Christchurch City Council	Resource Management Act 1991 Christchurch City Council Christchurch District Plan Plan Change Section 32 Evaluation	1

WOOLSTON RISK MANAGEMENT AREA

Introduction

The purpose of the proposed plan change is to provide updated District Plan provisions that manage low probability but potentially high impact risks which would arise from the location of sensitive activities in close proximity to two bulk fuel terminals in Woolston, Christchurch. It proposes provisions that seek to enable the ongoing efficient use of those facilities and prevent reverse sensitivity effects from arising that may affect their ongoing operation and growth. It does this through the identification of a risk management area, and related provisions which limit the extent to which new sensitive activities, including pre-schools, can locate within it. The change would continue to require other new discretionary or non-complying activities seeking to establish in the area to consider the issue of risk and ensure they meet relevant risk acceptance criteria appropriate to the nature of the proposed activities but without the need to undertake an individual quantitative risk assessment to support their proposals.

The proposed plan change has been prepared in accordance with the requirements of Section 32 (s32) of the Resource Management Act 1991 (RMA).

This report includes:

- An outline of resource management issues and possible options for addressing these;
- An overview of the proposed changes in the context of relevant legislative and planning policy documents;
- An evaluation of the policies, rules and other methods proposed, including an evaluation of costs, benefits of the reasonably practicable options considered;
- An evaluation of effectiveness and efficiency of each option based on the anticipated effects of implementing the plan change in such detail as corresponds with the scale and significance of the actual or potential environmental effects anticipated; and
- A conclusion as to the most appropriate option.

The report also contains supplementary technical assessments including:

1. Liquigas Terminal Quantitative Risk Assessment.
2. Woolston Oil Terminal Quantitative Risk Assessment.
3. Combined Summary of Quantitative Risk Assessments.

Table of contents

1 Introduction

1.1 Purpose of this report

1.1.1 Section 32 (s32) of the Resource Management Act 1991 (RMA) requires that Council provides an evaluation of the changes proposed in Plan Change 1 to the Christchurch District Plan (the Plan). The evaluation must examine whether the proposed provisions are the most appropriate way to achieve the objectives of the plan change and the purpose of the RMA. The report must consider reasonably practicable alternatives and assess the benefits and costs of inserting/amending/ deleting any objective, policy, rule or method in the Plan.

1.1.2 The purpose of this report is to fulfil these s32 requirements for proposed Plan Change 1 – Woolston Risk Management Area.

1.2 Section 32 evaluation overview

1.2.1 This section 32 evaluation includes:

- An outline of resource management issues and possible options for addressing these;
- An overview of the proposed changes in the context of relevant legislative and planning policy documents;
- An evaluation of the policies, rules and other methods proposed, including an evaluation of costs, benefits of the reasonably practicable options considered;
- An evaluation of effectiveness and efficiency of each option based on the anticipated environmental, economic, social and cultural effects of implementing the plan change in such detail as corresponds with the scale and significance of the actual or potential environmental effects anticipated; and
- A conclusion as to the most appropriate option.

1.3 The Plan Change overview

1.3.1 The proposed plan change relates to the Risk Management Areas identified in the Christchurch District Plan and relates to two bulk fuel terminals located at Chapmans Road, Woolston. The purpose of the proposed plan change is to provide updated District Plan provisions that:

(a) manage low probability but potentially high impact risks which would arise from the location of sensitive activities, including pre-schools, in close proximity to the two terminals;

(b) enable the ongoing efficient use of the facilities and prevent reverse sensitivity effects from arising; and

(c) continues to require other new discretionary or non-complying activities seeking to establish in the area to consider the issue of risk and ensure they meet relevant risk acceptance criteria appropriate to the nature of the proposed activities, when applying for resource consent but without the need to undertake individual Quantitative Risk Assessments (QRAs).

1.3.2 Liquigas and the Oil companies have themselves now completed new QRAs (May and June 2018, respectively), which provides the evidence base to support the ongoing use of a risk management area overlay in the district plan, amendments to its boundary and district plan provisions which seek to manage activities within the overlay area to avoid adverse effects on strategic infrastructure and minimise exposure to unacceptable risk for surrounding land uses. The proposed replacement risk management areas form the basis of this plan change.

2 Existing land-use context

2.1 Site Location

2.1.1 The plan change is based around two sites in the suburb of Woolston and identified in the Christchurch District Plan (District Plan) as strategic infrastructure. The site located at 79 Chapmans Road (referred in this report as the 'Woolston Oil Terminal') is owned by Mobil Oil New Zealand Limited (Mobil) and used by the Mobil, BP Oil and Z Energy (Oil Companies). The other site located at 50 Chapmans Road (referred in this report as the 'Liquigas Terminal') is owned by Liquigas Limited. The location of these two sites are shown in Figure 1 below.

2.1.2 Both sites contain bulk fuel storage terminals for LPG (Liquigas Terminal) and petroleum fuel products (Woolston Oil Terminal). Both sites are serviced via ship deliveries to the tank farm in Lyttelton, with product then transported via separate pipelines over the Port Hills to the main storage terminals in Woolston. These terminals then supply truck-based delivery and distribution across the City, wider region and the upper South Island. The Oil Companies use the Woolston Oil Terminal as a supply point for their distribution networks.

2.1.3 Both sites are comprised of heavy industrial buildings and fuel storage terminals. The Liquigas Terminal comprises LPG storage tanks that are buried within engineered gravel mounds, with the Woolston Oil Terminal storage located within above ground tanks. Associated control buildings, workshops, pipework, truck loading facilities and perimeter security fencing is also present.

Figure 1 Location Map

2.2 Surrounding area

2.2.1 Both sites are located within a wider industrial suburb that includes a mix of warehousing, distribution and manufacturing activities with ancillary offices. The Lyttelton Port Company has an inland port and container hub located west of the Liquigas Terminal and south-west of the Woolston Oil Terminal site. Small-scale cafes and commercial service businesses are also located within the wider area to support the industrial workforce.

2.2.2 The Liquigas Terminal is bounded to the north-east by the rail corridor that services Lyttelton Port, with the Heathcote River located north of the Woolston Oil Terminal on the far side of Chapmans Road.

2.3 Zoning

2.3.1 As shown in Figure 2 below, both sites are zoned Industrial Heavy (IH) in the Christchurch District Plan. The surrounding area also generally has an IH zoning, although there are areas of lighter Industrial General (IG) zoning east of both sites. A local park zoned Open Space Community Park (OCP) is located east of the Woolston Oil Terminal site on the far side of Chapmans Road, with the Heathcote River and riparian banks having an Open Space Water and Margins (OWM) zoning.

2.3.2 The IH and IG zones both provide for a range of predominantly industrial activities along with a limited range of other compatible activities. Both zones also restrict most sensitive activities such as residential accommodation, healthcare facilities and hospitals, although pre-schools are currently permitted in the IG Zone.

2.3.3 Planning Map 47A currently identifies Risk Management Area overlays around each of the bulk fuel terminals and a note on the planning map legend states that the geographic extent of those areas may be subject to a future plan change to have effect by 31st March 2019, with any such plan change needing to be based on the findings of a Quantitative Risk Assessment (QRA).

2.3.4 The District Plan currently classifies "sensitive activities"[1] as non-complying activities within the Risk Management Area overlay areas (Rule 4.1.4.1.5 NC2) although this rule (the "sunset clause") expires on 31 March 2019. The intent of this interim rule was that by this date the relevant bulk fuel storage facility operators would have completed new QRAs, the outcome of which would inform whether to retain, amend or delete the overlays and associated provisions via a formal RMA plan change process[2].

2.3.5 Without a plan change, Rule 4.1.4.1.5 (NC2) will cease to have effect on 31st March 2019, the implication being that the plan would have less controls on the location of sensitive activities in close proximity to the bulk fuel terminals, although the underlying rules would still require resource consent for the establishment of sensitive activities (other than preschools in the IG Zone which are permitted).

---

[1] Sensitive activities are defined in the District Plan as including residential activities, care facilities, education activities and preschools, and health care facilities.

[2] Independent Hearings Panel Decision 18 (March 2016) paragraphs 75-85.

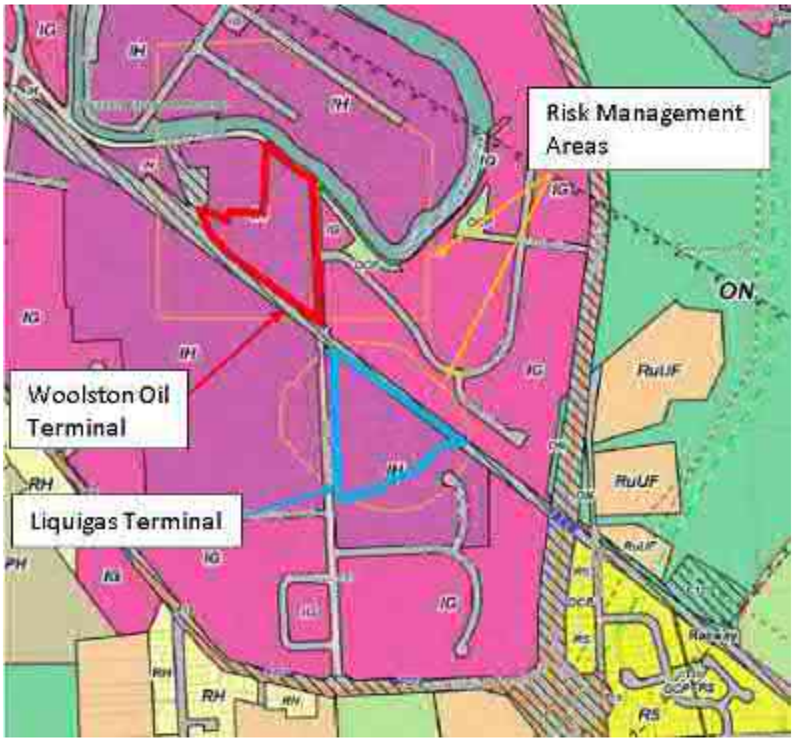


Figure 2 Extract of Operative Planning Map 47A

3 Resource management issues

3.1 Background

3.1.1 This plan change relates to two sites containing bulk fuel infrastructure, located at Chapmans Road, Woolston, operated by Liquegas and three oil companies (Mobil Oil, BP Oil, and Z Energy).

3.1.2 The Oil Companies receive, store and distribute refined petroleum products. They have commercial, shore and marine based aviation and bulk fuel storage facilities, and are owners of retail outlets and suppliers of petroleum products to individually owned retail outlets throughout the Canterbury region and the South Island. The Oil companies have bulk storage facilities in the Naval Point area of the Port of Lyttelton (the Lyttelton Terminals) and at Chapmans Road (the Woolston Oil Terminal). The Woolston Oil Terminal is supplied (continuously) by the Lyttelton Terminals via the Woolston pipeline. This pipeline transports the bulk of petroleum products for the Oil Companies to the Woolston Oil Terminal from which all three Oil Companies then load out for distribution to their networks.

3.1.3 Liquigas receives, stores and distributes liquid petroleum gas (LPG) that is used in homes, business, vehicles and industry throughout Canterbury and the upper South Island. The Liquigas Terminal has LPG supplied directly from ships via pipeline from Lyttelton (via a pumping station) as there is no large volume LPG storage facility in Lyttelton.

3.1.4 These bulk fuel terminals in Woolston comprise important infrastructure in the fuel supply chain for the Canterbury region and Christchurch City. The operators of the Terminals are identified as "lifeline utilities" under the Civil Defence and Emergency Management Act 2002, i.e. entities that produce, supply, or distribute manufactured gas or natural gas. Lifeline utilities must be able to function to the fullest possible extent during and after an emergency. Any disruption to the petroleum and/or LPG supply chains would have a major impact on the availability of fuel supplies and therefore on people's ability to meet their social and economic needs. It is important that the bulk fuel terminal operators are not unduly constrained in the way they use their land resource in order to operate successfully and remain viable.

3.1.5 Both Terminals are also designated as "Major Hazard Facilities" (MHFs) under the Health and Safety at Work (Major Hazard Facilities) Regulations 2016 (MHF Regulations) and must manage their activities in accordance with the Health and Safety at Work (Hazardous Substances) Regulations 2017 (HS Regulations). These provisions control and target the safety, design, operation and emergency response actions of those facilities. However, the MHF Regulations recognise that MHFs do not contain (or internalise) all residual risks on site. Strategic infrastructure needs to be managed through the district plan so as to protect it from incompatible development and activities by avoiding adverse effects from them, including reverse sensitivity effects[3].

3.1.6 Due to the nature and volume of fuels stored at both Woolston Terminals, they pose a potential risk to surrounding land uses, which cannot be fully contained, and could potentially give rise to emergency scenarios, such as a vapour cloud explosion, tank and bund fires[4]. Such emergency scenarios are of low probability but potentially high impact to people and property in the vicinity of the Terminals. Adverse effects of such events may include blast overpressure, fragments and heat radiation.

3.1.7 A key concern for the safe operation of this strategic infrastructure is the presence, or potential presence, of sensitive activities and/or potentially high numbers of people in the area in close proximity to bulk fuel storage facilities. If allowed to develop without appropriate safeguards, sensitive and some other activities have the potential to increase the risk profile of the Terminals, and result in a situation where the risks are such that the operation and development of the Terminal facilities may be compromised. This will, in turn, affect resilience and efficiency in region-wide fuel supplies.

3.1.8 This evaluation assesses the implications of the proposed Woolston Risk Management Area overlay, and the approach to avoiding sensitive activities and other activities not typically anticipated in the IH and IG zones, within that overlay. The proposed approach would require those other activities[5] that would be exposed to unacceptable risk to meet risk acceptability criteria appropriate to the applicable land use.

3.2 Findings of the Independent Hearings Panel on the Christchurch District Plan Review

3.2.1 Following the Canterbury earthquake sequence, the Christchurch City Plan was subject to a comprehensive review under the Canterbury Earthquake Recovery Act 2011 and associated Orders in Council. An Independent Hearings Panel (IHP) was established to consider evidence and to make decisions on the proposed replacement Christchurch District Plan. Decisions on the proposed plan were released in a number of stages; of particular relevance to this plan change are the decisions on the Strategic Directions, Industrial and Hazardous Substances chapters[6].

Chapter 4 Hazardous Substances and Contaminated Land

---

[3] Reverse Sensitivity is defined in the District Plan to mean *"means the effect on existing lawful activities from the introduction of new activities, or the intensification of existing activities in the same environment, that may lead to restrictions on existing lawful activities as a consequence of complaints"*.

[4] Sherpa Consulting (June 2018), Mobil Woolston Terminal Quantitative Risk Assessment for Determination of Planning Overlay, pp26-33.

[5] Discretionary and non-complying activities subject of Rule 16.4.1.4 D1, Rule 16.5.1.4, and Rule 16.5.1.5 NC1.

[6] Decisions 1, 11 and 18 respectively.

3.2.2 In summary, the two Woolston Terminals were found by the IHP to constitute 'strategic infrastructure', which is defined in the district plan as "those necessary infrastructure facilities, services and installations which are of greater than local importance…" and includes "bulk fuel supply and storage infrastructure, including terminals, wharflines and pipelines". As such, the subsequent District Plan provisions were required to give effect to the specific Strategic Direction Objective 3.3.12 concerning protection of strategic infrastructure (this objective and the wider District Plan policy framework are discussed in more detail below).

3.2.3 The Oil Companies and Liquigas presented evidence in support of their submissions on the Replacement District Plan setting out the rationale for a buffer area (and associated policy direction) around the two Terminals within which sensitive activities would be classified as non-complying activities, and other activities not generally anticipated in the IG and IH Zones[7] would be required to consider the level of risk associated with locating in close proximity to the terminals and therefore the appropriateness of establishing in that location.

3.2.4 The IHP agreed that, at least on an interim basis, that the use of an overlay and associated restrictions on sensitive and other activities was an appropriate method of providing for the future management of the Woolston Oil Terminal and the Liquigas Terminal. They confirmed a rule (Rule 4.1.4.1.5 NC2) that classifies all new sensitive activities within the risk management overlay, as non-complying activities.

3.2.5 However the Panel expressed concern that the risk management areas put forward by the bulk fuel terminal operators were based on outdated or non-quantitative risk assessments. Whilst confirming the risk management area and related provisions in Decision 18, they did so on an interim basis only, limiting the duration of Rule 4.1.4.1.5 NC2 by use of a sunset clause; such that it would cease to have effect after 31 March 2019 unless a plan change had occurred to confirm the need for, and extent of, the overlay and related provisions through new QRAs. The use of a sunset clause was seen as a tool for prompting the companies to progress QRAs in a timely manner.

3.2.6 The IHP noted that the sunset clause mechanism might lead to "*a number of potential outcomes including retention of the overlays and rule provisions as they are, their amendment or their deletion, and it is appropriate for these potential outcomes to be tested through a s32 process and publicly notified Plan Change which takes into account the information provided in the new QRAs and other relevant RMA factors at that time*"[8].

3.2.7 In setting the timeframe for the sunset clause, the IHP considered that there was 'ample time' for this background work and plan change to occur prior to March 2019. However, the Council has to date been unable to promote this plan change under Schedule 1 of the Resource Management Act because it has been prevented from preparing district plan changes under the Canterbury Earthquake (Christchurch Replacement District Plan) Order 2014 (OiC). In forming its view regarding timeframes in 2015, the IHP could not have foreseen that the 2014 OiC would be extended from 2016 to 2021 by the Greater Christchurch Regeneration Act 2016. Government has recently announced that it will be revoking the OiC on 18 March 2019, thereby enabling this plan change to proceed from this date.

[7] i.e. discretionary and non-complying activities in these zones.
[8] Independent Hearings Panel (15 March 2016) Decision 18 – Hazardous Substances and Contaminated Land – Stages 1 and 2 paragraph 85.

Chapter 16 Industrial

3.2.8 The provisions of the industrial chapter (Chapter 16) were confirmed ahead of those in Chapter 4 (Hazardous Substances and Contaminated Land)[9]. Policy 16.2.1.4 in the Industrial Chapter was therefore formulated and decided upon in advance of Chapter 4 that confirmed the overlay, and related policy, rule and sunset clause.

3.2.9 Policy 16.2.1.4 sets a management-based framework. For discretionary or non-complying proposals looking to locate in close proximity to the Terminals, the IHP considered that there should be additional explicit policy direction regarding reverse sensitivity associated with such activities to help inform decision-makers when they are considering resource consent applications. The current industrial policy approach requires all applicants seeking to establish sensitive and other activities in close proximity to the Terminals, to undertake their own QRA for their particular activity and submit this with their resource consent application. The purpose of the third party QRAs was to determine if they were locating in an area that would expose them to an unacceptable level of risk. The resource consent process enables an informed assessment of the best way to manage the risks to the relevant activity from major incidents at the Terminals to be made on a case-by-case basis. Under the current framework, the consent authority can assess the appropriateness of discretionary and non-complying activities locating in the Woolston Risk Management Area and be guided by Policy 16.2.1.4(b)(ii).

3.2.10 The matter of risk acceptability is an approach adopted elsewhere by the IHP for the Christchurch District Plan (e.g. including its approach to natural hazards).

3.2.11 Given that the QRAs for the Terminals have now been undertaken by Liquigas and the Oil Companies, the Chapter 16 policy obligation on third parties to undertake QRAs is no longer necessary as the QRAs establish in a more definitive manner, the geographic extent of the area where sensitive and other activities would likely be exposed to unacceptable risk. Such activities within the overlay could therefore more simply be subject to the District Plan's policy direction that sensitive activities are to be avoided, and other activities also avoided unless they meet the relevant risk acceptance criteria.

3.3 Use of New South Wales (NSW) Hazardous Industry Planning Advisory Papers (HIPAP) Framework

3.3.1 The required new QRAs have been prepared in accordance with the NSW HIPAP risk acceptance criteria. The general guidance in HIPAP No. 4 (Risk Criteria for Land Use Planning) is used to evaluate proposed land uses in a risk context. The use of the HIPAP criteria is considered to be appropriate for the following reasons:

- There are no specific New Zealand risk criteria available for use.
- The Christchurch District Plan already references the NSW criteria as being the appropriate guide for identifying appropriate risk acceptability criteria[10].

3.3.2 The HIPAP criteria have the following advantages:

- The criteria values have been set so that the risk level posed by industry (regarded as an involuntary risk exposure) is low in comparison to the voluntary risk exposures people accept in everyday life.

[9] Formerly Chapter 12 of the proposed Replacement Christchurch District Plan.
[10] Advice Note 3 to Policy 16.2.1.4, Chapter 16 Industrial.

- They set different risk criteria for different land use sensitivities.
- They set an upper limit risk target for risk at a site boundary.

3.3.3 The adopted criteria relates to individual fatality risk. Individual fatality risk represents the probability of a specified level of harm (usually fatality) occurring to a theoretical individual located permanently at a particular location, assuming no mitigating action such as escape can be taken. Hence, the criteria cover vulnerable individuals such as the very young, sick or elderly.

3.4 New Quantitative Risk Assessments

3.4.1 As mentioned above, since the release of the IHP decisions Liquigas and the Oil Companies have commissioned new QRAs for their respective sites, and these are attached as Appendices 1 and 2. Draft versions of the QRAs and the summary of the QRA findings in Appendix 3 were reviewed by Council staff and updated accordingly based on feedback received. Both QRAs have adopted the risk criteria contained in the NSW HIPAP. Whilst the QRAs for the Liquigas Terminal and the Woolston Oil Terminal were undertaken by separate consultants (WorleyParsons New Zealand Limited and Sherpa Consulting Proprietary Limited, respectively), the two QRAs have adopted and applied the same criteria to enable a consistent approach between them. Worley and Sherpa peer reviewed each other's assumptions and methodology. While there are some technical differences in approach (e.g., choice of software), Worley and Sherpa agreed that:

- The approach in each QRA is appropriate for the specific facilities.
- Both QRAs have been prepared to account for a reasonable future growth case hence is representative of risk levels for each site operation over the next 10 years (up to 2028).
- The QRA results are presented and assessed in a consistent manner, i.e. both QRAs use individual fatality risk as the basis for assessment and therefore can be used cumulatively.

3.4.2 The QRA purpose and methodology are set out in the respective reports. In summary, a QRA is a technical tool for establishing the extent of risk at varying levels of social acceptability. The outer extent of the proposed Woolston Risk Management Area has been based on a 0.5×10^{-6} individual fatality risk, which under the HIPAP criteria, equates to an acceptable level of risk for a sensitive activity.

3.4.3 It is important to note that the QRAs provide concentric circles demarcating differing levels of risk. The outer circle (which forms the basis of the Woolston Risk Management Area and which will be shown on Planning Map 47A) is for sensitive activities, with various types of non-sensitive activities (having lower risk attached to them) falling inside the outer contour. Within this outer contour there exist a number of smaller contours that represent the risk associated with activities that are comparatively less sensitive to effects on, and from, the bulk fuel terminals. As there is less risk attached to non-sensitive activities, those can theoretically locate closer to the Terminals.

3.4.4 The principal outcomes of the QRA work for each respective terminal are:

a. Changes to the geographic extent of the risk management areas; and

b. Removal of the need for third parties to undertake their own QRAs when seeking consent to establish discretionary or non-complying activities.

3.4.5 For the Woolston Oil Terminal, the extent of the overlay has reduced in comparison to that included in the operative District Plan, as shown in Figure 3. This is largely due to the original extent and associated risk limit having been generated by the application of a generically derived setback distance based on international research, with that generic setback now proposed to be replaced with a facility-specific QRA. The QRA for the Woolston Oil Terminal has therefore resulted in a reduction in the extent of risk and associated regulatory controls relative to the operative overlay.

Figure 3 Woolston Oil Terminal change to overlay

Key:

Extent of existing Risk Management Area

Extent of proposed Woolston Risk Management Area

3.4.6 The QRA for the Liquigas Terminal indicates the need for a larger overlay, as shown in Figure 4. The reasons underlying the increase in the geographic extent of the overlay are due primarily to changes in the modelling assumptions and improvements to the modelling software used, rather than any increase in risk/higher risk activities having recently established on the site. In short, the changes to the overlay are due to more sophisticated and up-to-date modelling rather than any physical 'on-the-ground' changes to the facility itself.

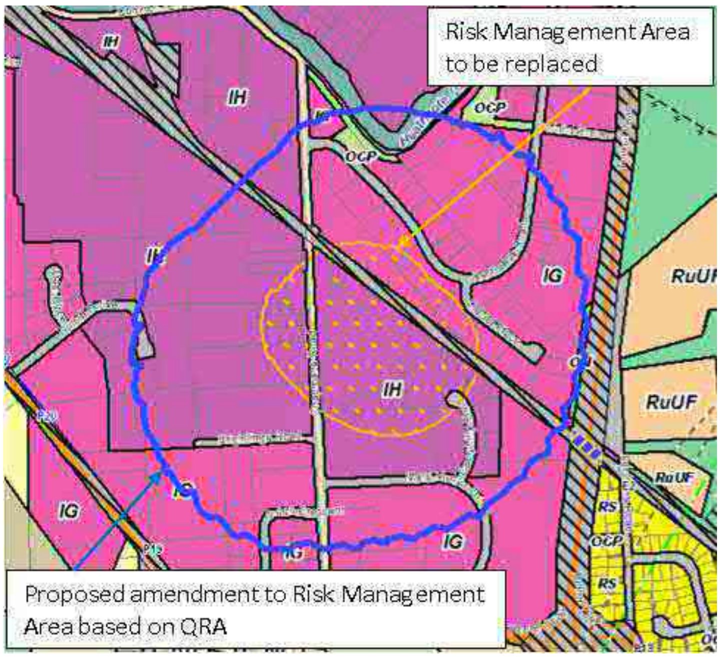


Figure 4 Liquigas Terminal change to overlay

Key:

Extent of existing Risk Management Area

Extent of proposed Woolston Risk Management Area

3.4.7 The outer edges of the two modelled QRAs now overlap. For graphical simplicity, it is proposed to show the overlay on the planning maps as a single outer boundary rather than as two overlapping areas, as shown in Figure 5. Collectively the area is proposed to be named the 'Woolston Risk Management Area' (WRMA). A summary of the QRA findings and discussion on the graphical representation as a single overlay has been prepared by the two companies responsible for the preparation of the QRAs and is attached as Appendix 3. Worley and Sherpa agreed that any differences in approach with respect to the assumptions for the specific terminals, the overall QRA methodology and reporting styles are not significant in the context of using the results for preparing a combined risk overlay to replace the existing risk management areas overlay.

Figure 5 Combined overlay – Proposed Woolston Risk Management Area

Key:

Extent of existing Risk Management Area

Extent of proposed Woolston Risk Management Area

3.4.8 Given that the overlay boundary represents the outer extent within which sensitive activities should not locate, it disguises other contours that are located within it. These are relevant for the consideration of activities that may not be sensitive in terms of the district plan definition of a sensitive activity, but that nonetheless *may* have a significant adverse effect on, or by affected by, the presence of the existing bulk fuel terminals. Examples cited by Liquigas and the Oil Companies include large entertainment complexes (e.g. trampoline world) or large high occupancy offices that would increase the risk to, and from, the terminals, in a location where these types of activities are not anticipated.

4 Proposed Plan Change Content

4.1.1 A full set of changes proposed within the Plan Change is set out in the plan change document (and copied into Appendix 4). In summary the proposed changes include:

- Amendments to the geographic extent of the existing Risk Management Areas by combining the risk contours for sensitive activities of the QRAs for both sites, to create a new single Risk Management Area, shown as a change to Planning Map 47A.
- Renaming "Risk Management Areas" to "Woolston Risk Management Area" for greater clarity, and removing the "sunset clause" from Chapter 4.1 Hazardous substances, Risk Management Area policy and rule, and the planning map legend.
- Updating the policy and advice note in Chapter 16 Industrial relating to the LPG and oil depots located at Woolston, to reflect that new QRAs have been produced and are available to inform resource consent proposals for discretionary and non-complying activities.
- In Chapter 16 Industrial, changing the status of preschool activities in the part of the Woolston Risk Management Area that overlays the Industrial General zone, from permitted to non-complying, consistent with the policy and rule for sensitive activities in Chapter 4.

5 Relevant statutory context

5.1 The Requirements of the RMA

Section 31 Functions of territorial authorities

5.1.1 Any plan change must assist the Council to carry out its functions so as to achieve the purpose of the Act. The functions of a territorial authority are set out in section 31 of the Act and include:

- establishing, implementing and reviewing objectives, policies, and methods to achieve integrated management of the effects of the use and development of land; and
- controlling actual or potential effects of the use and development of land.

5.1.2 The proposed plan change accords with these stated functions. The proposal provides for the use and development of land for industrial activities in an area zoned for such use, whilst concurrently providing a framework (along with health and safety regulations) for the appropriate management of risks generated by two long-established terminals and avoiding the reverse sensitivity effects and risks that would arise if sensitive and other activities established near the Terminals. The proposed management of activities and associated effects will likewise help to ensure the ongoing operation of the Terminals as regionally significant infrastructure.

Section 74 Matters to be considered

5.1.3 Section 74 RMA requires the Council to prepare and change its district plan in accordance with its functions under section 31, the provisions of Part 2, its duty under section 32, and any regulations.

5.1.4 Section 74(2) requires the Council to also have regard to proposed regional policy statements and plans, management plans and strategies prepared under other Acts, the New Zealand Heritage List, fisheries regulations or the RMA plans of adjoining territorial authorities to the extent that these may be relevant.

5.1.5 It is noted that the proposal does not involve any cross-territorial issues, nor matters of historical relevance or relevance to fisheries, nor matters addressed by management plans or strategies prepared under other Acts. With respect to Regional Policy Statements and Plans, these are identified and addressed further below.

5.1.6 Section 74(2A) also requires the Council to take into account relevant planning documents recognised by an iwi authority, to the extent that its content has a bearing on resource management issues. In the case of Christchurch District, the relevant document is the Mahaanui Iwi Management Plan 2013, which is discussed below.

Section 75 Contents of district plans

5.1.7 Section 75 requires a District Plan to state objectives for the District, policies to implement the objectives and rules to then implement the policies.

5.1.8 The proposal does not introduce any new, or alter any existing objectives. It only proposes amendments to policies, rules, advice notes and the planning map as set out in section 3 above.

5.1.9 The reasons for the amendments to the policies and rules are provided in this section 32 evaluation and the form of the proposed changes is consistent with s75(2) and the current format of the District Plan.

5.1.10 Section 75 requires a District Plan not to be inconsistent with Regional Plans. The Canterbury Regional Policy Statement, the Canterbury Land and Water Regional Plan, and Air Regional Plan are discussed below.

5.1.11 Sections 75(3)(a), (b) and (c) also require a District Plan to give effect to any National Policy Statement, the New Zealand Coastal Policy Statement, and the applicable Regional Policy.

5.2 Planning documents

National Policy Statements (NPS) and New Zealand Coastal Policy Statement (NZCPS)

5.2.1 There are four NPS documents to which consideration must be given. These are:

- NPS for Renewable Electricity Generation
- NPS for Electricity Transmission
- NPS for Freshwater Management
- NPS for Urban Development Capacity (NPS-UDC)

5.2.2 There is no direct connection or geographic proximity of the proposed Woolston Risk Management Area to renewable generation activities. The proposed Woolston Risk Management Area likewise does not cross or come into close proximity with strategic transmission infrastructure. The proposed District Plan amendments are limited to the management of activities within the Woolston Risk Management Area and as such do not have any relevance to the NPS for Freshwater Management. The proposed Woolston Risk Management Area is not located within the coastal environment or land adjacent to that environment and as such the NZCPS is not relevant.

5.2.3 The NPS-UDC requires councils in medium or high growth areas to demonstrate that there is sufficient feasible business (and housing) land to meet short, medium and long term demands. Christchurch City is a high growth area under NPS-UDC. The area within the Woolston Risk Management Area has long been zoned and largely utilised for industrial activities. Further development and intensification in the surrounding area is possible and provided for under the existing Industrial Heavy Zone and Industrial General Zone frameworks. The Woolston Risk Management Area does not limit development of sites for industrial or otherwise permitted activities and therefore does not reduce the ability of the area to accommodate future industrial growth and nor the growth of anticipated supporting activities.

5.2.4 In terms of the NPS-UDC, the proposed District Plan provisions would place restrictions on new sensitive and potentially some other activities and would therefore potentially displace these activities to other locations. However it is significant that the Business Capacity Assessment prepared pursuant to the NPS-UDC identifies a significant over-supply of industrial land in the City and therefore there are plenty of other locations available for any activity which is precluded from establishing within the WRMA under the proposed provisions.

Canterbury Regional Policy Statement (CRPS)

5.2.5 The strategic framework for managing and providing for the urban growth and recovery of greater Christchurch is set out in Chapter 6 of the CRPS. In summary, the CRPS seeks to provide for urban growth through a combination of greenfield expansion adjacent to the existing urban edge, and more intensive use and redevelopment of sites within the existing urban area. The recovery and development of infrastructure to support growth forms part of this broad approach, along with the need for growth to be appropriately managed so as to not give rise to either direct or reverse sensitivity effects on strategic infrastructure.

5.2.6 The infrastructure networks and terminals of Liquigas and the Oil Companies fall within the CRPS Chapter 6 definition of "strategic infrastructure" as they comprise "bulk fuel supply infrastructure including terminals, wharflines and pipelines".

Objective 5.2.1(f) CRPS requires that *"development is located so that it functions in a way that … is compatible with, and will result in the continued safe, efficient and effective use of regionally significant infrastructure"*. The explanation notes that regionally significant infrastructure provides considerable economic and social benefits to the region.

Objective 6.2.1 CRPS seeks that:

"Recovery, rebuilding and development are enabled within Greater Christchurch through a land use and infrastructure framework that:

…

(9) integrates strategic and other infrastructure and services with land use development;

(10) achieves development that does not adversely affect the efficient operation, use, development, appropriate upgrade, and future planning of strategic infrastructure and freight hubs;

(11) optimises use of existing infrastructure.

5.2.7 CRPS Policy 6.3.5 is an important method for implementing the above objectives. It is also the key CRPS policy concerning the management approach to infrastructure within the Greater Christchurch part of the region. Clauses (1) and (2) of this policy relate to the need to coordinate urban development with the provision of the infrastructure necessary to support that development. Clauses (3)-(5) then focus on providing for established infrastructure and the protection of such from the effects of incompatible urban growth, as follows:

"Policy 6.3.5 – Recovery of Greater Christchurch is to be assisted by the integration of land use development with infrastructure by

...

(3) Providing that the efficient and effective functioning of infrastructure, including transport corridors, is maintained, and the ability to maintain and upgrade that infrastructure is retained;

(4) Only providing for new development that does not affect the efficient operation, use, development, appropriate upgrading and safety of existing infrastructure[11] ...

(5) Managing the effects of land use activities on infrastructure, including avoiding activities that have the potential to limit the efficient and effective provision, operation, maintenance or upgrade of strategic infrastructure and freight hubs."

5.2.8 The CRPS includes as a method under Policy 6.3.5, a requirement that territorial authorities will, in reviewing their District Plans, include objectives, policies and rules (if any) to give effect to the Policy, including specific reference to the need to manage reverse sensitivity effects between strategic infrastructure and urban development.

5.2.9 In conclusion, the relevant strategic planning framework in the CRPS identifies the following key principles with respect to the development of strategic infrastructure:

(a) Strategic infrastructure is to be <u>integrated</u> with urban growth;

(b) Use and development of strategic infrastructure is to be <u>provided for</u>; and

(c) Any significant adverse effects of incompatible land use on strategic infrastructure are to be <u>avoided</u>.

(d) Conflict between incompatible activities is likewise to be <u>avoided</u>, especially when such will have a significant adverse effect on the health and safety of the community.

5.2.10 In order for the District Plan to give effect to the relevant strategic planning and statutory framework, the District Plan provisions therefore need to:

(a) Recognise the benefits and role of strategic infrastructure for enabling community wellbeing and meeting the community's functional needs;

(b) Provide for the ongoing use and development of strategic infrastructure;

(c) Manage the effects of land use activities on infrastructure, through avoiding activities that would limit the efficient and effective provision, operation, development, maintenance and upgrade of strategic infrastructure; and

(d) Integrate the provision of infrastructure and land use to ensure efficient and effective urban growth.

5.2.11 The proposed plan change provisions are consistent with the strategic approach set out in the CRPS. The purpose of the proposed Woolston Risk Management Area and associated District Plan policy direction and rules is to identify and manage the risk posed by existing strategic infrastructure and to make sure that incompatible activities do not locate in close proximity to the Terminals. This will mean that reverse sensitivity effects are avoided along with associated constraints on the ongoing operation and upgrading of the existing facilities.

Regional Plans

[11] The remainder of this clause is specific to development within the air noise contours.

5.2.12 The Canterbury Land and Water Regional Plan is focused on regional functions and therefore has limited, if any, relevance to the land use matters under consideration in this plan change. However, it should be noted that Objective 3.3 of that regional plan recognises the significance of regionally significant infrastructure. There are no specific objectives or policies relevant to land use risks from hazardous substances in that regional plan except in relation to discharges of contaminants.

Objective

3.3 Nationally and regionally significant infrastructure is enabled and is resilient and positively contributes to economic, cultural and social wellbeing through its efficient and effective operation, on-going maintenance, repair, development and upgrading.

5.2.13 The Canterbury Air Regional Plan is focused on the discharge of contaminants to air. As a consequence, it has no relevant objectives or policies relevant to the land use matters the subject of this plan change. However, it has three policies (set out below) that recognise the importance of regionally significant infrastructure and are illustrative (in terms of air discharges) of how the location of sensitive and potentially other activities is important to ensure they do not alter the receiving environment.

Policies

6.9 Discharges into air from new activities are appropriately located and adequately separated from sensitive activities, taking into account land use anticipated by a proposed or operative district plan and the sensitivity of the receiving environment.

6.10 If the sensitivity of the receiving environment is altered by authorised land use change so that an existing discharge results in significant adverse effects on the receiving environment, require the effects of that discharge to be reduced and provide a reasonable timeframe for achieving that reduction.

6.14 Recognise the contribution of nationally and regionally significant infrastructure to people's social and economic wellbeing and provide for discharges associated with the development, operation, and maintenance of that infrastructure.

Iwi Planning Documents

5.2.14 Ngāi Tahu prepared the Mahaanui Iwi Management Plan 2013 (IMP), being the relevant Iwi Management Plan for Christchurch. This document does not identify any specific concerns or direction with regard to the management of the risks posed by bulk fuel storage facilities. The IMP does highlight outcomes sought across a broad range of matters of cultural interest including the management of air and water quality, mahinga kai, and land development.

5.2.15 In accordance with the boundary definitions in Ngāi Tahu Claims Act 1996, Te Rūnanga o Ngāi Tūāhuriri are the kaitiaki Rūnanga for the Woolston area. There are no statutory acknowledgement areas, silent file areas or waahi taonga sites identified in the District Plan that could be directly affected by this plan change, and the area of the proposed Woolston Risk Management Area has been zoned and developed for industrial activities for many decades.

5.2.16 The proposed plan change is not considered to impact upon any cultural values or the principles articulated in the IMP. It is noted that Ngāi Tahu will have an opportunity to consider and respond to this plan change as part of the First Schedule RMA plan change process. Initial feedback has been sought from the Rūnanga (via Maahunui Kurataiao Limited) and did not raise any concerns (refer to section 7).

Other Plans

5.2.17 Other higher order plans include the Greater Christchurch Urban Development Strategy, the Recovery Strategy for Greater Christchurch, and the Land Use Recovery Plan. For completeness, it is noted that there are no Regeneration Plans prepared under the Greater Christchurch Regeneration Act 2016 that are of relevance to this plan change.

5.2.18 These higher order plans were all in place when the District Plan was prepared, and the IHP was mindful of their responsibility to either have regard to, or not be inconsistent with, the wider statutory planning framework. The current District Plan provisions of relevance to this plan change can therefore be deemed to be consistent with the outcomes sought in these higher order documents.

5.2.19 The proposed plan change seeks to continue the risk management framework of the District Plan, with the additional benefit of the geographic extent of that risk having been more accurately determined. As such the proposed plan change is considered to continue the risk management approach that the IHP determined as an effective tool that was consistent with the higher order framework, with minor but complementary amendments including the addition of a rule specifically to discourage pre-schools locating within the overlay area.

6 Section 32 evaluation

6.1 Introduction

6.1.1 Under Section 32 of the RMA, before the Council publicly notifies a plan change, it must carry out an evaluation to examine:

(a) The extent to which each objective is the most appropriate way to achieve the purpose of this Act.

(b) Whether the policies, rules, or other methods in the proposal are the most appropriate for achieving the objectives by:

- Consideration of other reasonable practicable options for achieving appropriate management of risk and the ongoing operation of Strategic Infrastructure.

- Assessment of the efficiency and effectiveness of the provisions in achieving the objective of the proposal. This assessment should identify the benefits and costs of environmental, economic, social and cultural effects, including opportunities for economic growth and employment.

(c) Whether the provisions in the proposal are the most appropriate to achieve the objective of the existing District Plan, to the extent that those are relevant.

(d) Assessment of the risks of acting or not acting.

The level of detail undertaken for the evaluation of the proposed plan change provisions must be determined by an assessment of the scale and significance of the environmental, economic, social and cultural effects that are anticipated from the implementation of the proposal (s32(1)(c).

6.2 Scale and significance evaluation

6.2.1 The level of detail in the evaluation of the proposal has been determined by the degree of shift of the proposed provisions from the status quo and the scale of effects anticipated from the proposal. Regard has been had to the criteria outlined in the Ministry for the Environment's Section 32 guide for assessing scale and significance[12].

1. Reasons for the change	*Giving effect to higher level RMA document and district plan strategic objective to protect Strategic Infrastructure.* *Responding to a decision of the Independent Hearings Panel on the Christchurch District Plan review.* *Initiated as a priority due to the imminent lapsing of sunset clause.*
2. Degree of shift from the status quo (status quo defined as the current approach)	*The degree of shift in the provisions from the status quo is not substantial because it primarily seeks to continue on a permanent basis, rules that already have effect in the district plan.* *Moreover, having regard to the controls already in place to manage the effects from and on Strategic Infrastructure and to protect the integrity of industrial zones, the proposed package of provisions doesn't significantly add to regulatory controls or the costs on communities to comply with them than presently exists.* *The plan change comprises a discrete package of provisions to deal with a single issue and which seeks largely to retain and modify existing provisions and give greater certainty that reverse sensitivity effects will be minimised and unacceptable risks from established facilities using, storing or disposing of hazardous substances will be avoided.*
3. Who and how many will be affected?	*The proposed change will only affect landowners / occupiers within the Woolston Risk Management Area.* *Many of those parties are already subject to similar regulatory controls.* *Less owners will be affected by the overlay controls than under the current framework (approved by Independent Hearings Panel).*[13] *There has already been a significant amount of public engagement on the matter (through the recent district plan review).* *The extent of effects on private property rights is tempered by the existing policies and rules of the industrial zones that seek to avoid activities in industrial zones with the potential to hinder or constrain the establishment or ongoing operation or development of strategic infrastructure.*

[12] Ministry for the Environment (2017) A guide to section 32 of the Resource Management Act: Incorporating changes as a result of the Resource Legislation Amendment Act 2017. pp31-32

[13] There are 54 new properties within the proposed overlay; 58 properties within the existing and proposed overlay; and 136 properties no longer within the existing overlay and outside the proposed overlay.

4. Degree of impact on, or interest from iwi/Māori	*The proposed plan change was discussed at a hui between MKT staff and the Kaitiaki Portfolio representatives for Te Ngāi Tūāhuriri Runanga. No concerns or recommendations were raised on the proposed plan change.*
5. When will effects occur?	*The effects of the regulation will be ongoing.*
6. Geographic scale of impacts	*Spatially confined to identify Risk Management Area around the Woolston bulk fuel terminals.*
7. Type of effect	*The provisions seek to manage the following effects:* - *The effects on surrounding land use activities related to an emergency incident. These are low probability but high consequence.* - *Reverse sensitivity effects on Strategic Infrastructure. These effects have the potential to significantly constrain the ongoing operation and development of the terminal facilities. Any disruption to the petroleum and/or LPG supply chains would have a major impact on the availability of fuel supplies and therefore on people's ability to meet their social and economic needs.* *Refer to section 6 for more detail.*
8. Degree of policy risk, implementation risk, or uncertainty	*Sufficient information is now available through the necessary QRAs having been prepared in a consistent manner and in accordance with recognised criteria.*

6.3 Evaluation of proposed provisions and reasonably practicable alternative options

Are the objectives of the proposal the most appropriate way to achieve the purpose of the Act? [s32(1)(a)]

6.3.1 The proposed plan change does not seek to alter any existing objectives of the Plan. In circumstances where objectives are not sought to be altered, s32(6)(b) states that references to 'objectives' means the 'purpose' of the proposal.

6.3.2 The purpose of this Plan Change is set out in Section 1.3 above. It seeks to provide amended District Plan provisions that enable the ongoing efficient use of the two bulk fuel storage facilities at Woolston, while managing low probability but potentially high impact risks to sensitive and potentially other non-industrial activities in the area. Accordingly, the evaluation must consider the extent to which the inclusion in the District Plan of the revised Woolston Risk Management Area and associated provisions in the district plan best achieve the purpose of the plan change, and ultimately the purpose of the RMA.

6.3.3 The purpose of the RMA is to promote sustainable management of natural and physical resources. This means managing the use, development and protection of natural and physical resources in a way, or at a rate, which enables people and communities to provide for their social, economic, and cultural well-being and for their health and safety while:

a. Sustaining the potential of natural and physical resources (excluding minerals) to meet the reasonably foreseeable needs of future generations; and

b. Safeguarding the life-supporting capacity of air, water, soil, and ecosystems; and

c. Avoiding, remedying, or mitigating any adverse effects of activities on the environment.

6.3.4 In summary, the proposal achieves the purpose of the RMA for the following reasons:

- It manages the use and development of sites in a location where they would be subject to an unacceptable level of risk if they were to be developed for sensitive activities (as defined in the district plan) or potentially some other non-industrial activities. Without such control, these activities would potentially unknowingly be exposed to an unacceptable level of risk and which in turn could result in undue constraints being imposed on the bulk fuel terminals (i.e. through reverse sensitivity/complaints) thereby imposing unnecessary costs and fuel supply issues to the wider community. It would therefore undermine the strategic directions in the District Plan aimed at ensuring regionally significant infrastructure operation and development is enabled.

- Provides the ongoing opportunity for individual landowners to develop their land for industrial and other permitted and appropriate activities (and thereby meet their economic needs) in accordance with the outcomes anticipated by the industrial zoning. (e.g. it doesn't constrain the activities permitted and anticipated in the industrial zones).

- In so doing, the plan change enables the community to provide for its economic wellbeing and employment, and thereby contributes to its social wellbeing, including their health and safety.

- It provides certainty in terms of the long-term operation and adaption of two existing strategic infrastructure facilities through proactively managing the potential for reverse sensitivity effects and ensuring activities (including sensitive activities) located within the Woolston Risk Management Area are compatible in terms of risk acceptance criteria.

Examine whether the provisions in the proposal are the most appropriate to achieve the objective (purpose) of the proposal by:

Identifying if there are other reasonably practicable options for achieving the proposal [s32(1)(b)(i)].

6.3.5 The provisions of the proposal are summarised in Section 3 above and a full copy of the proposed text changes is contained in Appendix 4.

6.3.6 Other reasonably practicable options for achieving the proposal include:

a. Status quo / do nothing.

b. Reliance on non-statutory methods.

c. Reliance on Health and Safety legislation.

These options are discussed below.

a. Status Quo / Do Nothing

6.3.7 Usually when considering plan changes, retention of the status quo is an option that merits consideration. In this case the status quo provisions are in the somewhat unusual situation of being subject to a sunset clause. As such, the status quo set of provisions cannot be retained beyond 31 March 2019. For the purposes of this evaluation, the status quo therefore comprises reliance on the underlying IG and IH zone provisions (and relevant wider district plan provisions) to manage the effects of, and on, sensitive and other activities within the Risk Management Area[14] (i.e. it assumes that the sunset clause has lapsed).

6.3.8 For both the IH and IG zones, sensitive activities are not currently enabled as permitted activities (other than preschools in the IG Zone). Any proposals to establish a sensitive activity other than a preschool would therefore fall to be considered as a fully discretionary activity in the IG zone and non-complying in the IH zone. This enables a full range of potential effects (including reverse sensitivity and risk matters) to be considered through the consent process. Resource consent applications for DA and NCA activities would need to be assessed against all relevant district plan policies including:

Objectives 3.3.12 and 3.3.14 which, *inter alia*, aim to protect the role and function of strategic infrastructure[15] from incompatible development and activities and avoid conflicts between incompatible activities where there may be significant adverse effects on the health, safety and amenity of people.

Policy 4.1.2.2.2 – Risk Management Area which seeks to avoid sensitive activities locating within the Risk Management Areas where these have the potential to be exposed to unacceptable risk and / or may otherwise constrain the development, operation, upgrading or maintenance of bulk fuel and gas terminals.

Policy 16.2.1.4 – Activities in Industrial Zones that limits the range of non-industrial activities in industrial zones to those that maintain and support the function of the zone and requires avoidance of any activity with the potential to hinder or constrain the establishment or ongoing operation or development of industrial activities and strategic infrastructure.

6.3.9 This policy (16.2.1.4) would continue to require proponents of new discretionary and non-complying activities to carry out their own QRAs (at their own cost) to support resource consent applications. This is despite the fact that Liquigas and the Oil Companies have now completed their own QRAs to determine the appropriate extent of the Woolston Risk Management Area and to inform the appropriateness of various land use activities locating within it.

6.3.10In summary it can be seen that the even without the subset clause, there are provisions which go a long way towards achieving the plan's objectives of protecting strategic infrastructure and risks associated with the infrastructure on sensitive or otherwise incompatible activities. Significantly however, preschools would be permitted in the IG zone close to the terminals, potentially undermining the district plan's wider policy framework regarding the protection and enablement of strategic infrastructure. Additionally, other sensitive activities in the IG Zone would be classified as discretionary activities, a less onerous consent pathway than the non-complying activity status proposed in this plan change (and currently in the plan but due to expire).

[14] Noting that the sunset clause only relates to rule 4.1.4.1.5 not the related policy (4.1.2.2.) or overlay itself which would continue to have effect.

[15] Defined in the district plan as "those necessary infrastructure facilities, services and installations which are of greater than local importance. It includes infrastructure that is nationally significant. This includes.(d) bulk fuel supply and storage infrastructure, including terminals, wharf lines and pipelines".

6.3.11 This approach would be less appropriate than the proposed plan change as it would have adverse effects on strategic infrastructure, the health and safety of sensitive (and potentially other) activities and would incur unnecessary costs on applicants and councils by retaining the policy requirement for third party QRAs, contrary to plan objectives 3.3.2, 3.3.12 and 4.1.2.2.

b. Reliance on Health & Safety Legislation

6.3.12 The Health and Safety at Work Act 2015 (HSWA) regulates activities in all work places by focusing on how activities at work places can be undertaken safely. The Major Hazard Facility (MHF) Regulations apply to activities being undertaken at the Terminals (being Upper Tier Facilities) under those regulations. Health and Safety legislation including the HSWA and the MHF Regulations regulate activities *within* individual sites, and do not regulate the interaction between sites or address the compatibility of land use activities on different sites.

6.3.13 The Health and Safety at Work Act 2015 (HSWA) and associated regulations, are complementary to the provisions of Policy 16.2.1.4 that seek to manage the location of risk sensitive activities within the Woolston Risk Management Area. The HSWA's focus is on the risks that can be controlled and managed in respect of each individual workplace, not for those arising from other workplaces in the vicinity.

6.3.14 Overall this method is considered to be less appropriate because it would be less effective and efficient than the package of provisions proposed by the plan change having regard to the adverse effects (costs) associated with increased risk to and from the strategic infrastructure.

c. Reliance on non-statutory methods

6.3.15 Primarily this method would focus on operators of the bulk fuel terminals seeking to manage risks to and from the terminals, by communicating with neighbours about the importance of emergency exit points and providing contact details. Aside from education, other non-statutory methods could include developing design guidelines for buildings and activities located in the Woolston Risk Management Area. However, non-statutory methods have their limits. Communication of these limits often occurs after land use activities have commenced and do not influence decision-making about site selection.

6.3.16 Without regulation, there is a greater risk of sensitive activities locating near the Terminals and being exposed to an unacceptable level of risk from them. The potential costs associated with this on those activities (low probability but high consequence) and on the terminals arising from reverse sensitive pressures, make this a less appropriate method than the proposed plan change provisions.

Assessing the efficiency and effectiveness of the proposed provisions in achieving the objective of the proposal [s32(1)(ii) and s32(2)].

6.3.17 Section 32 of the Act requires consideration of the benefits and costs of the proposal when assessing efficiency and effectiveness. These benefits and costs apply to the proposed provisions in respect of their environmental, social, cultural, and economic effects. Economic effects in particular are required to consider opportunities for economic growth [s32(2)(a)(i)] and employment [s32(2)(a)(ii)]. All effects are required to be quantified where practicable [s32(2)(b)]. The costs and benefits of the plan change package as a whole are summarised in the table below.

Economic, Social, Environmental & Cultural

Benefits	Costs
• Directs sensitive and (potentially) other activities to locate in areas where they won't be exposed to unacceptable risks to life and property. • Helps maintain and support the function of industrial zones, providing for primarily industrial activities. • Promotes long-term security for strategic infrastructure and the associated security of reliable fuel supplies including the ability of the existing strategic infrastructure to expand to meet demand as required. Flow on benefits accrue to downstream activities that are reliant on existing and future fuel supplies, including the employment opportunities they provide. • Removes requirement (and associated costs) for applicants of discretionary and non-complying activities seeking to establish near the Terminals to prepare individual full QRAs. • Given the policy direction in the industrial area it could be considered unlikely that a sensitive activity or other non-industrial activity could establish that would result in constraint on Terminal operations. However, that cannot be ruled out and the proposed provisions provide additional certainty for the regionally significant Terminal infrastructure, as one inappropriate activity can lead to significant constraint.	• No material social, environmental, or cultural costs are identified. • Sensitive activities will need to locate elsewhere, reducing locational choice/opportunity, noting however that as such activities are not generally permitted by the underlying zoning, the opportunity cost is minimal. • The proposal would strongly limit the ability for preschools to locate in proximity to the terminals however it is considered that the costs associated would be outweighed by the benefits of minimising risk to vulnerable children. It is noted that there are ample locational choices available for preschools within the wider area and therefore at a societal level the ability of local workers to access convenient child care facilities is not unduly limited by the proposed plan change. • Opportunity costs associated with the potential limitations on the establishment of other activities (such as entertainment or commercial activities) that may otherwise have been contemplated. However other district plan policies strongly limit the extent to which commercial type activities can locate in industrial zones, such that the opportunity cost would unlikely be significant.

Efficiency and Effectiveness of Provisions

The principle of an overlay as an appropriate tool for managing risk to sensitive and other discretionary and non-complying activities has already been found to be effective and efficient by the Independent Hearings Panel (IHP); at least on an interim basis. This plan change further improves the effectiveness and efficiency of the policy and rule package by updating the geographic extent of the overlay based on up-to-date QRAs.

