

Darwin LNG

Fugitive Emissions Management Plan

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Symbols and Acronyms

Term	Definition
%	Percent (percentage)
AEMR	Annual Environmental Monitoring Report
ALARP	As Low As Reasonably Practicable
CCR	Central Control Room
CMMS	Computerised Maintenance Management System
DLNG	Darwin LNG
EPL217-05	Environment Protection Licence 217-05
FEMP	Darwin LNG – Fugitive Emission Management Plan
FID	Flame Ionization Detector
GHG	Greenhouse Gas
IMS	Incident Management System
IRR	Integrated Risk Register
Km	Kilometre
LDAR	Leak Detection and Repair
LEL	Lower Explosive Limit
LNG	Liquefied Natural Gas
LOPC	Loss of Primary Containment
LPG	Liquefied Petroleum Gas
MOC	Management of Change
Mtpa	Million Tonnes per Annum
NGER	National Greenhouse and Energy Reporting
NT	Northern Territory
NT EPA	Northern Territory Environment Protection Authority
OGCI	Oil and Gas Climate Initiative
PID	Photo Ionization Detector
ppm	Parts per million
PV	Pressure valve
RBWS	Risk-Based Work Selection
related bodies corporate	As defined under the <i>Corporations Act 2001</i> (Cth)
Santos	Santos Limited
Santos Barossa	Santos NA Barossa Pty Ltd
Santos NA	Santos NA Darwin Pipeline Pty Ltd
SFAIRP	So Far As Is Reasonably Practicable
SMS	Santos Management System
UAV	Unmanned Aerial Vehicle
US EPA	United States Environmental Protection Agency
VOC	Volatile Organic Compound
WMPC Act	Waste Management and Pollution Control Act (NT)

1. Introduction

Santos NA Darwin Pipeline Pty Ltd (**Santos NA**) operates the Darwin Liquefied Natural Gas (**DLNG**) facility on behalf of Darwin LNG Pty Ltd. The DLNG facility receives dry natural gas from the Santos NA Barossa Pty Ltd (**Santos Barossa**) operated Barossa Field (located within Commonwealth petroleum production licence NT/L1) via the 385 kilometre (**km**) long Barossa Gas Export Pipeline.

The DLNG facility is located at Wickham Point on the Middle Arm Peninsula in Darwin Harbour, approximately six km's south to south-east of Darwin (**Figure 1-1**). The DLNG facility has a production capacity of 3.7 Mtpa from a single LNG train that utilises the Optimized Cascade® process.

DLNG operates under Environment Protection Licence 217-05 (**EPL217-05**) issued under Section 34 of the Northern Territory (**NT**) *Waste Management and Pollution Control Act 1998*. This Act is administered by the Northern Territory Environment Protection Authority (**NT EPA**) with departmental support provided by the Department of Lands, Planning and Environment (**DLPE**). This Fugitive Emissions Management Plan (**FEMP**) is a requirement of EPL217-05, specifically Condition 44, as referenced below:

44 Fugitive Emissions

The licensee must provide to the Northern Territory Environment Protection Authority a Fugitive Emissions Management Plan to prevent and manage fugitive emissions to a level that is ALARP and acceptable to the NT EPA. The Fugitive Emissions Management Plan must:

- 44.1 *include a leak detection and repair program that:*
 - (a) *annually tests all accessible components that could potentially leak VOCs or methane, such as flanges and other connections, valves, gaskets, pump and compressor seals, process drains and vents, pressure relief devices, vessels and tanks;*
 - (b) *is in accordance with US EPA method 21 (Optical Gas Imaging can be used to detect leaks and a calibrated FID or PID instrument used to measure the leak concentration);*
 - (c) *sets out what actions will be taken in the case of a leak detection; and*
 - (d) *defines the leak concentration above which repair will be undertaken, if possible, and the proposed timing to finalise repair.*
- 44.2 *include annual monitoring of fugitive methane emissions from the DLNG storage tank using best practice methods; and*
- 44.3 *be submitted within 6 months of the issue of this Licence.*

For the purpose of this plan, fugitive emissions can be defined as releases “*which could not reasonably pass through a stack, vent, or other functionally-equivalent opening*” (DEECCW, 2012) and is limited to Volatile Organic Compounds (**VOCs**), primarily methane.

Santos Limited including its related bodies corporate (**Santos**) is committed to continuous improvement of its emissions performance and reporting, is a member of the Oil and Gas Climate Initiative (**OGCI**), and a signatory to Aiming for Zero Methane Emissions. Santos continues to meet the OGCI 2025 target for methane emissions intensity, which is “below 0.2%”. Santos invests across the portfolio in emissions reduction where it has maximum impact.

1.1 Purpose

The purpose of the FEMP is to outline the requirements and detail the methodologies to prevent and manage fugitive emissions from DLNG to a level that is as low as reasonably practicable (**ALARP**) and acceptable to the NT EPA. This FEMP details a Leak Detection and Repair (**LDAR**) Program that meets the requirements of Condition 44.1 and includes a program for the annual monitoring of fugitive methane emissions from the DLNG storage tank using best practice methods that meets the requirements of Condition 44.2.

