd&lt;/sup&gt; February</td>
<td>1500 - 1800</td>
<td>SSW</td>
<td>7</td>
<td>26.2</td>
<td>WNW</td>
<td>20</td>
<td>33.6</td>
<td>26.0</td>
</tr>
<tr>
<td>Friday, 24&lt;sup&gt;th&lt;/sup&gt; February</td>
<td>0630 – 1100; 1200 – 1400</td>
<td>WNW</td>
<td>13</td>
<td>28.4</td>
<td>NNW</td>
<td>11</td>
<td>30.8</td>
<td>28.3</td>
</tr>
<tr>
<td>Saturday, 25&lt;sup&gt;th&lt;/sup&gt; February</td>
<td>0630 – 1100; 1200 – 1400</td>
<td>ENE</td>
<td>2</td>
<td>25.3</td>
<td>ESE</td>
<td>7</td>
<td>29.6</td>
<td>25.3</td>
</tr>
<tr>
<td>Sunday, 26&lt;sup&gt;th&lt;/sup&gt; February</td>
<td>0630 – 1100; 1200 – 1400</td>
<td>SSW</td>
<td>7</td>
<td>26.2</td>
<td>WNW</td>
<td>19</td>
<td>32.2</td>
<td>25.7</td>
</tr>
<tr>
<td>Monday, 27&lt;sup&gt;th&lt;/sup&gt; February</td>
<td>0630 – 1100; 1200 – 1400</td>
<td>S</td>
<td>6</td>
<td>25</td>
<td>NNW</td>
<td>15</td>
<td>33.4</td>
<td>24.2</td>
</tr>
<tr>
<td>Tuesday, 28&lt;sup&gt;th&lt;/sup&gt; February</td>
<td>0630 - 1100</td>
<td>WSW</td>
<td>7</td>
<td>25.2</td>
<td>NNW</td>
<td>15</td>
<td>32.7</td>
<td>23.9</td>
</tr>
</tbody>
</table>

The daily 10 minute Darwin Airport AWS observation, for each full day are presented below as Windroses.
Thursday, 23rd February

Friday, 24th February

Saturday, 25th February

Sunday, 26th February

Monday, 27th February

Tuesday, 28th February
8 FIELD INSPECTION RESULTS

During the assessment period TOU was able to make direct observations of the WWTP odours at the fence line (refer Figure 6: positions 20, 21-23). The odour character was typically characteristic of WWTP ponds, namely slight H$_2$S, stagnant and sour with a slight faecal (toilet) character. The odour character was not observed to be a strong odour at the fence line, that is, the odour intensity according to VDI 3882 Part 1 (refer Table 1) was less than a 4, and rarely observed as a 3. Although the character was clearly discernible, the intensity was not high.

It would appear that the ponds were operating well and that upset conditions such as inlet chamber malfunctions, or dried beds etc were not prevalent. Given TOU's observations on the fence line took in the entire breadth of the ponds, the observations were highly repeatable at the fence line.

When TOU moved away from the fence line and down Fitzmaurice Drive, still on the WWTP access road, the odour became far less observable and was lost within the dense bushlands. The character then became a dilute, slight wastewater odour which was observed offsite (away from the ponds) on few occasions.

There are a large amount of drainage ways and runoff catchments in the area, together with runoff creeks and the encroaching Buffalo Creek toward the WWTP. The existence of large accumulations of water, both flowing and stagnant, may be a source of low level odour in localised areas.

The Darwin area was in the wet season during the assessment period; however, the month of February had very low to nil rainfall (mm) in the second half of the month. This made for a suitable time to do the assessment in the wet season because high rain events that would purge and dilute the WWTP ponds were not prevalent in the lead up to the assessment period. It can be seen from Table 3 below that the week of the 15$^{th}$ – 21$^{st}$ February had only 12.4mm of rain, whilst during the week of the assessment rainfall was 87mm toward the end of February and those rainfall events were in the evening.
Table 3: Rainfall statistics for February 2017 (Darwin AP AWS)

<table>
<thead>
<tr>
<th>Date</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
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<tbody>
<tr>
<td>Day</td>
<td>Wed</td>
<td>Thurs</td>
<td>Friday</td>
<td>Sat</td>
<td>Sun</td>
<td>Mon</td>
<td>Tues</td>
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<tr>
<td>Rainfall (mm)</td>
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<td>9.2</td>
<td>6.2</td>
<td>4.2</td>
<td>201.8</td>
<td>56</td>
<td>5.6</td>
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<tr>
<td>Date</td>
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<td>9</td>
<td>10</td>
<td>11</td>
<td>12</td>
<td>13</td>
<td>14</td>
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<tr>
<td>Day</td>
<td>Wed</td>
<td>Thurs</td>
<td>Friday</td>
<td>Sat</td>
<td>Sun</td>
<td>Mon</td>
<td>Tues</td>
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<tr>
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<td>70.8</td>
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<td>16</td>
<td>17</td>
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<td>19</td>
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<td>21</td>
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<tr>
<td>Day</td>
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<td>Thurs</td>
<td>Friday</td>
<td>Sat</td>
<td>Sun</td>
<td>Mon</td>
<td>Tues</td>
</tr>
<tr>
<td>Rainfall (mm)</td>
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<td>0</td>
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<tr>
<td>Day</td>
<td>Wed</td>
<td>Thurs</td>
<td>Friday</td>
<td>Sat</td>
<td>Sun</td>
<td>Mon</td>
<td>Tues</td>
</tr>
<tr>
<td>Rainfall (mm)</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>15.4</td>
<td>49.8</td>
<td>21.8</td>
</tr>
</tbody>
</table>