The Plan Change rationalises Policy 16.2.1.4 by removing the obligation on third parties to undertake full QRAs as QRAs have now been completed by Liquigas and the Oil Companies. The proposed removal of this obligation improves the overall efficiency and effectiveness of the District Plan.

Rule 16.4.1.1 (P18) and Rule 16.4.1.5 (NC2) are proposed to manage the risk of preschools locating within that portion of the Industrial General Zone that falls within the Woolston Risk Management Area. NSW HIPAP guidance is that such activities within the risk areas would create an unacceptable level of risk through placing young children in a location where they may be exposed to the adverse consequences of an event occurring and where the nature of childcare for young children makes safe and timely evacuation out of the area challenging. As such, preschools are not contemplated as being acceptable within the risk management areas and therefore a non-complying activity status is considered to be an effective and efficient tool for managing risk.

Summarising the reasons for deciding on the provisions [s32(1)(b)(iii)].

6.3.18 The IHP process as part of the replacement Christchurch District Plan Review confirmed the need to concurrently protect and provide for strategic infrastructure and to appropriately manage the risks posed by bulk fuel storage facilities. The IHP therefore identified that there was merit, at least on an interim basis, in having a risk management area shown on the planning maps via an overlay and associated policy direction that sensitive and other discretionary and non-complying activities within the overlay would be avoided.

6.3.19 The proposed plan change seeks to update the geographic extent of the overlay, more efficiently and effectively apply the policy direction and controls on avoiding sensitive activities in this area and assessing the level of risk exposure for other non-industrial activities such as large scale commercial and recreational activities.

6.3.20 The proposed provisions are consequently considered to be more effective in managing risk than any of the available alternatives.

6.3.21 With respect to efficiency, it is considered that the provisions would result in a high degree of benefits while maintaining a relatively low level of cost. In summary, the provisions of the Plan Change would be efficient and effective in achieving the objective of the proposal whilst not unduly constraining the ability of anticipated industrial and otherwise permitted activities to occur in the surrounding area.

Risk of acting or not acting [s32(2)(c)]

6.3.22 The RMA requires assessment of the risk of acting, or not acting, if there is uncertain or insufficient information about the subject matter of the policies, rules, or other methods.

6.3.23 In relation to this proposed plan change there is no reason for not acting on the basis of insufficient or uncertain information. Sufficient information is now available through the necessary QRAs having been prepared in a consistent manner and in accordance with recognised criteria. The QRAs now provide an updated identification of the geographic extent of unacceptable risk for sensitive and some other non-industrial activities.

6.3.24 The risk of not acting, and instead maintaining the status quo (for a reversion to the underlying Industrial Zone provisions) is that sensitive and potentially other (albeit less sensitive) activities potentially occur in a location where they are subject to unacceptable risk, and/or that their establishment results in reverse sensitivity effects, that limit the ongoing operation and development of strategic infrastructure.

6.3.25 Furthermore, the new QRAs demonstrate that it is more appropriate to adopt the amended risk contour for planning purposes with the implication that some new properties now fall within the risk contour and some properties currently included in the risk management area will no longer be affected. A risk of not acting is that the district plan would otherwise contain a risk management area overlay that is out of date and does not manage all appropriate land and activities that ought to be managed based on best available information.

Examine whether the provisions in the proposal are the most appropriate means of to achieve the objectives of the existing District Plan to the extent that those are relevant [s32(3)]

6.3.26 In respect of each relevant existing District Plan objective (and associated policies), an assessment is provided which discusses the provisions of the plan change request and the manner in which they achieve the District Plan's operative objective and policy framework. These are assessed in the table below.

<table>
<tr><th colspan="2">Christchurch District Plan</th></tr>
<tr><th>Relevant Provisions</th><th>Assessment</th></tr>
<tr><th colspan="2">Chapter 3 Strategic Directions</th></tr>
<tr><td>3.3.1 Objective – Enabling recovery and facilitating the future enhancement of the district
a. The expedited recovery and future enhancement of Christchurch as a dynamic, prosperous and internationally competitive city, in a manner that:
i. Meets the community's immediate and longer term needs for housing, economic development, community facilities, infrastructure, transport, and social and cultural wellbeing; and
ii. Fosters investment certainty; and
iii. Sustains the important qualities and values of the natural environment.
3.3.2 Objective – Clarity of language and efficiency
a. The District Plan, through its preparation, change, interpretation and implementation:
i. Minimises:
A. transaction costs and reliance on resource consent processes; and
B. the number, extent, and prescriptiveness of development controls and design standards in the rules, in order to encourage innovation and choice; and
C. the requirements for notification and written approval; and
ii. Sets objectives and policies that clearly state the outcomes intended; and
iii. Uses clear, concise language so that the District Plan is easy to understand and use.</td><td>The proposed plan change seeks to meet the community's need for infrastructure and economic development through enabling the ongoing operation of existing strategic infrastructure. By avoiding the potential for reverse sensitivity effects to arise, the plan change fosters investment certainty for the ongoing operation and upgrading of strategic infrastructure. It also provides a higher level of direction for other landowners contemplating sensitive and other discretionary and non-complying activities regarding locations where such activities would not be exposed to an unacceptable level of risk.
Investment certainty is also fostered by more accurately identifying the geographic extent of risk from the terminals.
The proposed plan change would also remove the QRA obligations for new discretionary and non-complying activities seeking to establish in the Woolston Risk Management Area, thereby reducing transaction costs on third parties.</td></tr>
</table>

3.3.10 Objective – Commercial and industrial activities *a. The recovery and stimulation of commercial and industrial activities in a way that expedites recovery and long-term economic and employment growth through:* *i. Enabling rebuilding of existing business areas, revitalising of centres, and provision in greenfield areas; and* *ii. Ensuring sufficient and suitable land development capacity.* *3.3.12 Objective – Infrastructure* *a. The social, economic, environmental and cultural benefits of infrastructure, including strategic infrastructure, are recognised and provided for, and its safe, efficient and effective development, upgrade, maintenance and operation is enabled; and* *b. Strategic infrastructure, including its role and function, is protected from incompatible development and activities by avoiding adverse effects from them, including reverse sensitivity effects. This includes: ….* *c. The adverse effects of infrastructure on the surrounding environment are managed, having regard to the economic benefits and technical and operational needs of infrastructure.* *3.3.14 Objective – Incompatible activities* *a. The location of activities is controlled, primarily by zoning, to minimise conflicts between incompatible activities; and* *b. Conflicts between incompatible activities are avoided where there may be significant adverse effects on the health, safety and amenity of people and communities.*	The strategic objectives relating to industry and infrastructure establish a framework that recognises the role that industry will play in the recovery and growth of the City. As such, the District Plan needs to enable industrial growth and activities in appropriate locations. The proposed plan change does not limit or hinder the use of land within the Woolston Risk Management Area for industrial or otherwise permitted activities, and therefore does not frustrate this strategic direction. The terminals are therefore located in an appropriate zone for the activity. The strategic objectives likewise contain a clear direction regarding the role of infrastructure, and strategic infrastructure in particular, in facilitating the City's recovery. The benefits of strategic infrastructure are to be recognised and provided for, including their ongoing operation, development, and upgrading. Objective 3.3.12b makes explicit reference to the need to protect strategic infrastructure from incompatible activities, including reverse sensitivity effects. Objective 3.3.14 likewise seeks to avoid conflicts between incompatible activities where there may be significant adverse effects on the health and safety of people and communities. The proposed plan change achieves this, by clearly identifying an area around the terminals where the establishment of sensitive and other discretionary and non-complying activities may be incompatible with established bulk fuel storage facilities and where people could be exposed to an unacceptable risk to health and safety. Such activities, were they to establish, could also generate reverse sensitivity effects and could constrain their use/operations. The identification of the Woolston Risk Management Area and associated non-complying activity status for sensitive activities are effective tools to ensure that such incompatible activities are avoided.
Chapter 4 Hazardous Substances and Contaminated Land	

4.1.2.1 Objective – Adverse environmental effects a. *The residual risks associated with the storage, use, or disposal of hazardous substances in the district are managed to acceptable levels to not adversely affect people, property and the environment while recognising the benefits of facilities using hazardous substances.* *4.1.2.2 Objective – Risk and reverse sensitivity effects* a. *Sensitive activities are established at suitable locations to minimise reverse sensitivity effects on and avoid unacceptable risks from established facilities using, storing or disposing of hazardous substances.*	The Chapter 4 policy framework provides a three-fold direction. The first element is that hazardous substances are used and stored in locations and in a manner where they will not give rise to unacceptable effects. This policy direction is achieved through the identification of Industrial Heavy zones where the use and storage of hazardous substances is an anticipated component of industrial activities. The two terminals are likewise subject to a wide range of regulation to ensure that they are designed and operated in a safe manner where the risks associated with bulk fuel storage are minimised as far as practicable. The second policy direction is that the effects and associated residual risks of facilities using hazardous substances are identified and managed. Both Liquigas and the Oil Companies have undertaken QRAs to geographically map the extent of the residual risk posed by the facilities. The proposed Plan Change provides a tool for managing this residual risk, namely the avoidance of sensitive activities and ensuring some other discretionary and non-complying activities are located appropriately with reference to the relevant risk acceptance criteria. The third policy direction concerns the management of sensitive activities and the avoidance of such from locating in areas where they would be exposed to an unacceptable level of risk and/or would give rise to reverse sensitivity effects. Policy 4.1.2.2.2 makes explicit reference to this policy outcome regarding the Woolston terminals. This policy identifies the need for the extent of the Risk Management Area to be confirmed via QRAs which this plan change is seeking to achieve. The plan change again directly implements this policy direction by mapping the extent of the area (based on QRAs) in conjunction with a non-complying rule as a tool to avoid sensitive activities locating in an area where they would be exposed to unacceptable risk.
Chapter 16 Industrial	

Objective 16.2.1 – Recovery and growth *The recovery and economic growth of the district's industry is supported and strengthened in existing and new greenfield industrial zones.*	The proposed plan change does not seek to limit industrial activities within the Woolston Risk Management Area, nor complementary supporting activities that are permitted in the IG and IH zones. The recovery and economic growth of land within the WRMA would therefore continue to be supported by the plan change proposal.

6.3.27 Overall it is considered that the proposed plan change package of provisions is the most appropriate method for achieving the objectives of the Christchurch District Plan, having regard to their efficiency and effectiveness. In particular it would more appropriately recognise and provide for the ongoing use, operation and upgrading of strategic infrastructure, ensure that sensitive and/or incompatible activities are avoided in close proximity to this infrastructure whilst continuing to enable the function of the industrial zones to provide for primarily industrial related activities.

7 Assessment of Environmental Effects

7.1 Introduction

7.1.1 It is important to emphasise that the sites and the surrounding area already have an urban industrial zoning. This plan change does not seek to change the underlying zoning. The proposed amendments likewise do not seek to restrict or prevent industrial (or other permitted) activities from occurring with the overlay. The Plan Change simply inserts an amended overlay boundary, and makes consequential changes to the policy framework and related advice notes.

7.1.2 The scope of the Assessment of Environmental Effects (AEE) is therefore limited to the effects derived from the proposed amendments:

- Avoidance of sensitive activities and ensuring other non-industrial activities are located where they meet the relevant risk acceptance criteria.
- Reverse sensitivity and constraints on Strategic Infrastructure.

7.2 Avoidance of Sensitive Activities and (potentially) other Non-Industrial Activities

7.2.1 Both terminals are equipped to ensure the safety and security of operations carried out within their own boundaries. The operation of both terminals is under continuous review to ensure that the facilities are managed to mitigate risk as far as practicable. Liquigas and the Oil Companies likewise have responsibilities to as far as practicable provide a safe working environment for their staff and to prepare a safety case or associated major accident prevention policy under the MHF Regulations 2016. There is therefore considerable focus on managing risk at source as far as practicable.

7.2.2 The nature of the facilities and the product stored does nonetheless mean that complete elimination of risk or the restriction of such to within the site boundaries is not possible. Whilst the probability of an emergency incident occurring at one of the Terminals is extremely low, the impact of such an event is potentially high. For example, the vapour cloud explosion that occurred at the Buncefield Terminal in the United Kingdom in 2005 resulted in the destruction of buildings several hundred metres away from the fuel storage tank area and lesser effects, such as window breakage, up to 8km away[16].

7.2.3 The event at Buncefield highlighted that a vapour cloud explosion, which was historically never considered credible at a terminal site due to their unconfined nature was, in fact, a credible event. As a result, industry and regulator practice around the assessment of risk at fuel terminals has changed to include consideration of the potential for large vapour cloud explosions. This in turn has affected the modelling assumptions that input into the QRAs.

7.2.4 In addition to managing the safety of the facility, an approach to managing life safety risk also involves managing incompatible activities in close proximity to the facility, where those activities would result in an increase in the risk posed by the facility. Risk is the sum of the likelihood of an event occurring and the consequence of that event. A new activity that involves high rates of human occupancy or vulnerable populations increases the potential impact of an event, and therefore alters the risk profile of an established facility and constrains future development options on the site.

7.2.5 The acceptability of risk involves many considerations but in relation to land uses in close proximity to the bulk fuel storage terminals broadly ranges between tolerable for industrial type land uses to intolerable or unacceptable for sensitive activities (e.g. residential, child care, health care). It is therefore critical to ensure that land uses surrounding the terminal sites remain compatible with the level of risk associated with these activities.

7.2.6 Appropriate planning controls are required to manage risks to public health and safety, while enabling the efficient and effective operation, maintenance, upgrade and future development of the terminals and surrounding land.

7.2.7 The proposed plan change to amend the extent of the overlay will not in itself result in any direct effects on the environment. It is in nature different from a plan change to, for example, rezone land from rural to urban activities or to intensify an existing residential neighbourhood where the change in planning controls will over time result in a markedly different physical environment. The identification of risk is not a direct physical environmental effect in the same way as, for example, noise, odour, or visual amenity. Rather it involves the consequence of an event occurring together with its associated likelihood.

7.2.8 The effect of the overlay does not restrict the development of industrial or (except in relation to preschools) other permitted activities in the underlying zones. The physical environment will therefore continue to be able to be developed in accordance with the environmental outcomes anticipated by the Industrial Heavy and Industrial General Zones, and in accordance with the District Plan's policy framework for the area.

7.2.9 The plan change retains the operative District Plan's explicit policy direction and associated non-complying rule that the establishment of new sensitive activities within the Woolston Risk Management Area overlay will result in unacceptable risk and therefore is to be avoided, other non-industrial activities will only be able to be located where they meet the relevant risk acceptance criteria. The geographic extent of the overlay identifying the extent of unacceptable risk for sensitive activities has been updated and an advice note in chapter 16 will identify that the new QRAs are publicly available.

---

[16] Buncefield Major Incident Investigation Board (2008) The Buncefield Incident 11 December 2005: The final report of the Major Investigation Board, p10.

7.3 Reverse Sensitivity and Constraints on Strategic Infrastructure

7.3.1 The Liquigas Terminal and the Woolston Oil Terminal are regionally significant infrastructure and are two of the key components in the fuel supply chain for the Canterbury Region.

7.3.2 Proximity of sensitive activities and potentially other non-industrial activities that have a different risk profile) in and around the terminals have the potential to pose significant constraint on the ongoing operation and development of those facilities. As noted above, under the District Plan, 'reverse sensitivity' *"means the effect on existing lawful activities from the introduction of new activities, or the intensification of existing activities in the same environment, that may lead to restrictions on existing lawful activities as a consequence of complaints"*.

7.3.3 To date, operators consider that development in and around the terminals has largely been compatible with the terminal operations. However with the earthquake recovery and the need for substantial redevelopment across the Canterbury Region it is necessary that the District Plan includes provisions that adequately future proof and protect the resilience of the fuel supply chain to the Canterbury Region so that ongoing fuel demands can be met appropriately and safely.

7.3.4 The District Plan provisions need to ensure land uses in the vicinity of the terminal sites remain compatible with the level of risk associated with the terminals to avoid new sensitive and other incompatible non-industrial activities complaining about the risk that they are exposed to and thereby seeking to place restraints on the operations of strategic infrastructure.

7.3.5 In this regard, the District Plan needs to restrict the establishment of sensitive or other land uses that could give rise to an issue of reverse sensitivity or operational constraint due to an activity being considered to be exposed to an unacceptable level of risk from the terminals.

7.3.6 The nature of fuel supply means that bulk deliveries to Canterbury must come by ship and be discharged at Lyttelton. The two pipelines to transport this fuel from Lyttelton to Woolston are existing and represent significant fixed costs/value in strategic infrastructure. Operators consider that there are significant constraints on road transport of hazardous substances from Lyttelton given the loss of the Sumner Road access, the narrow, winding nature of that route when re-established, and restrictions on tunnel use. Transport by pipeline has been the most efficient, effective, and safest means of transporting these fuels in bulk.

7.3.7 The two terminals are located in Woolston to maximize pipeline efficiency over the Port Hills. The terminals are existing and located within an appropriate land use zone that anticipates these types of activities. The region's bulk fuel will continue to be stored and distributed from this location for the foreseeable future. As such it is critical that these terminals are able to continue to operate and be upgraded. The establishment of new sensitive or other non-industrial activities in close proximity to the terminals can lead to increased pressure to reduce operations or to prevent expansion due to both the perception and the potential reality that such works would result in increased risk to nearby properties.

8 Consultation

8.1.1 The principle of a Risk Management Area and associated rules were subject to the statutory submission process undertaken as part of the District Plan Review. As such, interested parties had the opportunity to become involved in the development of the operative District Plan's provisions and to present evidence through that hearing process.

8.1.2 On October 2018, the Linwood-Central-Heathcote Community Board was briefed on the upcoming proposed Plan Change 1 Woolston Risk Management Area. The process, timing and issues surrounding the upcoming proposed plan change was presented to Council at its meeting on December 2018.

8.1.3 Following direction from the Council, pre-notification consultation was held from mid-January to mid-February 2019. Letters were sent out to owners and owner-occupiers considered to be affected inviting them to comment on the draft plan change and to attend one of the public information drop-in sessions: (1) Tuesday, 5 February 2019, (2) Monday, 11 February 2019, and (3) Wednesday, 13 February 2019. Likewise, the Ministry for the Environment, Department of the Prime Minister and Cabinet (DPMC), Canterbury Regional Council and Ngāi Tahu were invited to provide comments on the draft plan change, in accordance with Clause 3(1), Schedule 1 of the RMA.

8.1.4 Affected parties were invited to call or email Council staff directly if unable to attend any of the scheduled drop-in sessions. Detailed information and the Quantitative Risk Assessments were made available at www.ccc.govt.nz/planchange and the Council Have Your Say webpage.

8.1.5 A total number of nine property owners representing 12 sites attended the scheduled public information drop-in sessions, broken down as follows into different groups:

- new properties within the proposed overlay – 5
- properties within the existing and proposed overlay – 7
- properties no longer within the existing overlay and outside the proposed overlay – 0

8.1.6 Feedback from the drop-in sessions showed general support for the plan change because they consider sensitive activities inappropriate to be located near their industrial activities.

8.1.7 Queries received via email were mainly clarification requests with respect to the boundary of the overlay in relation to properties. One specific query was received from the media (after seeing the plan change info at the Council Have Your Say webpage) about the process involved in revoking the OiC.

8.1.8 Three completed feedback forms were received via post: (1) One landowner noted no concerns as long as there are no further or additional restrictions placed on their current business use under the current plan; (2) One landowner would be very pleased to see this change take effect; and (3) the other landowner sought flexibility to operate offices in the IH Zone, within the overlay.

8.1.9 Feedback received via email from Mahaanui Kurataiao Ltd (MKT) stated that the proposed plan change was discussed at a recent hui between MKT staff and the Kaitiaki Portfolio representatives for Te Ngāi Tūāhuriri Rūnanga. No concerns or recommendations were raised on the proposed plan change.

8.1.10 Liquigas and the Oil Companies commented in support the draft plan change except for the change initially proposed to Policy 16.2.1.4 - Activities in industrial zones, as explained below.

8.1.11 The draft plan change made available during the informal pre-notification consultation proposed to delete the part of the policy that required discretionary and non-complying activities to prepare and submit a QRA with their resource consent application in order to demonstrate that their proposal meets the appropriate risk acceptability criteria for the type of land use. Council initially considered that this policy requirement was no longer necessary because QRAs had since been undertaken by Liquigas and the Oil Companies, and provisions in Chapter 4 (Hazardous Substances and Contaminated Land) of the District Plan now manage the location of sensitive activities within the Woolston Risk Management Area.

8.1.12 Liquigas and the Oil Companies conveyed their position that it remains appropriate for Council to consider the potential of discretionary and non-complying activities seeking consent to establish within the Woolston Risk Management Area. This is to enable an assessment of the extent to which these activities were likely to generate reverse sensitivity effects on the bulk fuel terminals and to consider the exposure of these activities to unacceptable risk. These potential effects may be relevant to all activities, not just those defined as sensitive in the District Plan[17]. Council staff now agree that it is appropriate to retain this policy requirement but that it is also appropriate to include reference to the existing QRAs to provide additional clarity to plan users via an advice note that:

- The QRAs prepared by the LPG and oil depot companies for the Woolston Risk Management Area will be made freely available to the public to inform the policy requirement; and

- The relevant discretionary and non-complying activities are only those the subject of Rule 16.4.1.4 D1, Rule 16.5.1.4, and Rule 16.5.1.5 NC1.

8.1.13 Liquigas and the Oil Companies also expressed strong support for inserting new rules relating to Site Emergency Management Plans (SEMPs) for the safety and protection of workers and visitors in the surrounding areas. However at the time of preparing the plan change and given the urgent focus of the plan change (i.e. the lapse sunset clause), Council considered that further analysis was required in order to test the SEMP provisions under section 32 of the Act.

8.1.14 In accordance with the 1st Schedule of the RMA, formal consultation on the proposed Plan Change will occur with all landowners within the operative Risk Management Areas and the proposed Woolston Risk Management Area. CCC is making an application to the Environment Court for Rule 4.1.4.1.5 and the associated revised overlay to have immediate legal effect on a date other than the date at which a decision on submissions to the rule is made[18]. The RMA requires that in such circumstances, the proposed plan change is publicly notified. Any other interested parties are able to put forward their views through the statutory public notification process.

9 Conclusion

9.1.1 This section 32 report and appendices present all of the relevant information required to enable the proposed plan change to be considered. The information provided is at a level of detail that is appropriate to the scale and significance of the issues concerned. Potential environmental effects have been identified and appropriately avoided, remedied or mitigated through the proposed provisions.

---

[17] E.g. residential, care facilities, education activities and preschools, guest accommodation, health care facilities, hospitals and custodial accommodation.

[18] Resource Management Act 1991, s86D

9.1.2 All of the matters of policy and statutory consideration have been identified and addressed, including for all relevant higher order documents. Consultation with stakeholders will be on-going as required, noting that all interested parties will have a formal opportunity to lodge submissions as part of this statutory plan change process.

9.1.3 The CRPS provides a framework within which the role and benefits of strategic infrastructure are recognised and provided for, along with the need to protect such infrastructure from the adverse effects of incompatible activities becoming established in locations that would result in constraints on the operation and development of strategic infrastructure.

9.1.4 The proposed amendments to the policy frameworks of the Industrial and Hazardous Substances Chapters likewise give effect to the higher order direction insofar as the policy direction relates to strategic infrastructure and the need to avoid incompatible activities that would have a significant adverse effect on the efficient functioning, use, and development of that infrastructure.

9.1.5 The proposed amended Woolston Risk Management Area boundary identifies the geographic extent of the sensitive area around the existing strategic infrastructure facilities where the location of new sensitive activities should be avoided and potentially other non-industrial activities assessed on the extent to which they meet the relevant risk criteria as an effective tool for managing incompatible activities in relation to bulk fuel storage facilities.

9.1.6 The proposed policy and rule amendments to remove the sunset clause and limit the establishment of preschools and other sensitive activities in the vicinity of the terminals are considered to better give effect to the CRPS and the Strategic Directions objectives than the operative District Plan provisions.

APPENDIX 1 – LIQUIGAS TERMINAL QUANTITATIVE RISK ASSESSMENT

LIQUIGAS

Woolston LPG Depot
Quantitative Risk Assessment

503402-RPT-R0001
May 2018

WorleyParsons New Zealand Ltd
25 Gill Street, New Plymouth 4310
PO Box 705, New Plymouth 4340

Telephone +64-6-759 6300
Facsimile +64-6-759 6301
www.worleyparsons.com

Rev	Description	Originator	Reviewer	WorleyParsons Approver	Date	Client Approval	Date
A	Issued for Review/Comment	Y Lee	D Phillis	D Phillis	10/2017		
0	Approved for Use	Y Lee	D Phillis	D Phillis	12/2017		
1	Re-Approved for Use	D Phillis	Y Lee	D Phillis	05/2018		

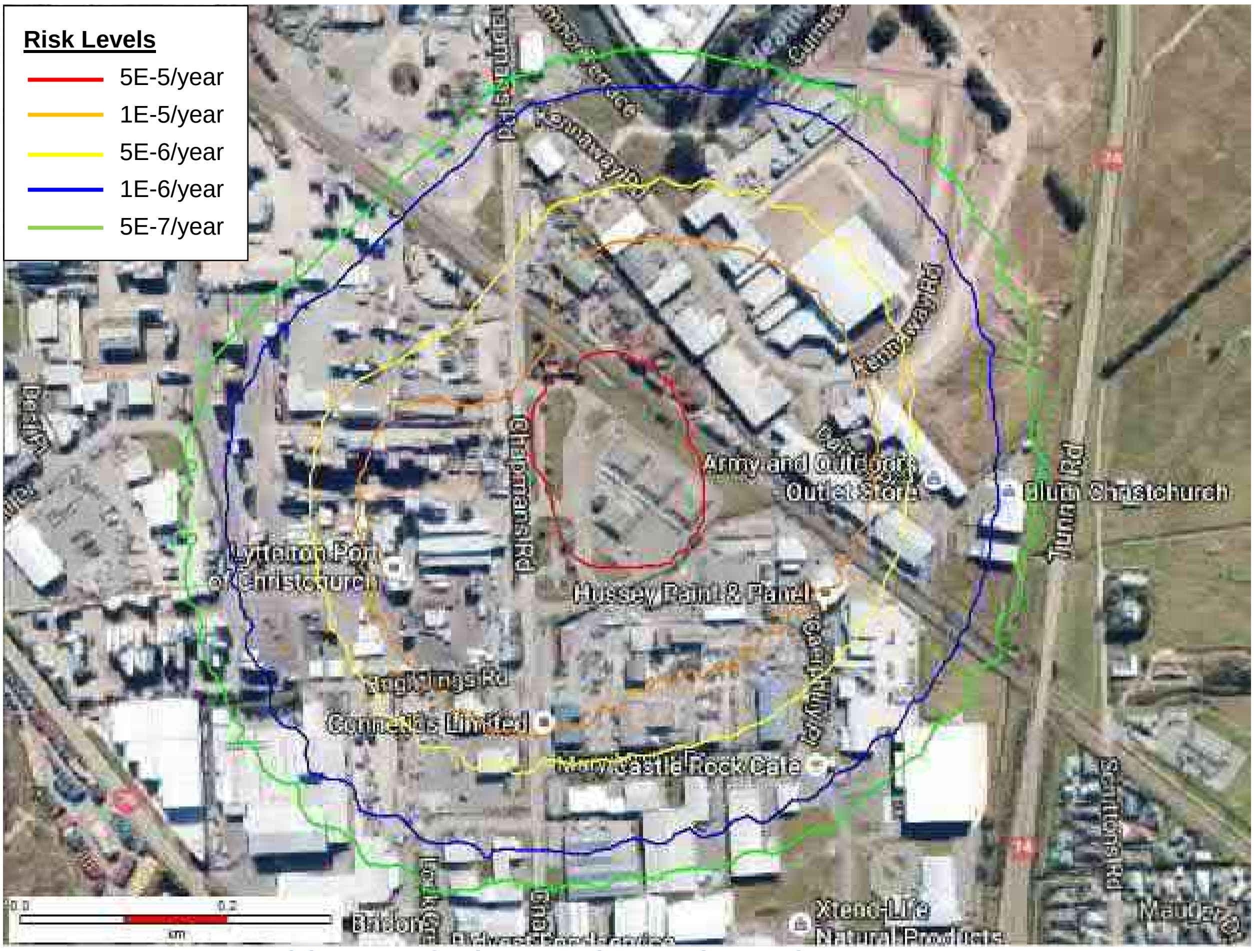
Y:\Liquigas\503402\2.Controlled Docs\503402-RPT-R0001-R1.docx

EXECUTIVE SUMMARY

A Quantitative Risk Assessment (QRA) has been conducted for the Liquigas Woolston LPG depot, which covers the currently operating Woolston LPG depot and the consented LPG storage upgrade. The key deliverable of the QRA is the individual fatality risk contours.

Base Case

The risk contour for the base case currently operating Woolston LPG depot is presented in the figure below.



Risk Contour for the Currently Operating Woolston LPG Depot

The risk results as assessed against the HIPAP4 criteria are presented in the table below.

LSIR Results as compared to the HIPAP4 Land Use Criteria for the Currently Operating Woolston LPG Depot

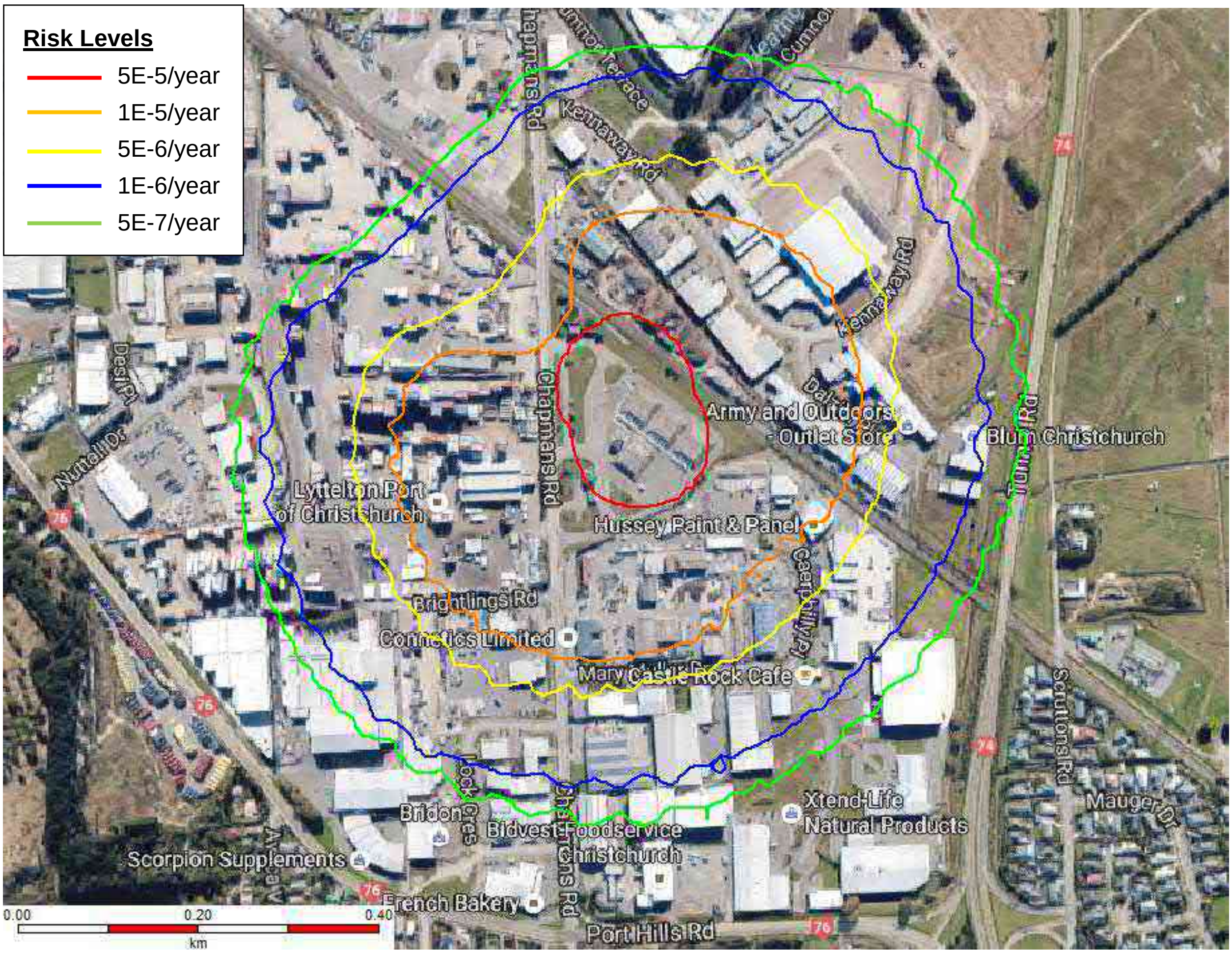
LSIR	Risk Contour	HIPAP4 Land Use Criteria	Result
5E-05 / year	Red	5E-05 / year risk contour should, as a target, be contained within the boundaries of the industrial site where applicable.	The 5E-05 / year risk contour extends beyond the site boundary at the North East direction on to the railway line and the recycling centre.

LSIR	Risk Contour	HIPAP4 Land Use Criteria	Result
1E-05 / year	**Orange**	1E-05 / year risk contour should not extend to sporting complexes and active open space	No impact. There are no sporting complexes and active open space within the proximity. However, the 1E-05 / year risk contour is impacting on the Chapmans Road on the western side.
5E-06/ year	**Yellow**	5E-06 / year risk contour should not extend to commercial developments including retail centres, offices and entertainment centres	The 5E-06 / year risk contour extends beyond the site boundary onto a few neighbouring facilities offices, including the Contact Energy Regional Office to the east, the Lyttelton Port of Christchurch offices to the west, and various commercial premises across the railway line to the north and north east. However, the area is zoned “industrial” as per the Christchurch District Plan. HIPAP4 [Ref. 7] states that a higher level of risk is generally considered acceptable in industrial areas (HIPAP4, p.8) in comparison to commercial land use areas. In the context of the report this is mentioned to differentiate between offices located in a ‘commercial’ area/zone and offices in an ‘industrial’ zone (where a higher level of risk acceptance may be appropriate).
1E-06 / year	**Blue**	1E-06 / year risk contour should not extend to residential, hotels, motels, tourist resorts	No impact. There are no residential, hotels, motels or tourist resorts within the proximity.
5E-07 / year	**Green**	5E-07 / year risk contour should not extend to hospitals, schools, childcare facilities, old age housing	No impact. There are no hospitals, schools, childcare facilities or old age housing within the proximity.

The results show that the near-field risks are mainly contributed by jet fires, whereas the far-field risks are mainly contributed by flash fires.

Consented LPG Storage Upgrade

The risk contour for the consented LPG storage upgrade is presented in the figure below.



Cumulative Risk Contour for the Currently Operating Woolston LPG Depot and the Consented LPG Storage Upgrade

The consented LPG storage upgrade only generated negligible incremental risk. The LSIR assessment against the HIPAP4 criteria is the same as for the currently operating Woolston LPG depot.

Sensitivity Analysis

Sensitivity analyses have been conducted for the following aspects of the QRA modelling, including:

- Different ignition probabilities – the QRA model were repeated by using (1) the "large plant gas LPG" ignition probability correlation; (2) Cox, Lees and Ang ignition probability. The results found that the risk contours generated by using the Cox, Lees and Ang ignition probability is significantly lower than the base case.

- Uniform wind profile – Phast Risk software generally applies Power Law to the wind profile where the wind speed is lower when nearer to the ground level. A sensitivity analysis was performed by applying uniform wind profile. The risk contour is similar to the base case with negligible risk increment. This shows that the wind speed changes with height do not have significant impact on the risk results.

- Different representative hole sizes – the QRA were repeated by using a different representative hole sizes that are also commonly used in QRA studies were considered. The result shows mixed impact on the risk levels, where the highest risk level (5E-05 / year) has extended further offsite but the 1E-05 / year risk and 5E-06 / year risk levels distances have reduced. There are negligible differences for the lower risk levels (1E-06 / year and 5E-07 / year).

TABLE OF CONTENTS

APPENDICES

1. ABBREVIATIONS AND DEFINITIONS

1.1 Abbreviations

BLEVE	Boiling Liquid Expanding Vapour Explosion
DNV GL	Det Norske Veritas Germanisher Lloyd
HIPAP4	Hazardous Industry Planning Advisory Paper No. 4
IRPA	Individual Risk Per Annum
LFL	Lower Flammable Limit
LPG	Liquefied Petroleum Gas
LSIR	Location Specific Individual Risk
MEM	Multi-Energy Method
P&ID	Piping and Instrumentation Diagram
PLL	Potential Loss of Life
QRA	Quantitative Risk Assessment
UKOOA	UK Offshore Operators Association
VCE	Vapour Cloud Explosion

1.2 Definitions

BLEVE	Event whereby a vessel containing a pressurised liquid such as LPG is subjected to fire impingement, causing buildup of vapour pressure and subsequent dropping of the liquid level in the vessel as the safety valve opens to relieve the pressure buildup. Eventual failure of the tank due to fire impingement on the vapour space of the vessel results in a damaging explosion and fireball, with missile generation likely over some distance.
Consequence	Outcome or impact of a hazardous incident, including the potential for escalation.
Flammability limit range	Concentration range over which a flammable mixture of gas or vapour in air can be ignited at a given temperature and pressure.
Flash fire	The combustion of a flammable vapour and air mixture in which flame passes through that mixture at low velocity, such that negligible overpressure is generated.
Flash point	The lowest temperature, corrected to a barometric pressure of 101.3 kPa, at which application of a test flame causes the vapour of the test portion to ignite under the specified conditions of test (AS 1940–2004).
Heat radiation	The propagation of energy in the infra-red region of the radiation electromagnetic spectrum, commonly ‘heat'.
Jet/spray fire	An intense directional fire resulting from ignition of a vapour or two phase release with significant momentum (i.e. pressurised) from an orifice (can occur at pressure 2barg or above).
Location Specific Individual Risk (LSIR)	The risk of fatality at a point in space to a hypothetical individual at that location for 365 days per year, 24 hours a day.
Vapour Cloud Explosion	The explosion resulting from the ignition of a cloud of flammable vapour, gas, or mist in which flame speeds accelerate to sufficiently high velocities to produce significant overpressure.

2. INTRODUCTION

Liquigas Limited (Liquigas) operates a liquefied petroleum gas (LPG) storage and distribution facility in Woolston Christchurch. LPG is delivered by sea tanker to the wharf in the Port of Lyttelton and then pipelined over the Port Hills, via a pumping station at Lyttelton, to mounded storage vessels located at the Woolston depot in Christchurch. It is then loaded out into LPG road tankers for distribution throughout the region.

Liquigas also has a resource consent to increase the LPG storage capacity from 2,000 tonnes to 3,575 tonnes through the installation of new vessels contained within a new mound.

WorleyParsons New Zealand Ltd has been engaged to undertake a Quantitative Risk Assessment (QRA), which covers the currently operating Woolston LPG depot and the consented LPG storage upgrade.

2.1 Objectives

The objectives of the QRA are to determine the location specific individual risk (LSIR) associated with the currently operating Woolston LPG depot, including the consented LPG storage upgrade. The QRA is likely to be used for a future update of the site major hazard facility risk management overlays as required by the Christchurch Replacement District Plan.

2.1.1 Exclusions

The following are excluded from this study:

- Third party risk contributors (external risks, e.g. from the Contact LPG Terminal).
- Loss of containment from pipeline sections outside the plant boundaries (pipeline inventories are included in scenarios within the plant boundary).
- Non-hydrocarbon risks (e.g. transportation risk, earthquake risk). The industry generic leak frequency database [Ref. 5] incorporates the frequency of equipment failure and loss of hydrocarbon containment due to seismic activities. Hence to avoid overestimating the leak frequencies, earthquake was not included in the leak frequency calculation as a standalone cause of loss of containment. It is noted that the tanks and equipment are designed to withstand seismic loading with a specific return period in accordance with AS/NZS 1170.5. Some pipework deformation or flange leak may be expected but catastrophic ruptures or structural collapse should not occur. This is consistent with the site effects from the February 2011 Christchurch earthquake where some pipework deformation was experienced but no leaks were experienced.
- Calculation of individual risk per annum (IRPA) and potential loss of life (PLL) for onsite personnel, and calculation of societal risk for offsite personnel.
- Calculation of injury risk, risk of property damage and accident propagation, and societal risk.

2.2 Facility Description

The Woolston LPG depot is located at 50 Chapmans Road in an industrial area at the foot of the Port Hills, and within a triangle of land formed by Chapmans Road, a railway line and an open drain. The depot receives LPG via the cross country pipeline from the pump station at Lyttelton. The LPG is routed to a series of mounded storage vessels on the site. Two loading bays facilitate the distribution of LPG from the site via road tankers. The LPG is also distributed to the adjacent Contact LPG Terminal and Elgas filling station via separate pipelines.

Figure 2-1: Woolston LPG Depot (Looking Southeast)

2.2.1 Currently Operating Woolston LPG Depot

The key facilities at the currently operating Woolston LPG depot include:

- Storage mounds – Four mounds with each containing 5 x 100 tonne LPG vessels, (20 vessels; 2000 tonnes in total). The LPG vessels have two turrets, one housing process pipework penetrations and the other housing the instrumentations. Manway entry is through the top of the vessel.
- Liquid header - used for the dispatch of LPG (generally “propane rich mix” when available), to the road load-out bays from dispatch vessels V-0511 to V-0515 (24 hr mode), bottle fill plants and internal transfers from vessel to vessel. This line also incorporates a 25 mm take off to the pipeline jockey pump (static leak detection) system.
- Liquid load-out header – used for the dispatch of LPG from mound one dispatch vessels V-0501 to V-0505 via the road tanker load-out bay, and bottle fill plants. Generally designated 60/40 mix product.
- Vapour headers – headers used to distribute LPG vapour, high and low pressure between storage vessels, and to and from the road tanker load-out bay.
- LPG compression – 5 Corken reciprocating compressors used to transfer product between vessels and the loading bay. Can be used in two modes of operation: pressurizing (product transferring/load out duty) and de-pressuring (vessel de-commissioning).
- Road tanker load-out – two load-out bays with spray cage fire protection.

- Utilities systems (e.g. utility header and water separation vessel, instrument air, drainage and firewater supply).

The LPG is odourised at the Lyttelton pumping station. As such, there is no odorant system on site.

The control building incorporates the control room, offices, workshop, switch gear room, toilets and lunch room. There is a garage adjacent to the control building which is used for storage. These are located outside LPG hazardous areas.

2.2.2 Consented LPG Storage Upgrade

The existing facility has capacity for storing 2,000 tonnes of LPG and has a resource consent to increase this capacity up to 3,575 tonnes through the installation of new LPG vessels. The key facilities for the consented LPG storage upgrade include:

- One storage mound – containing 3 x 500 tonne LPG vessels.
- Header extensions – Liquid and vapour headers to be extended by approximately 20 – 25 m to connect with new vessels.

The site layout is shown in Figure 2-2.

Figure 2-2: Woolston LPG Depot Layout

3. METHODOLOGY

The methodology followed for completing the QRA is aligned with good industry practice, and specified in in the WorleyParsons' Onshore QRA Method Statement [Ref. 1]. The generic process is illustrated in Figure 3-1 with the slight modification in that it does not include the calculation of individual risk per annum (IRPA) and potential loss of life (PLL).

Note that the reference to 'personnel' in Figure 3-1 should be interpreted as inclusive of both on- and off-site parties.

Set Context	Define the objectives, assumptions and rules set applicable to the QRA study and the targeted audience.
Hazard Identification	Identify credible hazardous events due to hydrocarbon releases from the facility for further evaluation.
Scenario Identification	Each accident category identified is divided into a series of contributing accidental events.
Consequence Modelling	Credible scenario outcomes are modelled based on the material composition and operating conditions to determine the impact of the hazardous event outcome upon loss of containment, e.g. fire, explosion, dispersion and etc.
Event Frequency Estimation	The failure frequency for each isolatable section is estimated using the parts count approach. Probabilities are assigned to each branch of event tree and the respective outcome event frequency is estimated.
Risk Assessment	Fatality estimation: Determine the fatality probabilities to personnel due to each event outcome. Risk analysis: Estimation of the risks posed to personnel. Risk summation: Summation of the risks to personnel from each event outcome. Risk evaluation: The risk levels are compared against defined risk acceptance criteria to determine its tolerability level.
Risk Mitigation	Controls and mitigating measures are proposed to reduce the likelihood and/or impact of the hazardous event outcome. Hence, reduce the risk to individuals.

Figure 3-1: QRA Methodology

3.1 Assessment Tools

Phast Risk [Ref. 2] is an integrated consequence and risk modelling package developed by DNV GL Software aimed at the onshore petrochemical and chemical process industry for assessing process plant risks via comprehensive QRA. It is designed to perform all the analytical, data processing and results presentation elements of a QRA within a structured framework.

3.2 Assumptions

An assumptions register [Ref. 3] was generated which outlines the basis of all assumptions and the input bases inherent in the QRA study. The assumptions register was issued to Liquigas for review and prior approval. Refer to Appendix 4 for the Assumptions Register and email correspondence confirming Liquigas approval.

3.3 Weather Parameters

Meteorological conditions impact the outcomes of release modelling, including downwind dispersion distance (influenced by atmospheric stability and wind speed), rate of vaporisation (ambient temperature), and atmospheric attenuation of radiant heat (temperature and relative humidity).

Wind data was obtained from the New Zealand National Climate Database [Ref. 4] for Christchurch Aerodrome station (station number 4843) for time period 2008 – 2012, and is presented in the form of a windrose in Figure 3-2.

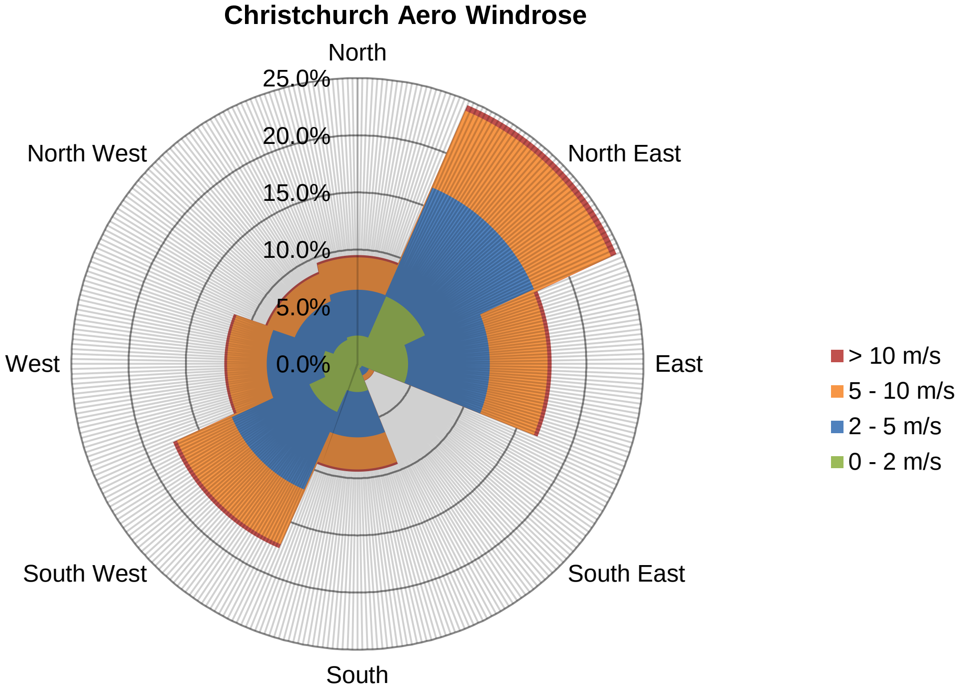


Figure 3-2: Christchurch Aero Windrose

The wind speed and atmospheric stability (Pasquill Stability) combinations is also presented in tabular format in Table 3-1 for input into the QRA model.

Table 3-1: Christchurch Aero Wind Data

Wind Speed / Pasquil Stability	North	North East	East	South East	South	South West	West	North West	Total
0 - 2 m/s / F	2.5%	6.4%	4.4%	0.4%	2.5%	4.6%	3.0%	2.3%	26.1%
2 - 5 m/s / D	4.0%	10.3%	7.1%	0.7%	4.0%	7.4%	4.9%	3.7%	42.1%
5 - 10 m/s / D	3.0%	7.8%	5.4%	0.5%	3.0%	5.6%	3.7%	2.8%	31.9%
Total	9.5%	24.6%	17.0%	1.6%	9.4%	17.5%	11.6%	8.7%	100.0%

Note:

- Pasquill Stability class F – stable, night with moderate clouds and light/moderate wind
- Pasquill Stability class D – neutral, little sun and high wind or overcast/windy night

The following weather parameters are also taken for the same weather station:

- Mean air temperature: 11.5°C
- Relative humidity: 82.2%

In this study, no allowance for solar radiation is included.

The surface roughness is the roughness of the ground (over which a flammable vapour cloud is moving). Degree of surface roughness depends on the size and number of roughness elements, which can range in size from blades of grass to buildings. Surface roughness generates air turbulence, which acts to mix air to the flammable vapour cloud and dilute the vapour. A higher surface roughness generally gives smaller hazard zone due to more dilution. For this study, a surface roughness of 0.1 m is applied, which generally representative of an area of “low crops, occasional large obstacles”.

3.4 Release Hole Sizes and Conditions

For every component failure, there is a range of credible hole sizes ranging from pinhole leak to full bore rupture. The hole size grouping from the DNV Failure Frequency Guidance [Ref. 5] together with the representative hole sizes used in the QRA are as given in Table 3-2.

Table 3-2: Hole Size Distribution

DNV Hole Size Group (mm)	Hole Representation (mm)
1 - 3	2
3 - 10	7
10 - 50	30
50 - 150	100
> 150	150

The height of release from all scenarios is assumed to be at 1 m above ground with the exception of releases from the mounded vessels where the height of release are assumed to be 5 m above ground. It is considered reasonable to assume 70% of the releases are horizontal release and 30% of the releases are vertical release.

3.5 Ignition Probability

Given a release, the probability of ignition is dependent on a range of factors including:

- Release rate
- Material state (liquid or gas)
- Material physical properties (flash point, density, flammability limits)
- Ignition sources present (hot work, uncertified equipment)

There are a range of correlations for applying an ignition probability to a release, and most are based on release rate and state. Oil and Gas UK (formerly UK Offshore Operators Association (UKOOA)) has generated a model for predicting ignition probability which takes into account the above, as well as the nature of the surrounding area with respect to potential ignition sources [Ref. 6]. This model has been used to generate a range of typical correlations. For this QRA, the following scenario is used:

- Tank Gas LPG Storage Industrial (Gas or LPG release from onshore tank farm sited adjacent to a plant or away from the plant in an industrial area), which is applicable to releases of flammable gases, vapour or liquids significantly above their normal boiling point from onshore outdoor storage tanks located in a 'tank farm' adjacent to plants or situated away from plants in an industrial or urban area.

The graph of ignition probabilities as a function of mass release rates is shown in Figure 3-3.

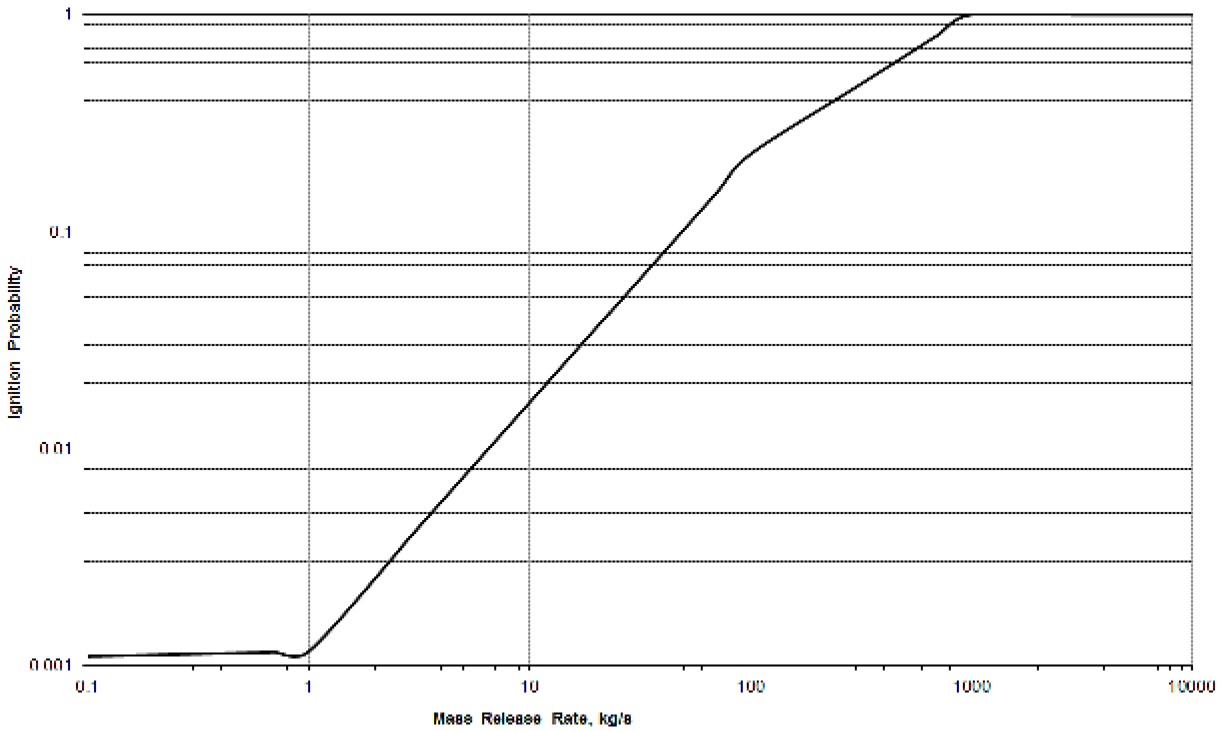


Figure 3-3: Ignition Probabilities

The graph represents the total ignition probability. An overall distribution for early to delayed ignition ratio of 30:70 to 50:50 split are typically applied. The timing of ignition is used as a means to predict the nature of the ignited event. Early ignition is taken to indicate a jet fire or a pool fire (depending on the released material). Delayed ignition is taken to indicate that the ignition would initially result in a flash fire or explosion. For this QRA, a 50:50 split for immediate:delayed ignition probability is used. The ignition probabilities for each scenario are listed in Appendix 3.

3.6 Radiant Heat

The method of calculating the probability of fatality for an individual in Phast Risk, given known exposure duration and thermal heat radiation levels, is undertaken by using a probit function. The probit function is a general formula which takes the same form, but with various constants used. The probit function is defined as follows:

$\text{Probit} = -36.38 + 2.56 \ln (t \times q^{4/3})$

Where:

t = exposure duration in seconds

q = thermal radiation level in W/m^2

Phast Risk program calculates the probit values during the analysis.

An exposure duration of 20 seconds has been used as a base case, although it is noted that personnel are likely to find some form of shielding protection within this time frame.

Note that Phast Risk also assumes that if a continuous release has a very short duration, the immediate ignition of the release may give effects which are closer to a fireball than to a jet fire, because a jet fire would not have time to establish itself. The cut-off time in Phast Risk is 20 seconds.

3.7 Flash Fire

If personnel are within the 100% lower flammable limit (LFL) of the gas plume, 100% fatality is assumed.