1.2 Scope

The scope of the DLNG FEMP includes all facilities within the DLNG boundary shown in **Figure 1-2**. Battery limits for DLNG are also detailed in the Darwin LNG – Operations Environmental Management Plan (1U00-650-EMP-0002).

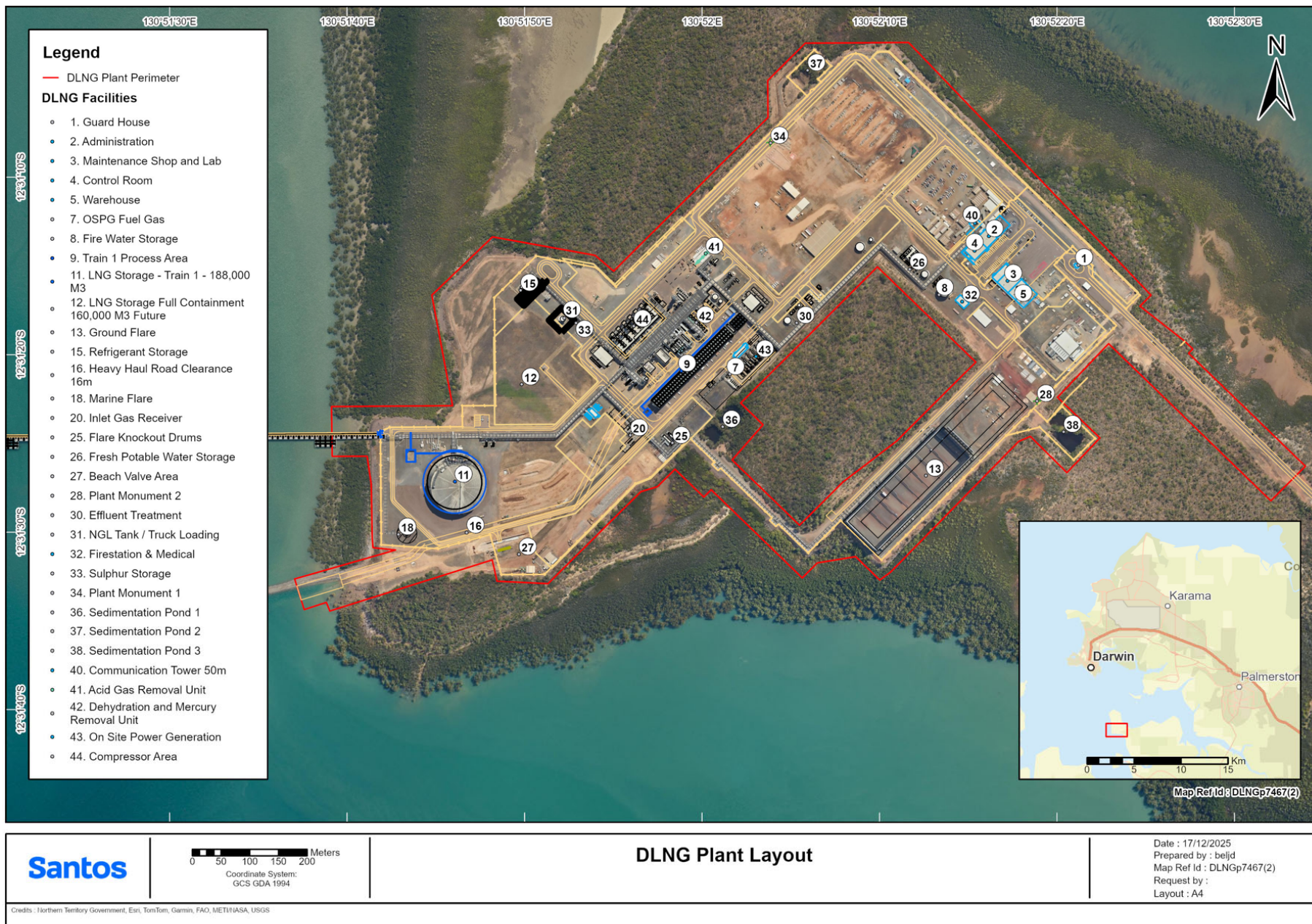


Figure 1-2: DLNG Plant Layout and Perimeter Boundary

2. Potential Sources of Fugitive Emissions

The DLNG facility occupies an area of approximately 65 hectares. The gas processing train is located in proximity to the centre of the site (**Figure 1-2**), with the LNG storage tank and jetty (partially shown in **Figure 1-2**) to the west of the DLNG facility.