8.1 Determination of Plume Extent (European Standard: EN 16841-2:2016)

The determination of the plume length and width was unable to be successfully completed due to the local topographical features (dense bush, tall grasses, dense housing etc) and the inability to achieve a clear line of sight to the WWTP. This was expected to some degree, although TOU was not previously aware of the obstructions between the WWTP and the assessment area.

Determining an odour plume, using the dynamic method, within a built up residential area, is often a difficult task because the stagnation and movement of the odour plume under very low wind conditions means that the plume often stalls.

Nonetheless, TOU was successful on Saturday, 25th February in determining the odour plume length and width in the early morning hours under a direct line of sight (easterly winds) and with winds in the typical range of 0.5 – 2.0m/s. The odour plume was determined to be approximately 5-600m long x 150m wide. The plume was observed on two occasions at those approximate dimensions when winds began to shift around the easterly bearing (Refer Figure 4).
Given the early time of day in observing the odour plume, it is likely that the WWTP was receiving waste during a peak AM period.

There were other observations of odour within the residential area; these were considered as "spot" locations where odour was observable but only in the immediate vicinity. Further investigation both up, and downwind of those spot locations showed no observable odour. Barratt Street on two occasions had an observable spot odour location. The odour did resemble a stagnant water/wastewater character, but given the lack of observations upwind of the location, the origin of the odour was not readily identified.

Overcoming this required TOU to make odour intensity observations at set locations (refer Figure 6) and record the presence, intensity and frequency of odour observations over discrete 10-minute periods.

8.2 Determination of Odour Intensity (German Standard: VDI 3940; 3882 Part 1)

TOU undertook field inspections for odour on each day of the project duration with the scope of undertaking a minimum of ten (10) discrete field inspection surveys.

The wind characteristics during each field inspection were largely stable in direction with typical intermittent lateral flux, although fluxing winds were very low and consequently odour plumes were largely directionally fixed during these field inspections with multiple periods of calm winds, or stalls in wind speed.

Observing odour beyond typically 5-600m was nil. The odour plumes tended to be localised along Fitzmaurice Drive, close to the Power and Water gate, due to a line of sight. There were no odour observations within the landholdings of 2CRU and Muirhead North. The density of the natural bushland and long grasses meant that ground level odours were trapped in periods of calms or stalls.

Breeze conditions following stalls failed to show plume stagnation and meander within the residential area beyond the intermittent plume extent; although spot odour along Barratt
Street was observed without successful determination of its origin. This spot odour was localised between two houses only and suggest that a local issue may be the origin.

The individual field inspections on each day are presented below as illustrations of the recorded odour intensity and frequency (pie charts) at each field inspection location on an assessment map. The maps are illustrative and do not specifically represent the exact locations down to the nearest metre, they do however show the relative position of observations and the wind vector within which observations are made.

Of the assessment days there were only two (2) days that observable odour was detected. The wind conditions made observing odour difficult due to topographical constraints under westerly and northerly conditions; as such the field inspections on these days was focused on finding other sources of upwind odour whilst also venturing as far deep, toward the WWTP, as local conditions would allow and accounting for personnel safety.

White pie charts indicate no odour was detected.

The light blue polygon represents the average wind direction for the duration of the field inspection/s where odour observations were made.
Defence Housing Australia, Darwin NT
Odour Impact Assessment - Field Odour Inspection of Leanyer-Sanderson WWTP, Darwin NT
9 RESULTS & CONCLUSIONS

The field inspection odour impact assessment resulted in low intensity and frequency of odour impacts being detected up to nominally 5-600m downwind of the nearest WWTP pond with intermittent observations. These observations were under easterly wind conditions with the least amount of physical obstructions between the observation locations and the WWTP ponds.

There were no additional odour sources in and around the assessment area other than natural accumulations of water in creeks, as well as rainfall runoff levees. At times these water sources exhibited very low stagnant water odours, but not characteristic of WWTP odours.