3.8 Explosion

Vapour cloud explosions (VCE) are modelled by using Extended Explosion Modelling, which is an extension in Phast Risk. The extended explosion method allows the definition of regions of congestion and confinement. The calculations then consider the interactions between the dispersing cloud and these regions, and calculate the pattern of overpressure across these regions. The relationship between overpressure and fatality probability for different groups of people (e.g. for people in different types of building) can also be defined. The Multi-Energy Method (MEM) is selected for the explosion modelling in this study.

4. HAZARD IDENTIFICATION

4.1 Hazardous Materials

The hazardous material considered in the QRA is LPG (propane and butane). The composition of LPG varies between winter and summer. The Woolston LPG depot normally handles propane in winter as it is more suitable for the South Island winter market, but it can also handle product from 50/50 (propane/butane) mix to 100% propane. For the purpose of QRA, it is assumed that the depot is handling 100% propane for 6 months per year, and 60/40 propane/butane (mole fraction) mix for the other 6 months.

Propane and butane are flammable materials. Propane has a flash point of -156°C with the flammability limit ranges from 2.1% to 9.5%. Butane has a flash point of -76°C with the flammability limit ranges from 1.8% to 8.4%.

LPG is normally stored as liquid under pressure. Accidental releases can either be liquid, which quickly vaporises, or in the gaseous mixture. As LPG gas is heavier than air, it will flow along grounds and tend to settle in low spots. Should the flammable vapour find an ignition source, the flame can flash back to the leak source and result in a jet fire. LPG releases were modelled as jet fire (in the event of early ignition) and flash fire and/or vapour cloud explosion (VCE) (in the event of delayed ignition). VCE was modelled within the expected congestion area.

As the LPG vessels are mounded, liquid releases from the vessels are not considered credible due to containment within the mounded structure protecting the vessels. There are no flanges or connections in the liquid phase. Flanges, instrumentation and connections are in the vapour phase (i.e. from the top of the mounded vessels). Hence releases from the vessels were modelled in the vapour phase only. The mounded nature of the LPG storage vessels also significantly reduces the credibility of a boiling liquid expanding vapour explosion (BLEVE).

4.2 Release Scenarios

Isolatable hydrocarbon inventories have been identified based on the location of isolation valves (e.g. closed valves and emergency shutdown valves) shown on piping and instrumentation diagrams (P&IDs). The release scenarios and the respective operating conditions considered in the QRA are given in Table 4-1. The highlighted sections in P&IDs are attached in Appendix 1.

Table 4-1: Release Scenarios and Operating Conditions

No.	Description	Pressure (barg)		Temp. (°C)	Inventory
		LPG	Propane		
Currently Operating Woolston LPG Depot					
S01A	Aboveground pipeline section to SDV-0212A (LPG, during discharge)	28	28	12	230 m^3
S01B	Aboveground pipeline section to SDV-0212A (no discharge, resting on LPG)	38	38	12	230 m^3
S02A	LPG Scraper Receiver (LYT-V-0213)	28	28	12	230 m^3
S03A	LPG liquid ship unloading line from SDV-0212A to PCV-0216A	28	28	12	5 m^3
S03B	LPG liquid ship unloading line PCV-0216A to PCV-0217A	15	20	12	5 m^3

No.	Description	Pressure (barg)		Temp. (°C)	Inventory
		LPG	Propane		
S03C	Rundown Header from PCV-0217A to SDVs on top of all LPG vessels	13	13	12	5 m^3
S04A	Liquid Loadout Header from SDV-0541C and SDV-0542C to SDVs on top of LPG Despatch Vessels (V-0501 to V-0505), British Oxygen Co and Rockgas, and Liquid Header from SDV-0501F to SDVs on top of LPG Storage Vessels (V-0506 to V-0510 and V-0516 to V-0520)	8	13	12	3 m^3
S05A	Liquid Header from SDV-0501F and SDV-0501G to road tanker SDVs (SDV-0541B and SDV-0542B)	8	13	12	2 m^3
S06A	Liquid Header from SDV-0501G to SDVs on top of LPG Storage Vessels (V-0511 to V-0515)	8	13	12	2 m^3
S07A	Loadout supply from SDV-0641A and SDV-0642A to Auxiliary Despatch Header and Auxiliary Storage Header	6.5	8.5	12	2 m^3
S07B	Loadout return to Compressor Suction Header (Loadout), to LPG Compressor Suction Vessels (V-0615 & V-0616) and SDV-0616A	3	6.5	12	2 m^3
S07C	Compressor Discharge Header (Loadout) from SDV-0616B to SDVs on top of the LPG Despatch Vessels	6.5	8.5	30	2 m^3
S07D	Liquid drainage from LPG Compressor Suction Vessel (V-0615 & V-0616) to Utility Header	3	8.5	12	2 m^3
S08A	Compressor Suction Header (Loadout) from SDV-0616A to LPG Loadout Compressors (K-0601/3/5/6) and LPG Auxiliary Compressor (K-0607)	3	6.5	12	2 m^3
S08B	Loadout Compressors (K-0601/3/5/6) and LPG Auxiliary Compressor (K-0607) discharge to Compressor Discharge Header (Loadout) to SDV-0616B	4	10.5	20	2 m^3
S09A	Auxiliary Despatch Header (Discharge) to SDV-0616C	6.5	8.5	12	2 m^3
S10A	Liquid loadout arm from SDV-0541A to SDV-0541B and SDV-0541C	6.5	8.5	12	2 m^3
S11A	Liquid loadout arm from SDV-0542A to SDV-0542B and SDV-0542C	6.5	8.5	12	2 m^3
S12A	Road loadout arm (vapour) (LA-0641) to SDV-0641A	3	6.5	20	2 m^3
S13A	Road loadout arm (liquid) (LA-0541) to SDV-0541A	6.5	8.5	20	2 m^3
S14A	Road loadout arm (vapour) (LA-0642) to SDV-0642A	3	6.5	20	2 m^3
S15A	Road loadout arm (liquid) (LA-0542) to SDV-0542A	6.5	8.5	20	2 m^3
S16A	LPG Despatch Vessel (V-0501)	3	8.5	12	100 tonne
S17A	LPG Despatch Vessel (V-0502)	3	8.5	12	100 tonne
S18A	LPG Despatch Vessel (V-0503)	3	8.5	12	100 tonne
S19A	LPG Despatch Vessel (V-0504)	3	8.5	12	100 tonne
S20A	LPG Despatch Vessel (V-0505)	3	8.5	12	100 tonne
S21A	LPG Storage Vessel (V-0506)	3	8.5	12	100 tonne
S22A	LPG Storage Vessel (V-0507)	3	8.5	12	100 tonne

No.	Description	Pressure (barg)		Temp. (°C)	Inventory
		LPG	Propane		
S23A	LPG Storage Vessel (V-0508)	3	8.5	12	100 tonne
S24A	LPG Storage Vessel (V-0509)	3	8.5	12	100 tonne
S25A	LPG Storage Vessel (V-0510)	3	8.5	12	100 tonne
S26A	LPG Storage Vessel (V-0516)	3	8.5	12	100 tonne
S27A	LPG Storage Vessel (V-0517)	3	8.5	12	100 tonne
S28A	LPG Storage Vessel (V-0518)	3	8.5	12	100 tonne
S29A	LPG Storage Vessel (V-0519)	3	8.5	12	100 tonne
S30A	LPG Storage Vessel (V-0520)	3	8.5	12	100 tonne
S31A	LPG Storage Vessel (V-0511)	3	8.5	12	100 tonne
S32A	LPG Storage Vessel (V-0512)	3	8.5	12	100 tonne
S33A	LPG Storage Vessel (V-0513)	3	8.5	12	100 tonne
S34A	LPG Storage Vessel (V-0514)	3	8.5	12	100 tonne
S35A	LPG Storage Vessel (V-0515)	3	8.5	12	100 tonne
Consented LPG Storage Upgrade					
S03C_MOD	Rundown Header from PCV-0217A to SDVs on top of all LPG vessels	13	13	12	5 m^3
S04A_MOD	Liquid Loadout Header from SDV-0541C and SDV-0542C to SDVs on top of LPG Despatch Vessels (V-0501 to V-0505), British Oxygen Co and Rockgas, and Liquid Header from SDV-0501F to SDVs on top of LPG Storage Vessels (V-0506 to V-0510 and V-0516 to V-0520)	8	13	12	3 m^3
S07A_MOD	Loadout supply from SDV-0641A and SDV-0642A to Auxiliary Despatch Header and Auxiliary Storage Header	6.5	8.5	12	2 m^3
S07B_MOD	Loadout return to Compressor Suction Header (Loadout), to LPG Compressor Suction Vessels (V-0615 & V-0616) and SDV-0616A	3	6.5	12	2 m^3
S07C_MOD	Compressor Discharge Header (Loadout) from SDV-0616B to SDVs on top of the LPG Despatch Vessels	6.5	8.5	30	2 m^3
S36A	LPG Despatch Vessel (V-0521)	3	8.5	12	500 tonne
S37A	LPG Despatch Vessel (V-0522)	3	8.5	12	500 tonne
S38A	LPG Despatch Vessel (V-0523)	3	8.5	12	500 tonne

In this study, it is assumed that the equipment and headers are always in use, i.e. always pressurised. The pressure within the process equipment and header might be lower when not in operation.

5. FREQUENCY ANALYSIS

Parts counts were completed for each QRA event (see Appendix 1) and the leak frequencies are given in the following sections. The most significant leak contributors are indicated in **red**. Parts counts were conducted based on the valve configurations as shown on the P&IDs, e.g. it is assumed that the pumps are not isolated when not in use, unless stated otherwise.

5.1 Currently Operating Woolston LPG Depot

The leak frequencies from each QRA events are given in Table 5-1 for the currently operating Woolston LPG depot only.

Table 5-1: Hydrocarbon Release Frequencies for the Currently Operating Woolston LPG Depot

No.	QRA Events	Leak Frequencies (per annum)						% Contri.
		1 - 3 mm	3 - 10 mm	10 - 50 mm	50 - 150 mm	> 150 mm	TOTAL	
1	S01A	2.69E-04	9.27E-05	4.00E-05	4.20E-06	3.42E-06	4.10E-04	0.1%
2	S01B	2.32E-03	7.98E-04	3.44E-04	3.61E-05	2.95E-05	3.53E-03	0.5%
3	S02A	8.98E-06	3.95E-06	1.90E-06	5.60E-07	2.50E-07	1.56E-05	0.0%
4	S03A	1.20E-02	4.63E-03	2.14E-03	3.31E-04	2.33E-04	1.93E-02	2.6%
5	S03B	3.37E-03	1.14E-03	4.66E-04	3.97E-05	6.79E-05	5.08E-03	0.7%
6	S03C	6.02E-02	2.00E-02	7.17E-03	1.69E-03	1.51E-03	9.06E-02	**12.0%**
7	S04A	3.47E-02	1.20E-02	4.62E-03	8.45E-04	1.43E-03	5.36E-02	**7.1%**
8	S05A	9.69E-03	3.67E-03	1.74E-03	1.72E-04	3.48E-04	1.56E-02	2.1%
9	S06A	9.64E-03	3.28E-03	1.26E-03	2.16E-04	3.75E-04	1.48E-02	2.0%
10	S07A	3.05E-02	1.10E-02	4.14E-03	1.26E-03	1.46E-03	4.84E-02	**6.4%**
11	S07B	2.48E-02	9.63E-03	4.39E-03	1.30E-03	2.04E-04	4.03E-02	5.4%
12	S07C	2.55E-02	1.03E-02	4.36E-03	2.24E-03	-	4.24E-02	5.6%
13	S07D	4.51E-02	1.58E-02	5.52E-03	2.58E-03	-	6.89E-02	**9.2%**
14	S08A	5.68E-03	2.31E-03	1.20E-03	1.74E-04	7.13E-05	9.44E-03	1.3%
15	S08B	9.17E-02	3.68E-02	1.51E-02	4.95E-03	6.85E-05	1.49E-01	**19.8%**
16	S09A	2.15E-03	7.59E-04	2.87E-04	1.45E-04	-	3.34E-03	0.4%
17	S10A	3.92E-03	1.25E-03	4.34E-04	1.40E-04	3.05E-06	5.75E-03	0.8%
18	S11A	3.92E-03	1.25E-03	4.34E-04	1.40E-04	3.05E-06	5.75E-03	0.8%
19	S12A	1.49E-03	6.84E-04	3.04E-04	5.09E-05	-	2.53E-03	0.3%
20	S13A	1.72E-03	8.97E-04	3.10E-04	6.94E-05	-	2.99E-03	0.4%
21	S14A	1.49E-03	6.84E-04	3.04E-04	5.09E-05	-	2.53E-03	0.3%
22	S15A	1.82E-03	9.33E-04	3.22E-04	7.25E-05	-	3.14E-03	0.4%
23	S16A	5.05E-03	1.87E-03	8.07E-04	2.06E-04	6.22E-06	7.94E-03	1.1%
24	S17A	5.05E-03	1.87E-03	8.07E-04	2.06E-04	6.22E-06	7.94E-03	1.1%
25	S18A	5.20E-03	1.94E-03	8.52E-04	1.96E-04	6.22E-06	8.20E-03	1.1%
26	S19A	5.28E-03	1.98E-03	8.61E-04	2.10E-04	6.22E-06	8.34E-03	1.1%
27	S20A	5.28E-03	1.98E-03	8.61E-04	2.10E-04	6.22E-06	8.34E-03	1.1%
28	S21A	5.28E-03	1.98E-03	8.61E-04	2.10E-04	6.22E-06	8.34E-03	1.1%

No.	QRA Events	Leak Frequencies (per annum)						% Contri.
		1 - 3 mm	3 - 10 mm	10 - 50 mm	50 - 150 mm	> 150 mm	TOTAL	
29	S22A	5.28E-03	1.98E-03	8.61E-04	2.10E-04	6.22E-06	8.34E-03	1.1%
30	S23A	5.28E-03	1.98E-03	8.61E-04	2.10E-04	6.22E-06	8.34E-03	1.1%
31	S24A	5.28E-03	1.98E-03	8.61E-04	2.10E-04	6.22E-06	8.34E-03	1.1%
32	S25A	5.28E-03	1.98E-03	8.61E-04	2.10E-04	6.22E-06	8.34E-03	1.1%
33	S26A	5.28E-03	1.98E-03	8.61E-04	2.10E-04	6.22E-06	8.34E-03	1.1%
34	S27A	5.28E-03	1.98E-03	8.61E-04	2.10E-04	6.22E-06	8.34E-03	1.1%
35	S28A	5.28E-03	1.98E-03	8.61E-04	2.10E-04	6.22E-06	8.34E-03	1.1%
36	S29A	5.28E-03	1.98E-03	8.61E-04	2.10E-04	6.22E-06	8.34E-03	1.1%
37	S30A	5.28E-03	1.98E-03	8.61E-04	2.10E-04	6.22E-06	8.34E-03	1.1%
38	S31A	5.28E-03	1.98E-03	8.61E-04	2.10E-04	6.22E-06	8.34E-03	1.1%
39	S32A	5.28E-03	1.98E-03	8.61E-04	2.10E-04	6.22E-06	8.34E-03	1.1%
40	S33A	5.06E-03	1.88E-03	8.22E-04	1.88E-04	6.22E-06	7.95E-03	1.1%
41	S34A	5.28E-03	1.98E-03	8.61E-04	2.10E-04	6.22E-06	8.34E-03	1.1%
42	S35A	5.28E-03	1.98E-03	8.61E-04	2.10E-04	6.22E-06	8.34E-03	1.1%
	TOTAL	4.77E-01	1.77E-01	7.20E-02	2.07E-02	5.93E-03	7.53E-01	100%
		63%	24%	9.6%	2.7%	0.8%		

The total leak frequency is 0.75 per annum, or equivalent to one leak every 1.33 years. The leak contribution is predominantly from the 1 - 3 mm hole size, which contributes to 63% of the total leak frequency.

The sections with the highest leak frequencies are:

- S08B (19.8%) – the section covers the loadout compressors (K-0601/3/5/6) and LPG auxiliary compressor (K-0607). The high leak frequency is mainly contributed by compressors.
- S03C (12.0%) – the section covers rundown header connecting all the LPG vessels.
- S07D (9.2%) – the section covers utility header.
- S04A (7.1%) – the section covers the liquid loadout header.
- S07A (6.4%) – the section covers the auxiliary despatch header and auxiliary storage header.

The leak frequencies from these scenarios contribute to approximately 55% of the total leak frequency. The common reason for the high leak frequencies for all the above QRA scenarios is mainly contributed by the significant length of aboveground pipework and the numbers of associated equipment (e.g. valves and flanges).

5.2 Consented LPG Storage Upgrade

The consented LPG storage upgrade project increases the overall leak frequencies with the addition of three (3) LPG storage vessels and header extensions. Table 5-2 shows the revised leak frequencies for the header extension sections and the leak frequencies for the additional QRA events.

Table 5-2: Hydrocarbon Release Frequencies for the Consented LPG Storage Upgrade

No.	QRA Events	Leak Frequencies (per annum)						% Contri.
		1 - 3 mm	3 - 10 mm	10 - 50 mm	50 - 150 mm	> 150 mm	TOTAL	
6	S03C_MOD Note 1	6.71E-02	2.22E-02	7.98E-03	1.91E-03	1.60E-03	1.01E-01	12.5%
7	S04A_MOD Note 1	4.10E-02	1.42E-02	5.43E-03	1.12E-03	1.53E-03	6.06E-02	7.5%
10	S07A_MOD Note 1	3.23E-02	1.16E-02	4.39E-03	1.35E-03	1.54E-03	4.97E-02	6.1%
11	S07B_MOD Note 1	2.77E-02	1.07E-02	4.90E-03	1.48E-03	2.04E-04	4.33E-02	5.4%
12	S07C_MOD Note 1	2.91E-02	1.15E-02	4.77E-03	2.49E-03	-	4.79E-02	5.9%
43	S36A	5.02E-03	1.89E-03	7.77E-04	2.80E-04	1.24E-05	7.98E-03	1.0%
44	S37A	5.02E-03	1.89E-03	7.77E-04	2.80E-04	1.24E-05	7.98E-03	1.0%
45	S38A	5.02E-03	1.89E-03	7.77E-04	2.80E-04	1.24E-05	7.98E-03	1.0%
TOTAL Note 2		5.13E-01	1.90E-01	7.71E-02	2.25E-02	6.23E-03	8.09E-01	
		63%	23%	10%	3%	0.8%		

Note 1: Leak frequencies from these sections have been revised to include the header extensions.

Note 2: inclusive of the total leak frequencies from the currently operating Woolston LPG depot.

The total leak frequency increases to 0.81 per annum, or equivalent to one leak every 1.24 years. The leak contribution is still predominantly from the 1 - 3 mm hole size, which contributes to 63% of the total leak frequency.

6. RISK ANALYSIS

6.1 Risk Criteria

LSIR is the risk of fatality at a point in space to a hypothetical individual at that location for 365 days per year, 24 hours a day. As there is no standard risk criteria which have been developed for the New Zealand context, this deliverable is assessed against the suggested risk criteria in the New South Wales Hazardous Industry Planning Advisory Paper No. 4 (HIPAP4) "Risk Criteria for Land Use Planning" [Ref. 7]. Table 6-1 summarises the HIPAP4 Individual Fatality Risk criteria and provides an interpretation for the risk assessment.

Table 6-1: Location Specific Individual Fatality Risk Criteria

Land Use	Risk Criteria Adopted (per annum)	Interpretation for QRA
Industrial	5E-05 (1 in 20,000)	5E-05 risk contour should, as a target, be contained within the boundaries of the industrial site where applicable.
Sporting complexes and active open space	1E-05 (1 in 100,000)	1E-05 risk contour should not extend to these areas.
Commercial developments including retail centres, offices and entertainment centres	5E-06 (1 in 200,000)	5E-06 risk contour should not extend to these areas.
Residential, hotels, motels, tourist resorts	1E-06 (1 in 1 million)	1E-06 risk contour should not extend to these areas.
Hospitals, schools, childcare facilities, old age housing	5E-07 (1 in 2 million)	5E-07 risk contour should not extend to these areas.

6.2 Risk Assessment Results

6.2.1 Currently Operating Woolston LPG Depot

The overall LSIR in the form of the risk contour for the currently operating Woolston LPG depot is presented in Figure 6-1.

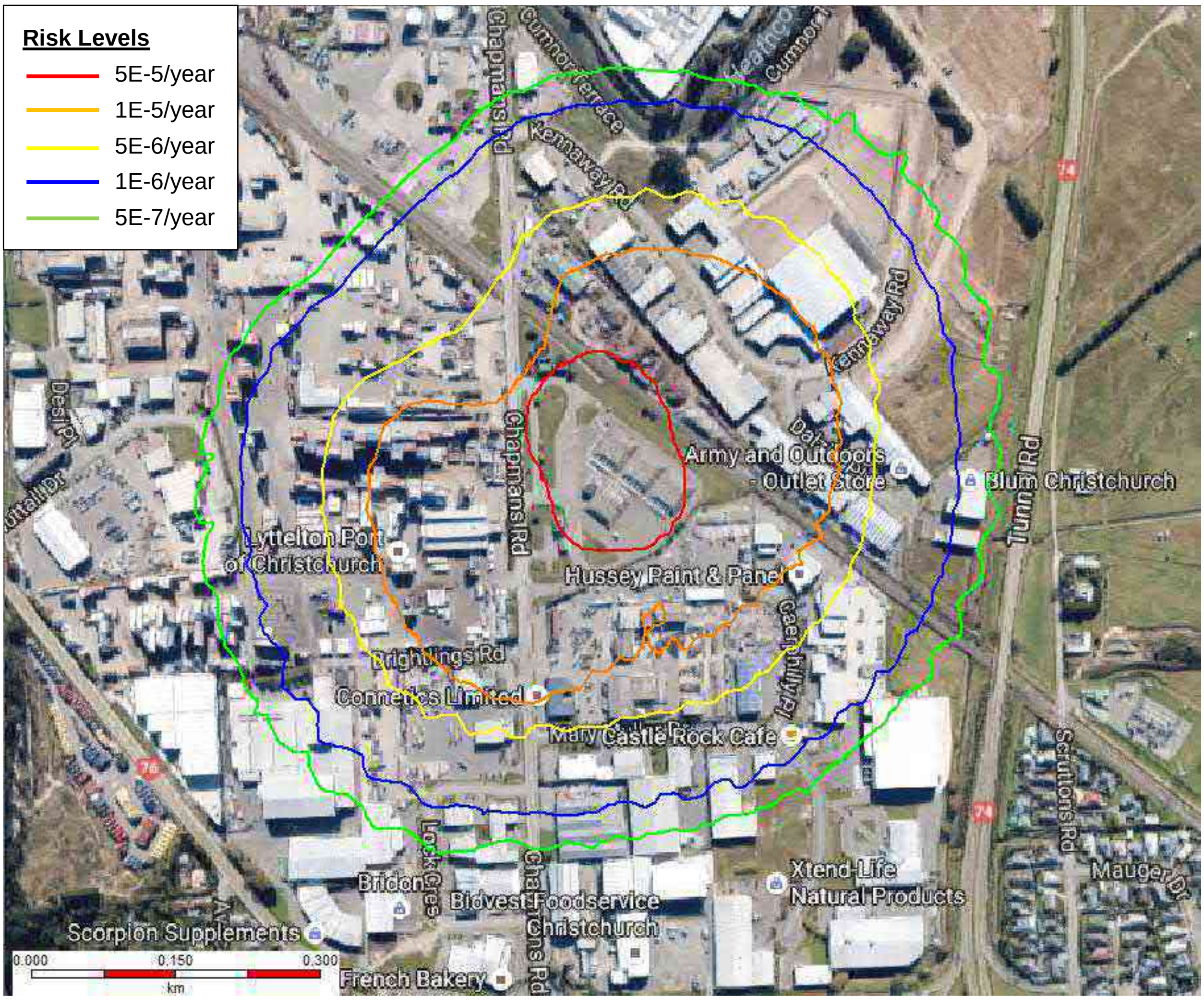


Figure 6-1: Risk Contour for the Currently Operating Woolston LPG Depot

The LSIR results as assessed against the HIPAP4 criteria are given in Table 6-2.

Table 6-2: LSIR Results as compared to HIPAP4 Land Use Criteria

LSIR	Risk Contour	HIPAP4 Land Use Criteria	Result
5E-05 / year	Red	5E-05 / year risk contour should, as a target, be contained within the boundaries of the industrial site where applicable.	The 5E-05 / year risk contour extends beyond the site boundary at the North East direction on to the railway line and the recycling centre.
1E-05 / year	Orange	1E-05 / year risk contour should not extend to sporting complexes and active open space	No impact. There are no sporting complexes and active open space within the proximity. However, the 1E-05 / year risk contour is impacting on of the Chapmans Road on the western side.

LSIR	Risk Contour	HIPAP4 Land Use Criteria	Result
5E-06/ year	**Yellow**	5E-06 / year risk contour should not extend to commercial developments including retail centres, offices and entertainment centres	The 5E-06 / year risk contour extends beyond the site boundary onto a few neighbouring facilities offices, including the Contact Energy Regional Office to the east, the Lyttelton Port of Christchurch offices to the west, and various commercial premises across the railway line to the north and north east. However, the area is zoned "industrial" as per the Christchurch District Plan. HIPAP4 [Ref. 7] states that a higher level of risk is generally considered acceptable in industrial areas (HIPAP4, p.8) in comparison to commercial land use areas. In the context of the report this is mentioned to differentiate between offices located in a 'commercial' area/zone and offices in an 'industrial' zone (where a higher level of risk acceptance may be appropriate).
1E-06 / year	**Blue**	1E-06 / year risk contour should not extend to residential, hotels, motels, tourist resorts	No impact. There are no residential, hotels, motels or tourist resorts within the proximity.
5E-07 / year	**Green**	5E-07 / year risk contour should not extend to hospitals, schools, childcare facilities, old age housing	No impact. There are no hospitals, schools, childcare facilities or old age housing within the proximity.

Specific Fire Scenario Risk Contribution

The risks contributed by different consequence scenarios are also presented separately. Figure 6-2 shows the risk contributed by jet fires only. The jet fire risk is high at the centre of the depot.

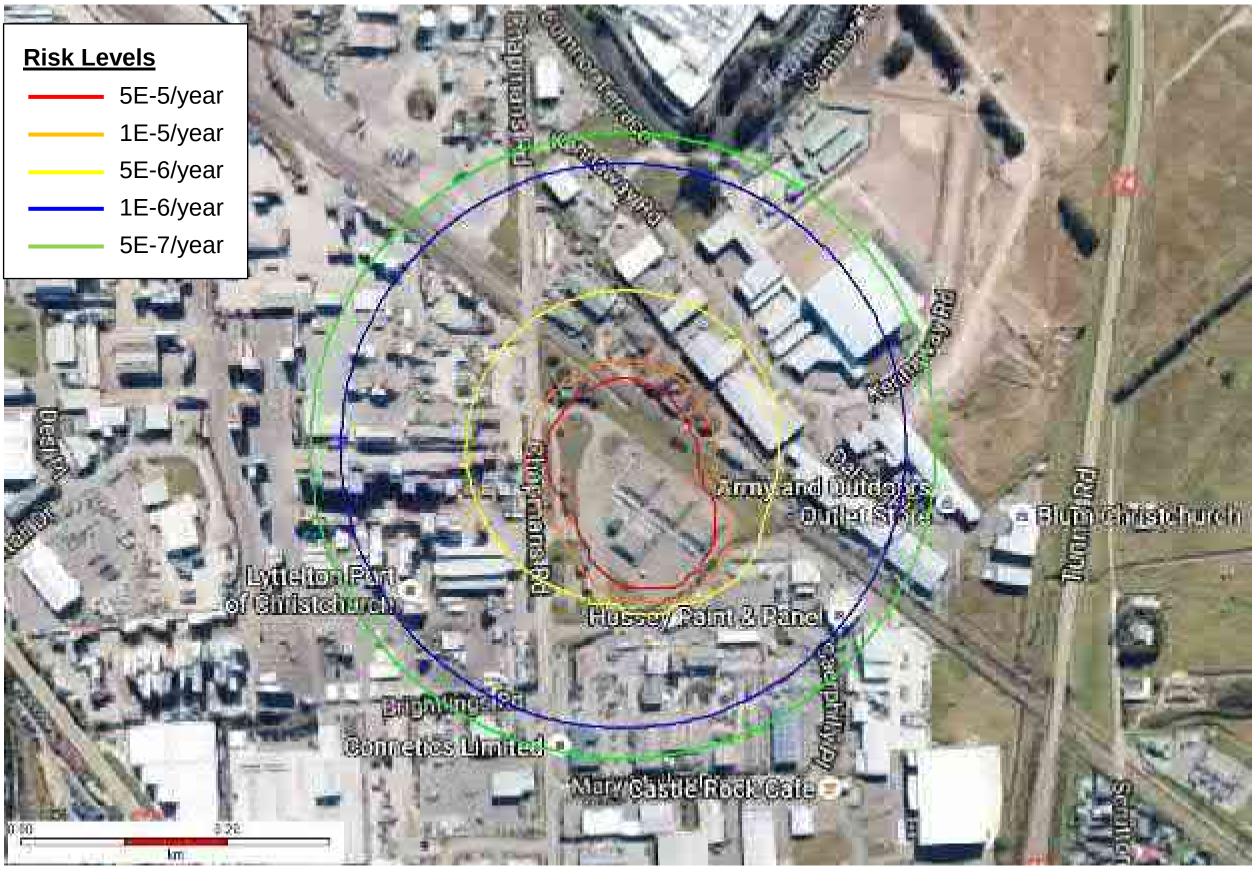


Figure 6-2: LSIR Contributed by Jet Fire Risk only

The jet fire risk is likely to be conservative as it is assumed that the equipment and headers are always in use, i.e. pressurised. The pressure within the process equipment and header might be lower when not in operation hence the extent of the jet fire would be less.

Figure 6-3 shows the risk contributed by flash fires only. The shape of the flash fire contours is particularly influenced by wind direction. The flash fire risk is lower at the plant but extends further offsite as the spread of flammable vapour cloud cannot be constrained.

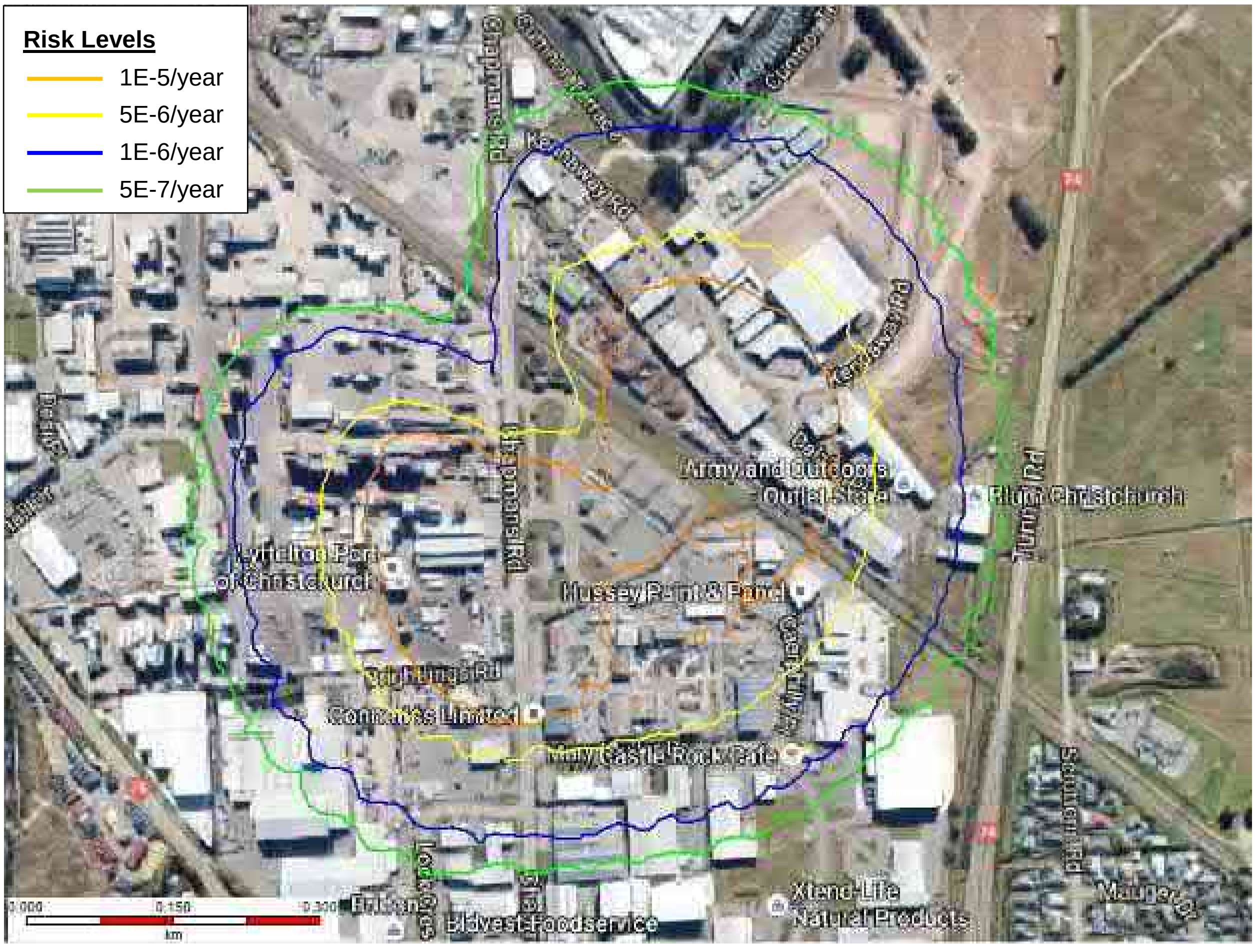


Figure 6-3: LSIR Contributed by Flash Fire Risk only

There is also risk contributed by pool fire events. The pool fire risk is shown in Figure 6-4. The risk is low and only localised at the depot. These are contributed by large LPG releases where the release rates are higher than the LPG flashing / evaporation rates. However, the size of the pool is small and evaporates rapidly.

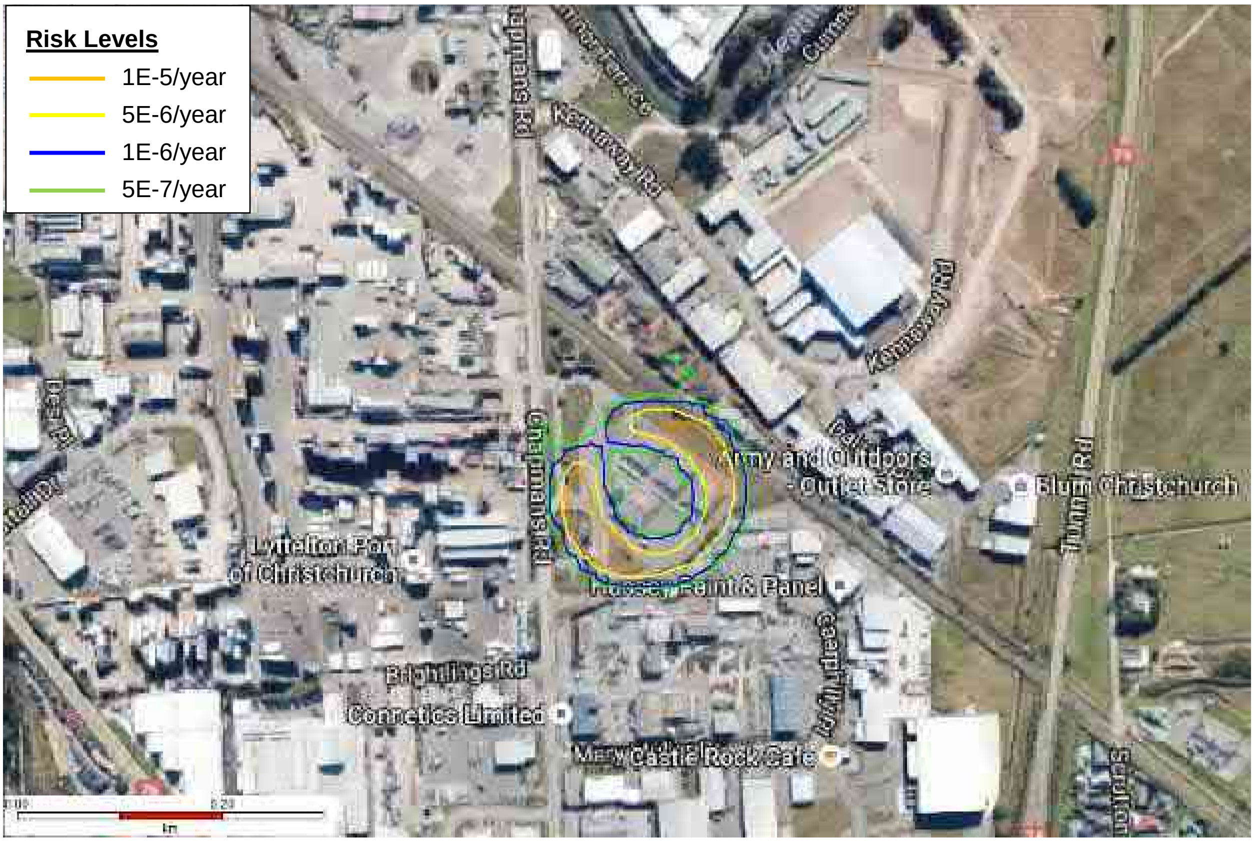


Figure 6-4: LSIR Contributed by Pool Fire Risk only

The breakdown of fire events show that the onsite risk is mainly contributed by jet fires, and the far-field offsite risk is mainly contributed by flash fires.

Risk Contributors Analysis

Risk ranking points can be located on the model, which are used to identify the risk contributors at various locations. For this model, the risk contributors at three locations are identified. The risk contributor analysis shows that:

- North east side (railway line) - The near-field offsite risk is contributed by fireball events due to large releases (100 mm and 150 mm hole sizes) and immediate ignition from S03A event (onsite ship unloading line). The fireballs are short duration events; however, these would cause immediate fatality to nearby personnel.
- West side (Chapmans Road) - The offsite risk is contributed by the flash fires from the rundown header and the utility header.
- South side (Contact LPG) – The offsite risk is contributed by the jet fire from S01B (aboveground pipeline section) and the flash fire event from the rundown header.

6.2.2 Consented LPG Storage Upgrade

The cumulative LSIR in the form of the risk contour for the currently operating Woolston LPG depot and the consented LPG storage upgrade is presented in Figure 6-5.

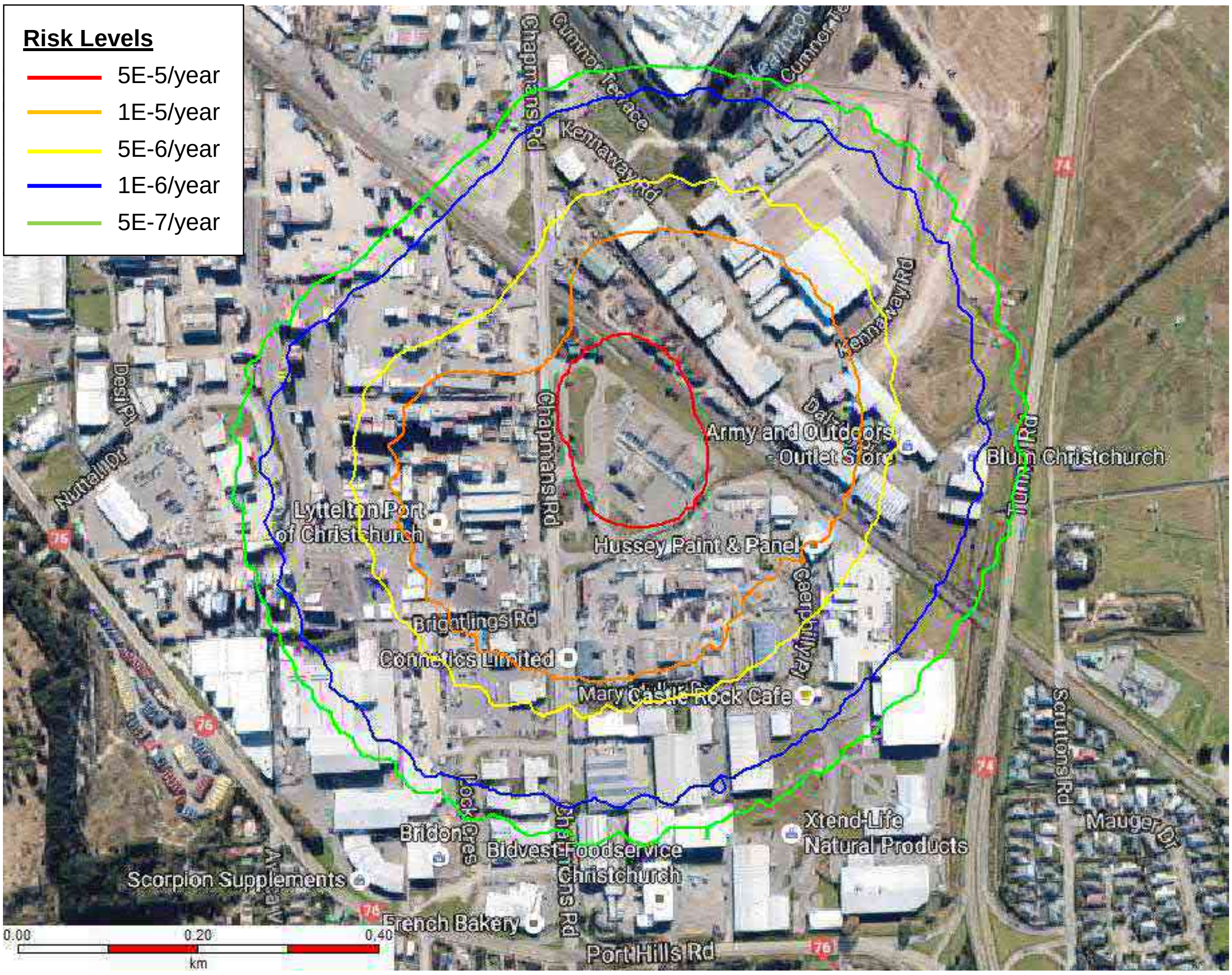


Figure 6-5: Cumulative Risk Contour for the Currently Operating Woolston LPG Depot and the Consented LPG Storage Upgrade

There is only negligible incremental risk due to the consented LPG storage upgrade. The LSIR assessment against the HIPAP4 criteria is the same as per given in Table 6-2 for the currently operating Woolston LPG depot, hence it is not repeated here.

7. SENSITIVITY ANALYSIS

Sensitivity analyses have been conducted for the currently operating Woolston LPG depot base case to study the impact of various modelling assumptions on the base case.

7.1 Sensitivity Analysis 1: Ignition Probabilities

In the base case, the ignition probability correlation from the Oil and Gas UK for “tank gas LPG storage industrial” was used. As sensitivity analyses, two other different ignition probability correlations were used, which include:

- Large plant gas LPG (gas or LPG release from large onshore plant).
- The conventional Cox, Lees and Ang ignition probability correlations for gas and liquid releases.

The ignition probabilities as a function of mass release rates for the different correlations are shown in Figure 7-1 for comparison purposes.

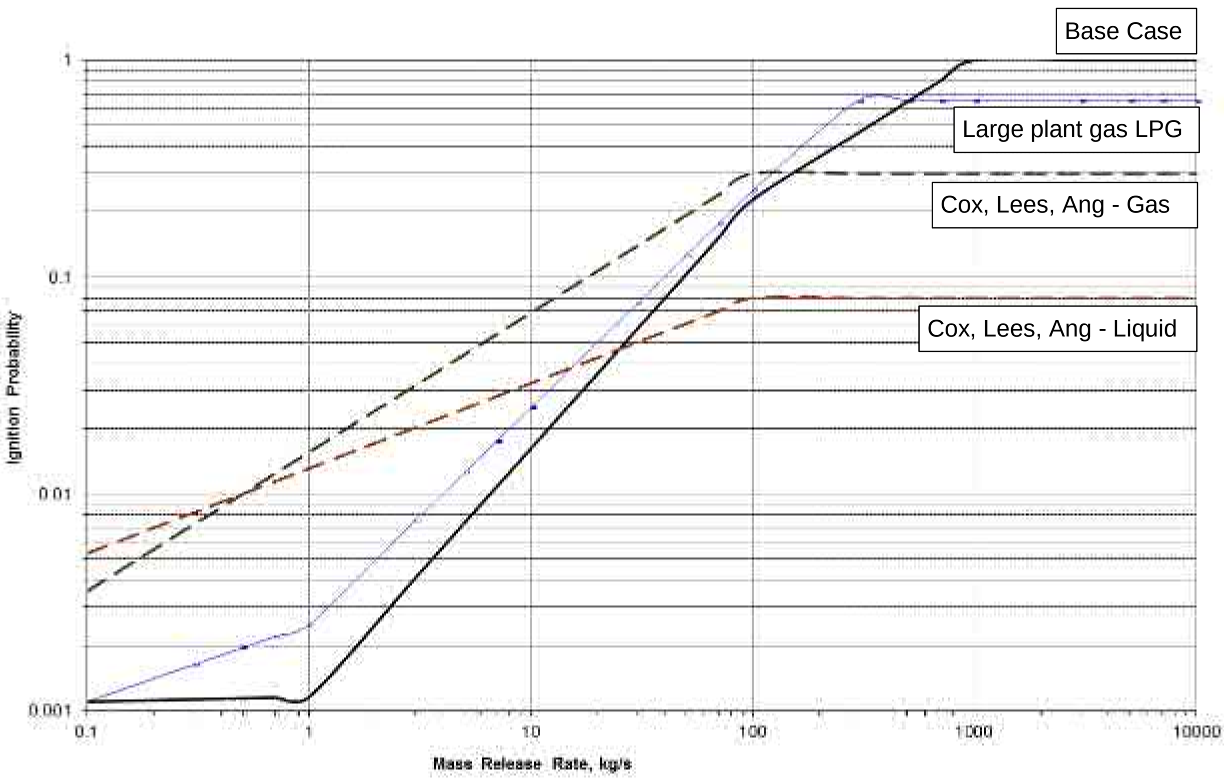


Figure 7-1: Different Ignition Probabilities Correlations

7.1.1 Large Plant Gas LPG

The “large plant gas LPG” is applicable to releases of flammable gases, vapour or liquid significantly above their boiling point from large onshore outdoor plants (plant area above 1,200 m^2, site area above 35,000 m^2), where the ignition probabilities for the smaller release rates are higher compared to the base case but with a lower maximum value of 0.65, whereas for the base case the maximum is 1. The risk contour for the sensitivity analysis using the “large plant gas LPG” correlation is shown in Figure 7-2.

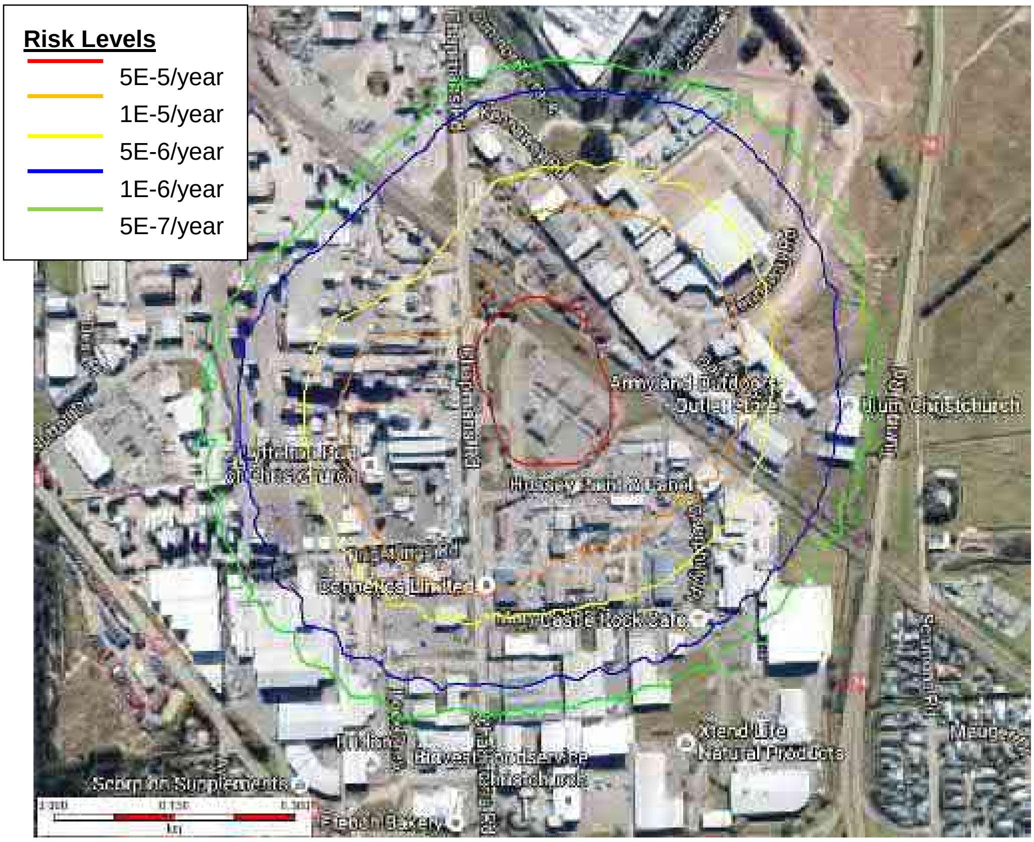


Figure 7-2: Risk Contour for using the “Large Plant Gas LPG” Correlation

The risk contour is similar to the base case with negligible risk increment, as the ignition probabilities are not vastly different.

7.1.2 Cox, Lees and Ang

The Cox, Lees and Ang ignition probabilities were widely used prior to the introduction of the Oil and Gas UK ignition probability correlations. The Cox, Lees and Ang ignition probabilities was also used in the previous Woolston LPG depot QRA for the resource consent. The risk contour for the sensitivity analysis using the Cox, Lees and Ang ignition probabilities is shown in Figure 7-3.

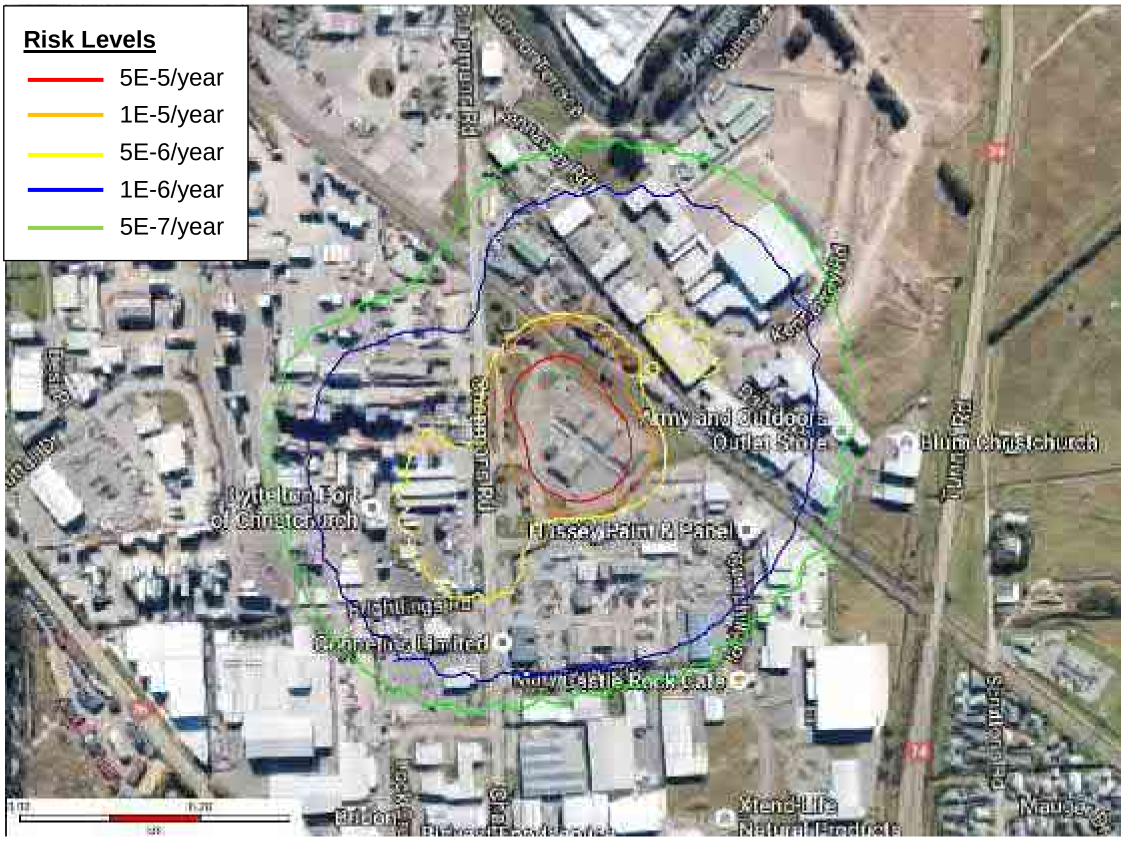


Figure 7-3: Risk Contour for using the Cox, Lees and Ang Ignition Probabilities

The risk contour for the sensitivity analysis is significantly smaller compared to the base case as the maximum ignition probabilities are significantly lower for the Cox, Lees and Ang ignition probabilities. However, as the Oil and Gas UK correlations also takes into account the types of plant, material of release, ignition source densities, offsite area, etc., it is considered a more appropriate means to assign ignition probabilities than the more generic approaches such as that proposed by Cox, Lees and Ang.

7.2 Sensitivity Analysis 2: Uniform Wind Profile

The Phast Risk model applies Power Law to the wind profile as the default, where the wind speed varies with height according to a power-law profile. The windspeed reference height, which is the datum-point for setting the profile as function of height, was set at 10 m above ground. The wind speed near the ground level is generally lower than the wind speed at the datum height. As a sensitivity analysis, a uniform wind profile was used, where Phast Risk used the same wind speed at all heights. The risk contour is shown in Figure 7-4.