The DLNG facilities relevant to the FEMP, their relevant Unit number and location within DLNG (as shown in **Figure 1-2**) are outlined below:

- Gas receiving facilities (including beach valve, pig receiver and meter station for the Barossa Gas Export Pipeline) (Unit 11) (refer to **Figure 1-2**, references 20 and 27);
- Acid gas removal (Unit 12) (**Figure 1-2**, reference 41);
- Dehydration and mercury removal (Unit 13) (**Figure 1-2**, reference 42);
- Propane refrigeration (Unit 14) (**Figure 1-2**, reference 9 and 44);
- Ethylene refrigeration (Unit 15) (**Figure 1-2**, reference 9 and 44);
- Liquification and methane compression (Unit 16) (**Figure 1-2**, reference 9 and 44);
- Heavies removal (Unit 17);
- Flare, vent and incineration systems (Unit 19) (**Figure 1-2**, references 13, 18, and 44);
- Refrigerant storage (Unit 20) (**Figure 1-2**, reference 15);
- Diesel storage and Natural Gas Liquid Storage and Transfer (Unit 21) (**Figure 1-2**, reference 31);
- Fuel gas system (Unit 22);
- LNG storage and loading (Unit 24) (**Figure 1-2**, reference 11);
- Effluent/stormwater/sewage treatment (Unit 29) (**Figure 1-2**, reference 30);
- Onsite power generation facility and standby generation (Unit 31) (**Figure 1-2**, reference 43); and
- Steam generation system (Unit 38).

3. Leak Detection and Repair Program

The LDAR program outlined below aligns with inspection processes, standards, and capabilities of the United States Environmental Protection Agency (US EPA) Method 21 – Determination of Volatile Organic Compound Leaks (US EPA, n.d.). The implementation of the LDAR program is integral to ensuring fugitive emissions are managed to ALARP. Some key principles of the LDAR program are outlined below:

- Instruments will be selected and operated to ensure that they are fit for purpose, increase the probability of detecting fugitive emissions to manage to ALARP, enhance safety and reduce gas product loss. Instruments used at DLNG are outlined in **Appendix A – Instruments**;
- All fugitive emission surveys will be conducted by suitably trained personnel using appropriate instruments that are maintained, calibrated and tested in accordance with manufacturer’s instructions; and
- Adherence to US EPA Method 21 operation and calibration procedures (as applicable to relevant instruments).

3.1 Emissions Classification

The Santos Management System (SMS) sets the mandatory requirements for how Santos manages and operates the business. The DLNG Operations Environmental Management Plan (1U00-650-EMP-0002) provides further details on the SMS. In the event of any inconsistency between the FEMP and SMS, the SMS requirements take precedence.

The SMS includes the Santos *Event Classification Technical Standard* that defines Process Safety Events and how to categorise and classify them. Fugitive emissions may be classified as a process safety event under the SMS where they represent an unplanned or uncontrolled loss of primary containment.

In the Santos *Event Classification Technical Standard*, the Tiered classification system is aligned with API RP 754 and intended to indicate the severity of the event with Tier 1 being the highest severity. Tier classification aligned with API RP 754 threshold quantities must be applied to all Loss of Primary Containment (LOPC) events.

The release thresholds for classifying LOPC Tier 1 & Tier 2 events are provided in **Table 3-1**. A Tier 3 LOPC is any LOPC event involving hazardous materials and release conditions that do not meet the definition of a Tier 1 or Tier 2 event.

Table 3-1: LOPC Tier 1 & Tier 2 Release Thresholds for Flammable Gases and Liquids

Hazardous Process Material Type and Release Conditions	Examples of common Santos process fluids of this type ¹	1-hour release thresholds			
		Tier 2		Tier 1	
		Outdoors	Indoors ⁵	Outdoors	Indoors ⁵
Flammable Gases	Raw gas, Sweet / Sales gas, Instrument gas, Ethane, Ethylene, Propane, Butane, Hydrogen	50 kg	25 kg	500 kg	50 kg
Liquids with initial boiling point ≤ 35°C and flash point < 23°C, ADG Class 3 Packing Group I	LNG, Unit Oil, Light condensate, Unstabilised crude, Light naphtha, LPG, Ethylene, Propane, Butane				
Note 1	This list is not comprehensive				
Note 5	The term 'indoors' is defined per API RP754 as being within a structure composed of four complete (floor to ceiling) walls, floor, and roof.				

The *Loss of Primary Containment release rate calculator (1541-012-WPR-0055)*, accessible via the Santos Incident Management System (IMS), allows calculation of the release size and hence Tier classification given the process material type, hole size, pressure and release duration. It assumes constant release rate for the full duration and is a simplified tool. The tool also provides estimates of the 'equivalent diameter' for holes that are not round.

3.2 Detection Methodology

Detection of fugitive emissions will be undertaken via the implementation of three planned methodologies as outlined below:

- Routine Operator Surveillance;
- Fixed Gas Detection; and
- Scheduled Detection and Quantification Surveys.

These methodologies are outlined in detail in the sections below.

3.2.1 Routine Operator Surveillance

DLNG facility inspections, as part of regular surveillance of facility performance and safe operations, are carried out daily. Each operations team member carries a Santos approved personal gas detector (refer to **Appendix A – Instruments**) during facility inspections to aid in the detection of fugitive emissions. Operators are trained in the use of the gas detectors. The gas detectors are calibrated and used in accordance with the manufacturer's requirements.

If an operator detects a gas in the atmosphere, they must identify the source if it is safe to do so; otherwise, follow the DLNG emergency response procedure. The operator then manages the fugitive emission as per **Section 3.3** and **3.4** of this plan.