During observable odour events, the plume was narrow and rarely meandered, in particular after calm periods where stagnation and subsequent meander would occur. The lack of observable odour during preferential wind conditions suggests a number of reasoning's, such as:

1. Good performance of process at the WWTP;
2. Lack of upset conditions such as inlet works breakdowns;
3. Lack of drying out of ponds where sludge may be exposed;
4. Control of sludge;
5. Lack of anaerobic conditions where algal blooms may occur;
6. Lack of cleared lands to sufficiently allow low intensity odour to carry large distances offsite.

However; the contrary to any of the above points 1-5 would in all likelihood generate odour impacts at distances greater than the observed. These types of odour impacts under those upset conditions would be the responsibility of the WWTP and its process operations rather than a typical event in the daily running and maintenance of modern WWTP’s and associated secondary and infiltration/evaporation ponds.

TOU did not find any conditions, nor reason to suggest that odour impacts would be of a sufficient strength, frequency and intensity to impact on the Muirhead North and 2CRU land holdings. Moreover, the dense residential development that separates the land...
holdings from the WWTP are already heavily populated and thus local complaints would be a more meaningful representation of odour impacts from the WWTP.

If odour impacts are recorded, the process conditions at the WWTP must be investigated to determine if upset conditions prevail. In TOU’s extensive experience with WWTP’s across Australia, the incidence of upset conditions, in particularly related to control of the inlet works and algal bloom events, can lead to increased odour impacts offsite; however, once an upset condition is known it can be communicated and remedied.

The Masterplan NT report, specifically the GHD contribution where an odour impact assessment was undertaken at the Leanyer-Sanderson WWTP, found that peak offsite odour impacts may occur under specific wind conditions, but that they also would arise under non-standard conditions such as:

a) Odour impacts from sludge exposure in lagoons (ponds) where supernatant falls to levels allowing exposure;
   a. can be managed and mitigated by ensuring supernatant levels are above the sludge layer,
   b) Continued use of uncovered inlet chambers;
   a. can be managed by installing covers with an expected decrease in the primary odour source emissions of 25%.

GHD also discussed the management of sludge which requires partial desludging of the ponds every 4-6 years, although typically on an as-needs basis and may extent out to ten years. An event such as desludging has the potential to create far reaching odour impacts offsite; however, the planning of this and communication with the residents allows for an upset condition to be prepared for and managed accordingly.

The GHD report found that the existing odour emissions under standard operating conditions, coupled with the planned increase in capacity at the WWTP over coming years would result in a Low risk for a subdivision application at approximately 500m downwind of the WWTP. The subdivision boundary is in line (generally) with the main gate at the Power and Water entry to site. In consideration of a refurbished WWTP the risk of nuisance odours at this distance is Low according to the GHD report.
It is the opinion of TOU that the findings of the odour impact field inspection within the north-west assessment area surrounding the Leanyer-Sanderson WWTP support the judgement that odour impacts on the DHA land holdings 2CRU and Muirhead North would be negligible and in all likelihood nil. This conclusion is based on the standard operations of the WWTP.

The separation distance for Muirhead North, (at least 1.3kms) is a considerable separation distance as is that for the 2CRU land holding where the separation distance is 1.9kms. There is also no line of sight to the WWTP.

In the event of upset conditions at the WWTP the incidence of far reaching odour impacts may prevail; however as discussed, upset conditions are non-standard practice and can be managed, mitigated, and in some instances planned for. The existence of high-density residential areas between the DHA land holdings and the WWTP further suggests that the WWTP is under more scrutiny to improve and maintain its performance given the encroachment of potential complainants. Approvals to develop these areas also suggest that confidence in the running of the WWTP is high or improving, and communication between the WWTP operators and local regulators is apparent.

The GHD report further solidifies TOU’s position given the extent to which the GHD report sampled and assessed the WWTP. The report showed at peak times and under proposed operations (i.e. expansion) a ground level concentration of 2ou would not reach the DHA land holdings. GHD referred to the Victorian EPA odour performance criterion of 1ou at the boundary, 3-minute averaging times at 99.9th percentile. This criterion is in TOU’s opinion excessive and largely untenable for a ponds configuration WWTP i.e. without covered inlets, extraction and bio-scrubber/bio-trickling filtration and subsequent exhaust via chemical treated stacks (or similar best-practices). If the predictions from the GHD report were realised then there would be significant odour complaints within the existing residential areas.

TOU holds the opinion that the Leanyer-Sanderson WWTP, operating at standard practices with all care taken to mitigate upset conditions would not have an odour impact on the DHA land holdings to the north-west of the WWTP.
REFERENCES

- BS EN 16841-2:2016. Ambient air. Determination of odour in ambient air by using field inspection. Plume method
- BS EN 16841-1:2016. Ambient air. Determination of odour in ambient air by using field inspection. Grid method
- VDI 3882-1:1992. Olfactometry; Determination Of Odour Intensity