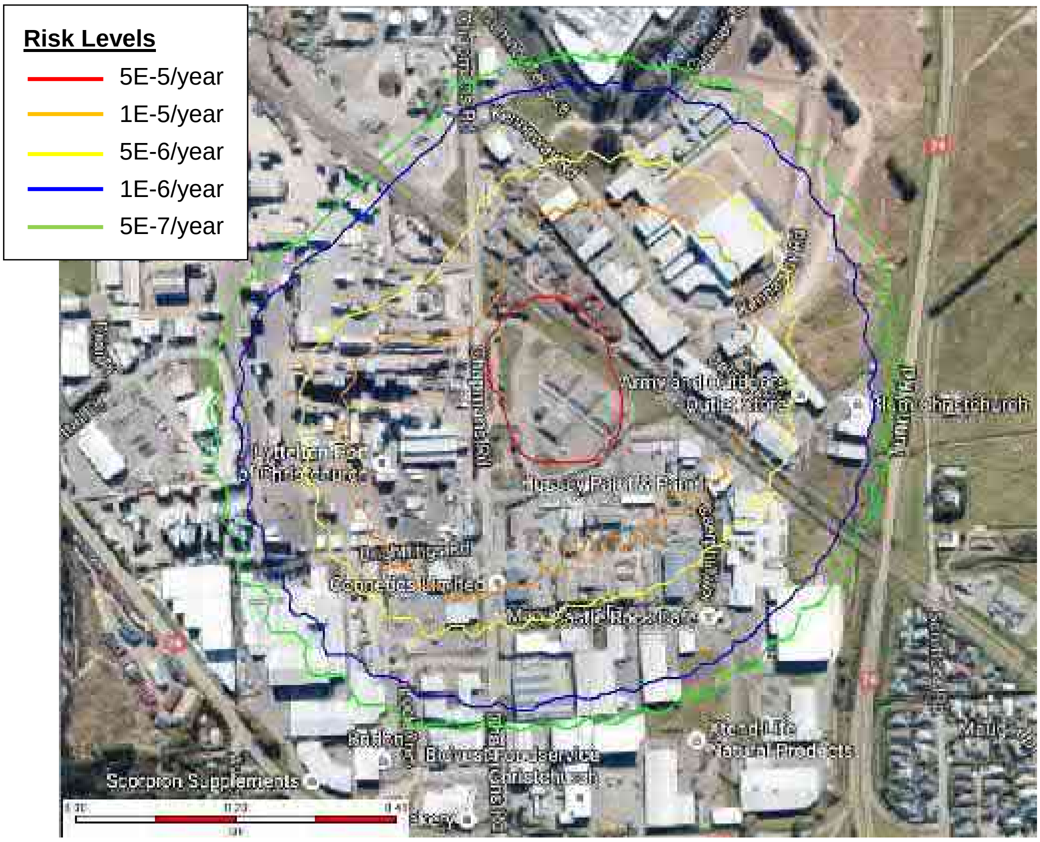


Figure 7-4: Risk Contour under the Uniform Wind Profile

The risk contour is similar to the base case with negligible risk increment. This shows that the wind speed changes with height do not have significant impact on the risk results.

7.3 Sensitivity Analysis 3: Representative Hole Sizes

The release hole sizes modelled in the QRA are discussed in Section 3.4. The ranges of release hole sizes were grouped and representative sizes where selected for each hole size range. In the base case, the median of each range were used. For the sensitivity analysis, different representative hole sizes that are also commonly used in QRA studies were considered. The hole sizes are as given in Table 7-1.

Table 7-1: Hole Size Distribution

Hole Size Group (mm)	Representative Hole Size (mm)	
	Base Case	Sensitivity
1 - 3	2	2
3 - 10	7	6
10 - 50	30	22
50 - 150	100	85
> 150	150	150

The risk contour is given in Figure 7-5.

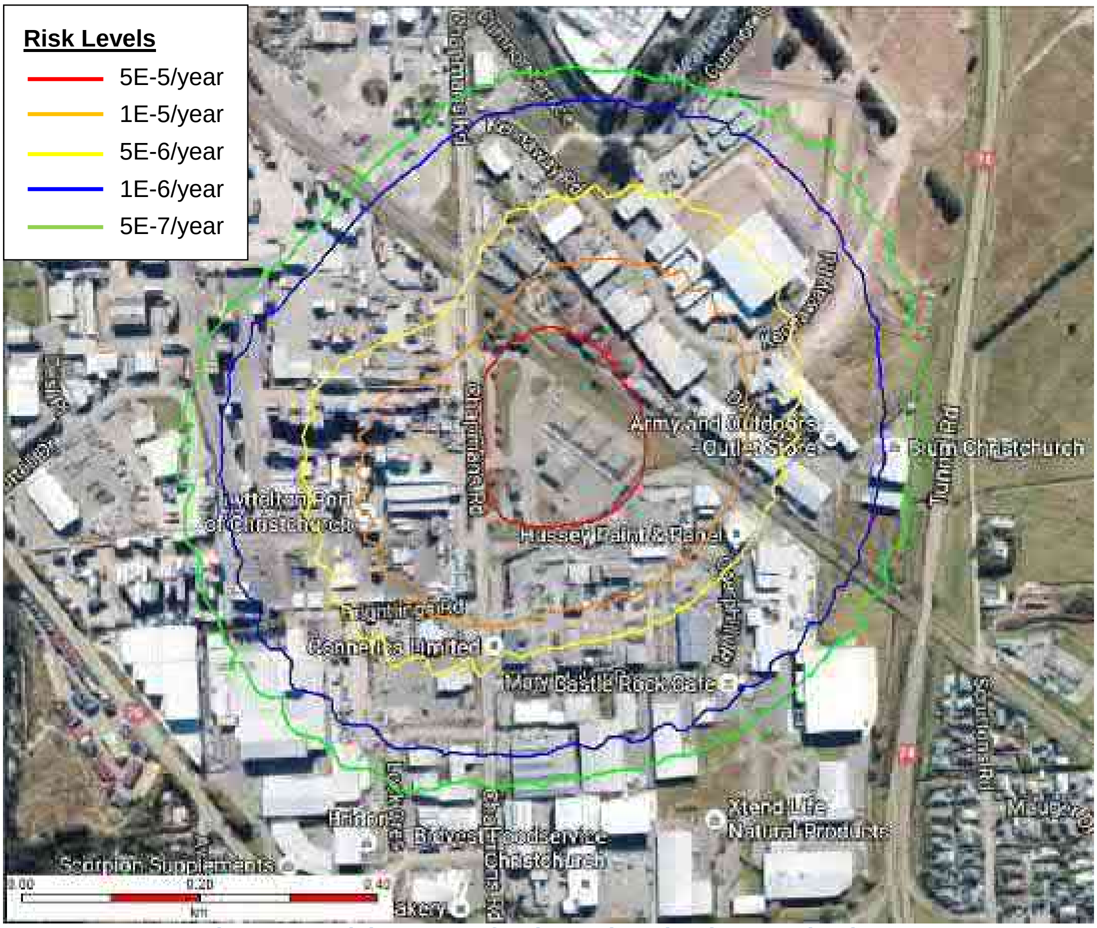


Figure 7-5: Risk Contour for the Reduced Release Hole Sizes

The change in the release hole sizes have mixed impact on the risk levels, where the highest risk level (5E-05 / year) has extended further offsite but the 1E-05 / year risk and 5E-06 / year risk levels distances have reduced. There are negligible differences for the lower risk levels (1E-06 / year and 5E-07 / year).

8. CONCLUSIONS

A QRA has been conducted for the Liquigas Woolston LPG depot, which covers the currently operating Woolston LPG depot and the consented LPG storage upgrade. The key deliverable of the QRA is the individual fatality risk contours. The risk results as assessed against the HIPAP4 criteria. The results show that:

- The 5E-05 / year risk contour extends beyond the site boundary at the North East direction on to the railway line and the recycling centre.
- The 1E-05 / year risk contour is impacting on the Chapmans Road on the western side.
- The 5E-06 / year risk contour extends beyond the site boundary onto a few neighbouring facilities offices, including the Contact Energy Regional Office to the east, the Lyttelton Port of Christchurch offices to the west, and various commercial premises across the railway line to the north and north east. However, the area is zoned “industrial” as per the Christchurch District Plan.

  HIPAP4 [Ref. 7] states that a higher level of risk is generally considered acceptable in industrial areas in comparison to commercial land use areas. In the context of the report this is mentioned to differentiate between offices located in a ‘commercial’ area/zone and offices in an ‘industrial’ zone (where a higher level of risk acceptance may be appropriate).
- Near-field risks are mainly contributed by jet fires, whereas far-field risks are mainly contributed by flash fires.

The consented LPG storage upgrade only generated negligible incremental risk. The LSIR assessment against the HIPAP4 criteria is the same as for the currently operating Woolston LPG depot.

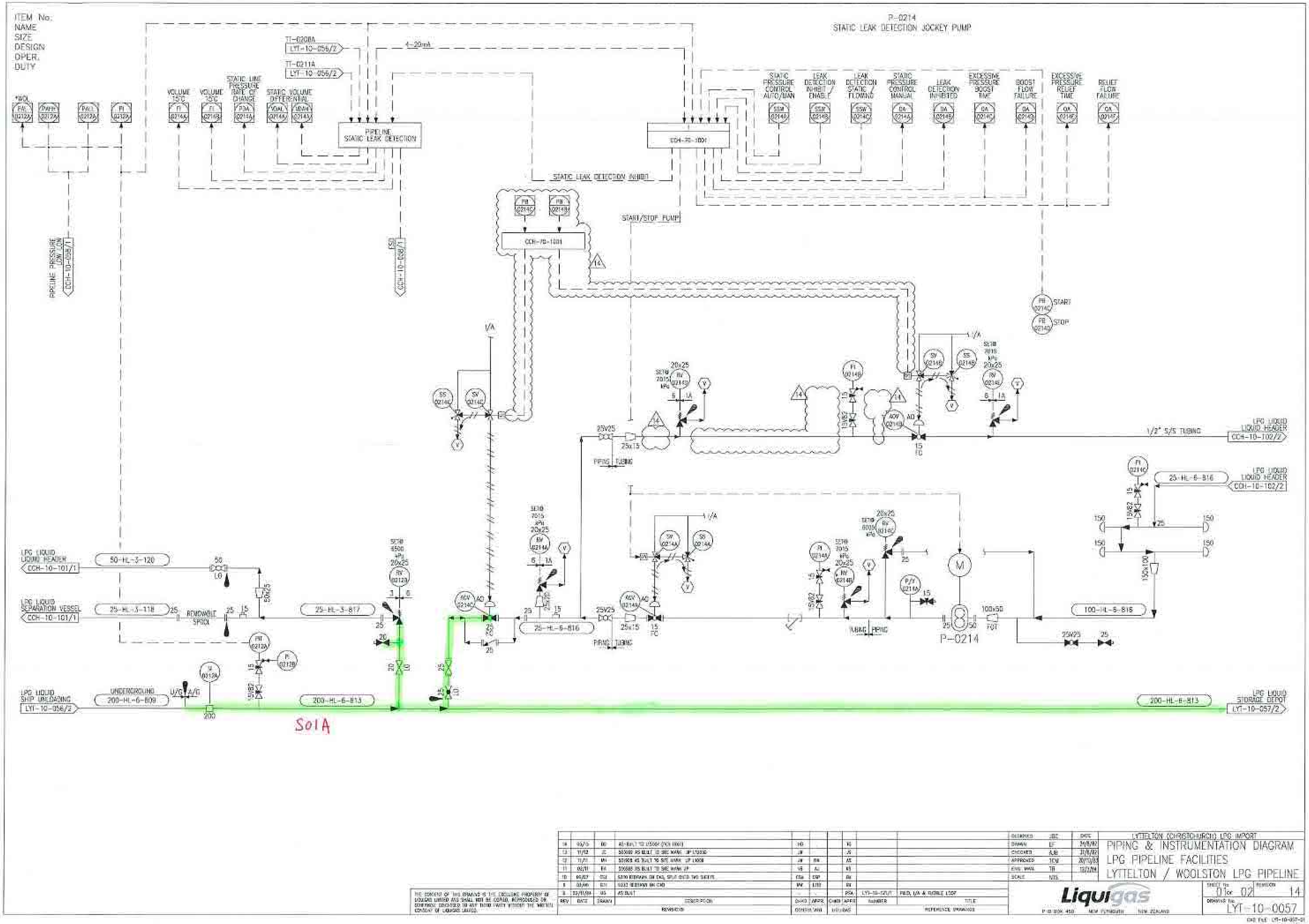
Sensitivity analyses have been conducted for the following aspects of the QRA modelling, including:

- Different ignition probabilities – the QRA model were repeated by using (1) the “large plant gas LPG” ignition probability correlation; (2) Cox, Lees and Ang ignition probability. The results found that the risk contours generated by using the Cox, Lees and Ang ignition probability is significantly lower than the base case.
- Uniform wind profile – Phast Risk software generally applies Power Law to the wind profile where the wind speed is lower when nearer to the ground level. A sensitivity analysis was performed by applying uniform wind profile. The risk contour is similar to the base case with negligible risk increment. This shows that the wind speed changes with height do not have significant impact on the risk results.
- Different representative hole sizes – the QRA were repeated by using a different representative hole sizes that are also commonly used in QRA studies were considered. The result shows mixed impact on the risk levels, where the highest risk level (5E-05 / year) has extended further offsite but the 1E-05 / year risk and 5E-06 / year risk levels distances have reduced. There are negligible differences for the lower risk levels (1E-06 / year and 5E-07 / year).

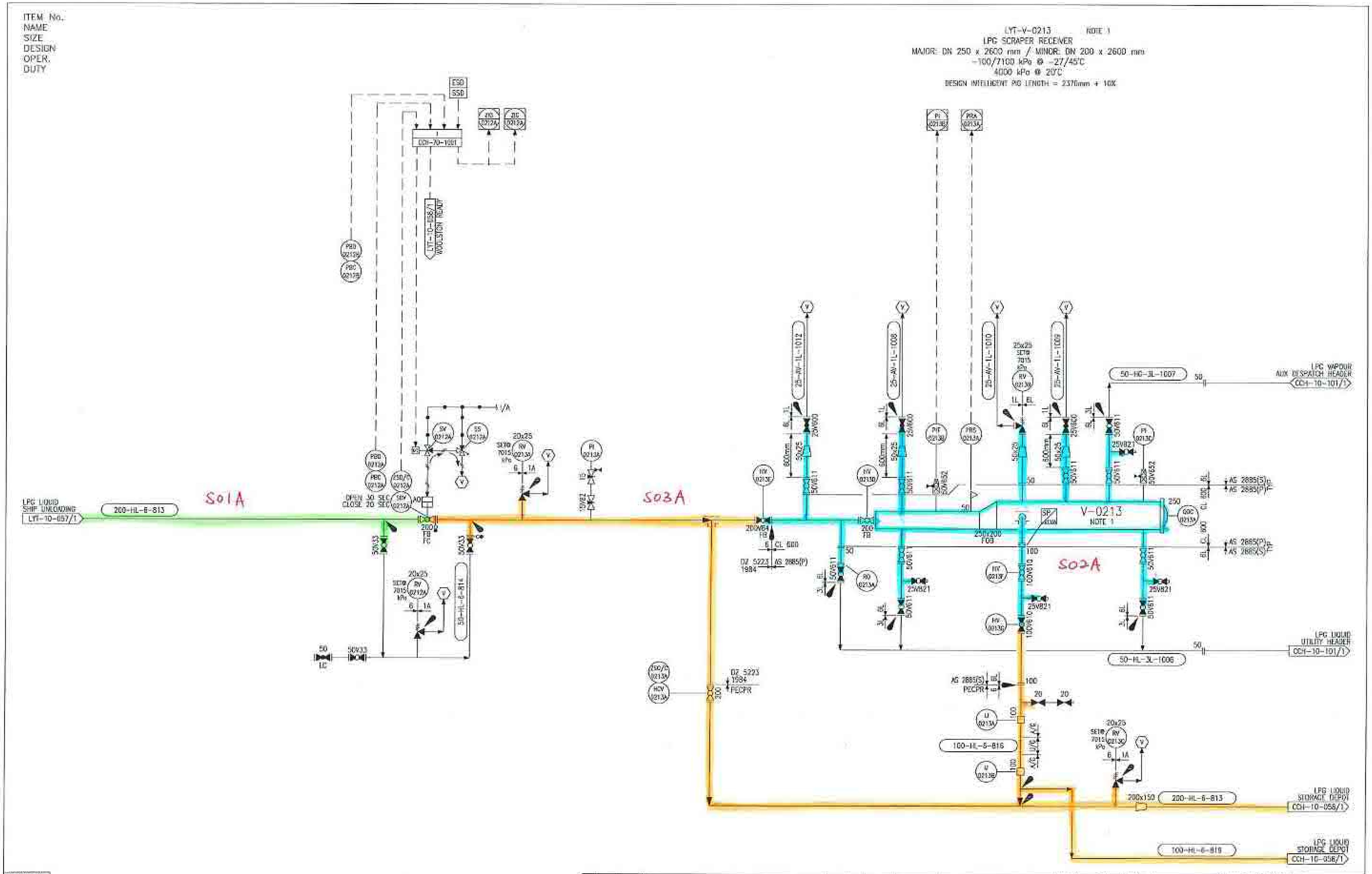
9. REFERENCES

1. Onshore QRA Method Statement – Using Phast Risk (PCD-473), May 2015.
2. DNV GL Phast Risk (Safeti) version 6.7 consequence modelling software.
3. Woolston LPG Depot, Assumptions Register for QRA, 503402-TCN-R0001
4. New Zealand National Climate Database (http://cliflo.niwa.co.nz/).
5. DNV Failure Frequency Guidance, Process Equipment Leak Frequency Data for use in QRA.
6. Ignition Probability Review, Model Development and Look-Up Correlations, Research Report published by the Energy Institute, January 2006. ISBN 978 0 85293 54 8.
7. Hazardous Industry Planning Advisory Paper No. 4 (HIPAP4), Risk Criteria for Land Use Safety Planning, January 2011.

Appendix 1.
Parts Count P&IDs



ITEM No.
NAME
SIZE
DESIGN
OPER.
DUTY
P-0214
STATIC LEAK DETECTION JOCKEY PUMP
TT-0208A
LYT-10-056/2
TT-0211A
LYT-10-056/2
4-20mA
PIPELINE
STATIC LEAK DETECTION
CCH-70-1001
STATIC LEAK DETECTION INHIBIT
START/STOP PUMP
STATIC PRESSURE CONTROL AUTO/MAN
LEAK DETECTION INHIBIT / ENABLE
LEAK DETECTION STATIC / FLOWING
STATIC PRESSURE CONTROL MANUAL
LEAK DETECTION INHIBITED
EXCESSIVE PRESSURE BOOST TIME
BOOST FLOW FAILURE
EXCESSIVE PRESSURE RELIEF TIME
RELIEF FLOW FAILURE
VOLUME 15°C
STATIC LINE PRESSURE RATE OF CHANGE
STATIC VOLUME DIFFERENTIAL
PIPELINE PRESSURE LOW LOW
CCH-10-098/1
ESD
CCH-10-098/1
START
STOP
1/2" S/S TUBING
LPG LIQUID
LIQUID HEADER
CCH-10-102/2
25-HL-6-816
LPG LIQUID
LIQUID HEADER
CCH-10-101/1
50-HL-3-120
LPG LIQUID
SEPARATION VESSEL
CCH-10-101/1
25-HL-3-118
REMOVABLE SPOOL
25-HL-3-817
25-HL-6-816
PIPING TUBING
TUBING PIPING
100-HL-6-816
P-0214
LPG LIQUID
SHIP UNLOADING
LYT-10-056/2
UNDERGROUND
200-HL-6-809
U/G A/G
200-HL-6-813
S01A
200-HL-6-813
LPG LIQUID
STORAGE DEPOT
LYT-10-057/2
LYTTELTON (CHRISTCHURCH) LPG IMPORT
PIPING & INSTRUMENTATION DIAGRAM
LPG PIPELINE FACILITIES
LYTTELTON / WOOLSTON LPG PIPELINE
DESIGNED JDC
DRAWN LF
CHECKED AJB
APPROVED TCM
ENG. MAN. TR
SCALE NTS
Liquigas
P O BOX 450 NEW PLYMOUTH NEW ZEALAND
SHEET No 01 OF 02
REVISION 14
DRAWING No. LYT-10-0057



REV	DATE	DRAWN	DESCRIPTION	CHKD	APPR.	SIVL. MAN.
12	08/12	CSM	AS BUILT - Use WORMS BARRED INSERT LYT-SP-0213A INSTALLED IN KICKER LOC.	LB	ADMc	KC
11	02/11	SA	500698 AS BUILT TO SITE MARK UP	VB	AJ	KS
10	05/08	CSM	3030 REDRAWN ON CAD, SPLIT ONTO TWO SHEETS	DPC	CEF	KS
9	03/06	CAH	8233 REDRAWN ON CAD	LW	WB	CK
8	22/11/01	MC	AS BUILT	-	-	PEK

REVISIONS — CONSULTANT — LIQUIGAS

NUMBER	TITLE
CCH-10-122/1	P&ID I/A & FUSIBLE LOOP

REFERENCE DRAWINGS

DESIGNED	JDC	24/8/92
DRAWN	CT	31/8/92
CHECKED	AJB	20/10/93
APPROVED	TCM	12/5/94
LIQ. MAN.	TB	
SCALE	NTS	

LYTTELTON LPG IMPORT

PIPING & INSTRUMENTATION DIAGRAM
LPG PIPELINE FACILITIES
LPG PIPELINE SCRAPER RECEIVER V-0213

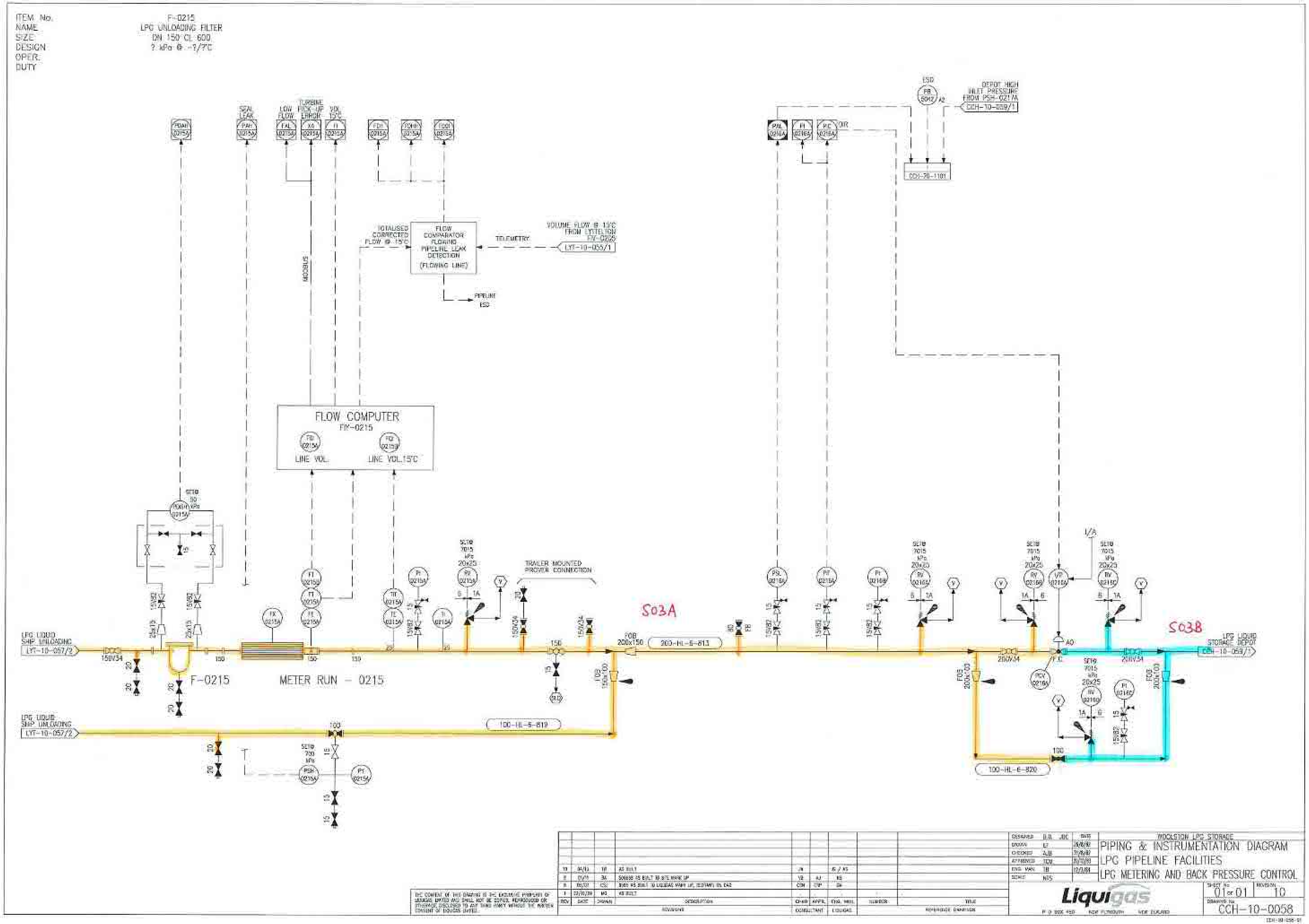
Liquigas
P O BOX 400 NEW PLYMOUTH NEW ZEALAND

SHEET No. 02 of 02 REVISION 12
DRAWING No. LYT-10-0057
CAD FILE: LYT-10-0057-02

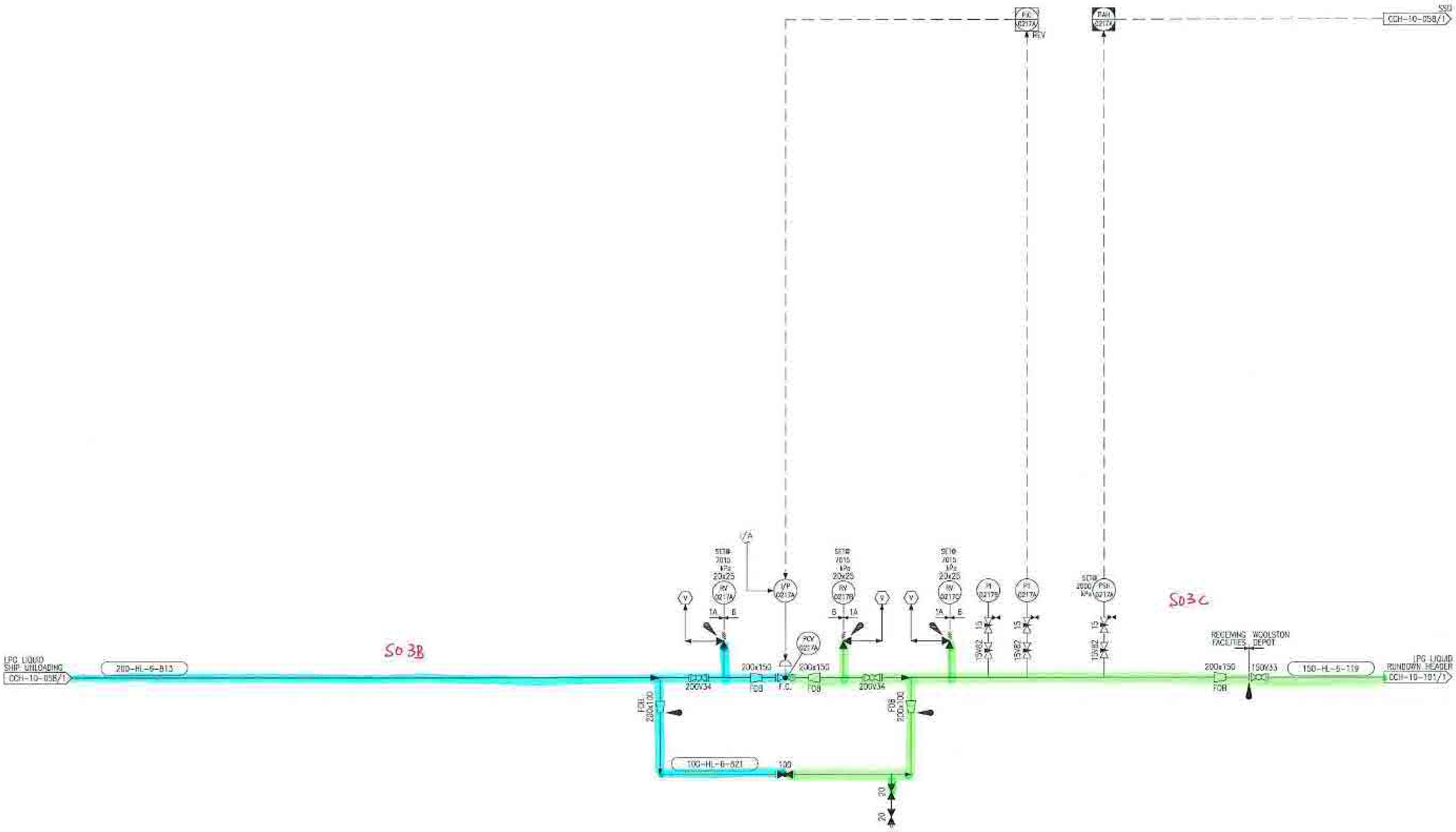
PROJECT No. 0526-03
OSD Pipelines

GENERAL NOTES:

1. FUSIBLE LOOP FIRE DETECTION SYSTEM, REFER P&ID CCH-10-122/1.



Master Document - 27-08-2013



REV	DATE	DRAWN	DESCRIPTION	CHKD	APPR	ENG. MAN.
7	26/13	TW	AS BUILT	JN		JS / KS
6	30/11	JA	[illegible] AS BUILT TO [illegible] MARK UP	YB	AJ	KS
5	08/97	[illegible]	[illegible] AS BUILT TO LIQUIGAS MARK UP, REDRAWN ON CAD	[illegible]	[illegible]	[illegible]
4	10/10/84	[illegible]	AS BUILT			

REVISIONS — CONSULTANT — LIQUIGAS — REFERENCE DRAWINGS

DESIGNED		DATE
DRAWN	DT	15/7/83
CHECKED	-	19/7/83
APPROVED	TCM	20/10/83
ENG. MAN.	TB	17/3/84
SCALE	NTS	

WOOLSTON LPG STORAGE

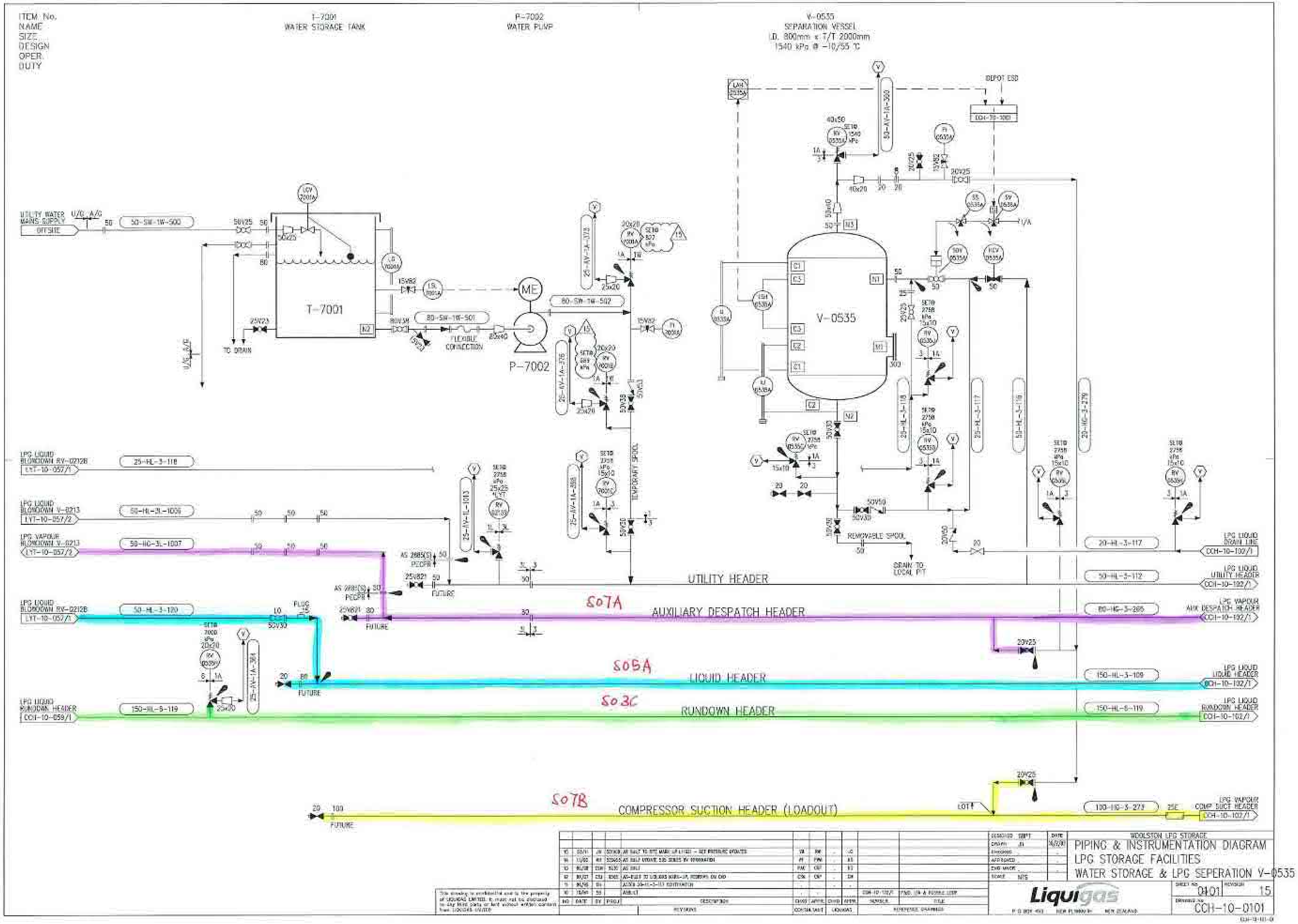
PIPING & INSTRUMENTATION DIAGRAM
LPG PIPELINE FACILITIES
LPG PRESSURE LET DOWN PCV-0217A

Liquigas

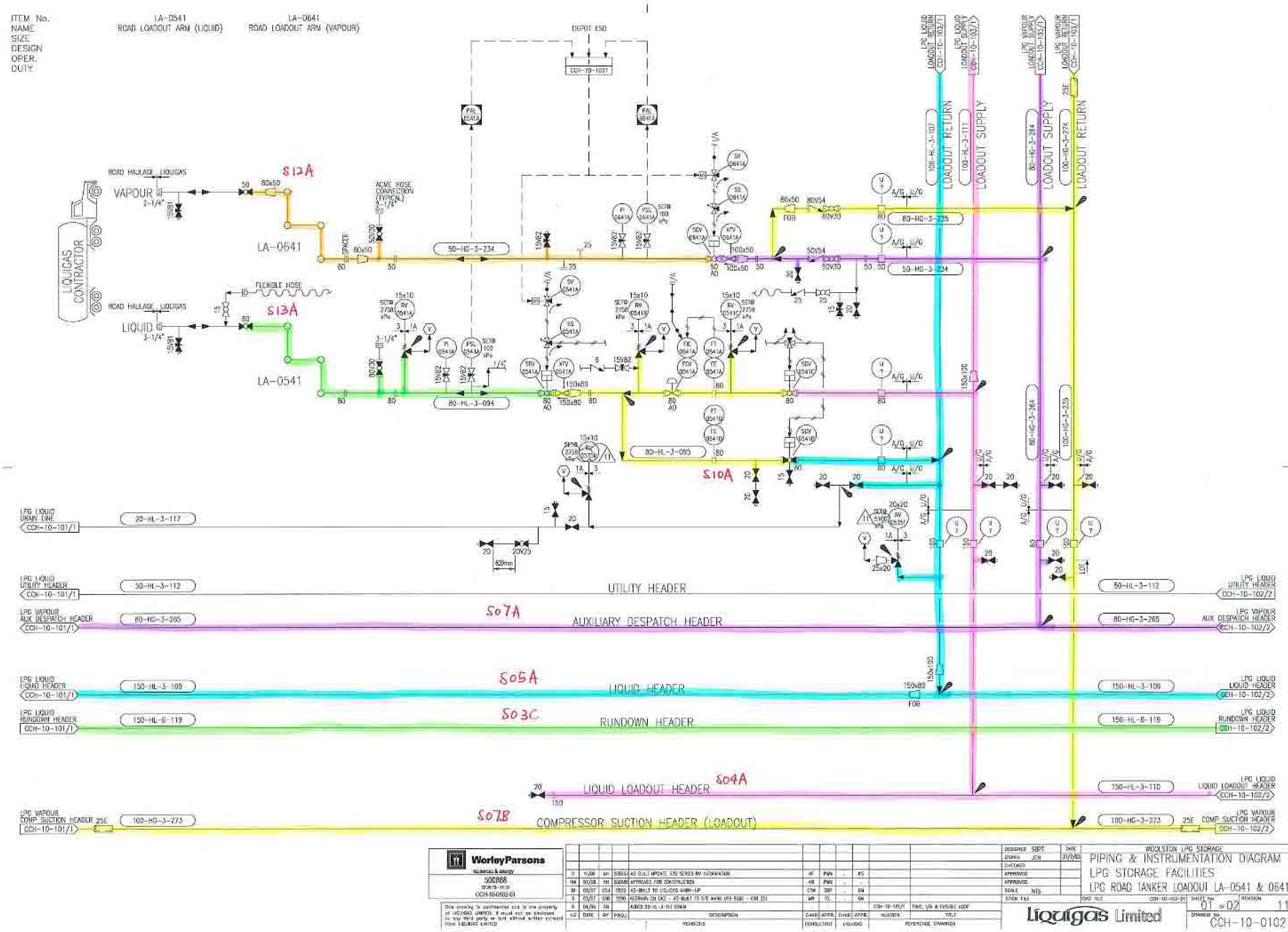
P.O. BOX 450 NEW PLYMOUTH NEW ZEALAND

SHEET No. 01 of 01 — REVISION 7

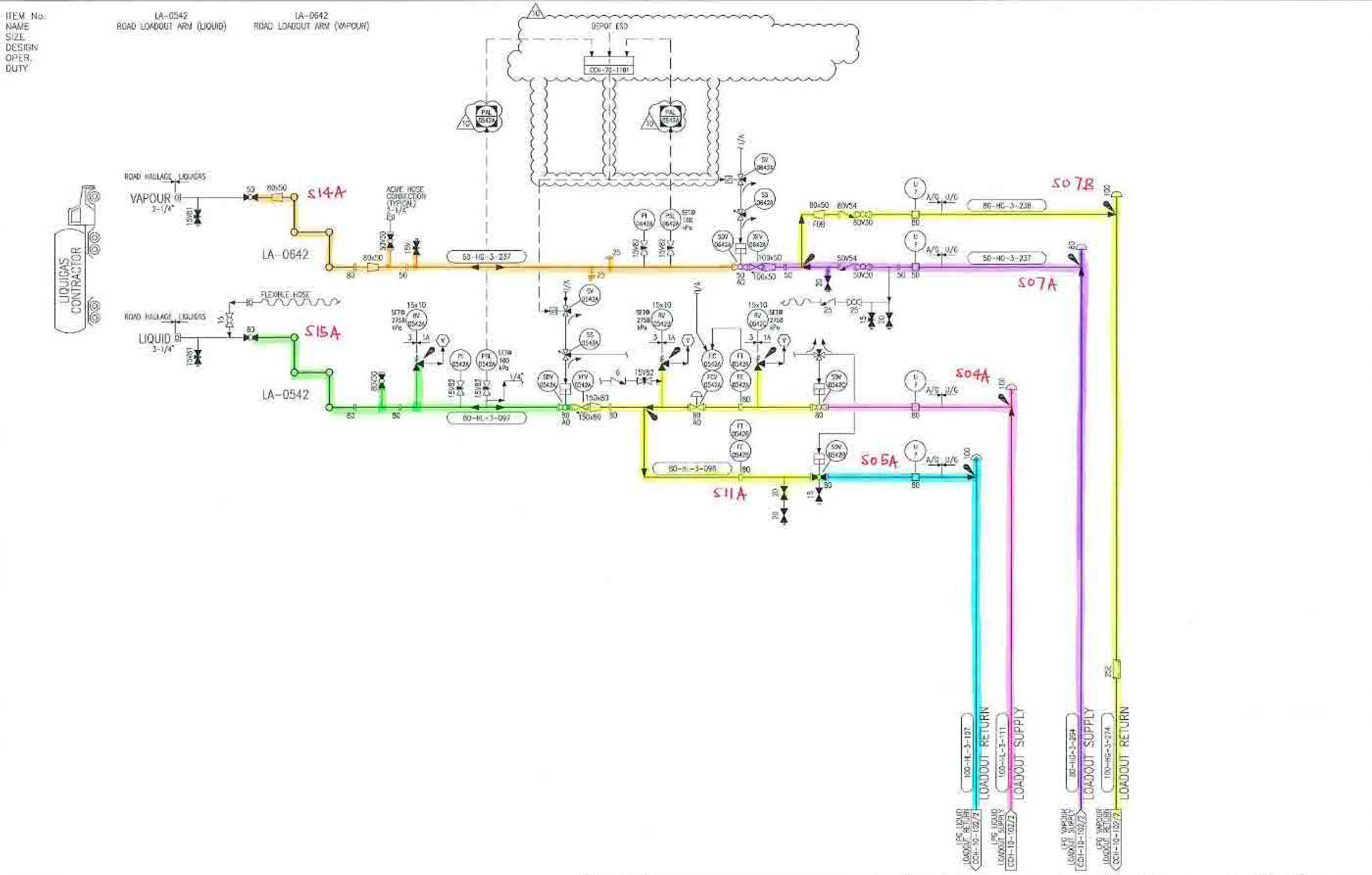
DRAWING No. CCH-10-0059



Master Document - 27-08-2013



Master Document - 27-08-2013



GENERAL NOTES:

1. "SNAP TITE" CONNECTION OR EQUIVALENT.

WOOLSTON LPG STORAGE

PIPING & INSTRUMENTATION DIAGRAM

LPG STORAGE FACILITIES

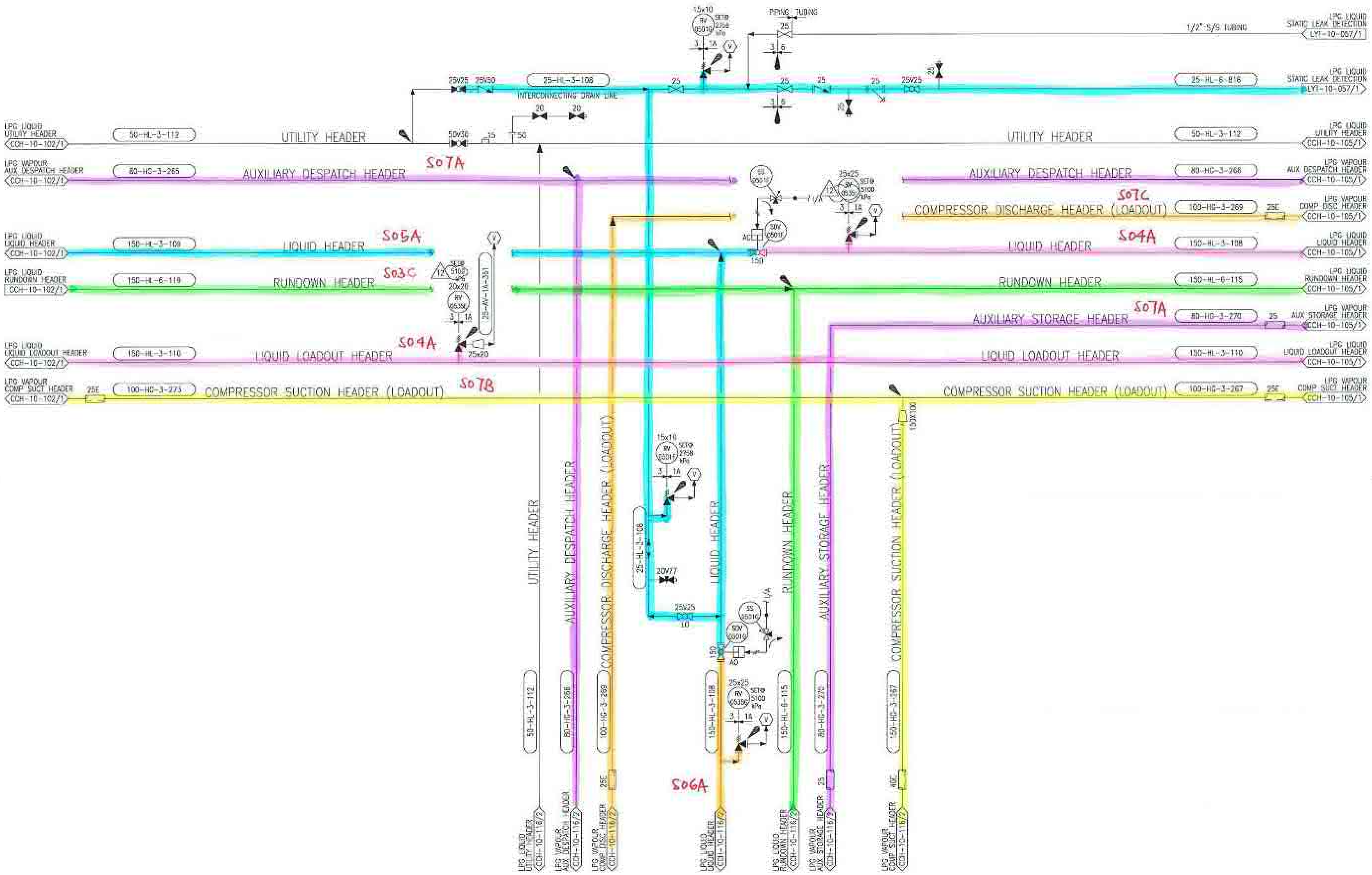
LPG ROAD TANKER LOADOUT LA-0542 & 0642

Liquigas

SHEET No. 01 of 01 | REVISION 10

DRAWING No. CCH-10-0103

Master Document - 27-08-2013



12	11/08	MH	530055	AS BUILT UPDATE 535 SERIES RV INFORMATION	MF	FAN		AS		
11	05/07	CSI	0006	AS-BUILT TO LIQUIGAS MARK-UP, REDRAWN IN CAD	CSM	CRP		GH		
10	06/07	DR		LIQUID HEADER VALVES ADDED	GH	DI			CCH-10-131/1	P&ID, I/A & FUSIBLE LOOP
NO	DATE	BY	PROJ	DESCRIPTION	CHKD	APPR	CHKD	APPR	NUMBER	TITLE
				REVISIONS	CONSULTANT		LIQUIGAS		REFERENCE DRAWINGS	

This drawing is confidential and is the property of LIQUIGAS LIMITED. It must not be disclosed to any third party or lent without written consent from LIQUIGAS LIMITED.

DESIGNED	ICS	
DRAWN	EM	30/12/01
CHECKED	EM	2/3/02
APPROVED	DMS	4/3/02
APPROVED	PSA	11/6/02
SCALE	NTS	

WOOLSTON LPG STORAGE

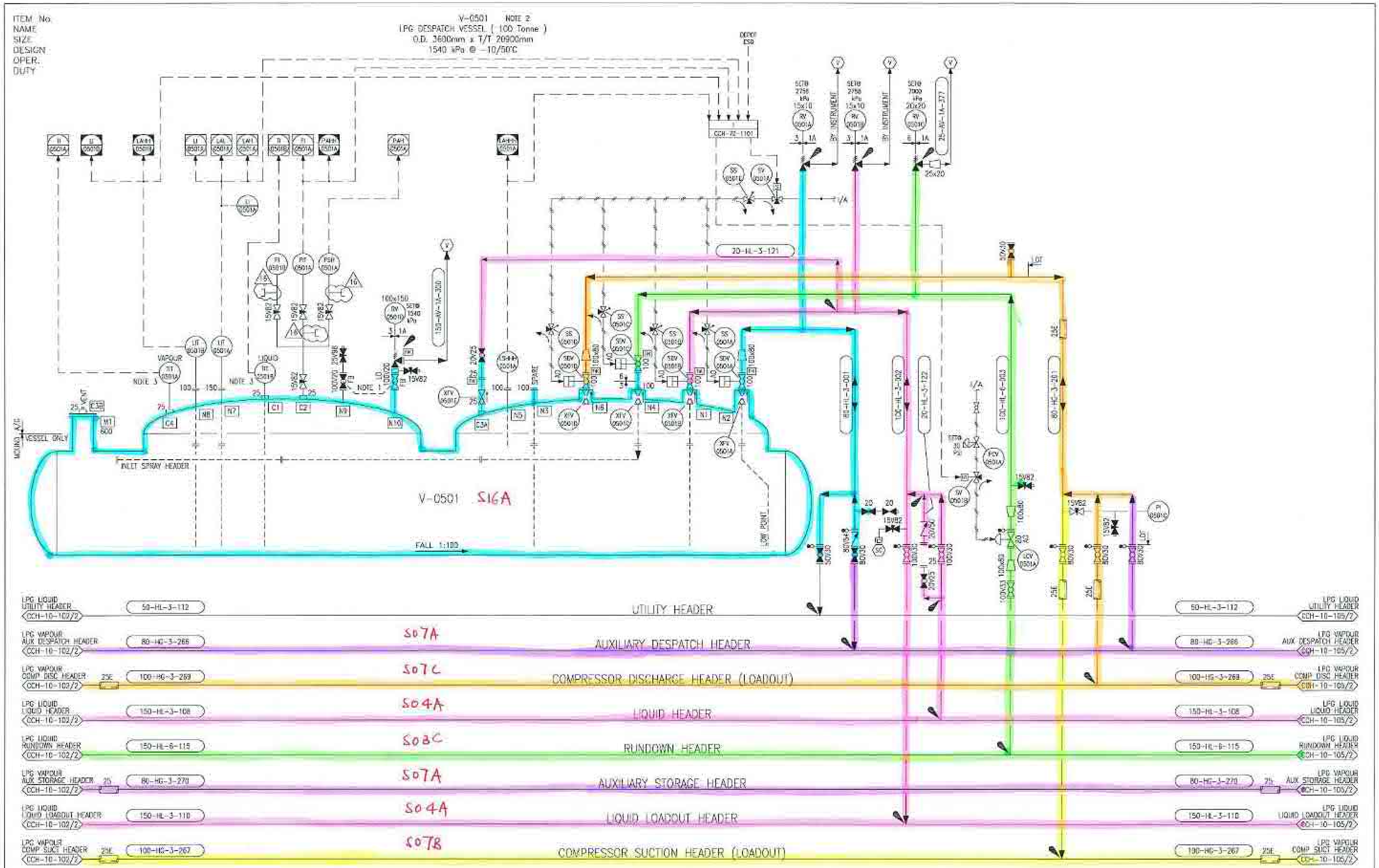
PIPING & INSTRUMENTATION DIAGRAM
LPG STORAGE FACILITIES
LPG STORAGE PIPERACK JUNCTION

STACK FILE
CAD FILE CCH-10-102-02
SHEET No 02 of 02 REVISION 12

Liquigas Limited

DRAWING No CCH-10-0102

Master Document - 27-08-2013



GENERAL NOTES:

1. NOZZLE N9 & N10 VALVES INTERLOCKED, REFER DWG: MOD-50-812/1.
2. FUSIBLE LOOP FIRE DETECTION SYSTEM, REFER DWG: CCH-10-122/1.
3. TI FITTED WITH THERMOWELL. THERMOWELL TO TIT CONNECTION 20mm BSP.

WorleyParsons
resources & energy
L16008
CCH-10-0105-01

ITEM	DATE	DRAWN	DESCRIPTION	CHKD	APPR.	APPR.	E.M.	NUMBER	TITLE
16	07/16	JRG	AS BUILT TO PCR 0132	KC	.	JC	HP		
15	10/15	SA	REMOVE INSTRUMENT SET POINTS FROM LPG VESSEL	HWO	AC	KB	HP		
14	01/14	DC	PCR-096 AS BUILT TO WSB L1600	JH			AC/DS		
13	05/12	TW	AS BUILT TO PROJECT 503803	KS	TS		KS		
12	05/11	SA	503683 & 503947 AS BUILT TO SITE MARK UP	KB	AJ		KS		
11	07/07	SW	[illegible] AS BUILT TO LIQUIGAS MARK UP, REDRAWN ON CAD	CDM	GPP		IH		
10	05/91	DS	LIQUID HEADER VALVES ADDED	GS	GH		KS	CCH-10-121/1	FUSIBLE LINK [illegible] LOOP
REVISIONS				CONSULTANT		LIQUIGAS		REFERENCE DRAWINGS	

		DATE
DESIGNED	ICS	
DRAWN	DM	30/12/81
CHECKED	DM	2/03/82
APPROVED	DVS	4/03/82
DVG. MAN.	PSA	11/6/82
SCALE	NTS	

WOOLSTON LPG STORAGE

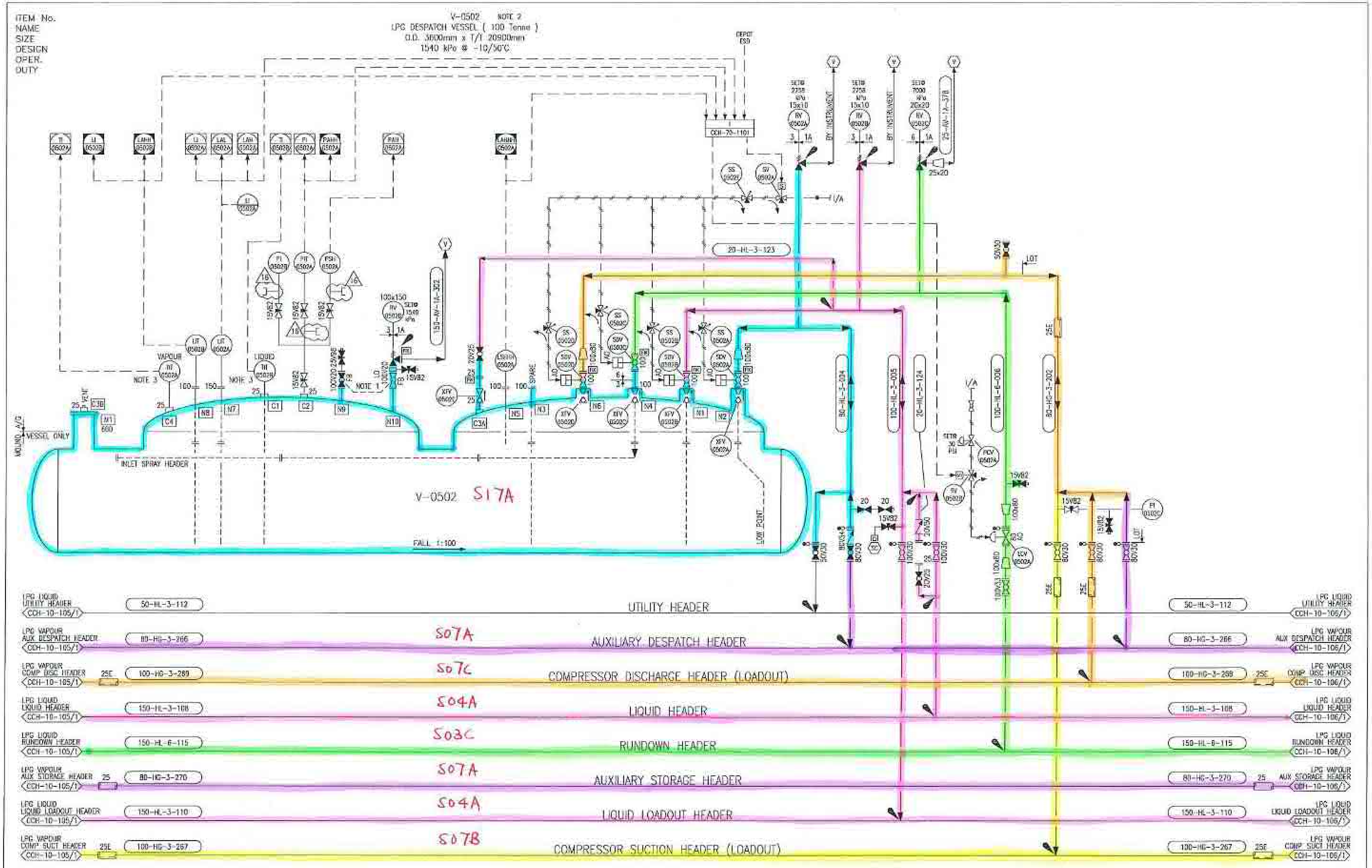
PIPING & INSTRUMENTATION DIAGRAM
LPG STORAGE FACILITIES
LPG STORAGE VESSEL V-0501

Liquigas
P.O. BOX 400 NEW PLYMOUTH NEW ZEALAND

SHEET No. 01 OF 02
REVISION 16
DRAWING No. CCH-10-0105

CCH-10-0105-01

As Built Master - PCR0132 - 20-07-2016 - e-signed



GENERAL NOTES:

1. NOZZLE N9 & N10 VALVES INTERLOCKED, REFER DWG: M00-50-012/1.
2. FUSIBLE LOOP FIRE DETECTION SYSTEM, REFER DWG: CCH-10-122/1.
3. TIT FITTED WITH THERMOWELL. THERMOWELL TO TIT CONNECTION 20mm DSF.