3.2.2 Fixed Gas Detection

The DLNG fixed gas detection system includes flammable gas detectors. Over 120 Infrared Point Gas Detectors (**IRPGDs**) and over 90 Open Path Gas Detectors (**OPGD**) are provided in the following locations:

- At optimised positions for area monitoring around pumps, groups of equipment, or facilities where methane or other lighter gases are being handled;
- Around the compressors handling flammable gases;
- Inside each analyser house (part of the packaged analyser systems);
- At each air intake of buildings which are normally pressurised; and
- At air intakes of compressors and fired equipment.

This system is aimed at detecting flammable gases to prevent major hazardous events such as explosions and fire, and also detects fugitive emissions from process equipment, pipelines, valves and flanges etc.

In the case of detection, an alarm would display in the Central Control Room (**CCR**). The CCR is monitored by trained personnel 24/7. A low alarm is set at 10% of the Lower Explosive Limit (**LEL**) of gas mixtures and a high alarm is set at 20% of LEL, at which point plant emergency shut down will be automatically initiated. The detected gas release shall be managed as per **Section 3.3** and **3.4** of this plan.

3.2.3 Scheduled Detection and Quantification Surveys

Gas detection and quantification surveys will be scheduled and undertaken at least annually on all accessible components that are potential sources of fugitive emissions using an Optical Gas Imaging (**OGI**) camera and/or portable Flame Ionization Detector (**FID**) (**Appendix A – Instruments**). Unit areas within the facility containing equipment identified as a potential source of fugitive emissions are detailed in **Section 2**.

Scheduled surveys are managed within Santos' computerised maintenance management system (**CMMS**) and tracked in a Santos compliance database.

3.2.3.1 Detection Survey

The following outlines the steps for conducting a gas detection survey that may be undertaken by Santos' personnel or contracted to specialised consultants. The survey will utilise a handheld OGI camera which allows detection of fugitive hydrocarbon emissions.

All accessible components that could potentially be a source of VOCs or methane emissions, such as flanges and other connections, valves, gaskets, pump and compressor seals, process drains and vents, pressure relief devices, vessels and tanks will be surveyed with an OGI camera.

If VOCs or fugitive methane emissions are detected, the following information (if practicable or safe to do so) shall be captured:

- OGI video showing hydrocarbon to atmosphere;
- P&ID mark-up to facilitate Work Order planning, scheduling and referencing;
- Attach a tag to the impacted asset/s;
- Marked-up 2D photos of release location - Close-up & wide angle for context; and
- Measure the concentration and emission rate if the OGI camera in use has quantification functionality.

Following detection of fugitive emissions, a quantification survey will be undertaken as described in **Section 3.2.3.2** below.

3.2.3.2 Quantification Survey

Quantification of fugitive emissions, to meet the requirement of Condition 44.1(b) of EPL217-05, will be completed using a calibrated FID (or equally suitable instrument) that will be used to quantify the fugitive emission concentration (and rate if practicable). The concentration will be assessed as per the requirements of US EPA Method 21.

3.3 Reporting and Management

As described in the *Santos Operations Risk Management Guide (1541-012-WPR-0010)*, several business applications are utilised to report on and manage operational risks which include fugitive emissions. These applications include:

- Incident Management System (**IMS**);
- Integrated Risk Register (**IRR**); and
- Computerised Maintenance Management System (**CMMS**).

The use of these business applications is described in **Sections 3.3.1 to 3.3.3**.

3.3.1 Incident Management System (IMS)

Where there is an unplanned or uncontrolled release of any material from primary containment in a process facility, i.e. LOPC, the event must be classified as a process safety event. The detection of fugitive emissions is typically entered into the Santos IMS as process safety events.

Process safety events are reported, investigated, and closed out in the Santos IMS in accordance with Santos *Events Reporting and Investigation Technical Standard*.

Incident management and investigations are managed within the Santos IMS. Process Safety Events are classified in the IMS as per the *Event Classification Technical Standard*, as described in **Section 3.1**.

3.3.2 Integrated Risk Register (IRR)

The IRR is a web-based application tool that combines all operational risks into a single repository, using a uniform approach to risk assessments, identifying and implementing interim controls, assessing risk concentration and having approval for continued operation or allowing informed decisions for system shutdown to be made.

The IRR is used to provide visibility of risk, with appropriate risk authority levels giving approval to either continue to operate with nominated interim controls, or to shut down and isolate the equipment of concern.

The IRR is used to support the management of barrier health where impacted barriers are identified. Risks are managed in the IRR until such time that the risk has been reduced So Far As Is Reasonably Practicable (SFAIRP)¹.

The Santos *Operations Risk Management Guide (1541-012-WPR-0010)* provides guidance on how to use the web-based application (IRR).

3.3.3 Computerised Maintenance Management System (CMMS)

The CMMS is used for scheduling and managing work for the purpose of repairing an impacted barrier (Corrective Maintenance – Work order generated based on Risk Based Work Selection). Work orders are generated and linked to IRR risk items. A work order generated through the CMMS seeks to return the system to its approved design.

3.4 Repair

3.4.1 Repair Threshold

Condition 44.1(d) of EPL217-05 requires the leak concentration, above which repair will be undertaken (if possible), to be defined. The process for managing repairs is determined through the *Operations Risk Management Guide (1541-012-WPR-0010)*, which describes how to manage impacted process safety barriers (e.g. fugitive emissions) using the IRR in accordance with the *Process Safety Technical Standard*.