WorleyParsons
resources & energy
L16008
CCH-10-0105-02

REV	DATE	DRAWN	DESCRIPTION	CHKD	APPR.	APPR.	E.M.	NUMBER	TITLE
16	07/16	AAC	AS BUILT TO PCR 0132	AC	.	AS	PP		
15	12/15	DA	REMOVE INSTRUMENT SET POINTS FROM LPG VESSEL	AMS	AC	AS	PP		
14	05/14	DG	PCR-060 AS BUILT TE AND LH001	AV		.	AC/AS		
13	03/13	TW	AS BUILT TO PROJECT 500003	AS	TD	.	AS		
12	01/11	DA	500469 AS BUILT TO SITE MARK UP	HB	AU	.	HS		
11	07/07	CDI	5500 AS BUILT TO LIQUIGAS MARK UP, REDRAWN ON CAD	CDI	CBP	.	GM		
10	05/01	GM	LIQUID HEADER VALVES ADDED	GM	GV	.	AS	CCH-10-121/1	PIPING, I/A & FUSIBLE LOOP
			REVISIONS	CONSULTANT		LIQUIGAS		REFERENCE DRAWINGS	

THE CONTENT OF THIS DRAWING IS THE EXCLUSIVE PROPERTY OF LIQUIGAS LIMITED AND SHALL NOT BE COPIED, REPRODUCED OR OTHERWISE DISCLOSED TO ANY THIRD PARTY WITHOUT THE WRITTEN CONSENT OF LIQUIGAS LIMITED.

			DATE
DESIGNED	JCS		
DRAWN	DM		30/12/81
CHECKED	DM		2/03/82
APPROVED	DWS		4/03/82
ENG. MAN.	PSA		11/6/82
SCALE	NTS		

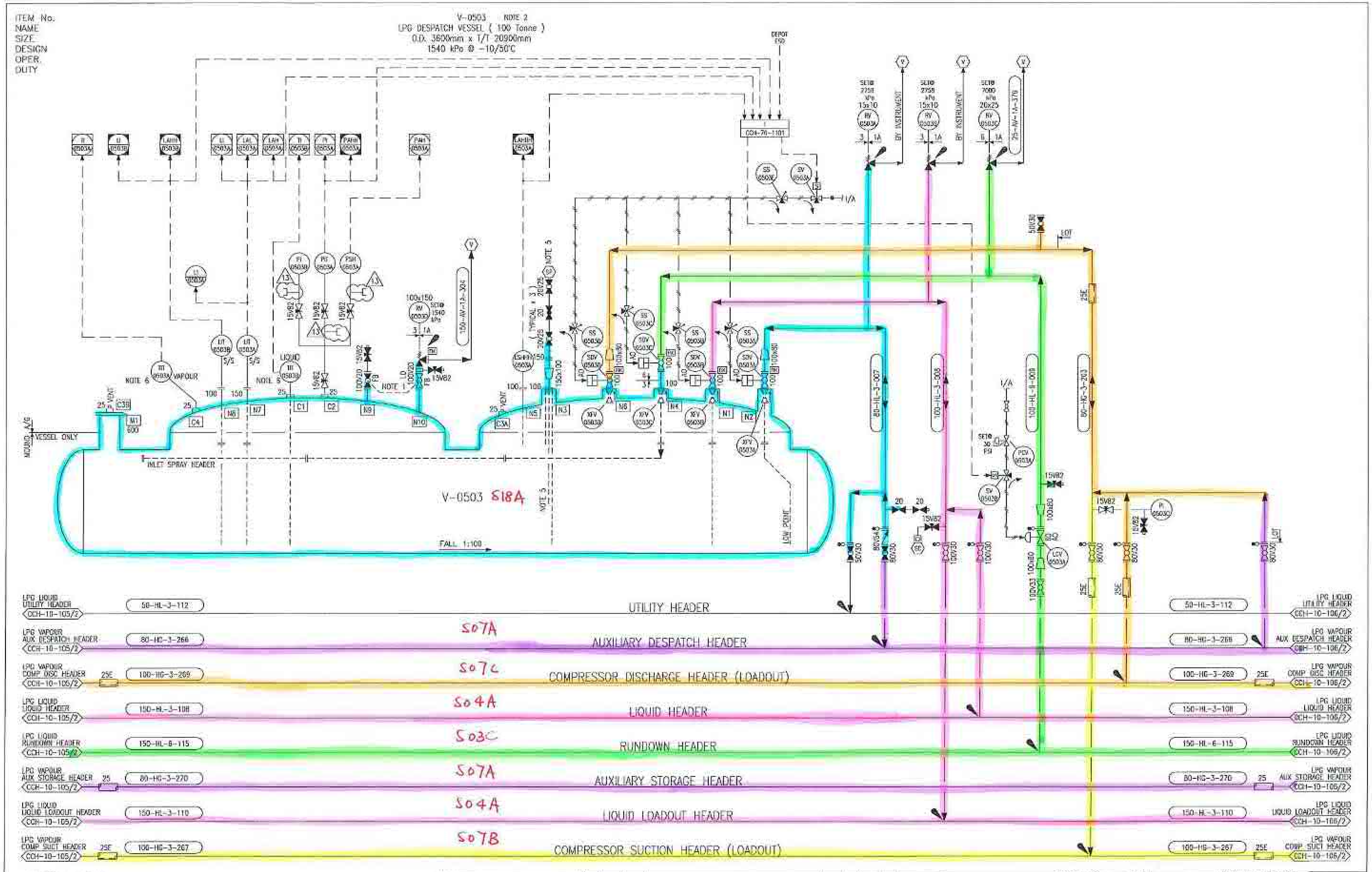
WOOLSTON LPG STORAGE
PIPING & INSTRUMENTATION DIAGRAM
LPG STORAGE FACILITIES
LPG STORAGE VESSEL V-0502

Liquigas
P O BOX 430 NEW PLYMOUTH NEW ZEALAND

SHEET No 02 of 02
REVISION 16
DRAWING No CCH-10-0105

CCH-10-0105-02

As Built Master - PCR0132 - 20-07-2016 - e-signed



GENERAL NOTES:

1. NOZZLE N9 & N10 VALVES INTERLOCKED, REFER DWG: MOD-50-012/1.
2. FUSIBLE LOOP FIRE DETECTION SYSTEM, REFER DWG: CCH-10-122/1.
3. LEVEL SETTING SHOWN IS APPLICABLE TO "MIXED" PRODUCT STORAGE ONLY.
4. GUIDED RADARS SHOW ACTUAL PRODUCT LEVEL.
5. STAGGERED SAMPLE POINT DRAW-OFF TUBING FOR CONTAMINATED PRODUCT INTERFACE SAMPLING.
6. TIT FITTED WITH THERMOWELL. THERMOWELL TO TIT CONNECTION 20mm BSP.

WorleyParsons
L16008
CCH-10-0106-01

REV	DATE	DRAWN	DESCRIPTION	CHKD	APPR.	APPR.	E.M.	NUMBER	TITLE
13	07/16	AMC	AS BUILT TO PCR 0132	AC	.	AC	RF		
13	11/15	[illegible]	REMOVE INSTRUMENT SET POINTS FROM LPG VESSEL	[illegible]	[illegible]	AB	RF		
11	06/12	[illegible]	AS BUILT TO PROJECT [illegible]	[illegible]	[illegible]	.	[illegible]		
10	01/11	[illegible]	[illegible] AS BUILT TO SITE MARK UP	[illegible]	[illegible]	.	[illegible]		
9	[illegible]	CSJ	[illegible] AS BUILT TO LIQUIGAS MARK UP, REDRAWN [illegible]	[illegible]	[illegible]	.	[illegible]		
8	12/09	[illegible]	[illegible]	.	.	.	.	CCH-10-122/1	[illegible] FUSIBLE LOOP
REVISIONS				CONSULTANT		LIQUIGAS		REFERENCE DRAWINGS	

DESIGNED	ICS	
DRAWN	BU	30/12/01
CHECKED	GM	2/03/02
APPROVED	DWS	4/03/02
ENG. APPR.	PSA	11/6/02
SCALE	NTS	

WOOLSTON LPG STORAGE

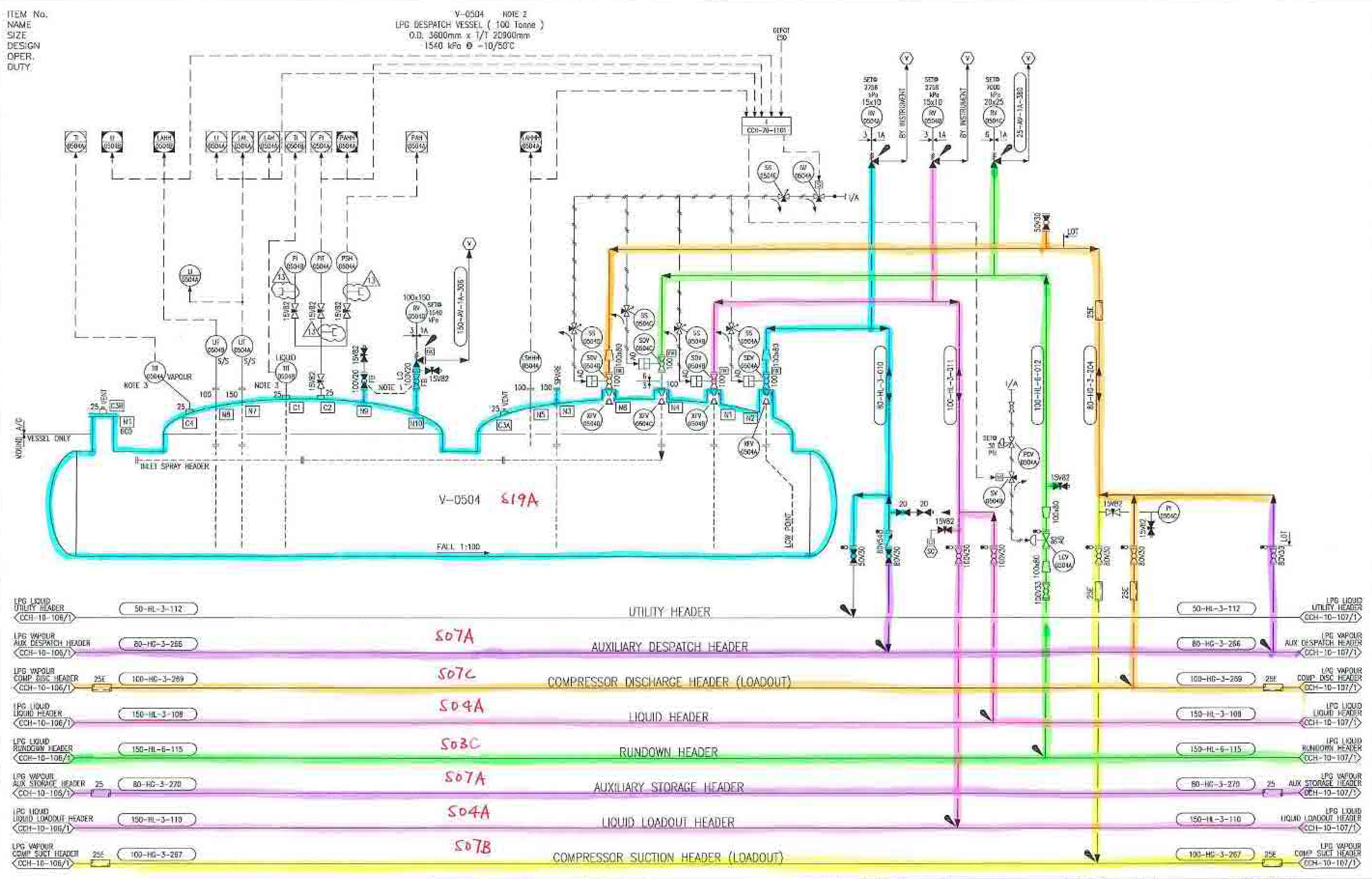
PIPING & INSTRUMENTATION DIAGRAM
LPG STORAGE FACILITIES
LPG STORAGE VESSEL V-0503

Liquigas
P O BOX 450 NEW PLYMOUTH NEW ZEALAND

SHEET No. 01 OF 02
REVISION 13
DRAWING No. CCH-10-0106

CCH-10-0106-01

As Built Master - PCR0132 - 20-07-2016 - e-signed



GENERAL NOTES:

1. NOZZLE N9 & N10 VALVES INTERLOCKED, REFER DWG: M00-50-012/1.
2. FUSIBLE LOOP FIRE DETECTION SYSTEM, REFER DWG: CCH-10-122/1.
3. TIT FITTED WITH THERMOWELL. THERMOWELL TO TIT CONNECTION 20mm BSP.
4. GUIDED RADARS SHOW ACTUAL PRODUCT LEVEL.

WorleyParsons
L16008
CCH-10-0106-02

REV	DATE	DRAWN	DESCRIPTION	CHKD	APPR	APPR	E.M.	NUMBER	TITLE
13	07/16	AMC	AS BUILT TO PCR 0132	AC	-	AC	PP		
12	10/15	[illegible]	[illegible] SET POINTS FROM LPG VESSEL	[illegible]	AC	AB	PP		
11	06/12	[illegible]	AS BUILT TO PROJECT [illegible]	AS	[illegible]	-	AS		
10	03/11	[illegible]	[illegible] AS BUILT TO SITE [illegible]	[illegible]	AJ	-	AS		
6	01/[illegible]	CSJ	[illegible] AS BUILT TO LIQUIGAS MARK UP, REDRAWN ON CAD	CSM	[illegible]	-	CM		
5	12/[illegible]	[illegible]	LAH / LAHH [illegible]	-	-	-	-	CCH-10-122/1	[illegible] FUSIBLE LOOP
REVISIONS				CONSULTANT		LIQUIGAS		REFERENCE DRAWINGS	

		DATE
DESIGNED	ICS	
DRAWN	DJJ	30/12/81
CHECKED	DJA	2/03/82
APPROVED	DMS	4/03/82
ENG. MAN.	PSL	11/6/82
SCALE	NTS	

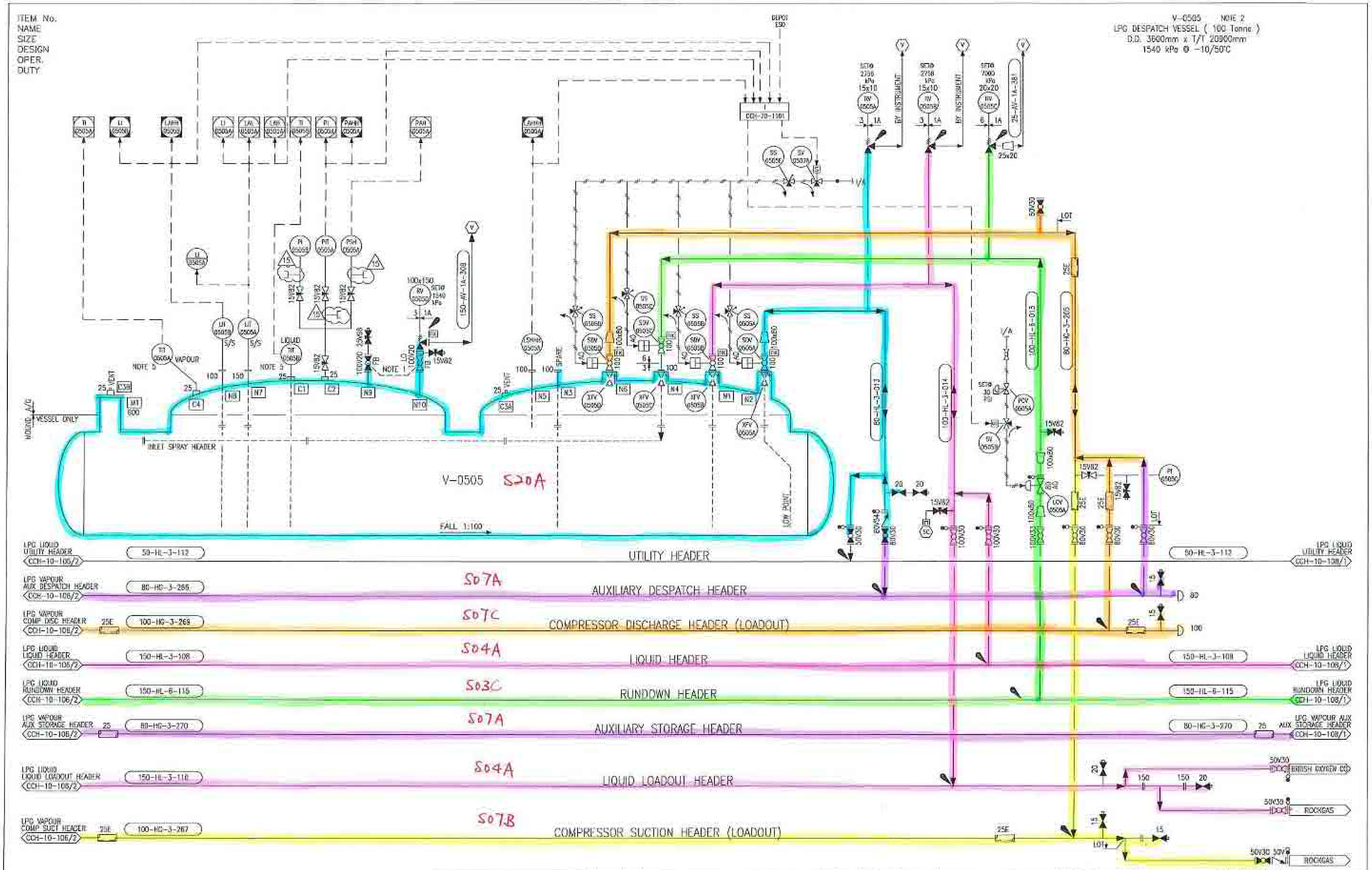
WOOLSTON LPG STORAGE

PIPING & INSTRUMENTATION DIAGRAM
LPG STORAGE FACILITIES
LPG STORAGE VESSEL V-0504

Liquigas
P O BOX 490 NEW PLYMOUTH NEW ZEALAND

SHEET No 02 OF 02
REVISION 13
DRAWING No CCH-10-0106

As Built Master - PCR0132 - 20-07-2016 - e-signed



GENERAL NOTES:

1. NOZZLE N9 & N10 VALVES INTERLOCKED, REFER DWG: MOD-50-012/1.
2. FUSIBLE LOOP FIRE DETECTION SYSTEM, REFER DWG: CCH-10-122/1.
3. LEVEL SETTING SHOWN IS APPLICABLE TO "MIXED" PRODUCT STORAGE ONLY.
4. GUIDED RADARS SHOW ACTUAL PRODUCT LEVEL.
5. TIT FITTED WITH THERMOWELL. THERMOWELL TO TIT CONNECTION 20mm BSP.

WorleyParsons

L16008

CCH-10-0107-01

DESIGNED	ICS	DATE	
DRAWN	DM	30/12/81	
CHECKED	DM	2/01/82	
APPROVED	DWS	4/01/82	
ENG. MAN.	PSA	11/5/82	
SCALE	NTS		

WOOLSTON LPG STORAGE

PIPING & INSTRUMENTATION DIAGRAM
LPG STORAGE FACILITIES
LPG STORAGE VESSEL V-0505

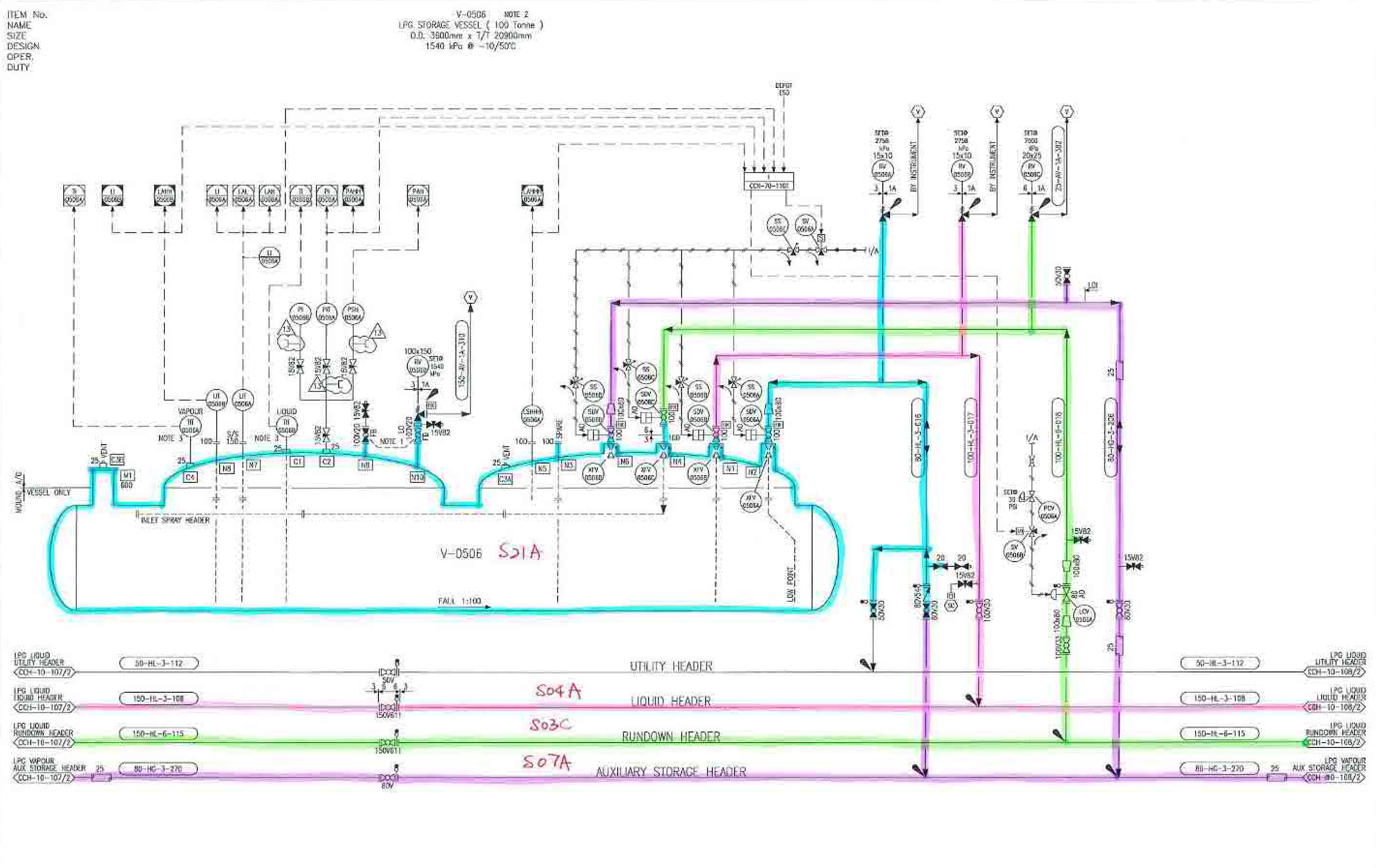
Liquigas
P O BOX 490 NEW PLYMOUTH NEW ZEALAND

SHEET No 01 OF 01 REVISION 15

DRAWING No CCH-10-0107

CCH-10-0107-01

As Built Master - PCR0132 - 20-07-2016 - e-signed



GENERAL NOTES:

1. NOZZLE N9 & N10 VALVES INTERLOCKED. REFER DWG: MOD-50-012/1.
2. FUSIBLE LOOP FIRE DETECTION SYSTEM, REFER DWG: CCH-10-122/1.
3. TIT FITTED WITH THERMOWELL. THERMOWELL TO TIT CONNECTION 20mm BSP.

WorleyParsons
resources & energy
L16008
CCH-10-0108-01

REV	DATE	DRAWN	DESCRIPTION	CHKD	APPR	APPRL	E.M.	NUMBER	TITLE
13	07/16	AWE	AS BUILT TO PCR 0132	AS	-	AC	PP		
12	10/15	JA	REMOVE INSTRUMENT SET POINTS FROM LPG VESSEL	MAS	AC	AR	PP		
11	08/14	JFK	AS BUILT- PIPEWORK RE-ALIGNMENT WOOLSTON PCR 0103 [118H]	LW	JT	-	AS		
10	06/12	TW	AS BUILT TO PROJECT 080003	AS	TS	-	AS		
9	03/11	AK	[illegible] AS BUILT TO SITE MARK UP	VB	AJ	-	AS		
8	07/07	CSJ	1065 AS BUILT TO LIQUIGAS MARK UP, REDRAWN ON CAD	GSM	DPP	-	GM		
7	12/82	BW	LAH / LAHH TRANSPOSED FOR [illegible] MOD.	-	-	-	-	CCH-10-122/1	FIRE I/A & FUSIBLE LOOP

REVISIONS | CONSULTANT | LIQUIGAS | REFERENCE DRAWINGS

		DATE
DESIGNED	ICS	
DRAWN	DM	30/12/81
CHECKED	DM	2/03/82
APPROVED	DMS	4/03/82
ENG. MAN.	PSA	11/6/82
SCALE	NTS	

WOOLSTON LPG STORAGE

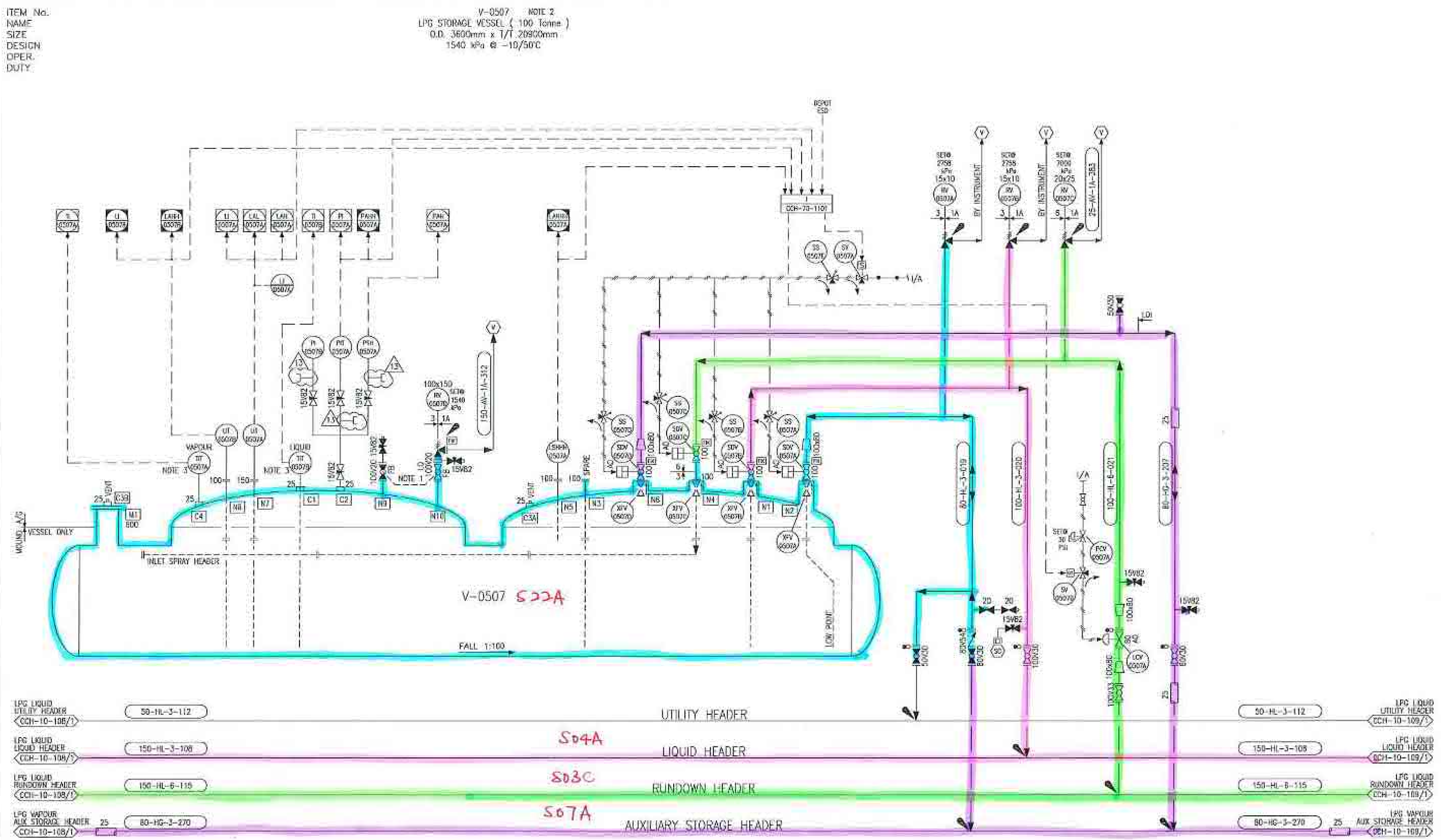
PIPING & INSTRUMENTATION DIAGRAM
LPG STORAGE FACILITIES
LPG STORAGE VESSEL V-0506

Liquigas
P O BOX 450 NEW PLYMOUTH NEW ZEALAND

SHEET No. 01 OF 02
REVISION 13
DRAWING No. CCH-10-0108

CCH-10-0108-01

As Built Master - PCR0132 - 20-07-2016 - e-signed



GENERAL NOTES:

1. NOZZLE N9 & N10 VALVES INTERLOCKED, REFER DWG: MOD-50-012/1.
2. FUSIBLE LOOP FIRE DETECTION SYSTEM, REFER DWG: CCH-10-122/1.
3. TIT FITTED WITH THERMOWELL. THERMOWELL TO TIT CONNECTION 20mm BSP.

WorleyParsons
L16008
CCH-10-0108-02

REV	DATE	DRAWN	DESCRIPTION	CHKD	APPD	APPD.	E.M.	NUMBER	TITLE
13	07/16	AMC	AS BUILT TO PCR 0132	AC	-	AC	PP		
12	05/16	[illegible]	DOCUMENT AS BUILDING	AM	-	AC	PP		
11	10/15	RA	REMOVE INSTRUMENT SET POINTS FROM LPG VESSEL	[illegible]	AC	AB	PP		
10	08/13	TH	AS BUILT TO PROJECT 500000	[illegible]	[illegible]	-	JS		
9	01/11	RA	[illegible] AS BUILT TO SITE MARK UP	[illegible]	AJ	-	[illegible]		
8	07/07	CSJ	[illegible] AS BUILT TO LIQUIGAS MARK UP, REDRAWN IN CAD	[illegible]	[illegible]	-	[illegible]		
7	12/03	RA	LAH / LAHH TRANSPOSED FOR [illegible]	-	-	-	-	CCH-10-122/1	[illegible] FUSIBLE LOOP
REVISIONS				CONSULTANT		LIQUIGAS		REFERENCE DRAWINGS	

DESIGNED	ICS	
DRAWN	DN	31/12/01
CHECKED	DN	2/03/02
APPROVED	DBS	4/03/02
ENG. MAN.	PSA	11/6/02
SCALE	NTS	

WOOLSTON LPG STORAGE

PIPING & INSTRUMENTATION DIAGRAM
LPG STORAGE FACILITIES
LPG STORAGE VESSEL V-0507

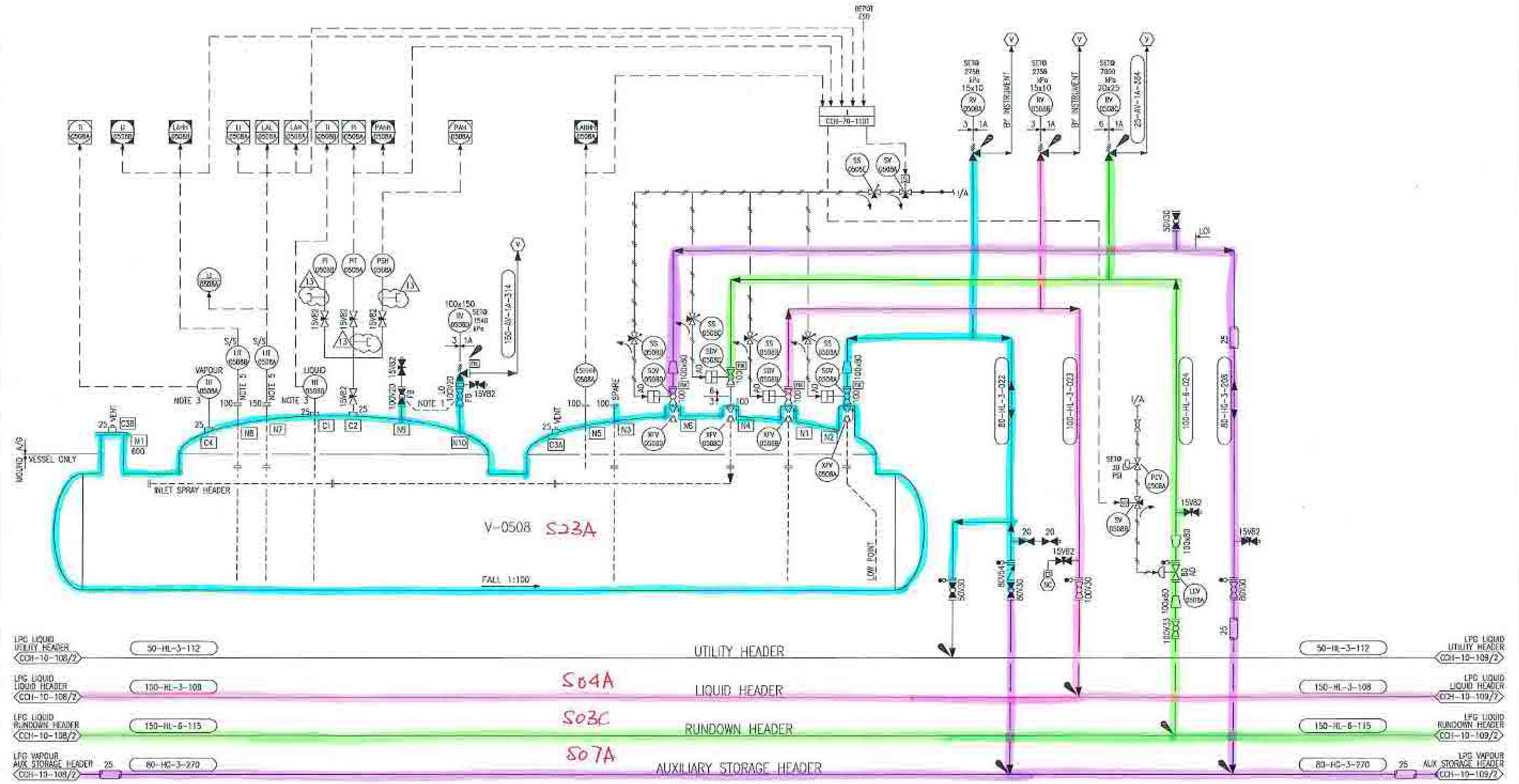
Liquigas
P O BOX 490 NEW PLYMOUTH NEW ZEALAND

SHEET No 02 OF 02 REVISION 13
DRAWING No CCH-10-0108

CCH-10-0108-02

As Built Master - PCR0132 - 20-07-2016 - e-signed

ITEM No. V-0508 NOTE 2
NAME LPG STORAGE VESSEL (100 Tonne)
SIZE O.D. 3600mm x T/T 20900mm
DESIGN 1540 kPa @ -10/50°C
OPER.
DUTY



GENERAL NOTES:

1. NOZZLE N9 & N10 VALVES INTERLOCKED, REFER DWG: MOD-50-012/1.
2. FUSIBLE LOOP FIRE DETECTION SYSTEM, REFER DWG: CCH-10-122/1.
3. TT FITTED WITH THERMOWELL. THERMOWELL TO TT CONNECTION 20mm BSP.
4. GUIDED RADARS SHOW ACTUAL PRODUCT LEVEL.
5. NOZZLE N7 & N8 C/W 40mm THICK RING SPACER, REFER DWG: STD-50-1001/1.

WorleyParsons
resources & energy
L10008
CCH-10-0109-01

REV	DATE	DRAWN	DESCRIPTION	DTRS	APPD.	APPD.	E.M.	NUMBER	TITLE
13	07/16	[illegible]	AS BUILT TO PCR 0132	AS		AC	PP		
12	11/15	[illegible]	REMOVE INSTRUMENT SET POINTS FROM LPG VESSEL	HMD	AC	KB	PP		
11	06/[illegible]	DW	AS BUILT TO PROJECT [illegible]	AS	TE	.	AS		
10	01/11	JA	[illegible] AS BUILT TO SITE MARK UP	TE	AJ		MS		
9	05/07	CSW	[illegible] AS BUILT	RAS	CRP	.	GM		
8	07/07	CSI	[illegible] AS BUILT TO LIQUIGAS MARK UP, REDRAWN ON CAD	DSW	CRP	.	GM		
7	12/96	[illegible]	LAH / LAHH TRANSPOSED FOR [illegible]					CCH-10-121/1	[illegible] I/A & FUSIBLE LOOP
REVISIONS				CONSULTANT		LIQUIGAS		REFERENCE DRAWINGS	

DESIGNED	CS	DATE
DRAWN	DM	30/12/81
CHECKED	DM	3/03/82
APPROVED	DNS	4/03/82
ENG. MAN.	PSA	11/8/82
SCALE	NTS	

WOOLSTON LPG STORAGE

PIPING & INSTRUMENTATION DIAGRAM
LPG STORAGE FACILITIES
LPG STORAGE VESSEL V-0508

Liquigas
P O BOX 400 NEW PLYMOUTH NEW ZEALAND

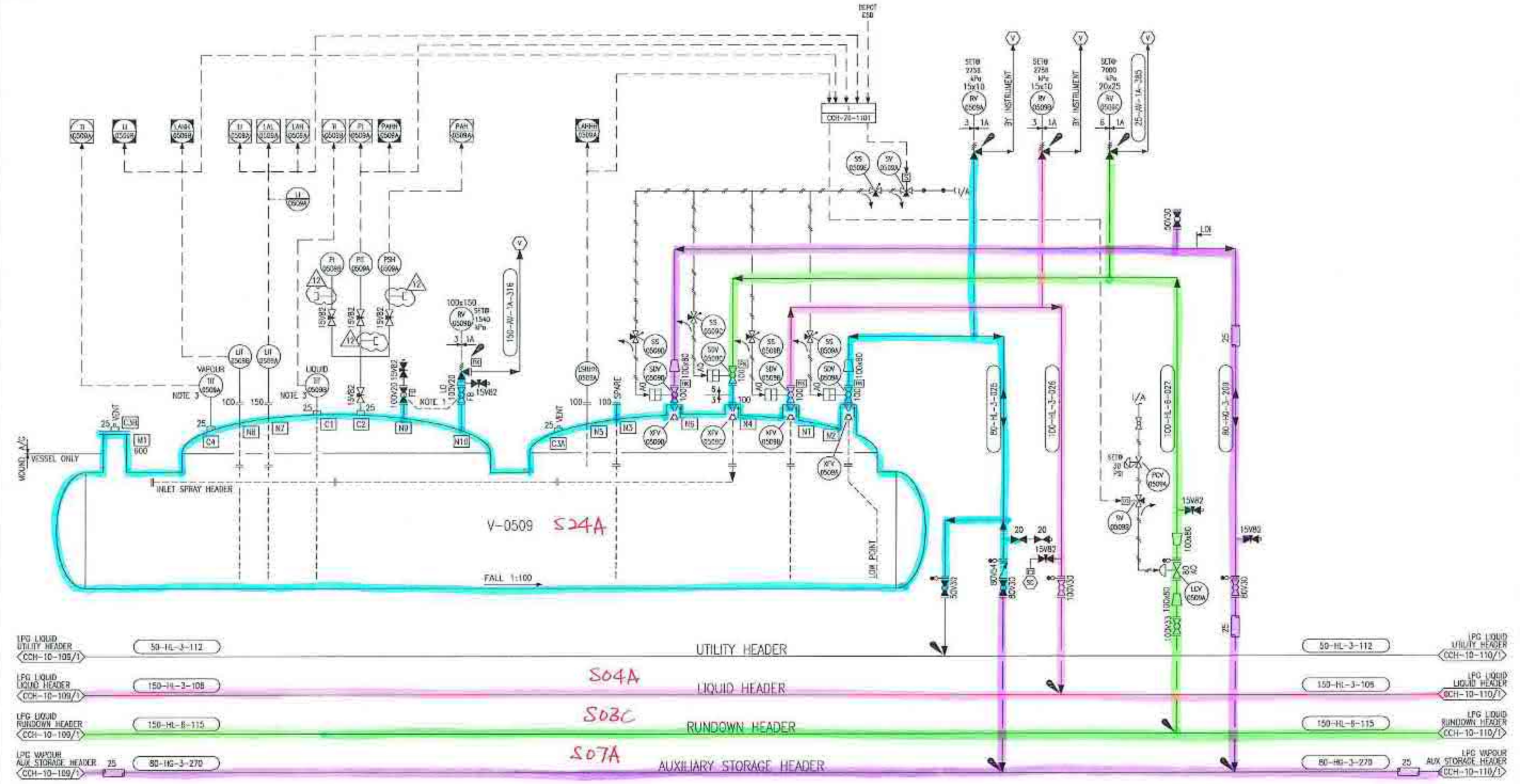
SHEET No 01 of 02
REVISION 13
DRAWING No CCH-10-0109

CCH-10-0109-01

AsBuilt for Liquigas Check - PCR0132 - 13-07-2016 - e-signed

ITEM No.
NAME
SIZE
DESIGN
OPER.
DUTY

V-0509 NOTE 2
LPG STORAGE VESSEL (100 Tonne)
O.D. 3600mm x T/T 20900mm
1540 kPa @ -10/50°C



GENERAL NOTES:

1. NOZZLE N9 & N10 VALVES INTERLOCKED, REFER DWG: MOD-50-012/1.
2. FUSIBLE LOOP FIRE DETECTION SYSTEM, REFER DWG: CCH-10-122/1.
3. TI FITTED WITH THERMOWELL. THERMOWELL TO TIT CONNECTION 20mm BSP.

WorleyParsons
resources & energy
L16008
CCH-10-0109-02

REV	DATE	DRAWN	DESCRIPTION	CHKD	APPR.	APPR.	ENG.	NUMBER	TITLE
12	07/10	AMC	AS BUILT TO PCR 0132	AC	.	AC	FP		
11	10/15	BA	REVISE INSTRUMENT SET POINTS FROM LPG VESSEL	AMC	AC	NB	FP		
10	05/12	TW	AS BUILT TO PROJECT 569605	AS	TC	.	AS		
9	05/11	BA	S00568 & 501947 AS BUILT TO SITE MARK UP	VB	AJ	.	KS		
8	07/02	CSJ	9535 AS BUILT TO LIQUIGAS MARK UP, REDRAWN ON CAD	CSB	CRF	.	GE		
7	12/83	IW	LAH / LAHH TRANSPOSED FOR AUSTRALIAN MOD.	.	.	.	.	CCH-10-121/1	PNID, I/A & FUSIBLE LOOP

REVISIONS — CONSULTANT — LIQUIGAS — REFERENCE DRAWINGS

		DATE
DESIGNED	ICS	30/12/81
DRAWN	DM	30/12/81
CHECKED	DM	2/03/82
APPROVED	D	4/03/82
ENG. MAN.	PSA	11/8/82
SCALE	NTS	

WOOLSTON LPG STORAGE

PIPING & INSTRUMENTATION DIAGRAM
LPG STORAGE FACILITIES
LPG STORAGE VESSEL V-0509

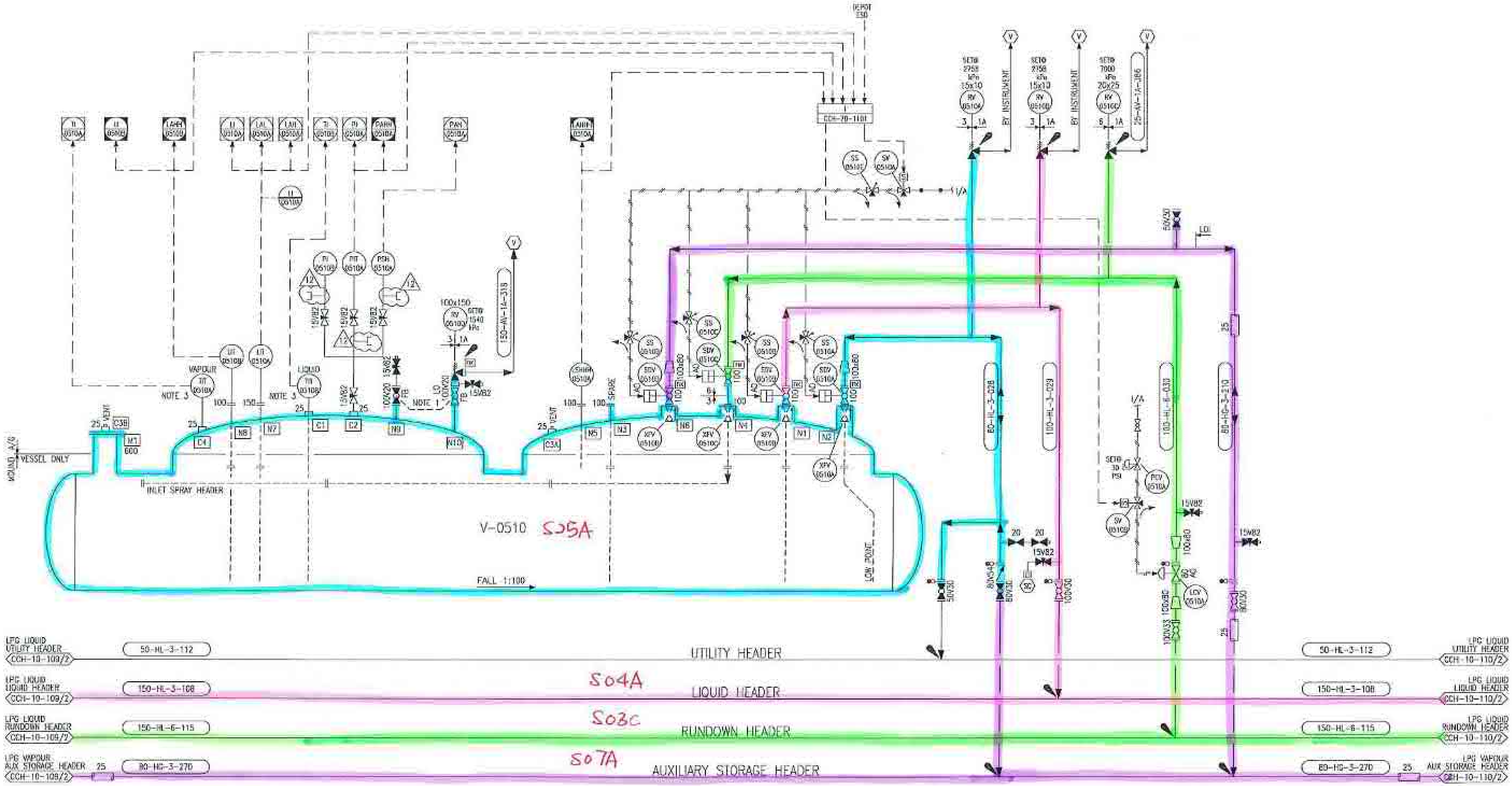
Liquigas
P O BOX 430 NEW PLYMOUTH NEW ZEALAND

SHEET No 02 OF 02
REVISION 12
DRAWING No CCH-10-0109

CCH-10-0109-02

As Built Master - PCR0132 - 20-07-2016 - e-signed

ITEM No. V-0510 NOTE 2
NAME LPG STORAGE VESSEL (100 Tonne)
SIZE O.D. 3600mm x T/T 20900mm
DESIGN 1540 kPa @ -10/50°C
OPER.
DUTY



GENERAL NOTES:

1. NOZZLE N3 & N10 VALVES INTERLOCKED. REFER DWG: MOD-50-012/1.
2. FUSIBLE LOOP FIRE DETECTION SYSTEM, REFER DWG: CCH-10-122/1.
3. TIT FITTED WITH THERMOWELL. THERMOWELL TO TIT CONNECTION 20mm BSP.

WorleyParsons
L16008
CCH-10-0110-01

REV	DATE	DRAWN	DESCRIPTION	CHKD	APPR	APPRL	CAL
12	07/16	ARC	AS BUILT TO PCR 0132	AC	.	KC	PP
11	10/15	DA	REMOVE INSTRUMENT SET POINTS FROM LPG VESSEL	MNC	AC	RB	PP
10	09/12	TW	AS BUILT TO PROJECT 000000	AS	TC	.	KS
9	10/11	DA	300008 & 50?? AS BUILT TO SITE MARK UP	RS	AJ	.	KS
8	07/07	GSJ	9303 AS BUILT TO LIQUIGAS MARK UP, REDRAWN ON CAD	CSH	GBP	.	GM
7	12/89	RK	LAH / LAHH TRANSPOSED FOR MAXIMUM MOD.	.	.	.	.

REVISIONS — CONSULTANT — LIQUIGAS

NUMBER	TITLE
CCH-10-122/1	FIRE I/A & FUSIBLE LOOP

REFERENCE DRAWINGS

DESIGNED	ICS	30/12/81
DRAWN	CM	
CHECKED	CBI	2/03/82
APPROVED	DMS	4/03/82
ENG. MAN.	PSA	11/8/82
SCALE	NTS	

WOOLSTON LPG STORAGE
PIPING & INSTRUMENTATION DIAGRAM
LPG STORAGE FACILITIES
LPG STORAGE VESSEL V-0510

Liquigas
P O BOX 450 NEW PLYMOUTH NEW ZEALAND

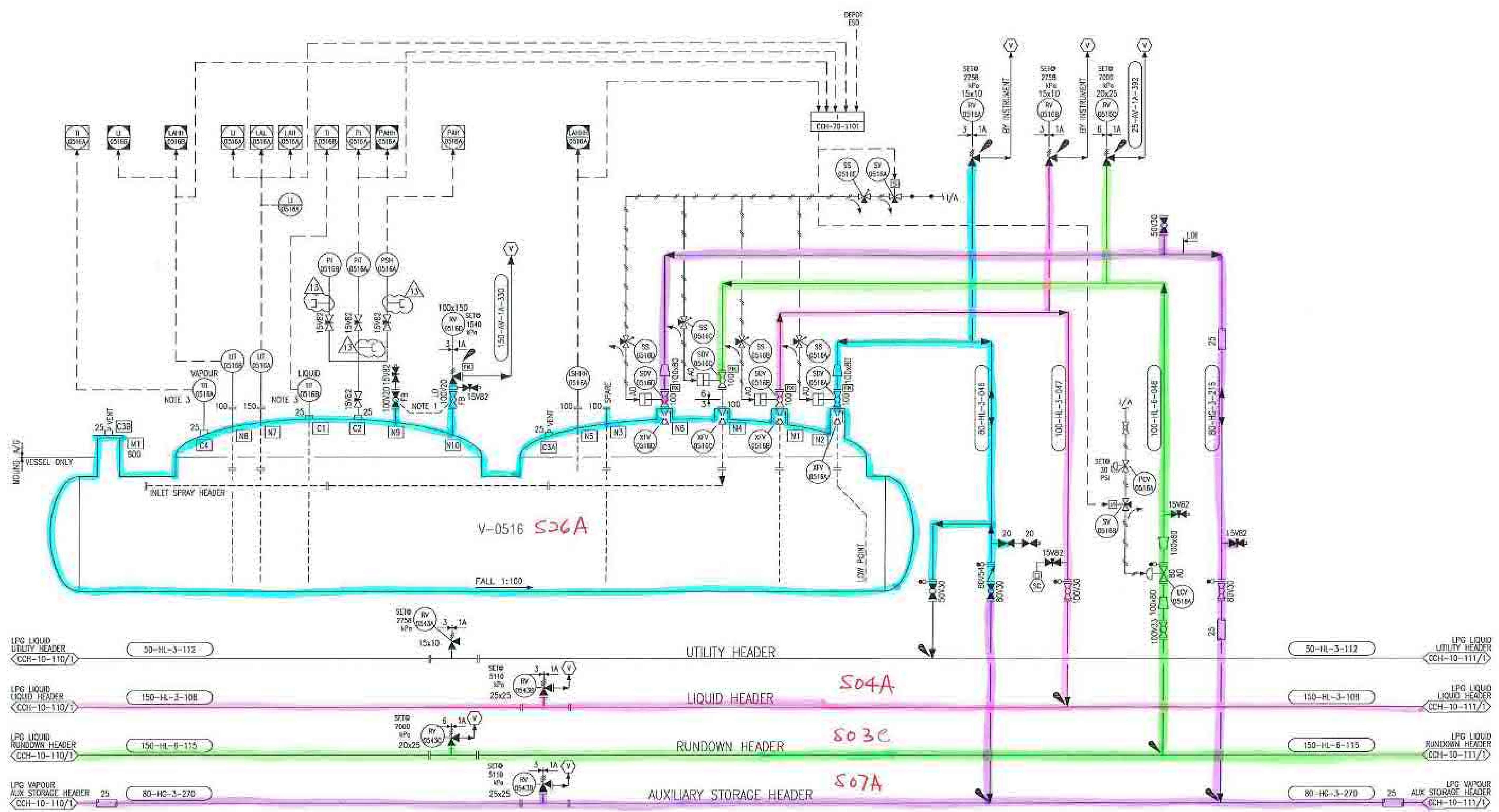
SHEET No. 01 of 02 REVISION 12
DRAWING No. CCH-10-0110

CCH-10-0110-01

As Built Master - PCR0132 - 20-07-2016 - e-signed

ITEM No.
NAME
SIZE
DESIGN
OPER.
DUTY

V-0516 NOTE 2
LPG STORAGE VESSEL (100 Tonne)
O.D. 3600mm x T/T 20900mm
1540 kPa @ -10/50°C



GENERAL NOTES:

1. NOZZLE N9 & N10 VALVES INTERLOCKED, REFER DWG. MOD-SO-012/1.
2. FUSIBLE LOOP FIRE DETECTION SYSTEM, REFER DWG. CCH-10-122/1.
3. TIT FITTED WITH THERMOWELL. THERMOWELL TO TIT CONNECTION 20mm BSP.

WorleyParsons
resources & energy
L16008
CCH-10-0110-02

REV	DATE	DRAWN	DESCRIPTION	CHKD	APPR	APPR	E.M.
13	07/16		AS BUILT TO PCR 0132				
12	10/15		REMOVE INSTRUMENT SET POINTS FROM LPG VESSEL				
11	03/14		AS BUILT - FIREWORX RE-ALIGNMENT WOOLSTON PCR-0106				
10	05/12		AS BUILT TO PROJECT				
9	01/11		AS BUILT TO SITE				
8	07/01		AS BUILT TO LIQUIGAS MARK UPS, REDRAWN ON CAD				
7	12/99		LAH / LAHH TRANSFERRED FOR MASONEILAN MOD				

REVISIONS

NUMBER	TITLE
CCH-10-122/1	FUEL I/A & FUSIBLE LOOP

REFERENCE DRAWINGS

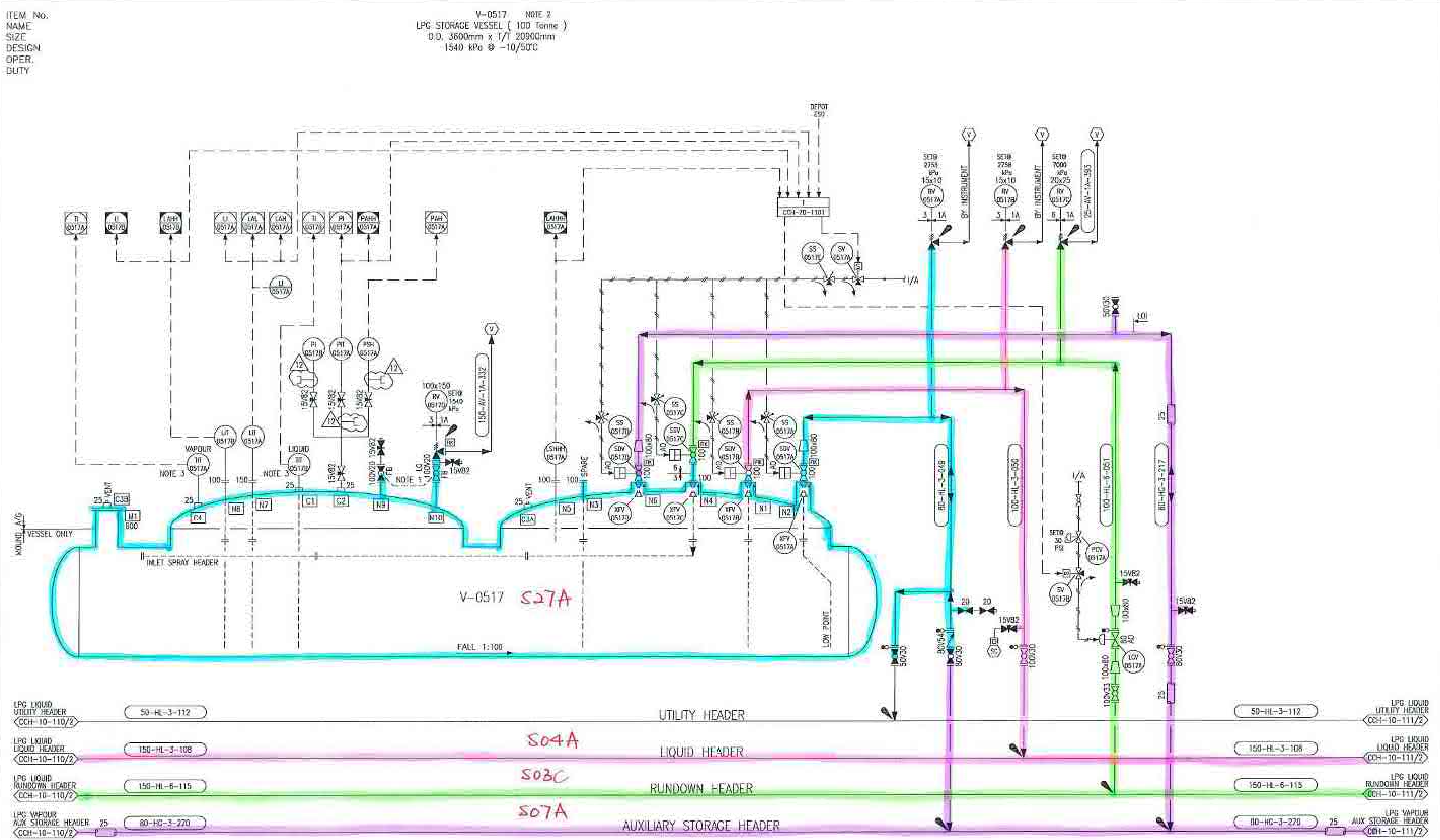
		DATE
DESIGNED	ICS	
DRAWN	DM	28/12/81
CHECKED	DM	2/03/82
APPROVED	DMS	4/03/82
ENG. MAN.	PSA	11/5/82
SCALE	NTS	

WOOLSTON LPG STORAGE
PIPING & INSTRUMENTATION DIAGRAM
LPG STORAGE FACILITIES
LPG STORAGE VESSEL V-0516

Liquigas
P O BOX 450 NEW PLYMOUTH NEW ZEALAND

SHEET No 02 OF 02
REVISION 13
DRAWING No CCH-10-0110

As Built Master - PCR0132 - 20-07-2016 - e-signed



GENERAL NOTES:

1. NOZZLE N9 & N10 VALVES INTERLOCKED, REFER DWG: M00-50-012/1.
2. FUSIBLE LOOP FIRE DETECTION SYSTEM, REFER DWG: CCH-10-122/1.
3. TIT FITTED WITH THERMOWELL. THERMOWELL TO TIT CONNECTION 20mm BSP.

WorleyParsons
resources & energy
L16008
CCH-10-0111-01

REV	DATE	DRAWN	DESCRIPTION	CHK'D	APPR.	APPD.	E.M.
12	07/16	AMC	AS BUILT TO PCR 0132	AC	-	AC	PP
11	10/15	PA	REMOVE INSTRUMENT SET POINTS FROM LPG SYSTEM	[illegible]	AC	AS	PP
10	08/12	TW	AS BUILT TO PROJECT 500033	KS	[illegible]	-	AS
9	04/11	BA	[illegible] AS BUILT TO SITE MARK UP	[illegible]	[illegible]	-	[illegible]
8	07/07	[illegible]	[illegible] AS BUILT TO LIQUIGAS MARK UP, REDRAWN ON CAD	[illegible]	[illegible]	-	[illegible]
7	10/03	[illegible]	LAH / LAHH TRANSPOSED FOR [illegible]	-	-	-	-

REVISIONS — CONSULTANT — LIQUIGAS

NUMBER	TITLE
CCH-10-121/1	FIRE, I/A & FUSIBLE LOOP

REFERENCE DRAWINGS

		DATE
DESIGNED	ICS	
DRAWN	DM	30/12/81
CHECKED	DM	2/03/82
APPROVED	DMS	4/03/82
ENG. MAN.	PSA	11/3/83
SCALE	NTS	

WOOLSTON LPG STORAGE

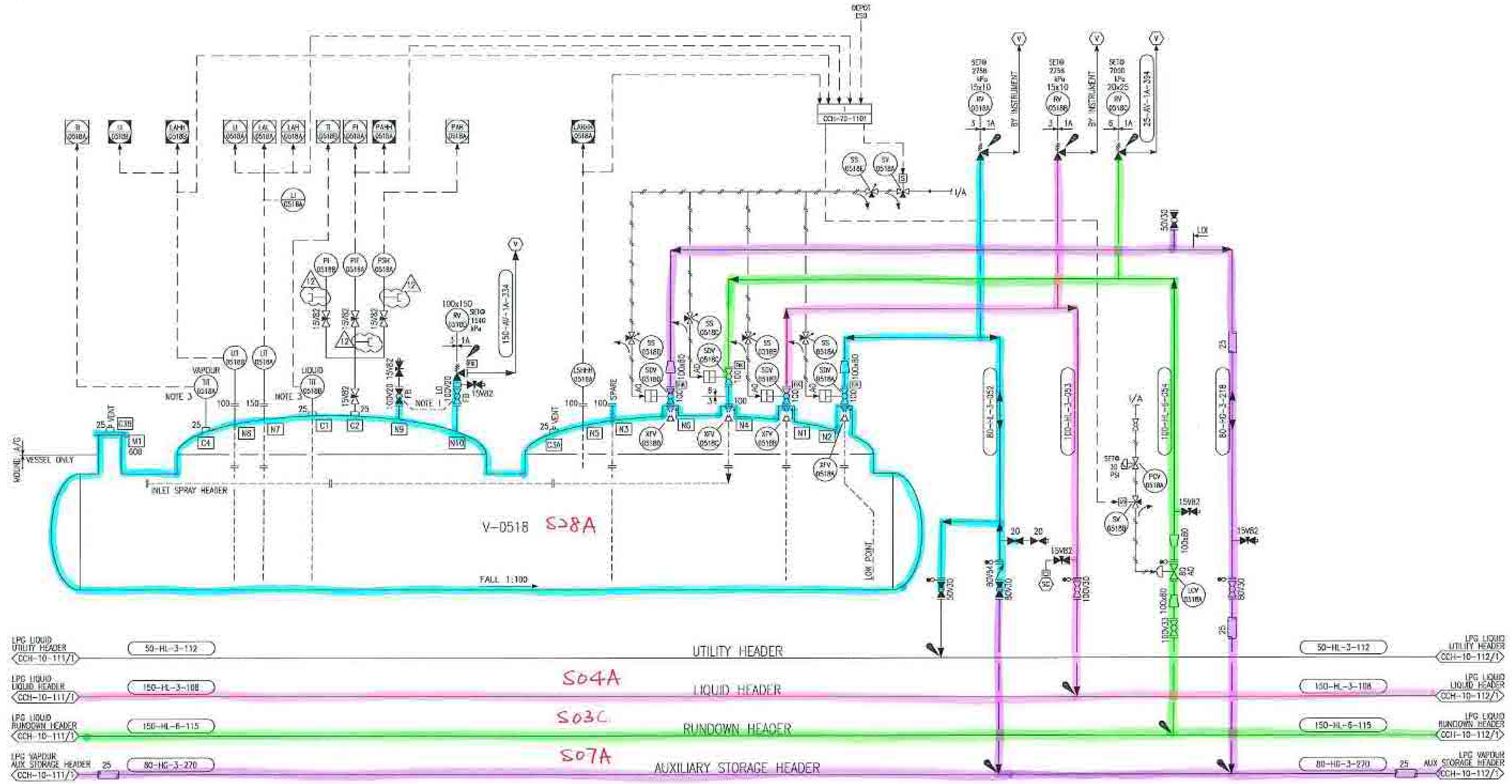
PIPING & INSTRUMENTATION DIAGRAM
LPG STORAGE FACILITIES
LPG STORAGE VESSEL V-0517

Liquigas
P O BOX 410 NEW PLYMOUTH NEW ZEALAND

SHEET No 01 of 02 — REVISION 12
DRAWING No CCH-10-0111

CCH-10-0111-01

ITEM No. V-0518 NOTE 2
NAME LPG STORAGE VESSEL (100 Tonne)
SIZE O.D. 3600mm x T/T 20900mm
DESIGN 1540 kPa @ -10/50°C
OPER.
DUTY



GENERAL NOTES:

1. NOZZLE N9 & N10 VALVES INTERLOCKED, REFER DWG: MDO-50-012/1.
2. FUSIBLE LOOP FIRE DETECTION SYSTEM, REFER DWG: CCH-10-122/1.
3. TIT FITTED WITH THERMOWELL. THERMOWELL TO TIT CONNECTION 20mm BSP.

WorleyParsons
resources & energy
L16008
CCH-10-0111-02

REV	DATE	DRAWN	DESCRIPTION	CHKD	APPR.	APPR.	E.M.	NUMBER	TITLE
12	07/16	AVC	AS BUILT TO PCR 0132	AC	-	AC	PP		
11	10/15	SA	REMOVE INSTRUMENT SET POINTS FROM LPG VESSEL	[illegible]	AC	AB	PP		
10	09/12	TH	AS BUILT TO PROJECT [illegible]	AC	[illegible]	-	AS		
9	05/01	SA	[illegible] AS BUILT TO SITE MARK UP	YB	AJ	-	AS		
8	97/07	[illegible]	[illegible] AS BUILT TO LIQUIGAS MARK UP, REDRAWN ON CAD	[illegible]	[illegible]	-	[illegible]		
7	12/84	[illegible]	[illegible] / [illegible] TRANSPOSED FOR [illegible]	-	-	-	-	CCH-10-121/1	P&ID, I/A & FUSIBLE LOOP
REVISIONS				CONSULTANT		LIQUIGAS		REFERENCE DRAWINGS	

DESIGNED	ICS	DATE
DRAWN	DH	30/12/81
CHECKED	DV	2/03/82
APPROVED	DMS	4/03/82
CHIEF ENG.	PSA	11/6/82
SCALE	NTS	

WOOLSTON LPG STORAGE
PIPING & INSTRUMENTATION DIAGRAM
LPG STORAGE FACILITIES
LPG STORAGE VESSEL V-0518

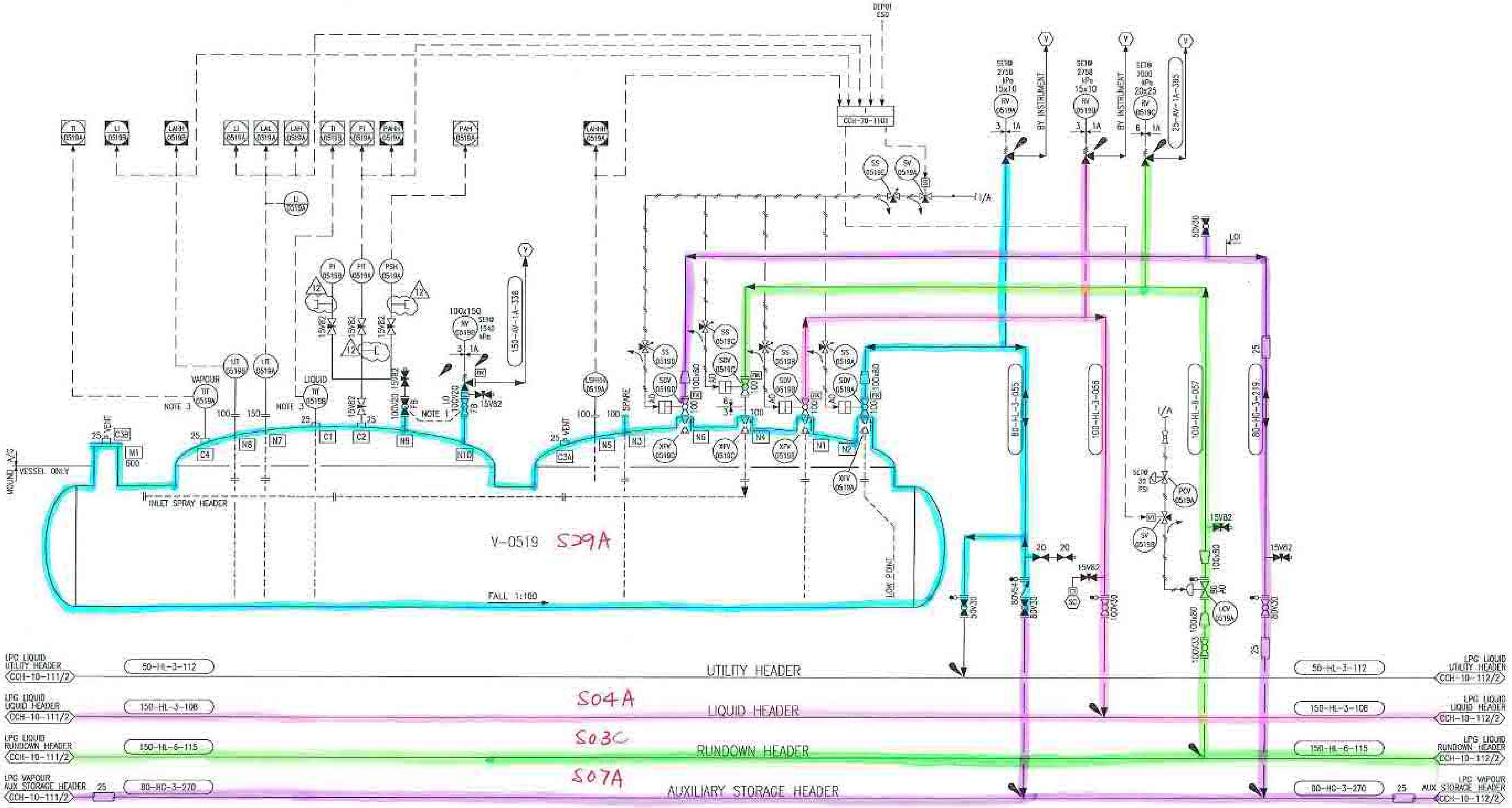
Liquigas
P O BOX 459 NEW PLYMOUTH NEW ZEALAND

SHEET No 02 of 02
REVISION 12
DRAWING No CCH-10-0111

CCH-10-0111-02

As Built Master - PCR0132 - 20-07-2016 - e-signed

ITEM No. V-0519 NOTE 2
NAME LPG STORAGE VESSEL (100 Tonne)
SIZE O.D. 3600mm x T/T 20900mm
DESIGN 1540 kPa @ -10/50°C
OPER.
DUTY



GENERAL NOTES:

1. NOZZLE N9 & N10 VALVES INTERLOCKED, REFER DWG: MOD-50-012/1.
2. FUSIBLE LOOP FIRE DETECTION SYSTEM, REFER DWG: CCH-10-122/1.
3. TIT FITTED WITH THERMOWELL. THERMOWELL TO TIT CONNECTION 20mm BSP.

WorleyParsons resources & energy
L16008
CCH-10-0112-01

REV	DATE	DRAWN	DESCRIPTION	CHKD	APPR.	APPR.	E.M.	NUMBER	TITLE
12	07/16	AAC	AS BUILT TO PCR 0132	AC	.	AC	PP		
11	10/15	EA	REMOVE INSTRUMENT SET POINTS FROM LPG VESSEL	DMG	AC	AR	PP		
10	05/13	TW	AS BUILT TO PROJECT 502003	XS	TG	AS	.		
9	01/11	DA	500808 & 501047 AS BUILT TO SITE MARK UP	YB	AJ	KS	.		
8	07/07	PSU	81007 AS BUILT TO LIQUIGAS MARK UP, REDRAWN ON CAD	CSN	CBP	DM	.		
7	10/89	RH	LAH / LAHH TRANSPOSED FOR KAIKOURA MOD.	.	.	.	.	CCH-10-121/1	P&ID, V/A & FUSIBLE LOOP

REVISIONS — CONSULTANT — LIQUIGAS — REFERENCE DRAWINGS

DESIGNED	KS	30/12/1981
DRAWN	RL	30/12/1981
CHECKED	BU	2/03/1982
APPROVED	DVS	4/03/1982
ENG. MAN.	FSA	11/5/82
SCALE	NTS	

WOOLSTON LPG STORAGE

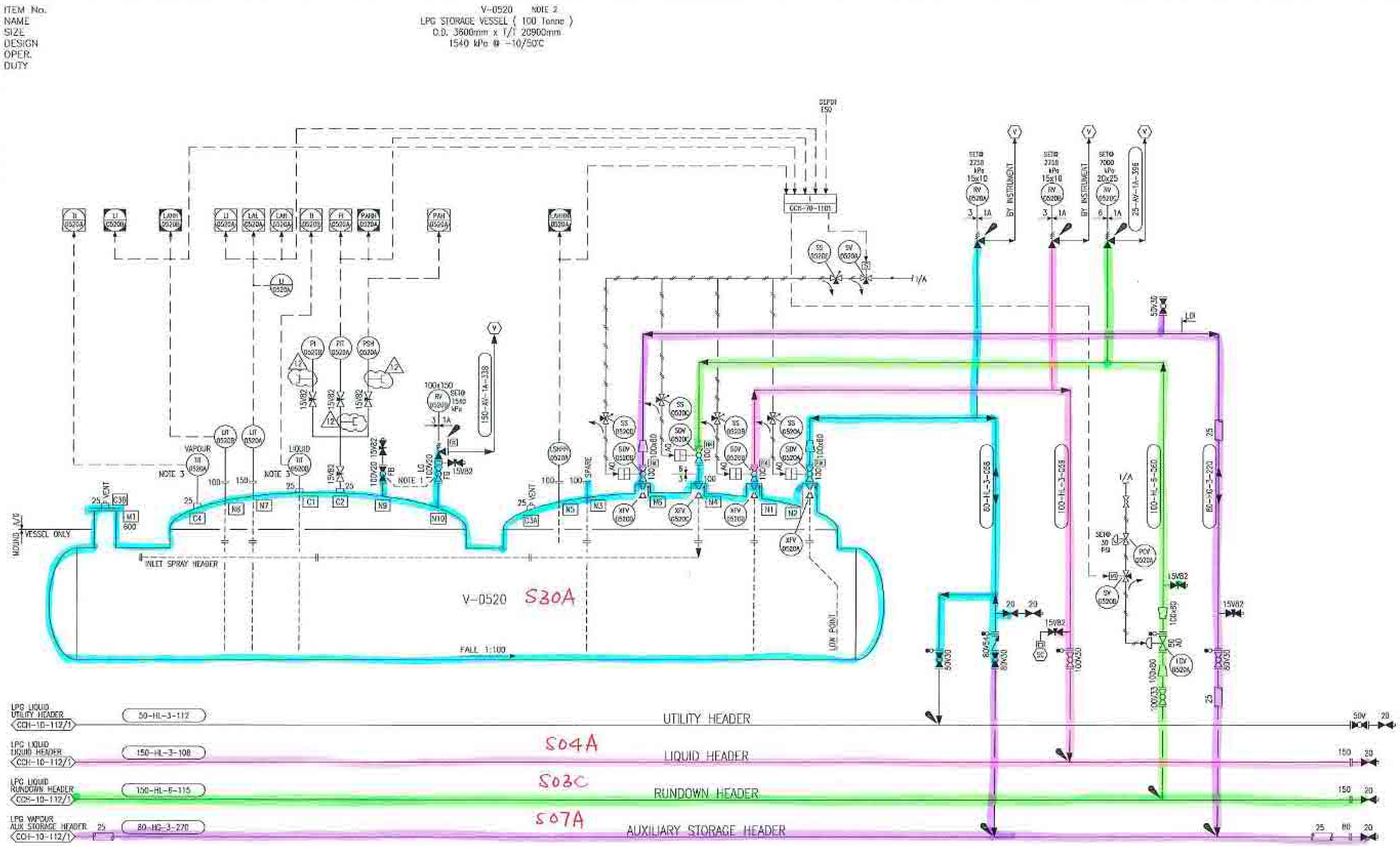
PIPING & INSTRUMENTATION DIAGRAM LPG STORAGE FACILITIES LPG STORAGE VESSEL V-0519

Liquigas
P.O. BOX 450 NEW PLYMOUTH NEW ZEALAND

SHEET No 01 of 02
REVISION 12
DRAWING No CCH-10-0112

CCH-10-0112-01

As Built Master - PCR0132 - 20-07-2016 - e-signed



GENERAL NOTES:

1. NOZZLE N9 & N10 VALVES INTERLOCKED, REFER DWG: M00-50-012/1.
2. FUSIBLE LOOP FIRE DETECTION SYSTEM, REFER DWG: CCH-10-122/1.
3. TIT FITTED WITH THERMOWELL. THERMOWELL TO TIT CONNECTION 20mm BSP.

WorleyParsons
resources & energy
L16008
CCH-10-0112-02

REV	DATE	DRAWN	DESCRIPTION	CHKD	APPR.	APPR.	E.M.	NUMBER	TITLE
12	07/15	MAC	AS BUILT TO PCR 0132	AC	-	AC	PP		
11	10/15	BA	REVISE INSTRUMENT SET POINTS FROM LPG VESSEL	MAC	AC	AE	PP		
10	08/12	DW	AS BUILT TO PROJECT 502003	AS	TD	-	AS		
9	01/11	BA	502008 & 502017 AS BUILT TO SITE MARK UP	YN	AJ	-	KS		
8	07/07	CSJ	9355 AS BUILT TO LIQUIGAS MARK UP, REDRAWN ON CAD	CDM	DRP	-	DA		
7	12/03	AW	LAH / LAHH TRANSPOSED FOR MARKHAM MOD	-	-	-	-	CCH-10-122/1	P&ID, I/A & FUSIBLE LOOP
	REVISIONS			CONSULTANT		LIQUIGAS		REFERENCE DRAWINGS	

		DATE
DESIGNED	JCS	
DRAWN	CW	30/12/81
CHECKED	LLU	2/03/82
APPROVED	DHG	4/03/82
ENG. MAN.	PSA	11/5/82
SCALE	NTS	

WOOLSTON LPG STORAGE

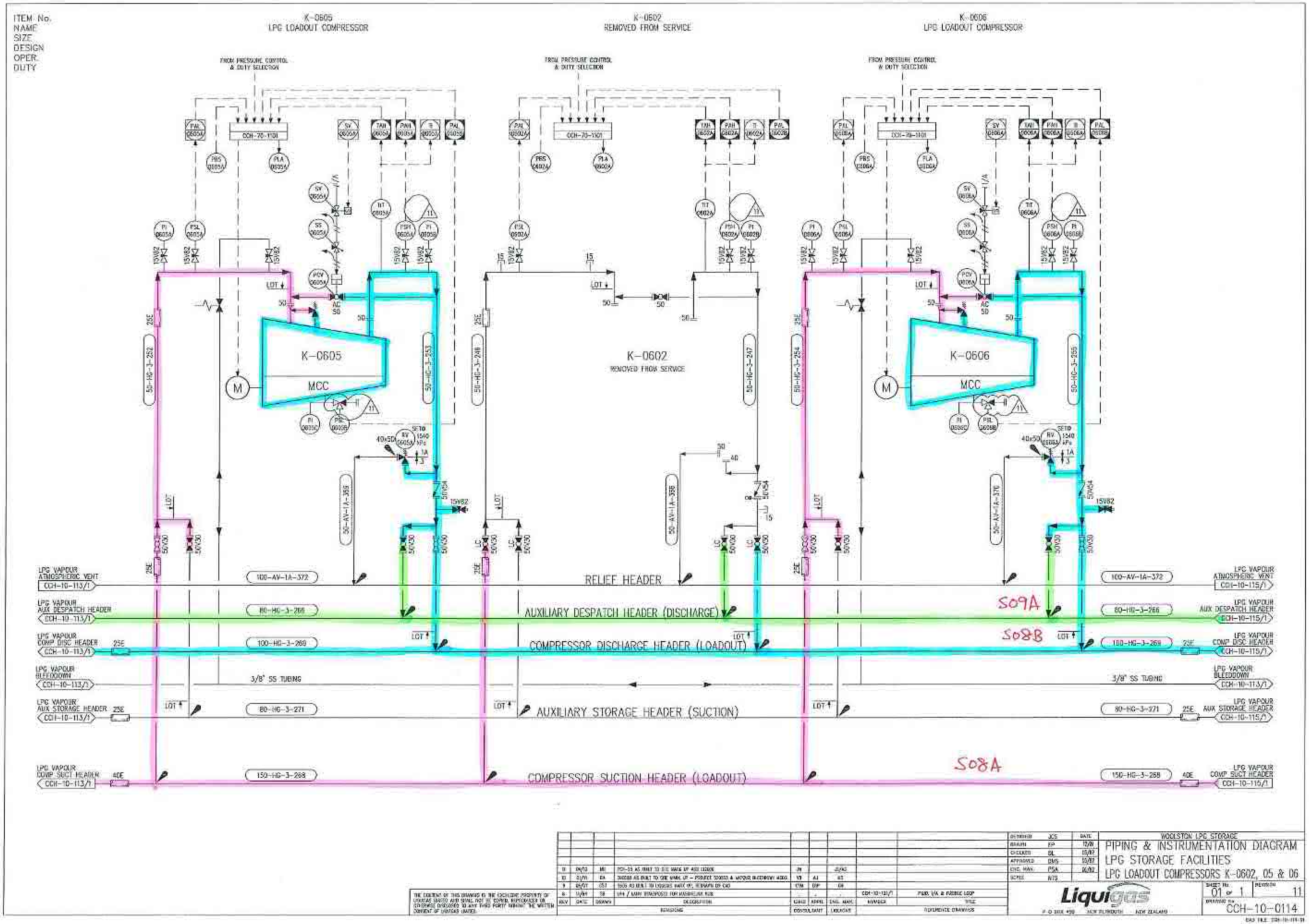
PIPING & INSTRUMENTATION DIAGRAM
LPG STORAGE FACILITIES
LPG STORAGE VESSEL V-0520

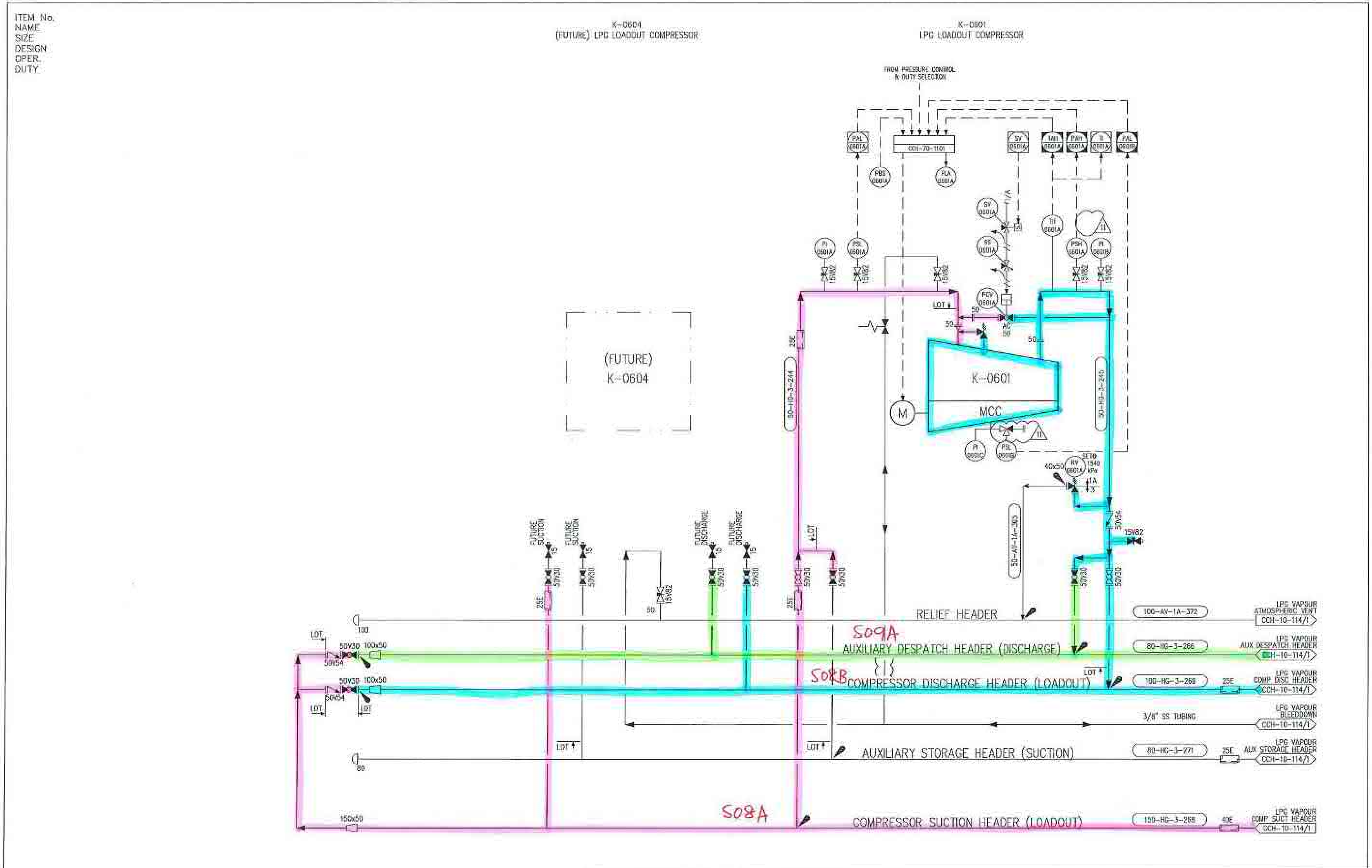
Liquigas
P O BOX 450 NEW PLYMOUTH NEW ZEALAND

SHEET No. 02 OF 02
REVISION 12
DRAWING No. CCH-10-0112

CCH-10-0112-02

As Built Master - PCR0132 - 20-07-2016 - e-signed


ITEM No.
NAME
SIZE
DESIGN
OPER.
DUTY
K-0605
LPG LOADOUT COMPRESSOR
K-0602
REMOVED FROM SERVICE
K-0606
LPG LOADOUT COMPRESSOR
FROM PRESSURE CONTROL & DUTY SELECTION
CCH-70-1101
CCH-70-1501
K-0605
MCC
K-0602
REMOVED FROM SERVICE
K-0606
MCC
50-HG-3-252
50-HG-3-253
50-HG-3-248
50-HG-3-247
50-HG-3-254
50-HG-3-255
50-AV-1A-359
50-AV-1A-358
50-AV-1A-370
LPG VAPOUR ATMOSPHERIC VENT
CCH-10-113/1
100-AV-1A-372
RELIEF HEADER
LPG VAPOUR AUX DESPATCH HEADER
80-HG-3-266
AUXILIARY DESPATCH HEADER (DISCHARGE)
S09A
LPG VAPOUR COMP DISC HEADER
100-HG-3-269
COMPRESSOR DISCHARGE HEADER (LOADOUT)
S08B
LPG VAPOUR BLEEDDOWN
3/8" SS TUBING
LPG VAPOUR AUX STORAGE HEADER
80-HG-3-271
AUXILIARY STORAGE HEADER (SUCTION)
LPG VAPOUR COMP SUCT HEADER
150-HG-3-268
COMPRESSOR SUCTION HEADER (LOADOUT)
S08A
CCH-10-115/1
WOOLSTON LPG STORAGE
PIPING & INSTRUMENTATION DIAGRAM
LPG STORAGE FACILITIES
LPG LOADOUT COMPRESSORS K-0602, 05 & 06
DESIGNED JCS
DRAWN KP
CHECKED BL
APPROVED DMS
SCALE NTS
Liquigas
P O BOX 450 NEW PLYMOUTH NEW ZEALAND
SHEET No. 01 of 1
REVISION 11
DRAWING No. CCH-10-0114

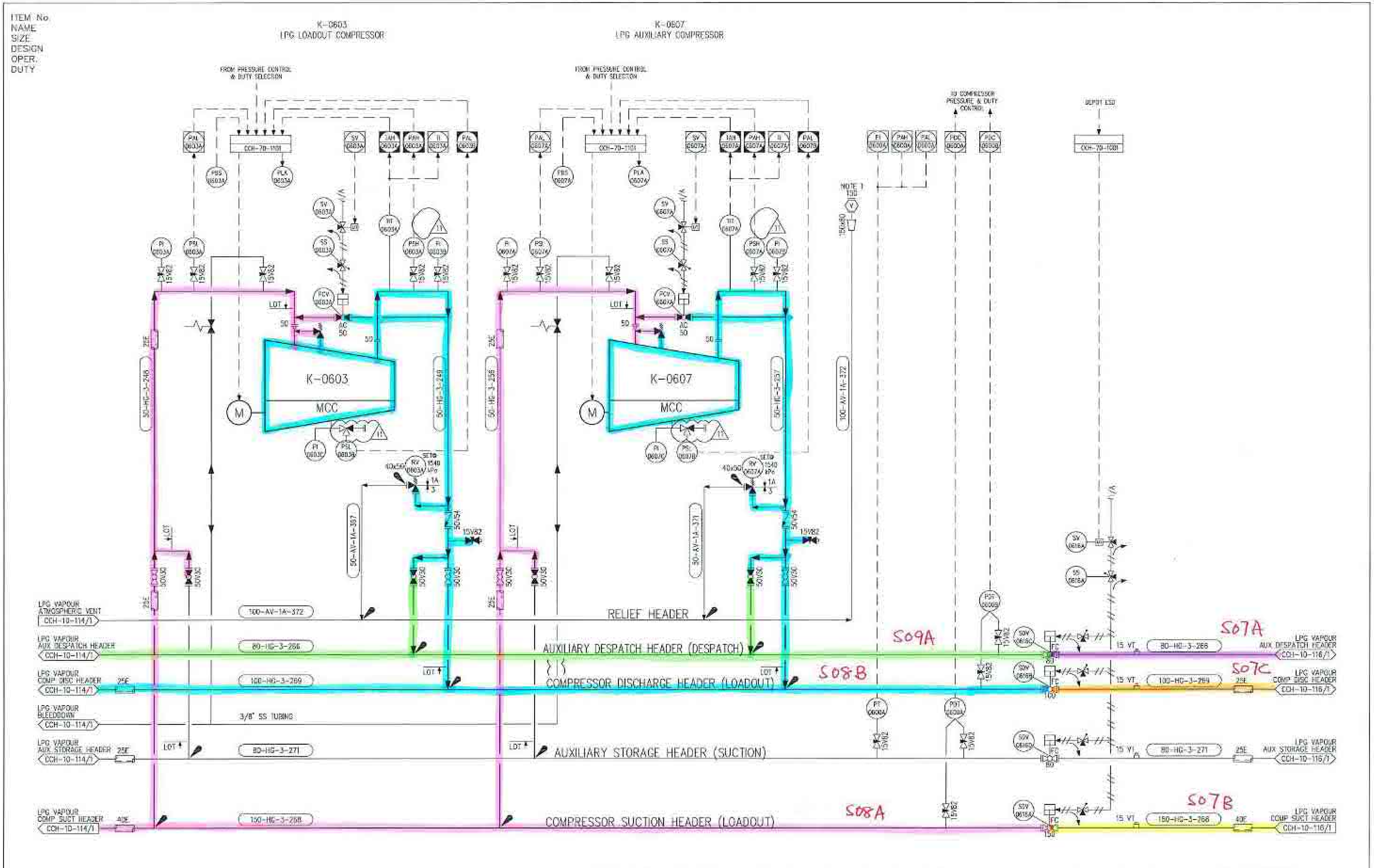


DESIGNED	JCS		WOOLSTON LPG STORAGE		
DRAWN	FP	12/81	PIPING & INSTRUMENTATION DIAGRAM		
CHECKED	DL	05/82	LPG STORAGE FACILITIES		
APPROVED	DWS	05/82	LPG LOADOUT COMPRESSOR K-0601		
ENG. MAN.	PSA	06/82			
SCALE	NTS				

Liquigas

SHEET No.	REVISION	DRAWING No.
01 of 1	11	CCH-10-0113

Master Document - 27-08-2013



GENERAL NOTES:

1. LPG VAPOUR VENT TO ATMOSPHERE 2m ABOVE ROOF LINE OF COMPRESSOR HOUSE.

REV	DATE	DRAWN	DESCRIPTION	CHKD	APPR.	ENG. MAN.	NUMBER	TITLE
11	04/12		AS BUILT TO SITE MARK UP					
10	01/11		AS BUILT TO SITE MARK UP – PROJECT					
9	08/07		AS BUILT TO LIQUIGAS MARK UP, REDRAWN ON CAD					
8	11/84		AS BUILT				CCH-10-101/1	P&ID, UA & TURBLE FOOP
			REVISIONS	CONSULTANT	LIQUIGAS		REFERENCE DRAWINGS	

		DATE
DESIGNED	JCS	
DRAWN	FP	12/81
CHECKED	DL	03/82
APPROVED	DWS	03/82
ENG. APPL.	PSA	06/82
SCALE	NTS	

WOOLSTON LPG STORAGE

PIPING & INSTRUMENTATION DIAGRAM

LPG STORAGE FACILITIES

LPG LOADOUT & AUXILIARY COMPRESSORS K-0603 & 07

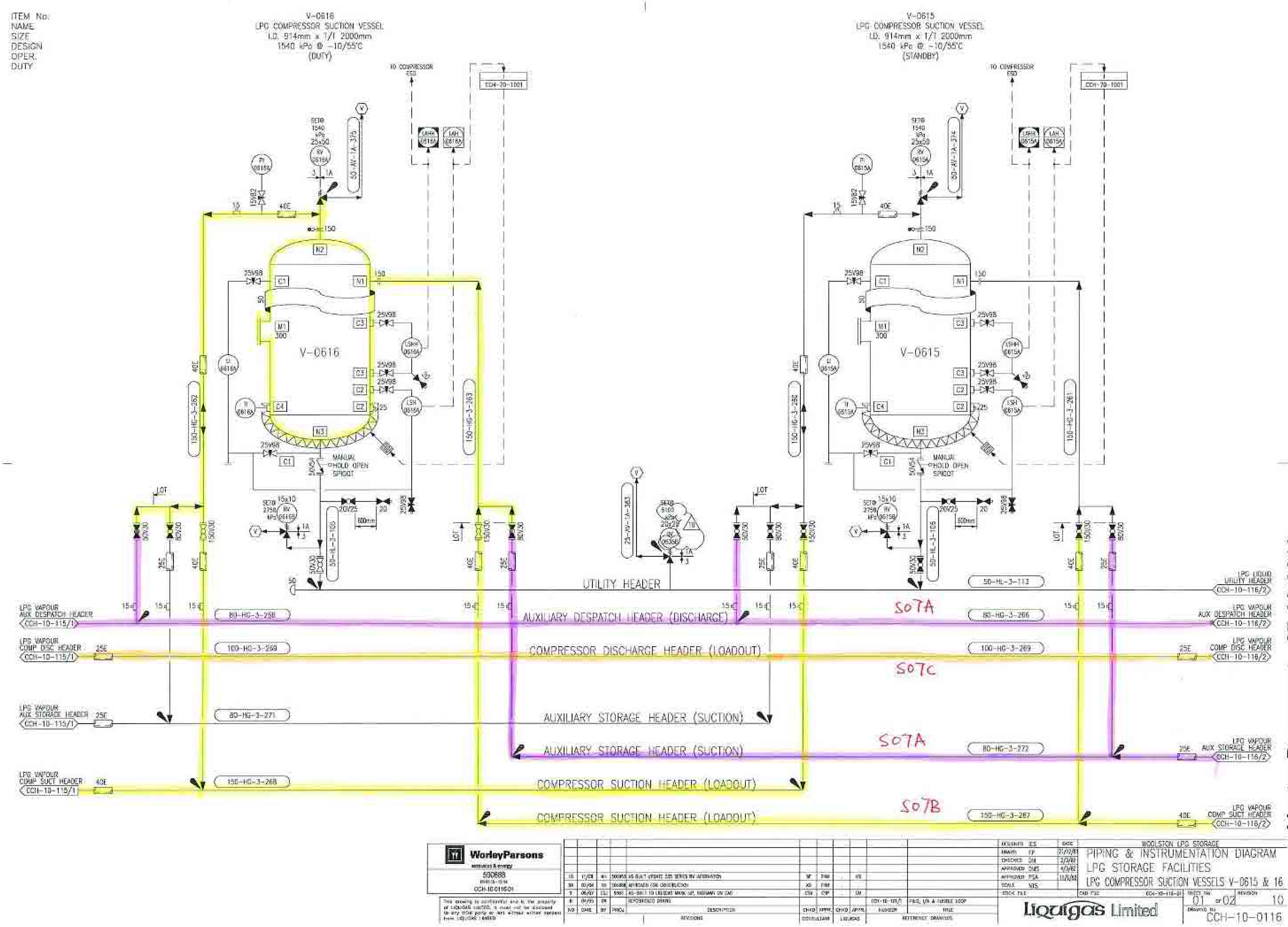
Liquigas

P O BOX 458 NEW PLYMOUTH NEW ZEALAND

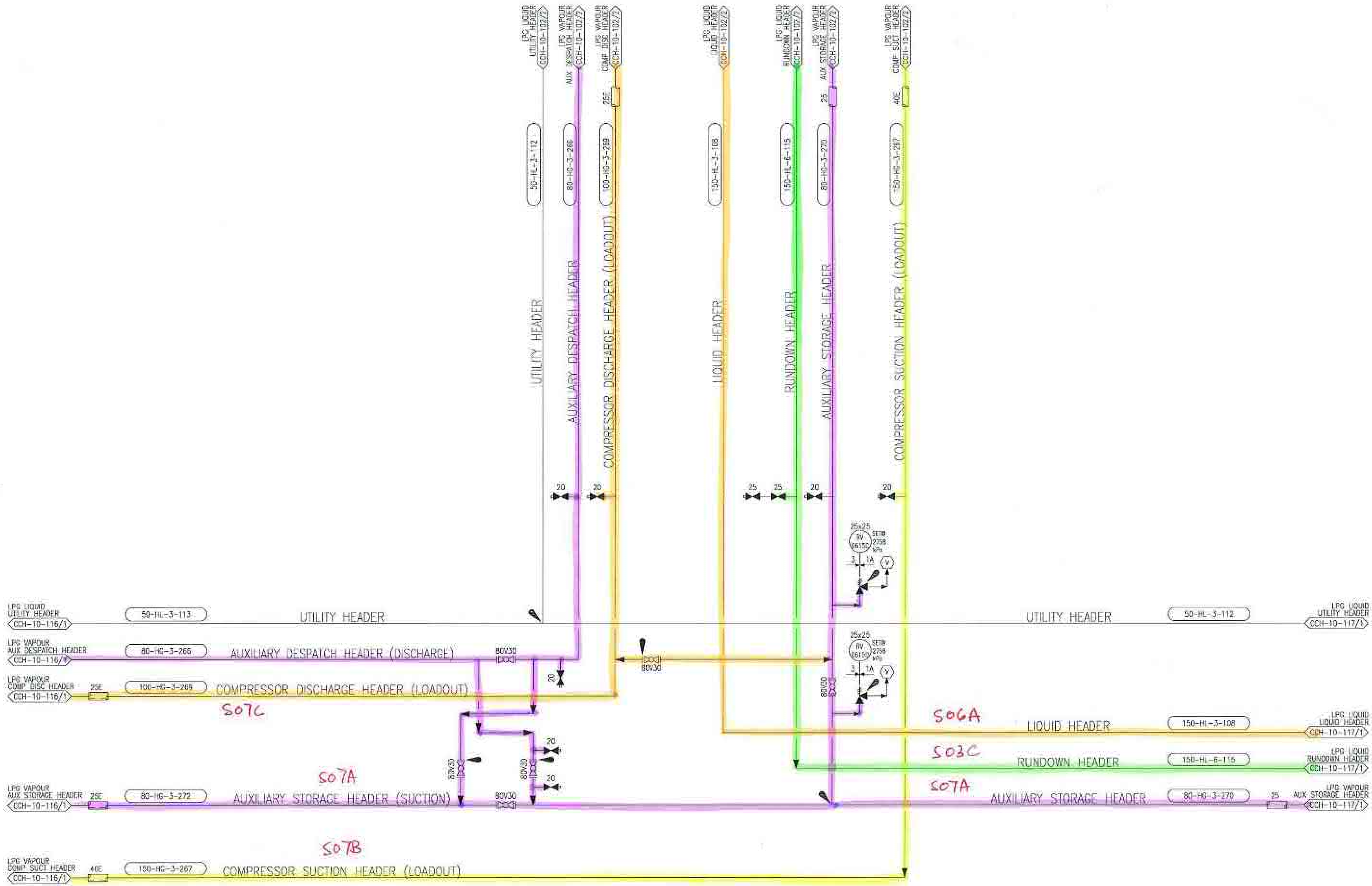
SHEET No. 01 OF 1 REVISION 11

DRAWING No. CCH-10-0115

Master Document - 27-08-2013



Master Document - 27-08-2013



11	06/07	CSJ	8305	AS-BUILT TO LIQUIGAS MARK-UP, REDRAWN ON CAD	DM	CRP	-	DN	
10	05/97	GN		CROSSOVER & RVS ADDED					
NO	DATE	BY	PROJ	DESCRIPTION	CHKD	APPR	CHKD	APPR	NUMBER / TITLE
				REVISIONS	CONSULTANT		LIQUIGAS		REFERENCE DRAWINGS

This drawing is confidential and is the property of LIQUIGAS LIMITED. It must not be disclosed to any third party or lent without written consent from LIQUIGAS LIMITED.

DESIGNED CS 27/10/81
DRAWN FP
CHECKED DM 2/3/82
APPROVED DMS 4/3/82
APPROVED PSA 11/6/80
SCALE NTS

WOOLSTON LPG STORAGE
PIPING & INSTRUMENTATION DIAGRAM
LPG STORAGE FACILITIES
LPG STORAGE PIPERACK JUNCTION

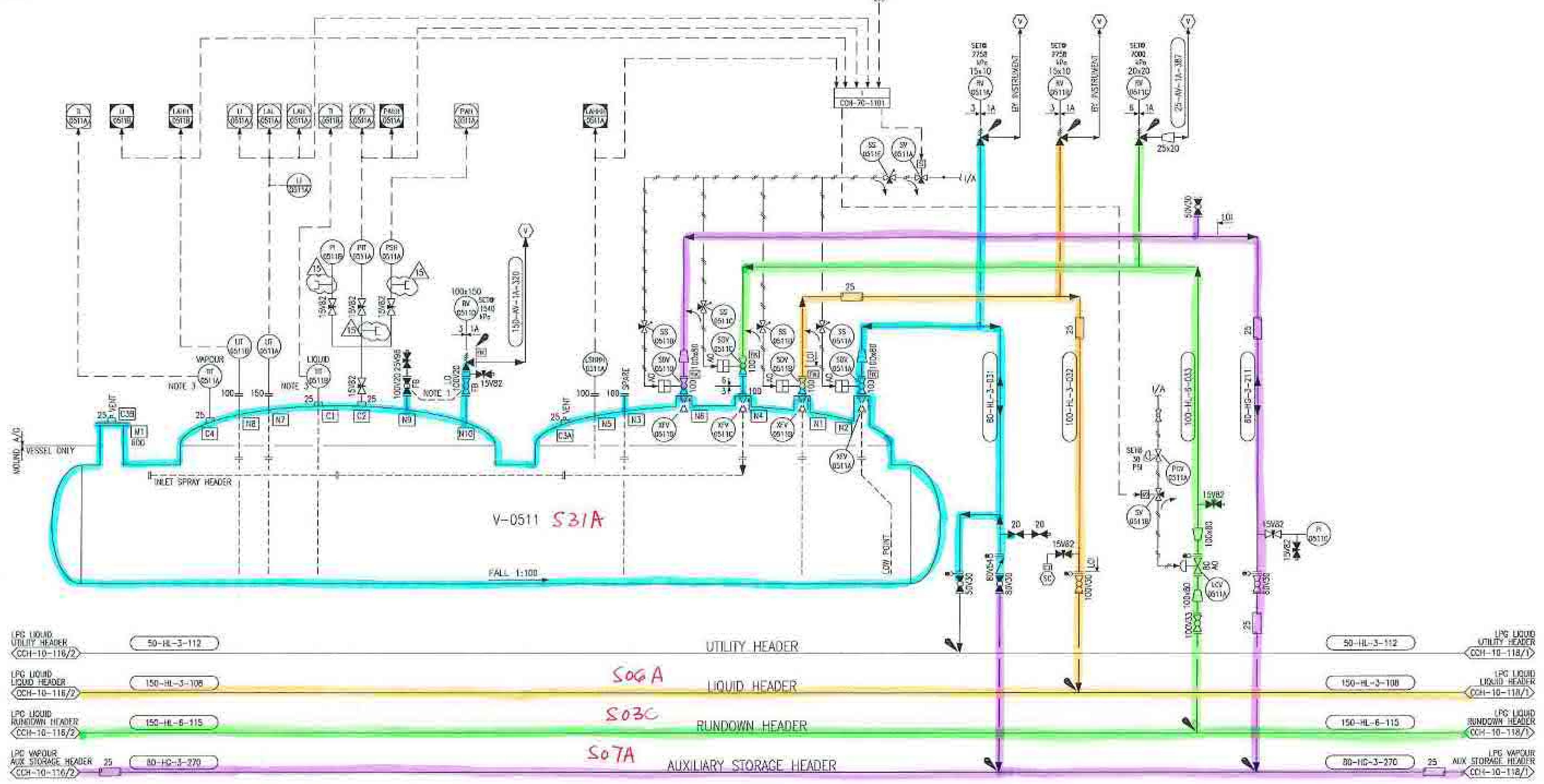
Liquigas Limited

SHEET No 02 of 02 REVISION 11
DRAWING No CCH-10-0116

Master Document - 27-08-2013

ITEM No.
NAME
SIZE
DESIGN
OPER.
DUTY

V-0511 NOTE 2
LPG STORAGE VESSEL (100 Tonne)
O.D. 3600mm x T/T 20900mm
1540 kPa @ -10/50°C



GENERAL NOTES:

1. NOZZLE N9 & N10 VALVES INTERLOCKED, REFER DWG: W00-50-012/1.
2. FUSIBLE LOOP FIRE DETECTION SYSTEM, REFER DWG: CCH-10-122/1.
3. TIT FITTED WITH THERMOWELL. THERMOWELL TO TIT CONNECTION 20mm BSP.

WorleyParsons
resources & energy
L16006
CCH-10-0117-01

DESIGNED	ICS	
DRAWN	DM	30/12/81
CHECKED	DM	2/03/82
APPROVED	DMS	4/03/82
ENG. MAN.	PSA	11/6/82
SCALE	NTS	

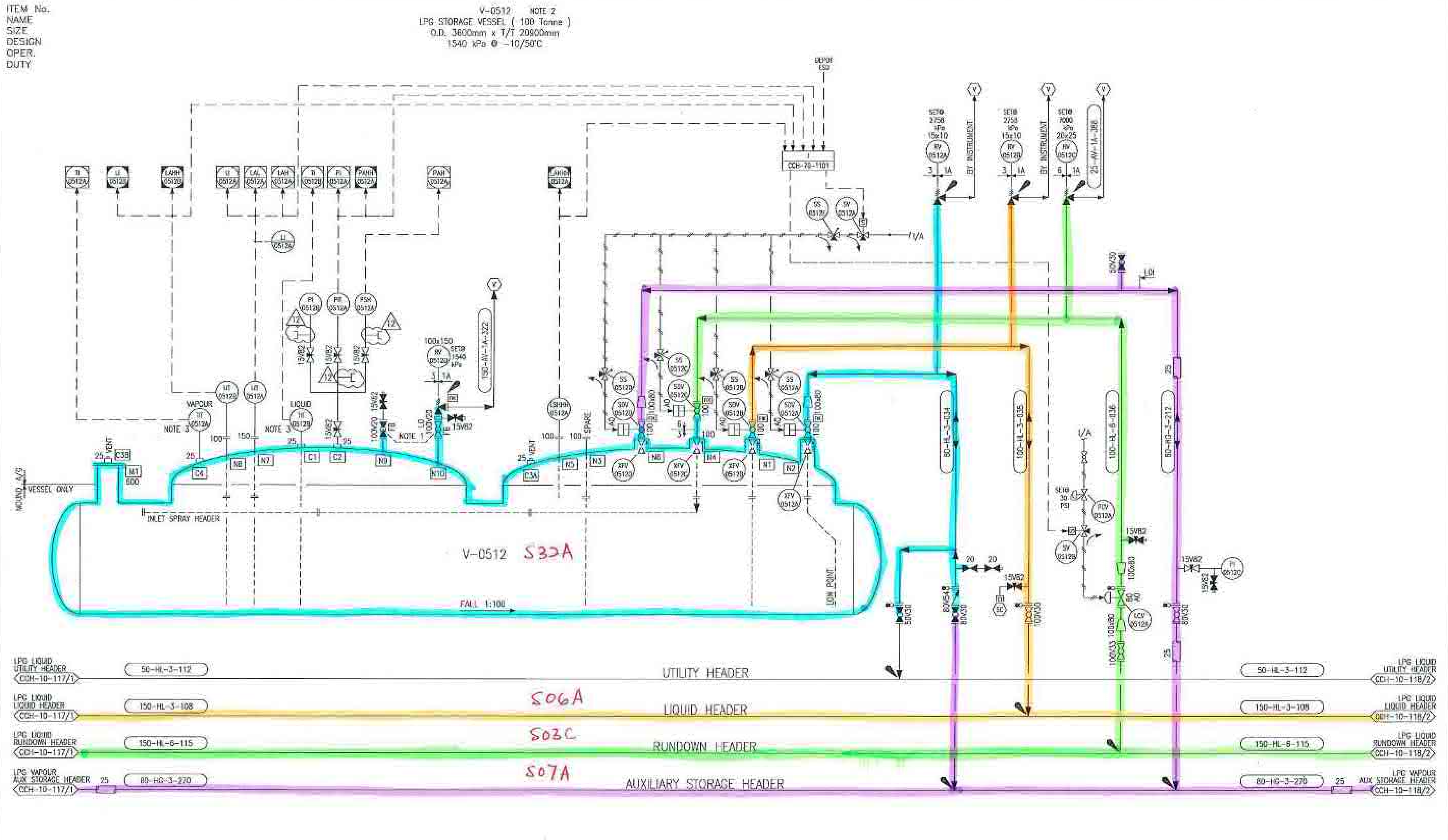
WOOLSTON LPG STORAGE
PIPING & INSTRUMENTATION DIAGRAM
LPG STORAGE FACILITIES
LPG STORAGE VESSEL V-0511

Liquigas
P O BOX 450 NEW PLYMOUTH NEW ZEALAND

SHEET No 01 OF 01
REVISION 15
DRAWING No CCH-10-0117

CCH-10-0117-01

As Built Master - PCR0132 - 20-07-2016 - e-signed



GENERAL NOTES:

1. NOZZLE N9 & N10 VALVES INTERLOCKED, REFER DWG: WOD-50-012/1.
2. FUSIBLE LOOP FIRE DETECTION SYSTEM, REFER DWG: CCH-10-122/1.
3. TIT FITTED WITH THERMOWELL. THERMOWELL TO TIT CONNECTION 20mm BSP.