The *Operations Risk Management Guide* details risk rectification and typically where a process safety barrier has been impacted; the system will be returned to its current approved design (i.e. identified sources of fugitive emissions will be repaired). Where change is required (away from current design intent) as part of the rectification of a risk, Management of Change (MOC) processes will be utilised.

All risks are required to be reduced SFAIRP (regardless of the specific concentration of fugitive emissions) as per **Figure 3-1**. Demonstration of SFAIRP is in the majority of cases, demonstrated through the reinstatement of the impacted barrier’s health (i.e. repair the source of fugitive emissions). The SFAIRP triangle below details how operations at DLNG shall respond to assessed risks.

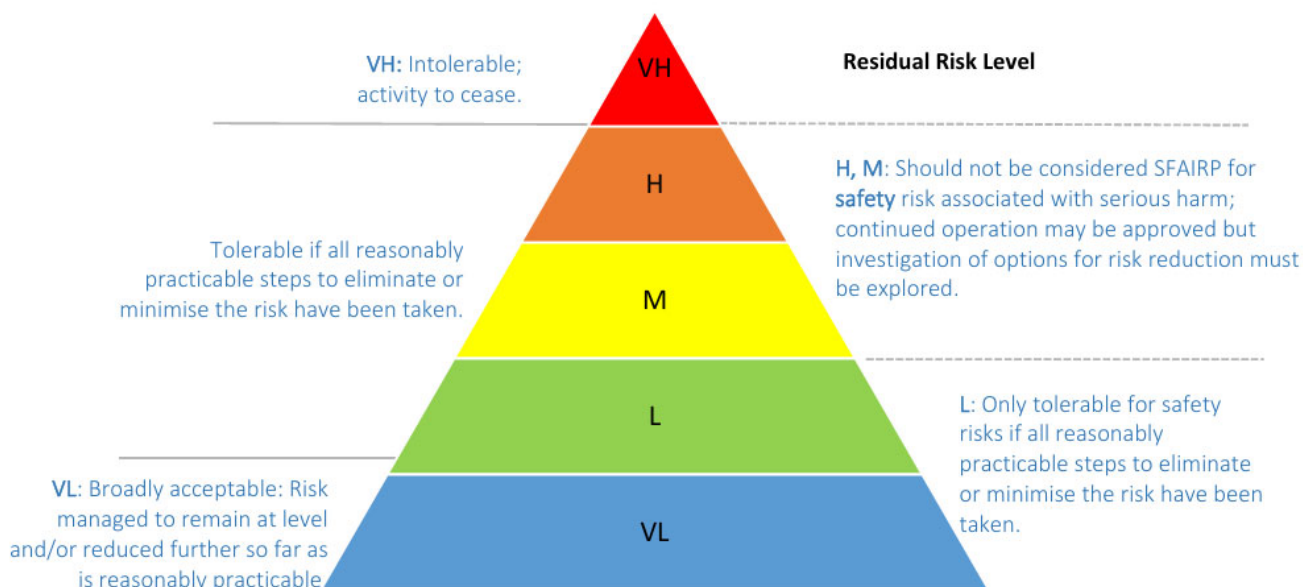


Figure 3-1: So Far As Is Reasonably Practicable (SFAIRP) Triangle

¹ For the purposes of this document, SFAIRP and ALARP are terms that are used interchangeably.

3.4.2 Repair Timeframes

Condition 44.1(d) of EPL217-05 requires the proposed timing to finalise repair to be defined. As per the *Operations Risk Management Guide (1541-012-WPR-0010)*, barrier impacts (including fugitive emissions) are required to be rectified in a reasonable time under a corrective work order (issued via the CMMS described in **Section 3.3.3**).

A reasonable time is defined by the late finish date of the corrective work order once assigned the appropriate priority during risk-based work selection (**RBWS**) which is described further in the *Santos Risk Based Work Selection (RBWS) Matrix (1541-294-TRM-0005)*.

The *RBWS Matrix* details the priority and associated timeframes for corrective maintenance based on the assessed level of risk. Where barriers have been impacted and an unwanted event (e.g. new source of fugitive emissions) has been identified, the following timeframes are relevant based on the following risk levels:

- 'Very High' risk rating and a Priority 1 for corrective maintenance timing (rectify within 48 hours);
- 'High' risk rating and a Priority 2 for corrective maintenance timing (rectify within 2 weeks); and
- 'Medium' risk rating and a Priority 3 for corrective maintenance timing (rectify within 12 weeks).

If a corrective work order cannot be raised or the late finish date of a corrective work order cannot be met, the actions detailed in the *Operations Risk Management Guide (1541-012-WPR-0010)* must be followed. This process involves raising a Continued Abnormal Operation record as soon as possible and managed until such time that the barrier impact (i.e. fugitive emission) is rectified. This ensures the risk has been assessed based on interim controls and has been accepted by the relevant Risk Authority for continued operation (or decision to shut down / isolate system).

4. Fugitive Emission Monitoring of the LNG Tank

DLNG commenced operations in 2006, processing Bayu-Undan gas from offshore Timor-Leste until the field reached end of life in mid-2025. Santos NA became the operator of the DLNG facility in 2020 after acquiring ConocoPhillips' Australia West assets.

The LNG Tank at the DLNG facility consists of a 9% nickel inner tank liner, a void filled with perlite for insulation, and a carbon steel vapour barrier. The outer wall of the tank is made of reinforced concrete with an insulation layer between the vapour barrier and outer wall. During initial commissioning of the DLNG facility in 2005-2006, LNG splashed into the space between the inner and outer walls of the tank creating a fugitive emissions pathway that would otherwise have been prevented.

During the DLNG refurbishment from 2023 to 2025, an extensive inspection programme of the DLNG tank by Santos and independent third party experts confirmed that the tank remains safe and fit for service for Barossa LNG and poses no safety risk in its existing condition. While options to repair the tank have been considered on several occasions, Santos and three expert contractors confirmed in 2023-24 that there was no safe and effective means to repair the tank during the DLNG refurbishment without significantly increasing personnel safety risks. Given the tank itself poses no safety risk in its existing condition, it would not have been appropriate to increase safety risks by attempting repair and exposing workers to isolated work in an extremely confined space.

Monitoring of fugitive emissions from the tank commenced in 2006. At the end of 2007 an external expert confirmed that fugitive emissions were stable with emissions levels too low to be of consequence. The expert recommended the tank continue to operate without any changes to procedures or hazardous area zoning.

As technologies to detect fugitive emissions at very low levels advanced, Santos investigated suitable methods to monitor fugitive emissions from the LNG tank. As part of this effort, Santos engaged CSIRO in 2021 to conduct an independent desktop review of the measurement methods used by Santos-commissioned third parties. The review considered the suitability of the monitoring methodologies applied, including downwind plume traversing approaches used to measure fugitive emissions from the tank. In its public statement, CSIRO noted that findings from the third-party monitoring indicated fugitive emissions from the storage tank remained within normal operating ranges for natural gas infrastructure (CSIRO, 2025). Based on the review by CSIRO, Santos is satisfied that the chosen methodology represents 'best practice methods' for measuring fugitive emissions from the LNG tank.

Based on the above process, Santos has determined that surveys using an Unmanned Aerial Vehicle (UAV) with an attached methane sensor in the form of a laser absorption spectrometer (**Appendix A**) represents the 'best practice methods' to monitor fugitive emissions from the LNG tank. The LNG tank and associated infrastructure will also be subject to routine operator surveillance (**Section 3.2.1**), fixed gas detection (**Section 3.2.2**) and detection and quantification surveys (**Section 3.2.3**).

4.1 Annual Survey

The primary method to monitor fugitive methane emissions annually from the LNG tank is by UAV survey which is undertaken by a specialist consultant contracted by Santos. An unmanned UAV platform is used for near-field point source quantification and vertical measurements up to 120 metres above ground level. This system detects methane by attaching a laser absorption spectrometer to the UAV. This sensor technology is accurate, precise, and highly selective for methane, and suitable for monitoring fugitive methane emissions from the LNG Tank.

Any methane releases from the LNG tank would be expected to form a plume and then disperse gradually following the direction of the prevailing winds. The laser spectrometer on the UAV measures methane concentration as the UAV is flown in crosswind transects back and forth across the methane release plume, at multiple altitudes and at a fixed distance downwind (**Figure 4-1**). The combination of UAV, laser spectrometer and wind speed data is then used to determine the overall fugitive methane emissions from the LNG tank.