WorleyParsons

L16008

CCH-10-0118-01

REV	DATE	DRAWN	DESCRIPTION	CHKD	APPVL	APPVL	ENG	NUMBER	TITLE
12	20/16	[illegible]	AS BUILT TO PCR 0132	AC	.	PC	SP		
11	13/[illegible]	RA	REMOVE INSTRUMENT SET POINTS FROM LPG VESSEL	[illegible]	AC	[illegible]	[illegible]		
10	[illegible]	[illegible]	AS BUILT TO PROJECT [illegible]	AS	[illegible]	.	AS		
9	01/11	[illegible]	[illegible] AS BUILT TO SITE MARK UP	[illegible]	[illegible]	.	HS		
8	07/07	CSI	[illegible] AS BUILT TO LIQUIGAS MARK UP, [illegible]	CSI	[illegible]	.	[illegible]		
7	[illegible]	[illegible]	[illegible]	.	.	.	.	CCH-10-121/1	[illegible] I/A & FUSIBLE LOOP
REVISIONS				CONSULTANT		LIQUIGAS		REFERENCE DRAWINGS	

DESIGNED	JCS	DATE
DRAWN	CW	30/12/81
CHECKED	DM	2/03/82
APPROVED	BMS	4/03/82
ENG. MAN.	25A	11/5/82
SCALE	NTS	

WOOLSTON LPG STORAGE

PIPING & INSTRUMENTATION DIAGRAM
LPG STORAGE FACILITIES
LPG STORAGE VESSEL V-0512

Liquigas

P O BOX 450 NEW PLYMOUTH NEW ZEALAND

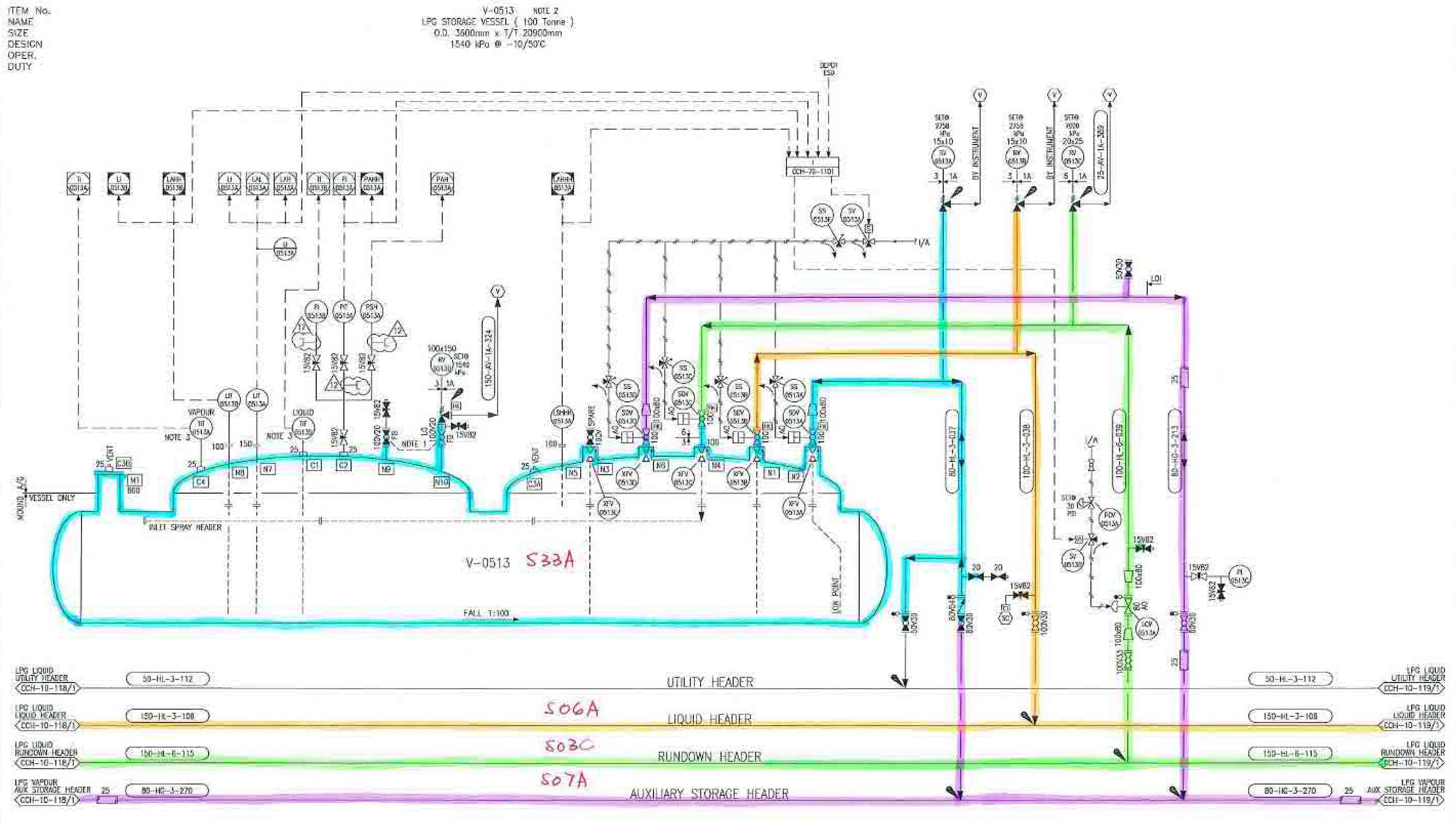
SHEET No. 01 of 02

REVISION 12

DRAWING No. CCH-10-0118

CCH-10-0118-01

As Built Master - PCR0132 - 20-07-2016 - e-signed



GENERAL NOTES:

1. NOZZLE N9 & N10 VALVES INTERLOCKED, REFER DWG: NOD-50-012/1.
2. FUSIBLE LOOP FIRE DETECTION SYSTEM, REFER DWG: CCH-10-122/1.
3. TIT FITTED WITH THERMOWELL. THERMOWELL TO TIT CONNECTION 20mm BSP.

WorleyParsons

L16008

CCH-10-0118-02

REV	DATE	DRAWN	DESCRIPTION	CHKD	APPR.	APPR.	E.M.	NUMBER	TITLE
12	07/16	AMC	AS BUILT TO PCR 0132	AS	..	AC	PP		
11	10/15	BA	[illegible]	[illegible]	AC	AB	PP		
10	09/13	TM	AS BUILT TO PROJECT [illegible]	AS	TB	..	AG		
9	01/11	BA	[illegible] AS BUILT TO SITE MARK UP	[illegible]	AJ	..	[illegible]		
8	07/02	CSM	[illegible] AS BUILT TO [illegible] MARK UP, REDRAWN [illegible]	CSM	DRP	..	[illegible]		
7	10/94	BA	[illegible]	..	..	..	..	CCH-10-122/1	FIRE, I/A & FUSIBLE LOOP
REVISIONS				CONSULTANT		LIQUIGAS		REFERENCE DRAWINGS	

DESIGNED	JCS	DATE	
DRAWN	CW	20/12/81	
CHECKED	DM	2/03/82	
APPROVED	DMS	4/03/82	
ENG. MAN.	PSA	11/6/82	
SCALE	NTS		

WOOLSTON LPG STORAGE

PIPING & INSTRUMENTATION DIAGRAM
LPG STORAGE FACILITIES
LPG STORAGE VESSEL V-0513

Liquigas

P.O. BOX 450 NEW PLYMOUTH NEW ZEALAND

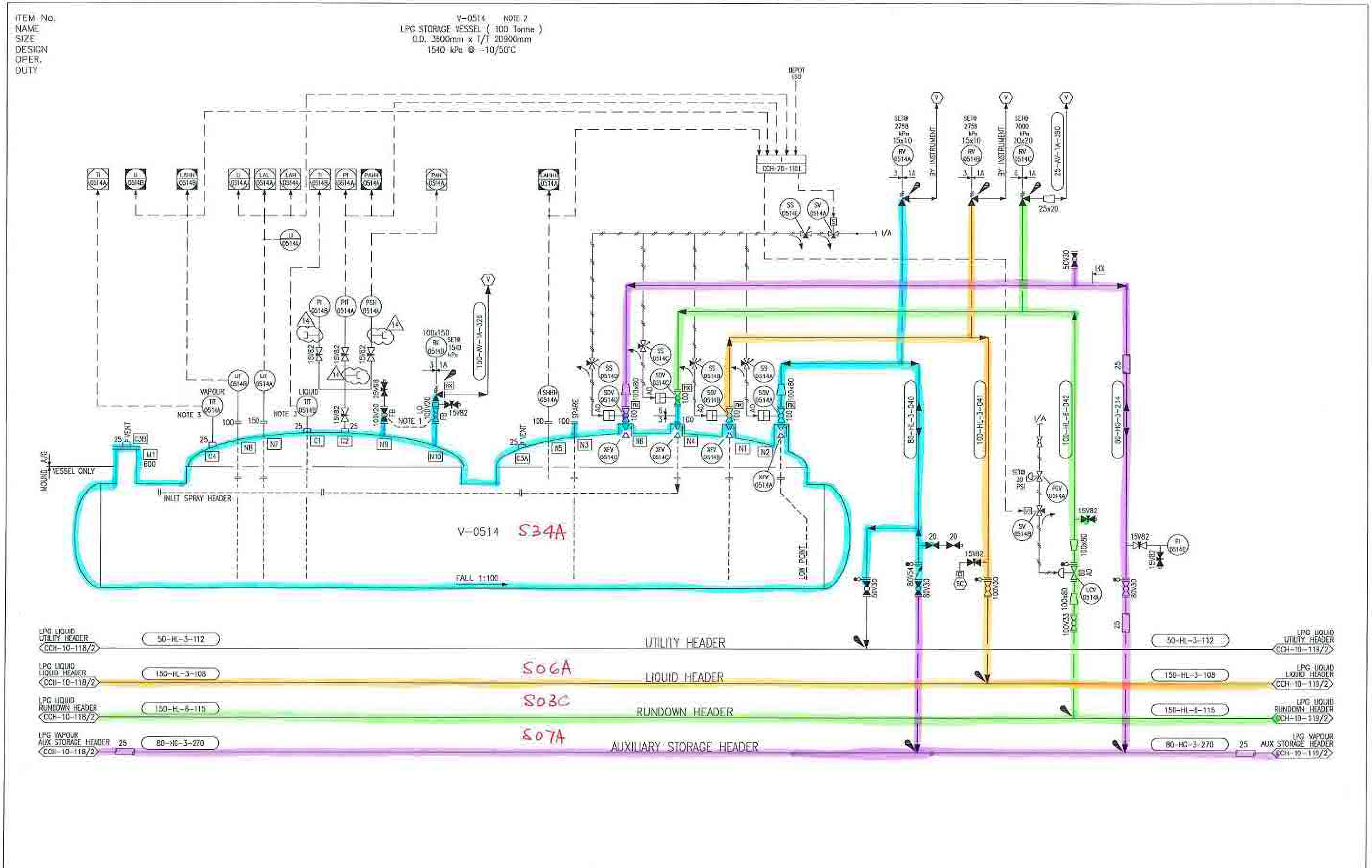
SHEET No 02 of 02

REVISION 12

DRAWING No CCH-10-0118

CCH-10-0118-02

As Built Master - PCR0132 - 20-07-2016 - e-signed



GENERAL NOTES:

1. NOZZLE N9 & N10 VALVES INTERLOCKED, REFER DWG: MOD-50-012/1.
2. FUSIBLE LOOP FIRE DETECTION SYSTEM, REFER DWG: CCH-10-122/1.
3. TIT FITTED WITH THERMOWELL. THERMOWELL TO TIT CONNECTION 20mm BSP.

WorleyParsons
resources & energy
L16008
CCH-10-0119-01

REV	DATE	DRAWN	DESCRIPTION	CHKD	APPR.	APPR.	E.M.	NUMBER	TITLE
14	07/16	AMC	AS BUILT TO PCR 0132	AC	.	AC	[illegible]		
13	10/05	BA	[illegible]	[illegible]	AC	AC	[illegible]		
12	08/12	TW	AS BUILT TO PROJECT [illegible]	[illegible]	TB	AS	.		
11	[illegible]	BA	[illegible] AS BUILT TO SITE MARK UP	[illegible]	AJ	[illegible]	.		
10	07/07	CSJ	[illegible] AS BUILT TO LIQUIGAS MARK UP. [illegible]	[illegible]	[illegible]	[illegible]	.		
9	12/99	[illegible]	[illegible]	.	.	.	.	CCH-10-131/1	[illegible], I/A & FUSIBLE LOOP
REVISIONS				CONSULTANT		LIQUIGAS		REFERENCE DRAWINGS	

DESIGNED	KS	
DRAWN	DM	31/12/1981
CHECKED	DM	2/03/1982
APPROVED	DHS	4/03/1982
ENG. MAN.	PSA	11/6/82
SCALE	NTS	

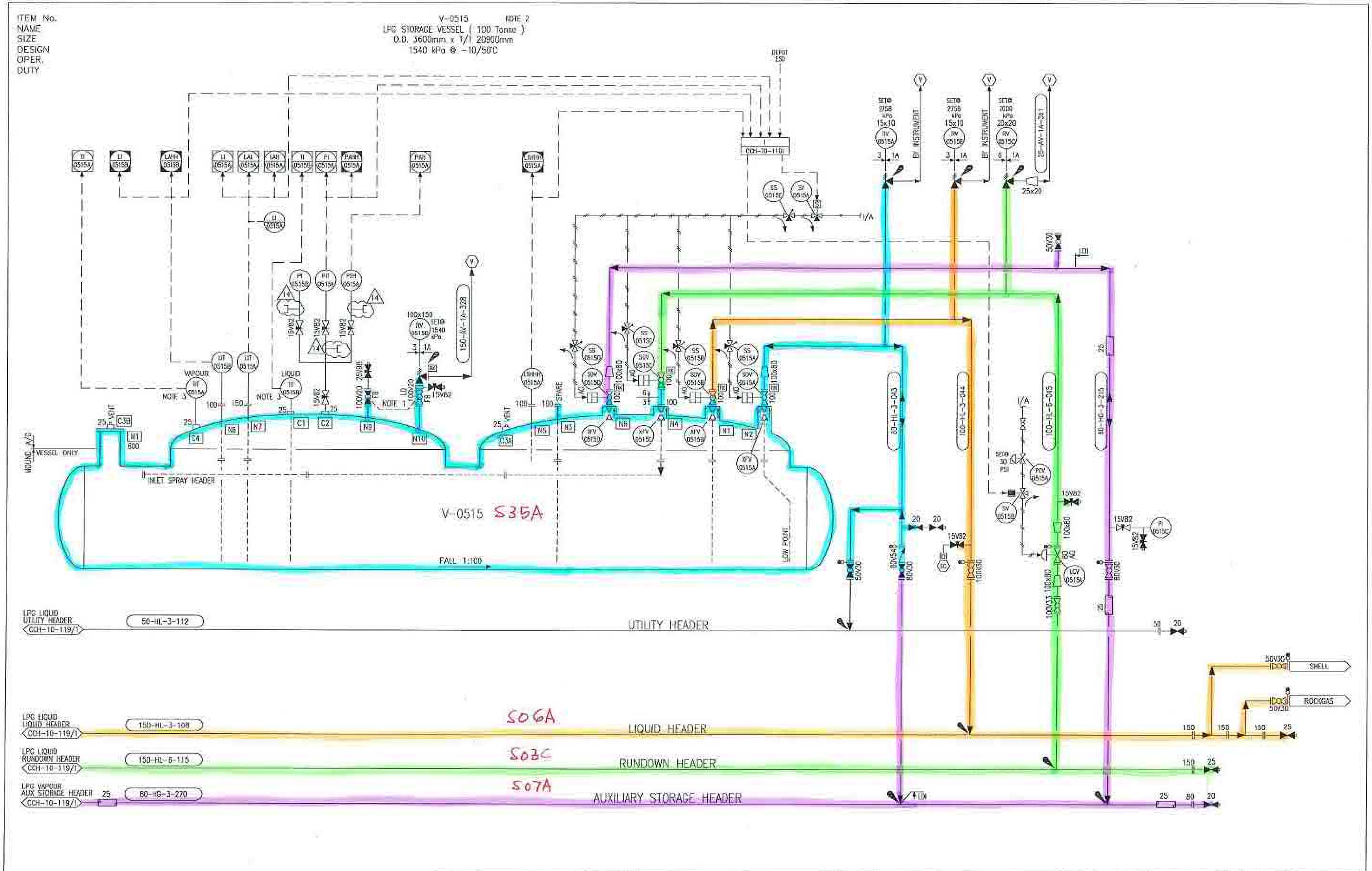
WOOLSTON LPG STORAGE

PIPING & INSTRUMENTATION DIAGRAM
LPG STORAGE FACILITIES
LPG STORAGE VESSEL V-0514

Liquigas
P O BOX 450 NEW PLYMOUTH NEW ZEALAND

SHEET No 01 OF 02
REVISION 14
DRAWING No CCH-10-0119

CCH-10-0119-01



GENERAL NOTES:

1. NOZZLE N9 & N10 VALVES INTERLOCKED, REFER DWG. MOD-50-012/1.
2. FUSIBLE LOOP FIRE DETECTION SYSTEM, REFER DWG. CCH-10-122/1.
3. TIT FITTED WITH THERMOWELL. THERMOWELL TO TIT CONNECTION 20mm BSP.

WorleyParsons
resources & energy
L18008
CCH-10-0119-02

REV	DATE	DRAWN	DESCRIPTION	CHKD	APPR.	APPR.	E.M.
14	07/16	AVC	AS BUILT TO PCR 0132	AC	.	AC	PP
13	10/15	JA	REMOVE INSTRUMENT SET POINTS FROM LPG VESSEL	[illegible]	AC	KB	PP
12	05/13	TP	AS BUILT TO PROJECT 300003	AS	TG	.	AS
11	01/11	JA	300008 & SCRIPT AS BUILT TO SITE WORK UP	YB	AJ	.	XS
10	07/07	ESI	N505 AS BUILT TO LIQUIGAS MARK UP, REDRAW ON CAD	CSM	CBP	.	GM
9	01/00	DP	ADDED BRANCH LINE FOR "ROCKGAS"	CH	CH	.	.

REVISIONS — CONSULTANT — LIQUIGAS

NUMBER	TITLE
CCH-10-122/1	P&ID I/A & FUSIBLE LOOP

REFERENCE DRAWINGS

		DATE
DESIGNED	ICS	
DRAWN	CM	30/12/81
CHECKED	DSI	2/03/82
APPROVED	DMS	4/03/82
CHG. MAN.	PSA	11/4/82
SCALE	NTS	

WOOLSTON LPG STORAGE

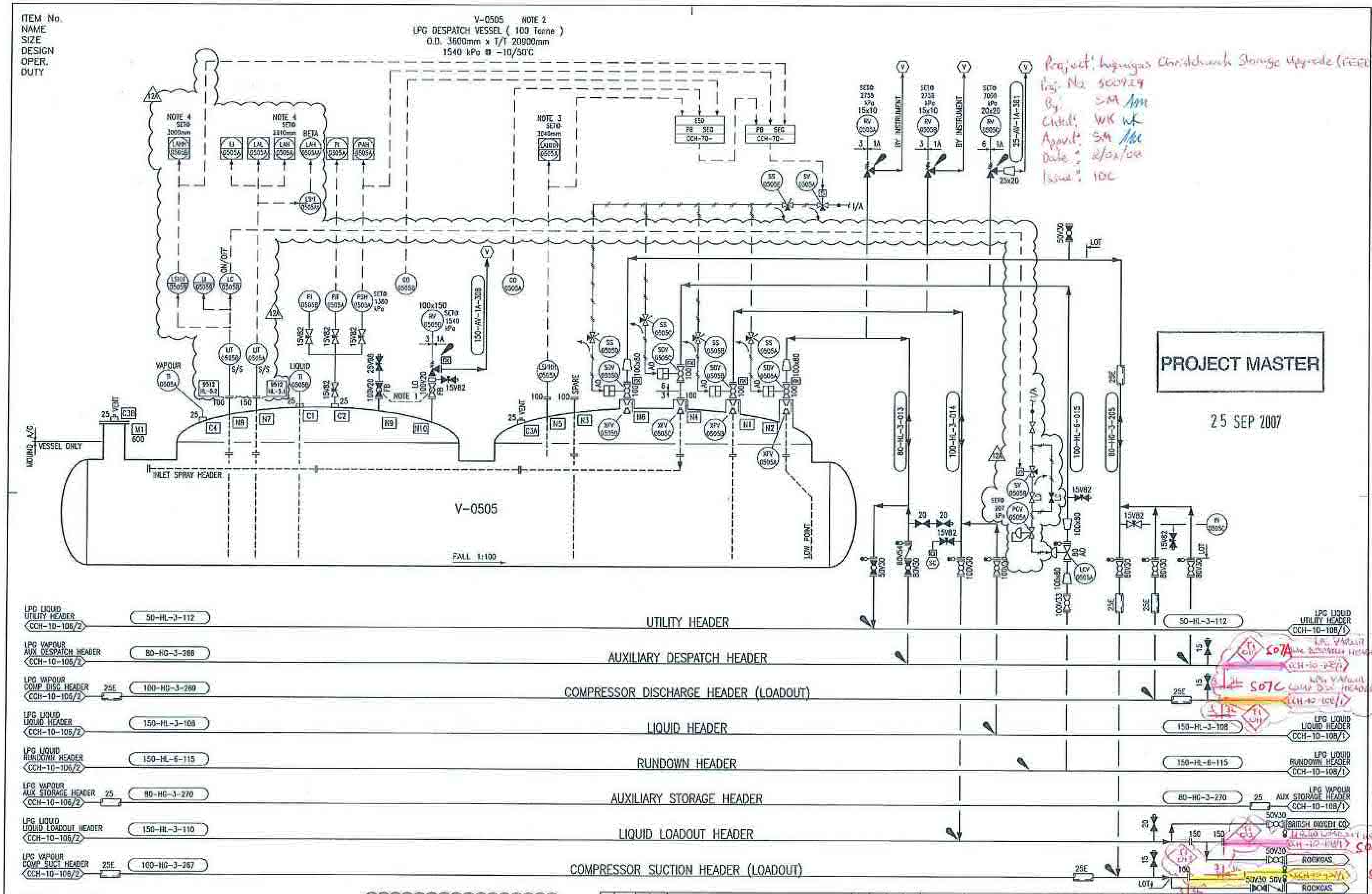
PIPING & INSTRUMENTATION DIAGRAM
LPG STORAGE FACILITIES
LPG STORAGE VESSEL V-0515

Liquigas
P O BOX 450 NEW PLYMOUTH NEW ZEALAND

SHEET No. 02 OF 02
REVISION 14
DRAWING No. CCH-10-0119

CCH-10-0119-02

As Built Master - PCR0132 - 20-07-2016 - e-signed



Project: Liquigas Christchurch Storage Upgrade (FEED)
Proj. No. 500929
By: SM
Chkd: WK
Apprd: SM
Date: 8/02/08
Issue: 10C

GENERAL NOTES:

1. NOZZLE N9 & N10 VALVES INTERLOCKED, REFER DWG: H00-50-012/1
2. FUSIBLE LOOP FIRE DETECTION SYSTEM, REFER DWG: CCH-10-122/1
3. LEVEL SETTING SHOWN IS APPLICABLE TO "MIXED" PRODUCT STORAGE ONLY.
4. GUIDED RADARS SHOW ACTUAL PRODUCT LEVEL.

PROJECT No 9512
NEW WORK SHOWN

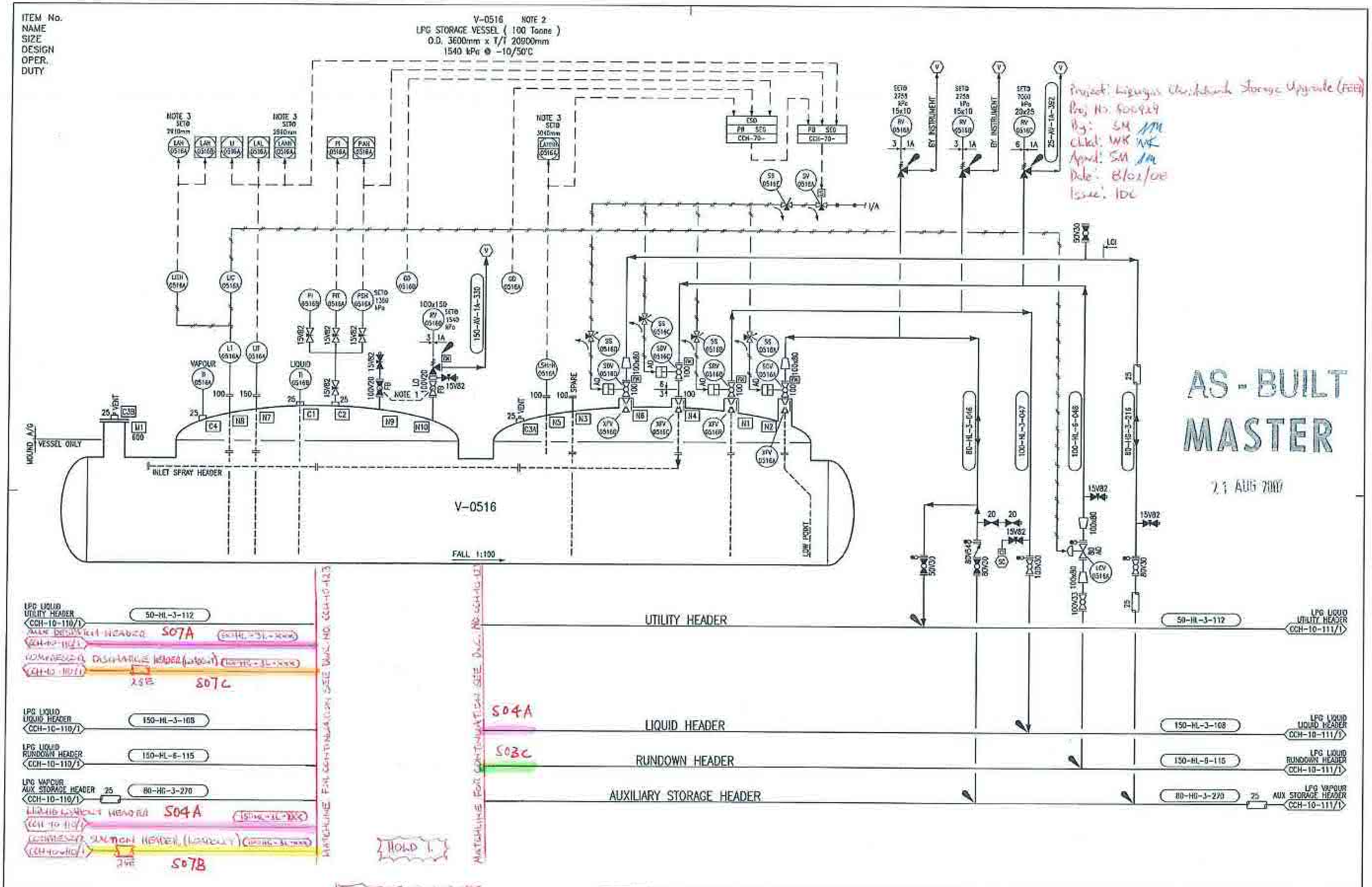
WOOLSTON LPG STORAGE

PIPING & INSTRUMENTATION DIAGRAM
LPG STORAGE FACILITIES
LPG DESPATCH VESSEL V-0505

DESIGNED	KS	
DRAWN	DN	
CHECKED	DN	
APPROVED	BMS	
APPROVED	TSA	
SCALE	NTS	

SHEET No. 1 of 1
REVISION 12B
DRAWING No. CCH-10-107

Liquigas Limited



GENERAL NOTES:

1. NOZZLE N9 & N10 VALVES INTERLOCKED, REFER DWG: NOD-50-012/1.
2. FUSIBLE LOOP FIRE DETECTION SYSTEM, REFER DWG: CCH-10-122/1.
3. LEVEL ALARM SETTINGS SHOWN ARE APPLICABLE TO "MIXED" PRODUCT STORAGE ONLY.

HOLDS
1. LOCATION OF TIE-IN

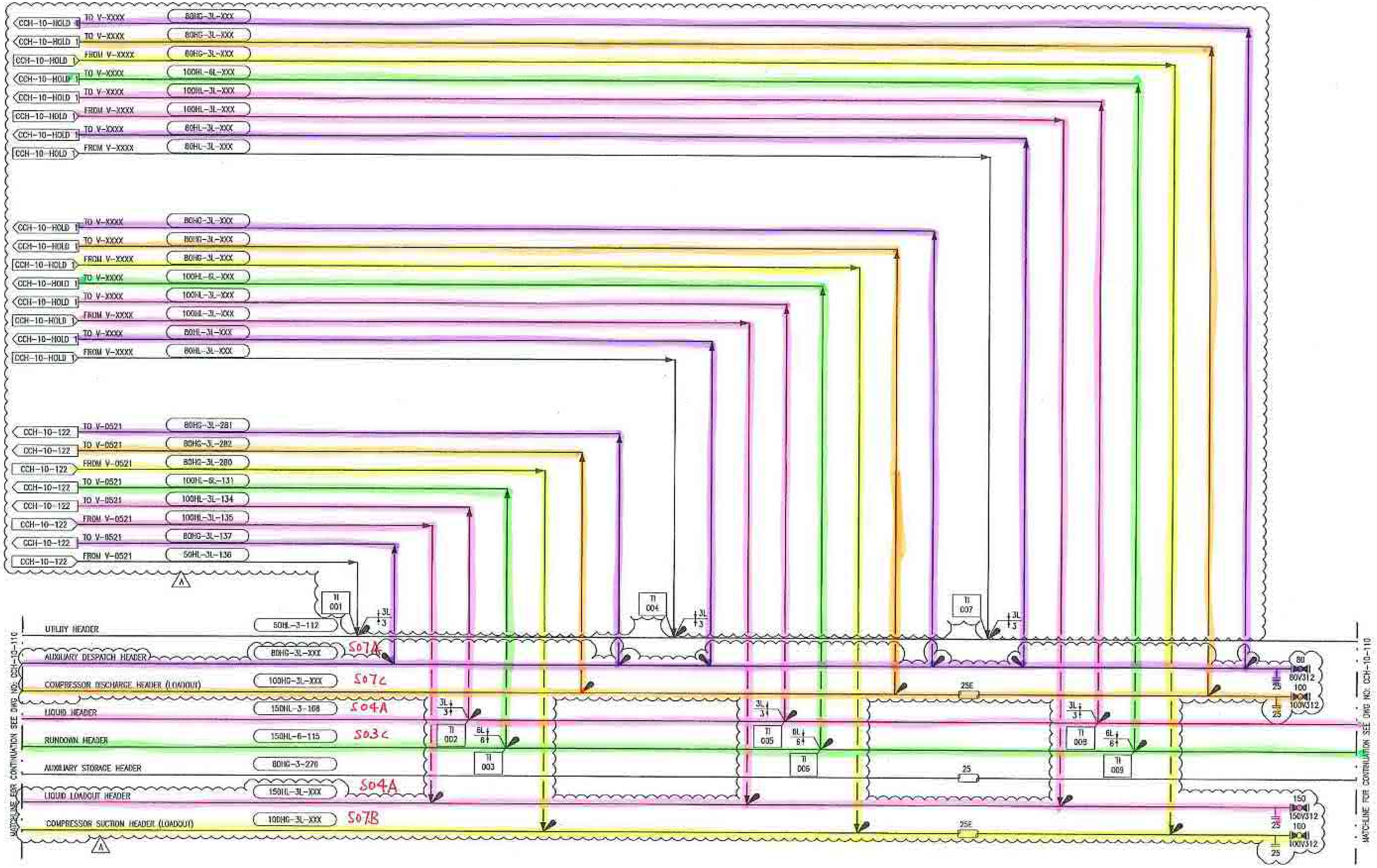
DESIGNED	JCS	DATE	
DRAWN	DM	30/10/98	
CHECKED	DM	2/3/99	
APPROVED	DWS	4/3/99	
APPROVED	PSA	11/6/99	
SCALE	NTS		

WOOLSTON LPG STORAGE

PIPING & INSTRUMENTATION DIAGRAM
LPG STORAGE FACILITIES
LPG STORAGE VESSEL V-0516

Liquigas Limited

SHEET No. 2 of 2 — REVISION 8 — DRAWING No. CCH-10-110



HOLDS:
1. DRAWING NUMBER.
2. ALL NEW LINE NUMBERS.

Transfield Worley Ltd.

PROJECT NUMBER 500929 | CAD FILE NAME CCH-10-0123

This drawing is confidential and is the property of LIQUIGAS LIMITED. It must not be disclosed to any third party or that without written consent from LIQUIGAS LIMITED.

NO	DATE	BY	PROJ	DESCRIPTION	CHKD	APPR	CHKD	APPR
A	01/08			ISSUED FOR				

WOOLSTON LPG STORAGE DEPOT

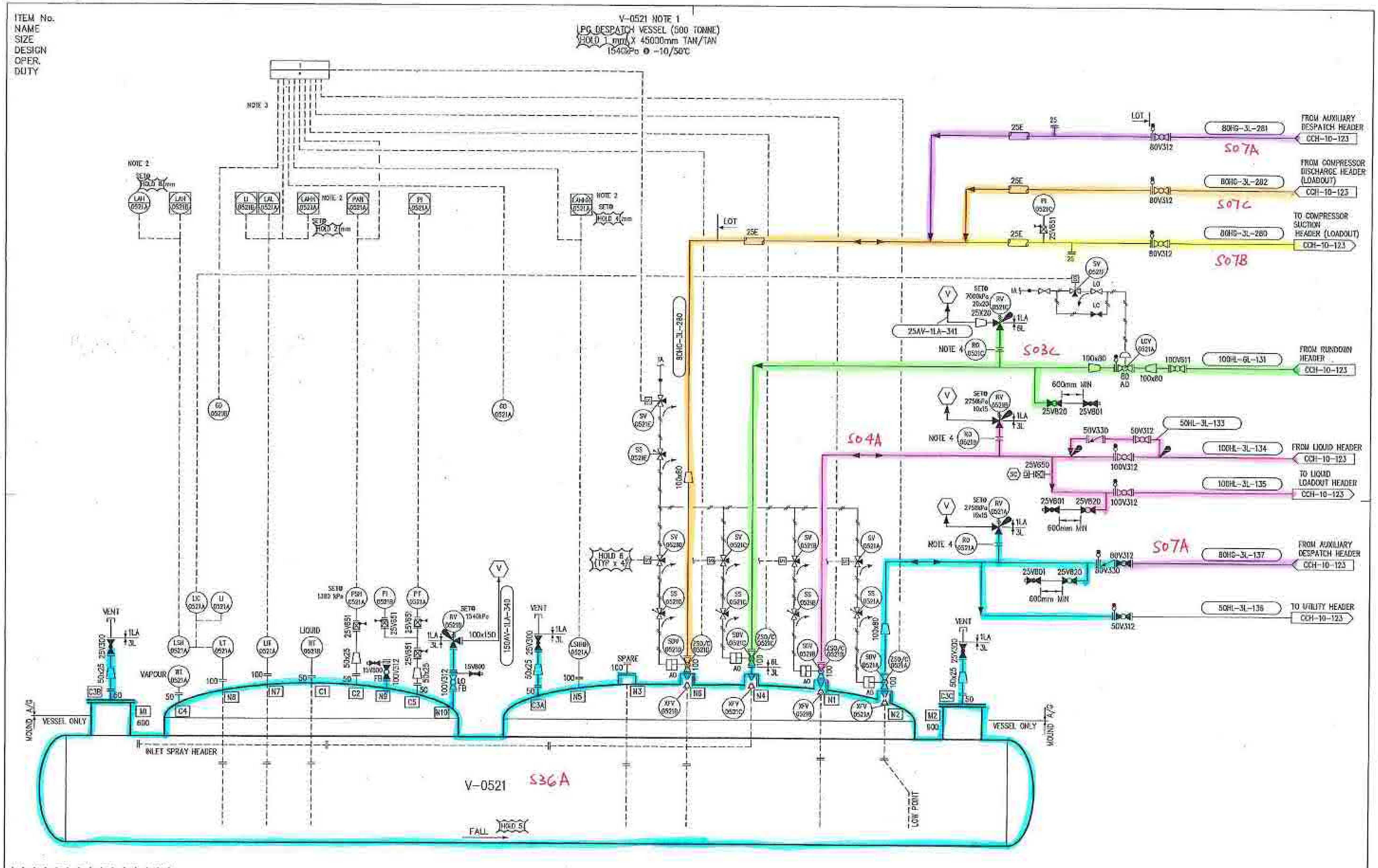
PIPING & INSTRUMENTATION DIAGRAM
LPG STORAGE FACILITIES
DESPATCH VESSELS CONNECTIONS

SCALE NTS

Liquigas Limited

SHEET No 1 of 1 | REVISION A

DRAWING No CCH-10-123



HOLDS:
1. OUTER DIAMETER OF VESSEL.
2. SET POINT OF LAHH.
3. DOCUMENT NUMBER.
4. SET POINT OF LAHHL.
5. VESSEL SLOPE.
6. INSTRUMENT DESIGNATION.
7. ALL EQUIPMENT TAGS, LINE NUMBERS & INSTRUMENT TAGS.
8. SET POINT OF LAH.

NOTES:

1. FUSIBLE LOOP FIRE DETECTION SYSTEM, REFER DWG: CCH-10-122/1.
2. LEVEL ALARM SETTINGS SHOWN ARE APPLICABLE TO "MIXED" PRODUCT STORAGE ONLY.
3. REFER TO CAUSE & EFFECT MATRIX. HOLD 3
4. 3mm DIAMETER RESTRICTION ORIFICE.

Transfield Worley Ltd.

PROJECT NUMBER	CAD FILE NAME	REVISED
500929	CCH-10-0122-	

WOOLSTON LPG STORAGE DEPOT

PIPING & INSTRUMENTATION DIAGRAM
LPG STORAGE FACILITIES
DESPATCH VESSEL V-0521

DESIGNED	
DRAWN	
CHECKED	
APPROVED	
APPROVED	
SCALE	NTS

Liquigas Limited

SHEET No 1 of 1
REVISION A
DRAWING No. CCH-10-122

Appendix 2.
Consequence Modelling Results

The consequence results for each QRA event for LPG and propane are presented in the tables below. Only the results for horizontal releases are presented as the horizontal releases generally generates the worse results compared to vertical releases.

Table 1 below gives the release rate and flammable gas dispersion distances for propane releases.

Table 1: Release Rates and LFL Dispersion Distances for Propane Release

No.	QRA Event	Pressure (barg)	Temp. (°C)	Hole Size (mm)	Propane	
					Release Rate (kg/s)	LFL Distance (m)
1	S01A_PNLPGD_L	28	12	2	0.10	3.6
1	S01A_PNLPGD_L	28	12	7	1.3	13
1	S01A_PNLPGD_L	28	12	30	24	86
1	S01A_PNLPGD_L	28	12	100	262	344
1	S01A_PNLPGD_L	28	12	150	589	522
2	S01B_PNLPGR_L	38	12	2	0.12	3.8
2	S01B_PNLPGR_L	38	12	7	1.5	14
2	S01B_PNLPGR_L	38	12	30	27	93
2	S01B_PNLPGR_L	38	12	100	305	371
2	S01B_PNLPGR_L	38	12	150	686	563
3	S02A_LPGPIG_L	28	12	2	0.10	3.6
3	S02A_LPGPIG_L	28	12	7	1.3	13
3	S02A_LPGPIG_L	28	12	30	24	86
3	S02A_LPGPIG_L	28	12	100	262	344
3	S02A_LPGPIG_L	28	12	150	589	522
4	S03A_SHPUN1_L	28	12	2	0.10	3.6
4	S03A_SHPUN1_L	28	12	7	1.3	13
4	S03A_SHPUN1_L	28	12	30	24	86
4	S03A_SHPUN1_L	28	12	100	262	336
4	S03A_SHPUN1_L	28	12	150	589	376
5	S03B_SHPUN2_L	20	12	2	0.09	3.4
5	S03B_SHPUN2_L	20	12	7	1.06	12
5	S03B_SHPUN2_L	20	12	30	20	77
5	S03B_SHPUN2_L	20	12	100	221	315
5	S03B_SHPUN2_L	20	12	150	498	367
6	S03C_RUNDWN_L	13	12	2	0.07	3.1
6	S03C_RUNDWN_L	13	12	7	0.88	11
6	S03C_RUNDWN_L	13	12	30	16	69
6	S03C_RUNDWN_L	13	12	100	179	282
6	S03C_RUNDWN_L	13	12	150	402	353

No.	QRA Event	Pressure (barg)	Temp. (°C)	Hole Size (mm)	Propane	
					Release Rate (kg/s)	LFL Distance (m)
7	S04A_LDOHDR_L	13	12	2	0.07	3.1
7	S04A_LDOHDR_L	13	12	7	0.88	11
7	S04A_LDOHDR_L	13	12	30	16	69
7	S04A_LDOHDR_L	13	12	100	179	282
7	S04A_LDOHDR_L	13	12	150	402	313
8	S05A_LQDHDR_L	13	12	2	0.07	3.1
8	S05A_LQDHDR_L	13	12	7	0.88	11
8	S05A_LQDHDR_L	13	12	30	16	69
8	S05A_LQDHDR_L	13	12	100	179	252
8	S05A_LQDHDR_L	13	12	150	402	287
9	S06A_LDHDR2_L	13	12	2	0.07	3.1
9	S06A_LDHDR2_L	13	12	7	0.88	11
9	S06A_LDHDR2_L	13	12	30	16	69
9	S06A_LDHDR2_L	13	12	100	179	252
9	S06A_LDHDR2_L	13	12	150	402	287
10	S07A_AUXHDR_V	8.5	12	2	0.01	0.74
10	S07A_AUXHDR_V	8.5	12	7	0.09	2.5
10	S07A_AUXHDR_V	8.5	12	30	1.7	10
10	S07A_AUXHDR_V	8.5	12	100	19	47
10	S07A_AUXHDR_V	8.5	12	150	42	81
11	S07B_SUCHDR_V	6.5	12	2	0.01	0.67
11	S07B_SUCHDR_V	6.5	12	7	0.07	2.3
11	S07B_SUCHDR_V	6.5	12	30	1.3	9.3
11	S07B_SUCHDR_V	6.5	12	100	15	42
11	S07B_SUCHDR_V	6.5	12	150	33	71
12	S07C_DISHDR_V	8.5	30	2	0.01	0.73
12	S07C_DISHDR_V	8.5	30	7	0.09	2.5
12	S07C_DISHDR_V	8.5	30	30	1.7	10
12	S07C_DISHDR_V	8.5	30	100	18	46
12	S07C_DISHDR_V	8.5	30	150	-	-
13	S07D_UTIHDR_L	8.5	12	2	0.06	2.8
13	S07D_UTIHDR_L	8.5	12	7	0.71	9.4
13	S07D_UTIHDR_L	8.5	12	30	13	61
13	S07D_UTIHDR_L	8.5	12	100	144	245
13	S07D_UTIHDR_L	8.5	12	150	-	-
14	S08A_LDOHDR_V	6.5	12	2	0.01	0.67
14	S08A_LDOHDR_V	6.5	12	7	0.07	2.3

No.	QRA Event	Pressure (barg)	Temp. (°C)	Hole Size (mm)	Propane	
					Release Rate (kg/s)	LFL Distance (m)
14	S08A_LDOHDR_V	6.5	12	30	1.3	9.3
14	S08A_LDOHDR_V	6.5	12	100	15	42
14	S08A_LDOHDR_V	6.5	12	150	33	71
15	S08B_COMDIS_V	10.5	20	2	0.01	0.80
15	S08B_COMDIS_V	10.5	20	7	0.11	2.7
15	S08B_COMDIS_V	10.5	20	30	2.0	12
15	S08B_COMDIS_V	10.5	20	100	23	52
15	S08B_COMDIS_V	10.5	20	150	51	91
16	S09A_AUXDIS_V	8.5	12	2	0.01	0.74
16	S09A_AUXDIS_V	8.5	12	7	0.09	2.5
16	S09A_AUXDIS_V	8.5	12	30	1.7	10
16	S09A_AUXDIS_V	8.5	12	100	19	47
16	S09A_AUXDIS_V	8.5	12	150	-	-
17	S10A_RDLOAD_L	8.5	12	2	0.06	2.8
17	S10A_RDLOAD_L	8.5	12	7	0.71	9.4
17	S10A_RDLOAD_L	8.5	12	30	13	61
17	S10A_RDLOAD_L	8.5	12	100	144	245
17	S10A_RDLOAD_L	8.5	12	150	325	278
18	S11A_RDLOAD_L	8.5	12	2	0.06	2.8
18	S11A_RDLOAD_L	8.5	12	7	0.71	9.4
18	S11A_RDLOAD_L	8.5	12	30	13	61
18	S11A_RDLOAD_L	8.5	12	100	144	245
18	S11A_RDLOAD_L	8.5	12	150	325	278
19	S12A_VLARM1_V	6.5	20	2	0.01	0.65
19	S12A_VLARM1_V	6.5	20	7	0.07	2.2
19	S12A_VLARM1_V	6.5	20	30	1.3	9.1
19	S12A_VLARM1_V	6.5	20	100	14	40
19	S12A_VLARM1_V	6.5	20	150	-	-
20	S13A_LLARM1_L	8.5	20	2	0.06	2.8
20	S13A_LLARM1_L	8.5	20	7	0.71	9.4
20	S13A_LLARM1_L	8.5	20	30	13	61
20	S13A_LLARM1_L	8.5	20	100	144	245
20	S13A_LLARM1_L	8.5	20	150	-	-
21	S14A_VLARM2_V	6.5	20	2	0.01	0.65
21	S14A_VLARM2_V	6.5	20	7	0.07	2.2
21	S14A_VLARM2_V	6.5	20	30	1.3	9.1
21	S14A_VLARM2_V	6.5	20	100	14	40

No.	QRA Event	Pressure (barg)	Temp. (°C)	Hole Size (mm)	Propane	
					Release Rate (kg/s)	LFL Distance (m)
21	S14A_VLARM2_V	6.5	20	150	-	-
22	S15A_LLARM2_L	8.5	20	2	0.06	2.8
22	S15A_LLARM2_L	8.5	20	7	0.71	9.4
22	S15A_LLARM2_L	8.5	20	30	13	61
22	S15A_LLARM2_L	8.5	20	100	144	245
22	S15A_LLARM2_L	8.5	20	150	-	-
23	S16A_DESPV1_V [Note 1]	8.5	12	2	0.01	*No hazard* [Note 2]
23	S16A_DESPV1_V [Note 1]	8.5	12	7	0.09	*No hazard* [Note 2]
23	S16A_DESPV1_V [Note 1]	8.5	12	30	1.7	*No hazard* [Note 2]
23	S16A_DESPV1_V [Note 1]	8.5	12	100	19	*No hazard* [Note 2]
23	S16A_DESPV1_V [Note 1]	8.5	12	150	42	*No hazard* [Note 2]

Note 1: S16A to S38A are the LPG storage vessels events and the consequences are the same, hence the consequences for S17A to S38A are not repeated.

Note 2: The LFL distances are read at 1 m above ground, which is the human impact height. For releases from the LPG storage vessels, the releases were modelled at 5 m above ground. Hence there are no hazards registered at 1 m above ground.

Table 2 below gives the release rate and flammable gas dispersion distances for LPG releases.

Table 2: Release Rates and LFL Dispersion Distances for LPG Release

No.	QRA Event	Pressure (barg)	Temp. (°C)	Hole Size (mm)	LPG	
					Release Rate (kg/s)	LFL Distance (m)
1	S01A_PNLPGD_L	28	12	2	0.11	4.1
1	S01A_PNLPGD_L	28	12	7	1.3	15
1	S01A_PNLPGD_L	28	12	30	24	99
1	S01A_PNLPGD_L	28	12	100	269	398
1	S01A_PNLPGD_L	28	12	150	606	593
2	S01B_PNLPGR_L	38	12	2	0.13	4.3
2	S01B_PNLPGR_L	38	12	7	1.5	16
2	S01B_PNLPGR_L	38	12	30	28	104
2	S01B_PNLPGR_L	38	12	100	314	412
2	S01B_PNLPGR_L	38	12	150	705	607
3	S02A_LPGPIG_L	28	12	2	0.11	4.1
3	S02A_LPGPIG_L	28	12	7	1.3	15
3	S02A_LPGPIG_L	28	12	30	24	99
3	S02A_LPGPIG_L	28	12	100	269	398
3	S02A_LPGPIG_L	28	12	150	606	593
4	S03A_SHPUN1_L	28	12	2	0.11	4.1

No.	QRA Event	Pressure (barg)	Temp. (°C)	Hole Size (mm)	LPG	
					Release Rate (kg/s)	LFL Distance (m)
4	S03A_SHPUN1_L	28	12	7	1.3	15
4	S03A_SHPUN1_L	28	12	30	24	99
4	S03A_SHPUN1_L	28	12	100	269	330
4	S03A_SHPUN1_L	28	12	150	606	468
5	S03B_SHPUN2_L	15	12	2	0.08	3.6
5	S03B_SHPUN2_L	15	12	7	0.97	13
5	S03B_SHPUN2_L	15	12	30	18	88
5	S03B_SHPUN2_L	15	12	100	197	302
5	S03B_SHPUN2_L	15	12	150	444	531
6	S03C_RUNDWN_L	13	12	2	0.07	3.5
6	S03C_RUNDWN_L	13	12	7	0.90	12
6	S03C_RUNDWN_L	13	12	30	17	85
6	S03C_RUNDWN_L	13	12	100	184	291
6	S03C_RUNDWN_L	13	12	150	413	515
7	S04A_LDOHDR_L	8	12	2	0.06	3.2
7	S04A_LDOHDR_L	8	12	7	0.71	11
7	S04A_LDOHDR_L	8	12	30	13	76
7	S04A_LDOHDR_L	8	12	100	144	267
7	S04A_LDOHDR_L	8	12	150	324	461
8	S05A_LQDHDR_L	8	12	2	0.06	3.2
8	S05A_LQDHDR_L	8	12	7	0.71	11
8	S05A_LQDHDR_L	8	12	30	13	76
8	S05A_LQDHDR_L	8	12	100	144	267
8	S05A_LQDHDR_L	8	12	150	324	461
9	S06A_LDHDR2_L	8	12	2	0.06	3.2
9	S06A_LDHDR2_L	8	12	7	0.71	11
9	S06A_LDHDR2_L	8	12	30	13	76
9	S06A_LDHDR2_L	8	12	100	144	267
9	S06A_LDHDR2_L	8	12	150	324	461
10	S07A_AUXHDR_V	6.5	12	2	0.006	0.69
10	S07A_AUXHDR_V	6.5	12	7	0.07	2.3
10	S07A_AUXHDR_V	6.5	12	30	1.4	9.7
10	S07A_AUXHDR_V	6.5	12	100	15	44
10	S07A_AUXHDR_V	6.5	12	150	34	75
11	S07B_SUCHDR_V	3	12	2	0.003	0.5
11	S07B_SUCHDR_V	3	12	7	0.04	1.8
11	S07B_SUCHDR_V	3	12	30	0.7	7.4

No.	QRA Event	Pressure (barg)	Temp. (°C)	Hole Size (mm)	LPG	
					Release Rate (kg/s)	LFL Distance (m)
11	S07B_SUCHDR_V	3	12	100	8.0	32
11	S07B_SUCHDR_V	3	12	150	18	52
12	S07C_DISHDR_V	6.5	30	2	0.006	0.7
12	S07C_DISHDR_V	6.5	30	7	0.07	2.3
12	S07C_DISHDR_V	6.5	30	30	1.4	10
12	S07C_DISHDR_V	6.5	30	100	15	44
12	S07C_DISHDR_V	6.5	30	150	-	-
13	S07D_UTIHDR_L	3	12	2	0.039	2.7
13	S07D_UTIHDR_L	3	12	7	0.48	8.7
13	S07D_UTIHDR_L	3	12	30	8.8	61
13	S07D_UTIHDR_L	3	12	100	98	229
13	S07D_UTIHDR_L	3	12	150	-	-
14	S08A_LDOHDR_V	3	12	2	0.003	0.53
14	S08A_LDOHDR_V	3	12	7	0.04	1.8
14	S08A_LDOHDR_V	3	12	30	0.7	7.4
14	S08A_LDOHDR_V	3	12	100	8	32
14	S08A_LDOHDR_V	3	12	150	18	52
15	S08B_COMDIS_V	4	20	2	0.004	0.58
15	S08B_COMDIS_V	4	20	7	0.05	2.0
15	S08B_COMDIS_V	4	20	30	0.9	8.0
15	S08B_COMDIS_V	4	20	100	10	35
15	S08B_COMDIS_V	4	20	150	23	59
16	S09A_AUXDIS_V	6.5	12	2	0.006	0.69
16	S09A_AUXDIS_V	6.5	12	7	0.07	2.4
16	S09A_AUXDIS_V	6.5	12	30	1.4	9.7
16	S09A_AUXDIS_V	6.5	12	100	15	44
16	S09A_AUXDIS_V	6.5	12	150	-	-
17	S10A_RDLOAD_L	6.5	12	2	0.05	3.1
17	S10A_RDLOAD_L	6.5	12	7	0.64	10
17	S10A_RDLOAD_L	6.5	12	30	12	72
17	S10A_RDLOAD_L	6.5	12	100	130	257
17	S10A_RDLOAD_L	6.5	12	150	292	439
18	S11A_RDLOAD_L	6.5	12	2	0.05	3.1
18	S11A_RDLOAD_L	6.5	12	7	0.64	10
18	S11A_RDLOAD_L	6.5	12	30	12	72
18	S11A_RDLOAD_L	6.5	12	100	130	257
18	S11A_RDLOAD_L	6.5	12	150	292	439

No.	QRA Event	Pressure (barg)	Temp. (°C)	Hole Size (mm)	LPG	
					Release Rate (kg/s)	LFL Distance (m)
19	S12A_VLARM1_V	3	20	2	0.003	0.53
19	S12A_VLARM1_V	3	20	7	0.04	1.8
19	S12A_VLARM1_V	3	20	30	0.7	7.4
19	S12A_VLARM1_V	3	20	100	8	32
19	S12A_VLARM1_V	3	20	150	-	-
20	S13A_LLARM1_L	6.5	20	2	0.05	3.1
20	S13A_LLARM1_L	6.5	20	7	0.64	10
20	S13A_LLARM1_L	6.5	20	30	12	72
20	S13A_LLARM1_L	6.5	20	100	130	257
20	S13A_LLARM1_L	6.5	20	150	-	-
21	S14A_VLARM2_V	3	20	2	0.003	0.53
21	S14A_VLARM2_V	3	20	7	0.04	1.8
21	S14A_VLARM2_V	3	20	30	0.7	7.4
21	S14A_VLARM2_V	3	20	100	8	32
21	S14A_VLARM2_V	3	20	150	-	-
22	S15A_LLARM2_L	6.5	20	2	0.05	3.1
22	S15A_LLARM2_L	6.5	20	7	0.64	10
22	S15A_LLARM2_L	6.5	20	30	12	72
22	S15A_LLARM2_L	6.5	20	100	130	257
22	S15A_LLARM2_L	6.5	20	150	-	-
23	S16A_DESPV1_V Note 1	3	12	2	0.004	*No hazard* Note 2
23	S16A_DESPV1_V Note 1	3	12	7	0.05	*No hazard* Note 2
23	S16A_DESPV1_V Note 1	3	12	30	0.8	*No hazard* Note 2
23	S16A_DESPV1_V Note 1	3	12	100	9.4	*No hazard* Note 2
23	S16A_DESPV1_V Note 1	3	12	150	21	*No hazard* Note 2

Note 1: S16A to S38A are the LPG storage vessels events and the consequences are the same, hence the consequences for S17A to S38A are not repeated.