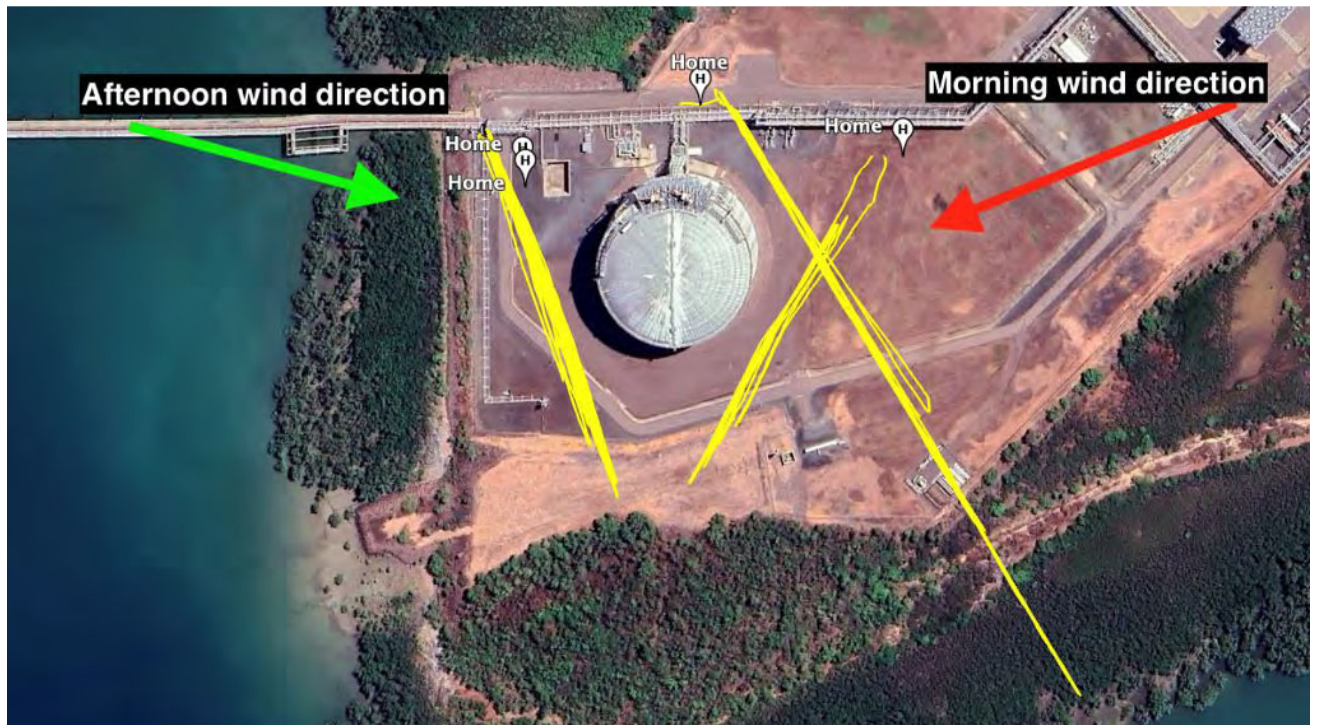


Figure 4-1: Example Flight Paths (shown in yellow) for Tank Emissions Monitoring

5. Review and Annual Reporting

5.1 FEMP Review

A review of this FEMP will occur at least every five (5) years or following any major change to SMS documents referenced in this FEMP. In undertaking the review, Santos will benchmark the effectiveness of current fugitive emissions detection practices against best available practices and technology.

As required by Condition 10 of EPL217-05, within 10 business days of any amendment being made to the FEMP, Santos will provide the amended document to the NT EPA, along with:

- a tabulated summary of the amendment(s) with document references (Condition 10.1);
- reasons for the amendment(s) (Condition 10.2); and
- an assessment of environmental risk associated with the amendment(s) (Condition 10.3).

5.2 Annual Reporting

Condition 60 of EPL217-05 requires Santos NA to complete and provide to the NT EPA an Annual Environmental Monitoring Report (**AEMR**), by 1 April for each year of the licence. The reporting period is the previous period of 1 January – 31 December from the commencement date of EPL217-05.

Of relevance to this FEMP, Condition 61.10 of EPL217-05 states that the AEMR shall include the outcomes of the LDAR program (undertaken in accordance with Condition 44) including:

- (a) the extent of compliance with the leak detection and repair program;
- (b) a summary of monitoring undertaken during the reporting period;
- (c) a summary of minor and significant leaks identified during the reporting period;
- (d) an explanation of any component which could not be repaired;
- (e) an estimation of the VOC and methane losses from leaking;
- (f) the percentage reduction or increase in VOC and methane losses from leaking items achieved since the last year of testing;
- (g) the methods used in calculating emissions; and
- (h) continual improvement measures for reducing fugitive emissions.

The AEMR will be provided to the NT EPA and subsequently made publicly available on the NT EPA website.

6. References

CSIRO (2025). *Statement: CSIRO response to ABC reporting on Darwin LNG plant*. Commonwealth Scientific and Industrial Research Organisation.

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U.S. Environmental Protection Agency (n.d.). *Method 21—Determination of Volatile Organic Compound Leaks*. 40 CFR Part 60, Appendix A-7. Retrieved [11/03/2026] from <https://www.epa.gov/emc/method-21-volatile-organic-compound-leaks>

Appendix A Instruments to Detect Fugitive Emissions

A list of common technologies used to detect and measure fugitive emissions at DLNG are summarised in the Table below. A summary description of capabilities and limitations for each technology type is also provided in this Appendix.

Common Technologies Used to Detect and Measure Fugitive Emissions at DLNG

Equipment / System	Technology Type	Technology Type	Detectable Gases	Typical Applications	US EPA Method 21 compliant for methane (CH ₄)
FLIR Gx620 Optical Gas Imaging Camera	Mobile	Infrared Optical Gas Imaging	CH ₄ , VOCs	Detection of fugitive emissions	No ¹
Infrared Point Gas Detectors	Fixed	Infrared	CH ₄	Remote detection of fugitive emissions, facility monitoring	No
Open Path Gas Detectors	Fixed	Infrared	CH ₄ , H ₂ S, CO ₂	Remote detection of fugitive emissions, facility monitoring	No
LGR-ICOS™ M-GGA-918 Microportable Greenhouse Analyser	Mobile	Tuneable diode laser absorption spectroscopy	CH ₄ , CO ₂ and H ₂ O	Detection of fugitive emissions and emission rate monitoring	No
Honeywell BW Flex4 [IR sensor]	Mobile	Infrared	LEL (CH ₄), H ₂ S, CO, O ₂ , SO ₂	Detection of fugitive emissions (safe working environment)	No
Laser absorption spectrometer - UAV	Mobile	Laser absorption spectrometer	CH ₄	Detection of fugitive emissions and emission rate monitoring	No
Honeywell UltraRAE 3000	Mobile	Photoionization Detector (PID)	Non-methane VOCs, C ₆ H ₆	Detection of fugitive emissions (safe working environment)	No
Honeywell MiniRAE 3000	Mobile	PID	Non-methane VOCs	Detection of fugitive emissions (safe working environment)	No
DLNG Lab GC - FID	Fixed	Flame Ionization Detector (FID)	C _x H _y – Total Hydrocarbons	Detection of fugitive emissions and emission rate monitoring	No
Portable FID	Mobile	FID	C _x H _y – Total Hydrocarbons	Detection of fugitive emissions and emission rate monitoring	Yes – detection and rate

¹ The US EPA's Method 21 Alternative Work Practice allows facilities to use OGI cameras, rather than Method 21 sniffing instruments, to detect volatile organic compounds (VOC) and hazardous fugitive emissions. Condition 44.1(b) also states, in relation to US EPA Method 21, that Optical Gas Imaging can be used to detect leaks.

Optical Gas Imaging Camera

Optical Gas Imaging (OGI) cameras use infrared (IR) (electromagnetic radiation) gas detection designed to detect fugitive methane emissions quickly, accurately, and safely without shutting down systems. This allows inspectors to scan broad sections of equipment rapidly and survey areas that are hard to reach with traditional contact measurement tools. OGI cameras can also detect fugitive emissions from a safe distance, displaying these invisible gases as clouds of smoke.

Santos utilise a FLIR Gx620 OGI camera to detect fugitive methane emissions. The camera can detect methane at a minimum detected emission rate of 0.6 g/hr and propane at 0.6 g/hr. Methane is easily

identifiable on the camera as a gas plume. The FLIR G-Series cameras embed advanced quantification analytics so that fugitive emissions can be measured to determine relative severity.

Infra-Red Point Gas Detectors

Infrared Point Gas Detectors (**IRPGDs**) rely upon the absorption of infrared radiation at wavelengths as this passes through a volume of gas. IR detection technology combines a light source and light detector which measure the intensity of two distinct wavelengths - both at absorption and outside of absorption wavelengths. IR point detectors possess a fixed path length between the IR source and the IR receiver. This path length is generally short (just a few inches) and it is assumed that gas concentration is uniform across the path. By using a fixed path length, it is possible to directly express measurement of IR beam absorption by the gas measured (% LEL in this instance). A point IR detector is therefore able to provide true measurement of gas concentration at the point of detection.

Open Path Gas Detector

Open Path Gas Detectors (**OPGD**) also utilise IR detection. OPGD IR detectors are able to expand a gas sampling path from inches (as per **IRPGDs**) to 150 meters, enabling the monitoring of large facilities for potential gas clouds. OPGDs gas detectors are preferred over point-type detectors: where buoyant releases in large areas may be expected; for perimeter monitoring; and for the detection of migrating gases.

Personal Detectors

Site personnel wear portable gas detectors as part of site operations practices, providing additional detection capability in the facility in general.

The Honeywell BW Flex4 are carried by operators at all times whilst onsite at production facilities. They are used as personal gas monitors and are considered a safety device. They do identify fugitive emissions, however, are not used for formal fugitive emission surveys. The gas monitors are configured to detect oxygen, carbon monoxide, hydrogen sulphide and % LEL for hydrocarbons. LEL measurement range is 1 – 100%.

Each area has shift rounds, requiring operators to visit different areas of the facility. The top of the tank is visited at least once every week.

Laser Absorption Spectrometer

Laser absorption spectrometer is accurate, precise, and highly selective for methane, making it ideal for unmanned aerial vehicle (**UAV**) surveys of methane source areas such as the DLNG LNG tank.

The quadcopter UAV platforms are an ideal solution for near-field point source quantification and vertical measurements up to 120 meters above ground level.

From a fugitive emission source, an invisible plume of methane spreads out and is carried downwind. The laser spectrometer on the UAV measures methane as the UAV is flown in crosswind transects back and forth across the plume at multiple altitudes at a fixed distance downwind.

The UAV data then define the methane plume cross section in the air. The methane emission rate is calculated by multiplying methane enhancements on each transect by the wind speed, binning these transect flux values by altitude, and adding up the binned fluxes over the altitude profile of the plume. Each curtain plot and its corresponding flux profile represents one emission rate quantification for a site.

Quantifying emissions from individual sources on a site is possible under appropriate wind directions relative to the site equipment layout.

Flame Ionization Detector / Photo Ionization Detector

An instrument meeting US EPA Method 21 will be utilised to detect and measure fugitive emissions of VOCs from individual sources. As required by Condition 44.1(b) a FID or PID will be utilised for emissions quantification.

An FID measures organic compounds by burning them in a hydrogen flame and detecting the resulting ions. It is valued for its wide dynamic range and robust nature and is especially effective for detecting hydrocarbons. A PID uses ultraviolet light to detect and measure low concentrations of volatile organic compounds and other hazardous gases in the air.