Note 2: The LFL distances are read at 1 m above ground, which is the human impact height. For releases from the LPG storage vessels, the releases were modelled at 5 m above ground. Hence there are no hazards registered at 1 m above ground.

Table 3 below gives the jet fire downwind thermal radiation distances for propane releases.

Table 3: Jet Fire Downwind Thermal Radiation Distances for Propane Releases

No.	QRA Event	Hole Size (mm)	Jet Flame length (m)	Jet Fire Downwind Thermal Radiation Distances (m)				
				35 kW/m^2	23 kW/m^2	12.6 kW/m^2	4.7 kW/m^2	2.1 kW/m^2
1	S01A_PNLPGD_L	2	5.2	6.3	6.7	7.3	8.7	10
1	S01A_PNLPGD_L	7	16	20	21	23	28	33

No.	QRA Event	Hole Size (mm)	Jet Flame length (m)	Jet Fire Downwind Thermal Radiation Distances (m)				
				35 kW/m^2	23 kW/m^2	12.6 kW/m^2	4.7 kW/m^2	2.1 kW/m^2
1	S01A_PNLPGD_L	30	55	72	76	85	103	127
1	S01A_PNLPGD_L	100	155	209	223	248	306	379
1	S01A_PNLPGD_L	150	218	298	319	355	440	547
2	S01B_PNLPGR_L	2	5.5	6.7	7.1	7.7	9.3	11
2	S01B_PNLPGR_L	7	17	21	22	24	29	35
2	S01B_PNLPGR_L	30	59	76	81	90	110	135
2	S01B_PNLPGR_L	100	164	222	237	263	325	403
2	S01B_PNLPGR_L	150	232	317	339	377	467	582
3	S02A_LPGPIG_L	2	5.2	6.3	6.7	7.3	8.7	10
3	S02A_LPGPIG_L	7	16	20	21	23	28	33
3	S02A_LPGPIG_L	30	55	72	76	85	103	127
3	S02A_LPGPIG_L	100	155	209	223	248	306	379
3	S02A_LPGPIG_L	150	218	298	319	355	440	547
4	S03A_SHPUN1_L	2	5.2	6.3	6.7	7.3	8.7	10
4	S03A_SHPUN1_L	7	16	20	21	23	28	33
4	S03A_SHPUN1_L	30	55	72	76	85	103	127
4	S03A_SHPUN1_L	100	107	209	223	248	306	379
4	S03A_SHPUN1_L	150	218	298	319	355	440	547
5	S03B_SHPUN2_L	2	4.9	5.8	6.2	6.7	8.1	9.7
5	S03B_SHPUN2_L	7	15	18	19	21	25	18
5	S03B_SHPUN2_L	30	51	67	71	78	96	117
5	S03B_SHPUN2_L	100	145	195	208	231	285	353
5	S03B_SHPUN2_L	150	204	279	298	331	410	510
6	S03C_RUNDWN_L	2	4.5	5.5	5.7	6.2	7.4	8.9
6	S03C_RUNDWN_L	7	13	17	18	19	23	28
6	S03C_RUNDWN_L	30	47	61	65	72	88	108
6	S03C_RUNDWN_L	100	133	178	190	211	261	322
6	S03C_RUNDWN_L	150	187	255	272	303	375	465
7	S04A_LDOHDR_L	2	4.5	5.5	5.7	6.2	7.4	8.9
7	S04A_LDOHDR_L	7	13	17	18	19	23	28
7	S04A_LDOHDR_L	30	47	61	65	72	88	108
7	S04A_LDOHDR_L	100	133	178	190	211	261	322
7	S04A_LDOHDR_L	150	187	255	272	303	375	465
8	S05A_LQDHDR_L	2	4.5	5.5	5.7	6.2	7.4	8.9
8	S05A_LQDHDR_L	7	13	17	18	19	23	28
8	S05A_LQDHDR_L	30	47	61	65	72	88	108
8	S05A_LQDHDR_L	100	133	178	190	211	261	322

No.	QRA Event	Hole Size (mm)	Jet Flame length (m)	Jet Fire Downwind Thermal Radiation Distances (m)				
				35 kW/m^2	23 kW/m^2	12.6 kW/m^2	4.7 kW/m^2	2.1 kW/m^2
8	S05A_LQDHDR_L	150	187	255	272	303	375	465
9	S06A_LDHDR2_L	2	4.5	5.5	5.7	6.2	7.4	8.9
9	S06A_LDHDR2_L	7	13	17	18	19	23	28
9	S06A_LDHDR2_L	30	47	61	65	72	88	108
9	S06A_LDHDR2_L	100	133	178	190	211	261	322
9	S06A_LDHDR2_L	150	187	255	272	303	375	465
10	S07A_AUXHDR_V	2	1.4	*Not reached*	*Not reached*	*Not reached*	1.4	1.5
10	S07A_AUXHDR_V	7	4.1	2.9	3.9	4.1	4.6	5.1
10	S07A_AUXHDR_V	30	15	19	19	20	22	26
10	S07A_AUXHDR_V	100	51	56	59	63	72	91
10	S07A_AUXHDR_V	150	68	77	81	87	105	134
11	S07B_SUCHDR_V	2	1.2	1.4	1.5	1.6	1.9	2.3
11	S07B_SUCHDR_V	7	3.8	4.8	4.8	5.3	6.3	7.5
11	S07B_SUCHDR_V	30	14	17	18	20	24	29
11	S07B_SUCHDR_V	100	40	52	55	60	73	89
11	S07B_SUCHDR_V	150	57	74	79	87	106	130
12	S07C_DISHDR_V	2	1.4	*Not reached*	*Not reached*	*Not reached*	1.4	1.5
12	S07C_DISHDR_V	7	4.1	2.9	3.9	4.1	4.6	5.0
12	S07C_DISHDR_V	30	15	18	19	20	22	25
12	S07C_DISHDR_V	100	44	49	53	59	72	90
12	S07C_DISHDR_V	150	-	-	-	-	-	-
13	S07D_UTIHDR_L	2	4.1	5.1	5.2	5.7	6.8	8.1
13	S07D_UTIHDR_L	7	12	15	16	18	21	26
13	S07D_UTIHDR_L	30	43	56	60	66	80	98
13	S07D_UTIHDR_L	100	122	163	174	193	238	294
13	S07D_UTIHDR_L	150	-	-	-	-	-	-
14	S08A_LDOHDR_V	2	1.2	1.4	1.5	1.6	1.9	2.3
14	S08A_LDOHDR_V	7	3.8	4.8	4.8	5.3	6.3	7.5
14	S08A_LDOHDR_V	30	14	17	18	20	24	29
14	S08A_LDOHDR_V	100	40	52	55	60	73	89
14	S08A_LDOHDR_V	150	57	74	79	87	106	130
15	S08B_COMDIS_V	2	1.5	*Not reached*	*Not reached*	*Not reached*	1.8	1.8
15	S08B_COMDIS_V	7	4.5	3.1	3.5	4.5	5.1	5.6
15	S08B_COMDIS_V	30	16	20	21	22	24	28
15	S08B_COMDIS_V	100	54	61	63	68	79	99

No.	QRA Event	Hole Size (mm)	Jet Flame length (m)	Jet Fire Downwind Thermal Radiation Distances (m)				
				35 kW/m^2	23 kW/m^2	12.6 kW/m^2	4.7 kW/m^2	2.1 kW/m^2
15	S08B_COMDIS_V	150	73	83	87	93	114	146
16	S09A_AUXDIS_V	2	1.4	*Not reached*	*Not reached*	*Not reached*	1.4	1.5
16	S09A_AUXDIS_V	7	4.1	2.9	3.9	4.1	4.7	5.1
16	S09A_AUXDIS_V	30	15	19	19	20	22	26
16	S09A_AUXDIS_V	100	51	56	59	63	72	91
16	S09A_AUXDIS_V	150	-	-	-	-	-	-
17	S10A_RDLOAD_L	2	4.1	5.1	5.2	5.7	6.8	8.1
17	S10A_RDLOAD_L	7	12	15	16	18	21	26
17	S10A_RDLOAD_L	30	43	56	60	66	80	98
17	S10A_RDLOAD_L	100	122	163	174	193	238	294
17	S10A_RDLOAD_L	150	172	233	249	277	342	424
18	S11A_RDLOAD_L	2	4.1	5.1	5.2	5.7	6.8	8.1
18	S11A_RDLOAD_L	7	12	15	16	18	21	26
18	S11A_RDLOAD_L	30	43	56	60	66	80	98
18	S11A_RDLOAD_L	100	122	163	174	193	238	294
18	S11A_RDLOAD_L	150	172	233	249	277	342	424
19	S12A_VLARM1_V	2	1.2	*Not reached*	*Not reached*	*Not reached*	1.7	1.7
19	S12A_VLARM1_V	7	3.7	2.5	3.1	3.7	4.1	4.5
19	S12A_VLARM1_V	30	16	16	17	18	19	22
19	S12A_VLARM1_V	100	46	51	53	56	64	80
19	S12A_VLARM1_V	150	-	-	-	-	-	-
20	S13A_LLARM1_L	2	4.1	5.1	5.2	5.7	6.8	8.1
20	S13A_LLARM1_L	7	12	15	16	18	21	26
20	S13A_LLARM1_L	30	43	56	60	66	80	98
20	S13A_LLARM1_L	100	122	163	174	193	238	294
20	S13A_LLARM1_L	150	-	-	-	-	-	-
21	S14A_VLARM2_V	2	1.2	*Not reached*	*Not reached*	*Not reached*	1.7	1.7
21	S14A_VLARM2_V	7	3.7	2.5	3.1	3.7	4.1	4.5
21	S14A_VLARM2_V	30	16	16	17	18	19	22
21	S14A_VLARM2_V	100	46	51	53	56	64	80
21	S14A_VLARM2_V	150	-	-	-	-	-	-
22	S15A_LLARM2_L	2	4.1	5.1	5.2	5.7	6.8	8.1
22	S15A_LLARM2_L	7	12	15	16	18	21	26
22	S15A_LLARM2_L	30	43	56	60	66	80	98
22	S15A_LLARM2_L	100	122	163	174	193	238	294

No.	QRA Event	Hole Size (mm)	Jet Flame length (m)	Jet Fire Downwind Thermal Radiation Distances (m)				
				35 kW/m^2	23 kW/m^2	12.6 kW/m^2	4.7 kW/m^2	2.1 kW/m^2
22	S15A_LLARM2_L	150	-	-	-	-	-	-
23	S16A_DESPV1_V Note 1	2	1.4	*Not reached*	*Not reached*	*Not reached*	*Not reached*	*Not reached*
23	S16A_DESPV1_V Note 1	7	4.1	*Not reached*	*Not reached*	*Not reached*	*Not reached*	*Not reached*
23	S16A_DESPV1_V Note 1	30	15	*Not reached*	*Not reached*	17	22	25
23	S16A_DESPV1_V Note 1	100	41	54	58	63	73	88
23	S16A_DESPV1_V Note 1	150	56	76	80	87	105	134

Note 1: S16A to S38A are the LPG storage vessels events and the consequences are the same, hence the consequences for S17A to S38A are not repeated.

Note 2: Results are shown as “Not reached” as the jet fires flame emissive power is lower than the thermal radiation levels of interest. Also, for LPG storage vessels event, the results are read at 1 m aboveground, whereas the releases were modelled at 5 m above ground. Hence there were no thermal radiation impacts at 1 m.

Table 4 below gives the jet fire downwind thermal radiation distances for LPG releases. For QRA events where pool fire is likely to form, the pool diameter and downwind distances are also presented.

No.	QRA Event	Hole Size (mm)	Jet Fire Downwind Thermal Radiation Distances (m)						Pool Fire Downwind Thermal Radiation Distances (m)					
			Jet Flame length (m)	35 kW/m^2	23 kW/m^2	12.6 kW/m^2	4.7 kW/m^2	2.1 kW/m^2	Pool Fire Diameter (m)	35 kW/m^2	23 kW/m^2	12.6 kW/m^2	4.7 kW/m^2	2.1 kW/m^2
1	S01A_PNLPGD_L	2	5.4	6.6	7.0	7.6	9.2	11						
1	S01A_PNLPGD_L	7	16	20	22	24	29	35						
1	S01A_PNLPGD_L	30	56	74	79	88	109	134						
1	S01A_PNLPGD_L	100	156	215	230	258	321	401						
1	S01A_PNLPGD_L	150	291	307	330	369	461	579	19	109	119	134	164	201
2	S01B_PNLPGR_L	2	5.7	6.9	7.4	8.1	9.7	12						
2	S01B_PNLPGR_L	7	17	21	23	25	31	37						
2	S01B_PNLPGR_L	30	59	79	84	93	115	142						
2	S01B_PNLPGR_L	100	164	228	244	273	340	425						
2	S01B_PNLPGR_L	150	232	326	349	391	488	614						
3	S02A_LPGPIG_L	2	5.4	6.6	7.0	7.6	9.2	11						
3	S02A_LPGPIG_L	7	16	20	22	24	29	35						
3	S02A_LPGPIG_L	30	56	74	79	88	109	134						
3	S02A_LPGPIG_L	100	156	215	230	258	321	401						
3	S02A_LPGPIG_L	150	291	307	330	369	461	579	19	109	119	134	164	201
4	S03A_SHPUN1_L	2	5.4	6.6	7.0	7.6	9.2	11						
4	S03A_SHPUN1_L	7	16	20	22	24	29	35						
4	S03A_SHPUN1_L	30	56	74	79	88	109	134						

No.	QRA Event	Hole Size (mm)	Jet Fire Downwind Thermal Radiation Distances (m)						Pool Fire Downwind Thermal Radiation Distances (m)					
			Jet Flame length (m)	35 kW/m^2	23 kW/m^2	12.6 kW/m^2	4.7 kW/m^2	2.1 kW/m^2	Pool Fire Diameter (m)	35 kW/m^2	23 kW/m^2	12.6 kW/m^2	4.7 kW/m^2	2.1 kW/m^2
4	S03A_SHPUN1_L	100	156	215	230	258	321	401						
4	S03A_SHPUN1_L	150	291	307	330	369	461	579	19	109	119	134	164	201
5	S03B_SHPUN2_L	2	4.8	5.8	6.2	6.8	8.2	9.9						
5	S03B_SHPUN2_L	7	14	18	19	21	26	31						
5	S03B_SHPUN2_L	30	50	66	70	78	96	119						
5	S03B_SHPUN2_L	100	138	191	204	228	284	354						
5	S03B_SHPUN2_L	150	195	272	292	327	408	511	7.7	85	87	92	106	122
6	S03C_RUNDWN_L	2	4.7	5.7	6.0	6.6	7.9	9.6						
6	S03C_RUNDWN_L	7	14	17	19	21	25	30						
6	S03C_RUNDWN_L	30	48	64	68	76	93	115						
6	S03C_RUNDWN_L	100	134	185	198	221	276	344						
6	S03C_RUNDWN_L	150	189	264	283	317	396	496	8.1	84	87	91	105	123
7	S04A_LDOHDR_L	2	4.2	5.2	5.4	6.0	7.2	8.6						
7	S04A_LDOHDR_L	7	13	16	17	19	23	27						
7	S04A_LDOHDR_L	30	44	58	62	69	84	104						
7	S04A_LDOHDR_L	100	122	168	179	200	249	310	0.49	*Not reached*	*Note reached*	13	50	50
7	S04A_LDOHDR_L	150	172	239	256	287	358	448	6.9	78	81	83	93	109
8	S05A_LQDHDR_L	2	4.2	5.2	5.4	6.0	7.2	8.6						
8	S05A_LQDHDR_L	7	13	16	17	19	23	27						
8	S05A_LQDHDR_L	30	44	58	62	69	84	104						
8	S05A_LQDHDR_L	100	122	168	179	200	249	310	0.49	*Not*	*Note*	13	50	50

No.	QRA Event	Hole Size (mm)	Jet Fire Downwind Thermal Radiation Distances (m)						Pool Fire Downwind Thermal Radiation Distances (m)					
			Jet Flame length (m)	35 kW/m^2	23 kW/m^2	12.6 kW/m^2	4.7 kW/m^2	2.1 kW/m^2	Pool Fire Diameter (m)	35 kW/m^2	23 kW/m^2	12.6 kW/m^2	4.7 kW/m^2	2.1 kW/m^2
										reached	*reached*			
8	S05A_LQDHDR_L	150	172	239	256	287	358	448	6.9	78	81	83	93	109
9	S06A_LDHDR2_L	2	4.2	5.2	5.4	6.0	7.2	8.6						
9	S06A_LDHDR2_L	7	13	16	17	19	23	27						
9	S06A_LDHDR2_L	30	44	58	62	69	84	104						
9	S06A_LDHDR2_L	100	122	168	179	200	249	310	0.49	*Not reached*	*Note reached*	13	50	50
9	S06A_LDHDR2_L	150	172	239	256	287	358	448	6.9	78	81	83	93	109
10	S07A_AUXHDR_V	2	1.3	Not reached	Not reached	Not reached	1.7	1.7						
10	S07A_AUXHDR_V	7	3.8	2.5	3.2	3.8	4.3	4.6						
10	S07A_AUXHDR_V	30	17	17	18	19	20	23						
10	S07A_AUXHDR_V	100	47	52	54	58	66	83						
10	S07A_AUXHDR_V	150	63	72	74	80	91	114						
11	S07B_SUCHDR_V	2	1.0	Not reached	Not reached	Not reached	1.5	1.5						
11	S07B_SUCHDR_V	7	2.9	Not reached	2.1	2.8	3.2	3.4						
11	S07B_SUCHDR_V	30	13	14	14	14	15	17						
11	S07B_SUCHDR_V	100	38	42	43	45	50	61						
11	S07B_SUCHDR_V	150	51	60	59	62	72	91						
12	S07C_DISHDR_V	2	1.3	Not reached	Not reached	Not reached	1.7	1.7						

No.	QRA Event	Hole Size (mm)	Jet Fire Downwind Thermal Radiation Distances (m)						Pool Fire Downwind Thermal Radiation Distances (m)					
			Jet Flame length (m)	35 kW/m^2	23 kW/m^2	12.6 kW/m^2	4.7 kW/m^2	2.1 kW/m^2	Pool Fire Diameter (m)	35 kW/m^2	23 kW/m^2	12.6 kW/m^2	4.7 kW/m^2	2.1 kW/m^2
12	S07C_DISHDR_V	7	3.8	2.5	3.2	3.8	4.3	4.6						
12	S07C_DISHDR_V	30	17	17	18	19	20	23						
12	S07C_DISHDR_V	100	47	52	54	58	66	83						
12	S07C_DISHDR_V	150	-	-	-	-	-	-						
13	S07D_UTIHDR_L	2	3.6	4.6	4.6	5.1	6.1	7.3						
13	S07D_UTIHDR_L	7	11	13	14	16	19	23						
13	S07D_UTIHDR_L	30	38	49	52	58	72	88						
13	S07D_UTIHDR_L	100	104	142	152	170	211	262	0.68	45	45	45	45	46
13	S07D_UTIHDR_L	150	-	-	-	-	-	-						
14	S08A_LDOHDR_V	2	0.98	Not reached	Not reached	Not reached	1.5	1.5						
14	S08A_LDOHDR_V	7	2.9	*Not reached*	2.1	2.8	3.2	3.4						
14	S08A_LDOHDR_V	30	13	14	14	14	15	17						
14	S08A_LDOHDR_V	100	38	42	43	45	50	61						
14	S08A_LDOHDR_V	150	51	60	59	62	72	91						
15	S08B_COMDIS_V	2	1.1	*Not reached*	*Not reached*	*Not reached*	1.6	1.6						
15	S08B_COMDIS_V	7	3.2	*Not reached*	2.4	3.2	3.5	3.8						
15	S08B_COMDIS_V	30	12	15	15	16	17	19						
15	S08B_COMDIS_V	100	32	45	46	49	55	68						
15	S08B_COMDIS_V	150	44	61	64	68	80	101						

No.	QRA Event	Hole Size (mm)	Jet Fire Downwind Thermal Radiation Distances (m)						Pool Fire Downwind Thermal Radiation Distances (m)					
			Jet Flame length (m)	35 kW/m^2	23 kW/m^2	12.6 kW/m^2	4.7 kW/m^2	2.1 kW/m^2	Pool Fire Diameter (m)	35 kW/m^2	23 kW/m^2	12.6 kW/m^2	4.7 kW/m^2	2.1 kW/m^2
16	S09A_AUXDIS_V	2	1.3	*Not reached*	*Not reached*	*Not reached*	1.7	1.7						
16	S09A_AUXDIS_V	7	3.8	2.5	3.2	3.8	4.3	4.6						
16	S09A_AUXDIS_V	30	17	17	18	19	20	23						
16	S09A_AUXDIS_V	100	47	52	54	58	66	83						
16	S09A_AUXDIS_V	150	-	-	-	-	-	-						
17	S10A_RDLOAD_L	2	4.1	5.1	5.2	5.7	6.9	8.3						
17	S10A_RDLOAD_L	7	12	15	16	18	22	26						
17	S10A_RDLOAD_L	30	42	55	59	66	81	99						
17	S10A_RDLOAD_L	100	117	160	172	192	239	297	0.71	49	49	49	50	50
17	S10A_RDLOAD_L	150	165	229	246	275	428	229	5.7	74	77	78	85	98
18	S11A_RDLOAD_L	2	4.1	5.1	5.2	5.7	6.9	8.3						
18	S11A_RDLOAD_L	7	12	15	16	18	22	26						
18	S11A_RDLOAD_L	30	42	55	59	66	81	99						
18	S11A_RDLOAD_L	100	117	160	172	192	239	297	0.71	49	49	49	50	50
18	S11A_RDLOAD_L	150	165	229	246	275	428	229	5.7	74	77	78	85	98
19	S12A_VLARM1_V	2	1.0	*Not reached*	*Not reached*	*Not reached*	1.5	1.5						
19	S12A_VLARM1_V	7	2.9	*Not reached*	2.1	2.8	3.2	3.4						
19	S12A_VLARM1_V	30	13	14	14	14	15	17						
19	S12A_VLARM1_V	100	38	42	43	45	50	61						

No.	QRA Event	Hole Size (mm)	Jet Fire Downwind Thermal Radiation Distances (m)						Pool Fire Downwind Thermal Radiation Distances (m)					
			Jet Flame length (m)	35 kW/m^2	23 kW/m^2	12.6 kW/m^2	4.7 kW/m^2	2.1 kW/m^2	Pool Fire Diameter (m)	35 kW/m^2	23 kW/m^2	12.6 kW/m^2	4.7 kW/m^2	2.1 kW/m^2
19	S12A_VLARM1_V	150	-	-	-	-	-	-						
20	S13A_LLARM1_L	2	4.1	5.1	5.2	5.7	6.9	8.3						
20	S13A_LLARM1_L	7	12	15	16	18	22	26						
20	S13A_LLARM1_L	30	42	55	59	66	81	99						
20	S13A_LLARM1_L	100	117	160	172	192	239	297	0.71	49	49	49	50	50
20	S13A_LLARM1_L	150	-	-	-	-	-	-						
21	S14A_VLARM2_V	2	1.0	*Not reached*	*Not reached*	*Not reached*	1.5	1.5						
21	S14A_VLARM2_V	7	2.9	*Not reached*	2.1	2.8	3.2	3.4						
21	S14A_VLARM2_V	30	13	14	14	14	15	17						
21	S14A_VLARM2_V	100	38	42	43	45	50	61						
21	S14A_VLARM2_V	150	-	-	-	-	-	-						
22	S15A_LLARM2_L	2	4.1	5.1	5.2	5.7	6.9	8.3						
22	S15A_LLARM2_L	7	12	15	16	18	22	26						
22	S15A_LLARM2_L	30	42	55	59	66	81	99						
22	S15A_LLARM2_L	100	117	160	172	192	239	297	0.71	49	49	49	50	50
22	S15A_LLARM2_L	150	-	-	-	-	-	-						
23	S16A_DESPV1_V Note 1	2	1.1	*Not reached*	*Not reached*	*Not reached*	*Not reached*	*Not reached*						
23	S16A_DESPV1_V Note 1	7	3.1	*Not reached*	*Not reached*	*Not reached*	*Not reached*	*Not reached*						
23	S16A_DESPV1_V	30	12	*Not*	*Not*	*Not*	14	18						

No.	QRA Event	Hole Size (mm)	Jet Fire Downwind Thermal Radiation Distances (m)						Pool Fire Downwind Thermal Radiation Distances (m)					
			Jet Flame length (m)	35 kW/m^2	23 kW/m^2	12.6 kW/m^2	4.7 kW/m^2	2.1 kW/m^2	Pool Fire Diameter (m)	35 kW/m^2	23 kW/m^2	12.6 kW/m^2	4.7 kW/m^2	2.1 kW/m^2
	Note 1			*reached*	*reached*	*reached*								
23	S16A_DESPV1_V Note 1	100	32	41	44	47	54	67						
23	S16A_DESPV1_V Note 1	150	43	58	61	66	77	98						

Note 1: S16A to S38A are the LPG storage vessels events and the consequences are the same, hence the consequences for S17A to S38A are not repeated.

Note 2: Results are shown as “Not reached” as the jet fires flame emissive power is lower than the thermal radiation levels of interest. Also, for LPG storage vessels event, the results are read at 1 m aboveground, whereas the releases were modelled at 5 m above ground. Hence there were no thermal radiation impacts at 1 m.

Appendix 3.
Ignition Probabilities

The ignition probabilities for the QRA scenarios are given in the table below.

QRA Event	Hole Size	Propane		LPG	
		Release Rate (kg/s)	Probability of Ignition	Release Rate (kg/s)	Probability of Ignition
S01A	2 mm	0.1	1.10E-03	0.11	1.10E-03
S01A	7 mm	1.3	1.54E-03	1.3	1.59E-03
S01A	30 mm	24	4.34E-02	24	4.47E-02
S01A	100 mm	262	4.23E-01	269	4.31E-01
S01A	150 mm	589	7.16E-01	606	7.29E-01
S01B	2 mm	0.1	1.11E-03	0.13	1.11E-03
S01B	7 mm	1.5	1.84E-03	1.5	1.90E-03
S01B	30 mm	27	5.16E-02	28	5.33E-02
S01B	100 mm	305	4.67E-01	314	4.76E-01
S01B	150 mm	686	7.90E-01	705	8.04E-01
S02A	2 mm	0.1	1.10E-03	0.11	1.10E-03
S02A	7 mm	1.3	1.54E-03	1.3	1.59E-03
S02A	30 mm	24	4.34E-02	24	4.47E-02
S02A	100 mm	262	4.23E-01	269	4.31E-01
S02A	150 mm	589	7.16E-01	606	7.29E-01
S03A	2 mm	0.1	1.10E-03	0.11	1.10E-03
S03A	7 mm	1.3	1.54E-03	1.3	1.59E-03
S03A	30 mm	24	4.34E-02	24	4.47E-02
S03A	100 mm	262	4.23E-01	269	4.31E-01
S03A	150 mm	589	7.16E-01	606	7.29E-01
S03B	2 mm	0.1	1.10E-03	0.08	1.09E-03
S03B	7 mm	1.1	1.24E-03	0.97	1.16E-03
S03B	30 mm	20	3.49E-02	18	3.13E-02
S03B	100 mm	221	3.80E-01	197	3.52E-01
S03B	150 mm	498	6.42E-01	444	5.95E-01
S03C	2 mm	0.1	1.09E-03	0.07	1.09E-03
S03C	7 mm	0.9	1.16E-03	0.90	1.16E-03
S03C	30 mm	16	2.80E-02	17	2.88E-02
S03C	100 mm	179	3.30E-01	184	3.36E-01
S03C	150 mm	402	5.59E-01	413	5.69E-01
S04A	2 mm	0.1	1.09E-03	0.06	1.09E-03
S04A	7 mm	0.9	1.16E-03	0.71	1.15E-03
S04A	30 mm	16	2.80E-02	13	2.18E-02
S04A	100 mm	179	3.30E-01	144	2.87E-01
S04A	150 mm	402	5.59E-01	324	4.86E-01
S05A	2 mm	0.1	1.09E-03	0.06	1.09E-03
S05A	7 mm	0.9	1.16E-03	0.71	1.15E-03
S05A	30 mm	16	2.80E-02	13	2.18E-02
S05A	100 mm	179	3.30E-01	144	2.87E-01
S05A	150 mm	402	5.59E-01	324	4.86E-01

QRA Event	Hole Size	Propane		LPG	
		Release Rate (kg/s)	Probability of Ignition	Release Rate (kg/s)	Probability of Ignition
S06A	2 mm	0.1	1.09E-03	0.06	1.09E-03
S06A	7 mm	0.9	1.16E-03	0.71	1.15E-03
S06A	30 mm	16	2.80E-02	13	2.18E-02
S06A	100 mm	179	3.30E-01	144	2.87E-01
S06A	150 mm	402	5.59E-01	324	4.86E-01
S07A	2 mm	0.01	1.04E-03	0.01	1.03E-03
S07A	7 mm	0.1	1.10E-03	0.07	1.09E-03
S07A	30 mm	1.7	2.10E-03	1.4	1.67E-03
S07A	100 mm	19	3.32E-02	15.27	2.63E-02
S07A	150 mm	42	8.40E-02	34	6.67E-02
S07B	2 mm	0.01	1.03E-03	0.003	1.02E-03
S07B	7 mm	0.1	1.09E-03	0.04	1.08E-03
S07B	30 mm	1.3	1.60E-03	0.72	1.15E-03
S07B	100 mm	15	2.53E-02	8.0	1.26E-02
S07B	150 mm	33	6.41E-02	18	3.20E-02
S07C	2 mm	0.01	1.04E-03	0.01	1.03E-03
S07C	7 mm	0.1	1.10E-03	0.07	1.09E-03
S07C	30 mm	1.7	2.07E-03	1.4	1.67E-03
S07C	100 mm	18	3.27E-02	15	2.63E-02
S07C	150 mm	-	-	-	-
S07D	2 mm	0.1	1.09E-03	0.04	1.08E-03
S07D	7 mm	0.7	1.15E-03	0.48	1.14E-03
S07D	30 mm	13	2.19E-02	8.8	1.40E-02
S07D	100 mm	144	2.88E-01	98	2.22E-01
S07D	150 mm	-	-	-	-
S08A	2 mm	0.01	1.03E-03	0.003	1.02E-03
S08A	7 mm	0.1	1.09E-03	0.04	1.08E-03
S08A	30 mm	1.3	1.60E-03	0.72	1.15E-03
S08A	100 mm	15	2.53E-02	8.0	1.26E-02
S08A	150 mm	33	6.41E-02	18	3.20E-02
S08B	2 mm	0.01	1.04E-03	0.004	1.02E-03
S08B	7 mm	0.1	1.10E-03	0.05	1.08E-03
S08B	30 mm	2.0	2.61E-03	0.91	1.16E-03
S08B	100 mm	23	4.12E-02	10	1.63E-02
S08B	150 mm	51	1.04E-01	23	4.14E-02
S09A	2 mm	0.01	1.04E-03	0.01	1.03E-03
S09A	7 mm	0.1	1.10E-03	0.07	1.09E-03
S09A	30 mm	1.7	2.10E-03	1.4	1.67E-03
S09A	100 mm	19	3.32E-02	15	2.63E-02
S09A	150 mm	-	-	-	-

QRA Event	Hole Size	Propane		LPG	
		Release Rate (kg/s)	Probability of Ignition	Release Rate (kg/s)	Probability of Ignition
S10A	2 mm	0.1	1.09E-03	0.05	1.08E-03
S10A	7 mm	0.7	1.15E-03	0.64	1.15E-03
S10A	30 mm	13	2.19E-02	12	1.94E-02
S10A	100 mm	144	2.88E-01	130	2.69E-01
S10A	150 mm	325	4.87E-01	292	4.54E-01
S11A	2 mm	0.1	1.09E-03	0.05	1.08E-03
S11A	7 mm	0.7	1.15E-03	0.64	1.15E-03
S11A	30 mm	13	2.19E-02	12	1.94E-02
S11A	100 mm	144	2.88E-01	130	2.69E-01
S11A	150 mm	325	4.87E-01	292	4.54E-01
S12A	2 mm	0.01	1.03E-03	0.003	1.02E-03
S12A	7 mm	0.1	1.09E-03	0.04	1.08E-03
S12A	30 mm	1.3	1.56E-03	0.72	1.15E-03
S12A	100 mm	14	2.47E-02	8.0	1.26E-02
S12A	150 mm	-	-	-	-
S13A	2 mm	0.1	1.09E-03	0.05	1.08E-03
S13A	7 mm	0.7	1.15E-03	0.64	1.15E-03
S13A	30 mm	13	2.19E-02	12	1.94E-02
S13A	100 mm	144	2.88E-01	130	2.69E-01
S13A	150 mm	-	-	-	-
S14A	2 mm	0.01	1.03E-03	0.003	1.02E-03
S14A	7 mm	0.1	1.09E-03	0.04	1.08E-03
S14A	30 mm	1.3	1.56E-03	0.72	1.15E-03
S14A	100 mm	14	2.47E-02	8.0	1.26E-02
S14A	150 mm	-	-	-	-
S15A	2 mm	0.1	1.09E-03	0.05	1.08E-03
S15A	7 mm	0.7	1.15E-03	0.64	1.15E-03
S15A	30 mm	13	2.19E-02	12	1.94E-02
S15A	100 mm	144	2.88E-01	130	2.69E-01
S15A	150 mm	-	-	-	-
S16A – S38A	2 mm	0.01	1.04E-03	0.004	1.02E-03
S16A – S38A	7 mm	0.1	1.10E-03	0.05	1.08E-03
S16A – S38A	30 mm	1.7	2.10E-03	0.84	1.16E-03
S16A – S38A	100 mm	19	3.32E-02	9.4	1.50E-02
S16A – S38A	150 mm	42	8.40E-02	21	3.81E-02

Appendix 4.
Assumptions Register (inc. approval correspondence)

LIQUIGAS

Woolston LPG Depot
Assumptions Register for QRA

503402-TCN-R0001
September 2017

WorleyParsons New Zealand Ltd
25 Gill Street, New Plymouth 4310
PO Box 705, New Plymouth 4340

Telephone +64-6-759 6300
Facsimile +64-6-759 6301

www.worleyparsons.com

Rev	Description	Originator	Reviewer	WorleyParsons Approver	Date	Client Approval	Date
A	Issued for Review/Comment	Y Lee	D Phillis	D Phillis	09/2017		

Y:\Liquigas\503402\2.Controlled Docs\503402-TCN-R0001-RA.docx

TABLE OF CONTENTS

1 ABBREVIATIONS

BLEVE	Boiling Liquid Expanding Vapour Explosion
DNV GL	Det Norske Veritas Germanisher Lloyd
ESDV	Emergency Shutdown Valve
HCRD	Hydrocarbon Releases Database
HIPAP4	Hazardous Industry Planning Advisory Paper No. 4
LFL	Lower Flammable Limit
LOC	Loss of containment
LPG	Liquefied Petroleum Gas
LSIR	Location Specific Individual Risk
ME	Multi-Energy
NAP	Normal Atmospheric Pressure
P&ID	Piping and Instrumentation Diagrams
QRA	Quantitative Risk Assessment
UK HSE	United Kingdom Health and Safety Executive
UKOOA	UK Offshore Operators Association
VCE	Vapour Cloud Explosion

2 ASSUMPTIONS

2.1 Introduction

This document sets out the assumptions to be used for a Quantitative Risk Assessment (QRA) for the Liquigas Woolston Liquefied Petroleum Gas (LPG) Depot. The overall methodology and general assumptions for the QRA shall be consistent with the WorleyParsons Onshore QRA Method Statement – using Phast Risk (PCD-473) [Ref. 1].

2.2 Scope of Work

The scope for the Liquigas Woolston LPG Depot QRA covers the following:

1. Existing Woolston LPG depot facilities
2. Proposed LPG Storage Upgrade facilities

The scope for the QRA begins at the first pipeline section that emerges from underground within the plant boundary. The QRA model will be set up using DNV GL Phast Risk version 6.7 [Ref. 2].

2.3 Parts Count Methodology

2.3.1 Definition of Parts Count Sections

Each potential leak source will be associated with a particular isolatable inventory. Primarily the isolatable inventories will be defined by emergency shutdown valve (ESDV) boundaries. These sections may be further broken down where warranted; however, the entire contained inventory will be considered as available for release. Further breakdown may be warranted due to:

- Significant change in operating parameters (temperature and pressure)
- Significant change in stream composition
- Change in stream phase
- Equipment location

At isolatable boundaries, the valve will be assumed as the last component of the upstream inventory.

The following potential release points are excluded from the parts count:

- For normally closed valves, both the valve and upstream flange will be counted, but not any equipment items downstream of the valve unless this is exposed to a live inventory (e.g. on a bypass line).
- If a cap or blind flange is shown against a valve, it is assumed to be closed, even if not indicated as such.

2.3.2 Components

The definition of components within the parts count will be aligned with failure rate data published in the DNV Failure Frequency Guidance [Ref. 3]. The parts count will consider the following:

- Equipment items
- Valves
- Flanges

- Instrumentation and small bore fittings
- Pipework

The parts count will be recorded in an MS Excel spreadsheet, with each section broken down by piping and instrumentation diagrams (P&IDs). Marked up P&IDs will be attached with the QRA report. The P&IDs will be sourced from the following references:

- Woolston LPG Depot facilities – BlueCielo Meridian Web database for Liquigas.
- Proposed LPG storage upgrade facilities – Woolston LPG Depot Storage Upgrade project (WorleyParsons Project Number 500929).

Equipment that are on standby are normally not considered in the QRA, this includes:

- Only two LPG compressors (out of five) (K-0601/3/5/6/7) will be considered.

Note 1: As per P&ID CCH-15-0116, Rev. 10 (sheet 1 of 2), the LPG Compressor Suction Vessels (V-0615/V-0616) were shown as in duty/standby configuration. However, as confirmed with the Woolston depot supervisor [Ref. 4], both suction vessels are in used and hence will be included.

2.4 Failure Frequency Data and Hole Size Distributions

2.4.1 General Leak Frequencies

The leak frequencies for process equipment, pressurized storage vessel and tanks in general will be taken from the DNV Failure Frequency Guidance [Ref. 3]. DNV's data is derived from the Hydrocarbon Release Database (HCRD) which has been compiled by the UK HSE over a 20 year period, and is subsequently amended (smoothed) by DNV.

Failure frequency data from the HCRD contains detailed historical information on offshore hydrocarbon release incidents occurring in the UK offshore environment, and is considered an industry standard for offshore QRA applications. The database categorises failure rates on a detailed basis of equipment type and size, and provides a probabilistic hole size distribution associated with the failure.

The HCRD data are also normally used for QRA at onshore facilities, although the use of offshore failure rate may considered to be conservative for use in most onshore applications, on the basis that:

- Offshore environments tend to be harsher, both external (saliferous environment) and internal (produced sand), increasing the rate of equipment corrosion and erosion;
- Congestion at offshore facilities increases the likelihood of damage through impact; and
- Restricted access to offshore facilities may limit maintenance campaigns, increasing the likelihood of failure.

There is inadequate industry data to estimate the frequencies of failures of buried or mounded vessels/tanks. Industry guidance also notes that a leak from a buried or mounded vessel/tank is likely first to be into the surrounding soil and may not reach the open air; even if it does, it may not eject the intervening soil and so be limited in in rate and velocity by this [Ref. 5]. Given this uncertainty in release frequency data for a mounded vessel and the expected insignificant contribution to the risk profile of the site, a release frequency from the body of the mounded LPG vessel has not been assigned. However, releases from nozzles, piping connections and instrumentation connected to the mounded vessel will be included.

DNV Failure Frequency Guidance (or HCRD) does not contain leak information for road transport units for loading/unloading activities that may be present in an establishment. Frequencies of loss of containment (LOC) for road tankers will be taken from the TNO Purple Book [Ref. 6], which are shown in Table 2-1.

Table 2-1: Frequencies of LOCs for Road Tankers and Tank Wagons in an Establishment

LOC for Road Tankers and Tank Wagons in an establishment	Tanker, Pressurised
Instantaneous release of the complete inventory	5×10^{-7} per year
Continuous release from a hole size of the largest connection	5×10^{-7} per year
Full bore rupture of the loading/unloading arm	3×10^{-8} per hour
Leak of the loading/unloading arm (10% of the nominal diameter, with a maximum of 50 mm)	3×10^{-7} per hour
External impact	In general, LOC for road tanker accident do not have to be considered if measures have been taken to reduce road accidents, e.g. speed limits.
Fire under tank	Note 1

Note 1: Fire under a road tanker may lead to the instantaneous release of the complete inventory of the road tanker. Various causes of failure may lead to a fire under a tanker:

- Leakage of the connections under the tanker followed by ignition:
  - 1×10^{-6} per year (pressurised tanker)
- Fire in the surroundings of the tanker. The failure frequency is determined by the local situation. Important aspects are the presence of flammable inventories nearby and failure during loading/unloading of flammable substances. This will be considered on case-by-case basis.

For LPG road tanker unloading, 45 loading operations per week is assumed with each loading operation taking up to 45 minutes. The loading arms remain pressurised up to the SDVs even when not loading.

Hole Sizes

For every component failure, there is a range of credible hole sizes ranging from pinhole leak to full bore rupture. The hole size grouping from the DNV Failure Frequency Guidance together with the representative hole sizes to be used in the QRA is as follows:

Table 2-2: Hole Size Distribution

DNV Hole Size Group (mm)	QRA Hole Representation (mm)
1 - 3	2
3 - 10	7
10 - 50	30
50 - 150	100
>150	Full bore rupture

2.5 Pigging Frequency

A pig receiver (LYT-V-0213) is located at the Woolston facility for retrieval of the pig or sphere used to clean, condition and/or monitor the pipeline from the port. Pigging is assumed to be a half day operation that is performed once a year [Ref. 7].

Table 2-3: Pigging Frequency and Modification Factor

Description	Average Pigging Frequency (per year)	Average Pigging Duration (hours)	Modification Factor
Pig Receiver (LYT-V-0213)	1	12	0.0014

2.6 Hazardous Material on-site and Consequences

The only hazardous material considered in the QRA is LPG (propane and butane). The composition of LPG varies between winter and summer. The facility normally handles propane in winter as it is more suitable for the South Island winter market, but it can also handle product from 50/50 (propane/butane) mix to 100% propane. For the purpose of QRA, it is assumed that the facility is handling 100% propane for 6 months per year, and 60/40 propane/butane (mole fraction) mix for the other 6 months. Propane has a flash point of -156°C with the flammability limit ranges from 2.1% to 9.5%. Butane has a flash point of -76°C with the flammability limit ranges from 1.8% to 8.4%.

LPG is normally maintained as liquid under pressure. Pressurised release can either be liquid, which quickly vaporises, or in the gaseous mixture (2-phase). LPG releases will be modelled as flash fire and jet fire (spray fire) with the possibility of rainout or pool fire. LPG gas is heavier than air, once ignited, the flame can flash back to the leak source. Vapour cloud explosion (VCE) will be modelled with reference to the expected level of congestion (see Section 2.10.4).

2.7 Release Scenarios

Release Rates

Release rates will be calculated based on the release hole sizes and fluid pressure. Table 2-4 shows the approximate isolatable hydrocarbon inventories contained within the LPG equipment together with the operating conditions (pressure and temperature).

Table 2-4: Operating Conditions and Inventory

System	Operating Pressure Note 1 (barg)	Operating Temperature (°C)	Material Phase	Volume (m^3)
Existing Woolston LPG Depot Facilities				
Aboveground liquid pipeline (LPG) – during ship discharge (assume 38 ship discharges per year)	28	12	Liquid	230
Aboveground liquid pipeline (LPG) – no ship discharge (pipeline resting on LPG for 327 days per year)	38	12	Liquid	230
Ship unloading line (upstream of PCV-0216A)	28	12	Liquid	5
Ship unloading line (downstream of PCV-0216A)	15 - 20	12	Liquid	5
Ship unloading line (downstream of PCV-0217A)	13	12	Liquid	5
Liquid rundown header	10.3	12	Liquid	2
Road tanker loadout (liquid) – during loading	6.5 - 8.5	20	Liquid	0.1

System	Operating Pressure Note 1 (barg)	Operating Temperature (°C)	Material Phase	Volume (m^3)
Road tanker loadout (vapour) – during loading	3 - 6.5	20	Vapour	0.1
Road tanker loadout (liquid) – when not loading	6.5 - 8.5	20	Liquid	0.1
Road tanker loadout (vapour) – when not loading	3 - 6.5	20	Vapour	0.1
Auxiliary despatch header	6.5 - 8.5	12	Vapour	4.5
Compressor suction header	3 - 6.5	12	Vapour	0.72
Compressor discharge header	6.5 - 8.5	20	Vapour	0.72
LPG compressors	4 - 10.5	20	Vapour	0.72
Storage and Despatch Vessels (each)	3 - 8.5	12	Vapour Note 2	171 (100 tonne)
Note 1: The lower pressure is for handling 60/40 propane/butane mixed LPG whereas the higher pressure is for handling propane. Note 2: Releases from the LPG vessels will be modelled as vapour phase only.				
Proposed Storage Upgrade Facilities				
Storage Vessels (V-0521, V-0522 and V-0523) (each)	8.5	12	Vapour Note 2	500 tonne
Header extensions (liquid and vapour headers to be extended by approximately 20 – 25 m to connect with new vessels)	As per the conditions for the respective headers as above.			

The total volume released is driven by either the release rate prior to isolation or the stored volume available for release post isolation (estimated by equipment sizes and locations of isolation valves). For each release case, the worst case scenario (release at operating pressure until detection) is determined and used as representative for the release cases. For modelling purposes, the following release assumptions will be applied:

- Release of the entire inventory is assumed (implying the release is at the low point)
- Jet fires are modelled based on the initial release conditions, and do not take into account of the depressurisation that occurs over time

It is important to note that regardless of volume, the LPG release rate from a mounded vessel or a header is essentially constant, given that the pressure in the equipment will be maintained at the saturated vapour pressure. As the volume of vapour in the equipment decreases due to outflow (through the release point), the LPG will vaporise (boil) to maintain the containment pressure.

Release Location and Containment

Releases from the LPG vessels will be modelled as releases from the vapour space only. As the LPG vessels are mounded, release in liquid phase will not be modelled due to containment within the mounded structure protecting the vessels. Flanges, instrumentation and connections are in the vapour space of the vessel and there are no flanges or connections in the liquid space.

The height of release from all scenarios will be assumed to be at 1 m above ground with the exception of releases from the mounded vessels where the height of release will be assumed to be at 5 m above ground. It is considered reasonable to assume 70% of the releases are horizontal release and 30% of the releases are vertical release.

2.8 Environmental Conditions for Modelling

Meteorological conditions impact the outcomes of release modelling, including downwind flammable and toxic vapour cloud dispersion distance (influenced by atmospheric stability and wind speed), rate of pool vaporisation (ambient temperature), and atmospheric attenuation of radiant heat (temperature and relative humidity).

The weather data for Christchurch Aerodrome station (station number 4843) was obtained from the New Zealand National Climate Database [Ref. 8] for time period 2008 - 2012. The windrose is shown in Figure 2-1.

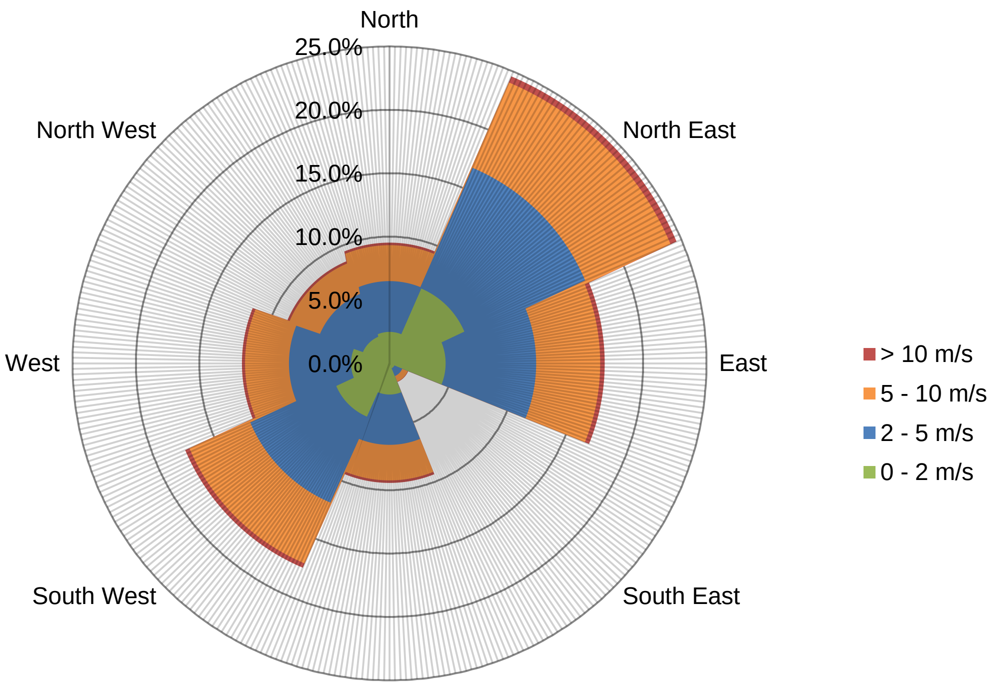


Figure 2-1: Christchurch Aero Windrose

The following wind speed and atmospheric stability (Pasquill stability) combinations will be used in the QRA. The wind data in tabular format is given in Table 2-5.

Table 2-5: Christchurch Aero Wind Data

Wind Speed / Pasquil Stability	North	North East	East	South East	South	South West	West	North West	Total
0 - 2 m/s / F	2.5%	6.4%	4.4%	0.4%	2.5%	4.6%	3.0%	2.3%	26.1%
2 - 5 m/s / D	4.0%	10.3%	7.1%	0.7%	4.0%	7.4%	4.9%	3.7%	42.1%
5 - 10 m/s / D	3.0%	7.8%	5.4%	0.5%	3.0%	5.6%	3.7%	2.8%	31.9%
Total	9.5%	24.6%	17.0%	1.6%	9.4%	17.5%	11.6%	8.7%	100.0%

Note:

1. Pasquill Stability F – stable, night with moderate clouds and light/moderate wind
2. Pasquill Stability D – neutral, little sun and high wind or overcast/windy night

The following weather parameters taken from the same weather station will also be used for modelling in the QRA:

- Mean air temperature: 11.5°C
- Relative humidity: 82.2%

For dispersion modelling, surface roughness of 0.10 m will be applied, representative of an area with "low crops, occasional large obstacles".

In this study, no allowance for solar radiation will be included.

2.9 Ignition Probabilities

Given a release, the probability of ignition is dependent on a range of factors, including:

- Release rate
- Material state (liquid or gas)
- Material physical properties (flash point, density, flammable limits)
- Ignition sources present

There are a range of correlations for applying an ignition probability to a release, and most are based on release rate and state. The UK Offshore Operators Association (UKOOA) has generated a model for predicting ignition probability [Ref. 9] which takes into account the above, as well as the nature of the surrounding area with respect to potential ignition sources. This model has been used to generate a range of typical correlations. For this QRA, the following scenario will be used:

- Scenario 8 - "Large plant gas LPG (gas or LPG release from large onshore plant)", which is applicable for releases of flammable gases, vapour or liquids significantly above their normal (normal atmospheric pressure (NAP)) boiling point from large onshore plants (plant area above 1200 m^2, site area above 35,000 m^2).

Note that Scenario 8 is assumed to particularly apply to LPG 'plant' whereby LPG processing takes place. This may be a conservative correlation for the Woolston Depot as it is a storage facility only. An alternative correlation model from the same reference is Scenario 5 – "Small plant gas LPG (gas or LPG release from small onshore plant; plant area below 1200 m^2, site area above 35,000 m^2). However, for the purpose of this QRA Scenario 8 is considered more representative of the Woolston site due to the size of the site and the proximity of neighbouring facilities and Chapmans Road.

The graphs for ignition probabilities as a function of mass release rates are shown in Figure 2-2. For comparison, Figure 2-2 includes the correlations for Scenario 5 and it shows that the ignition probabilities for the two scenarios are similar and hence are not expected to lead to significant differences in the risk results. Also included are the Cox, Lee, Ang ignition probability correlations which are sometimes used in QRA studies, but have been questioned by the UKOOA guidance.

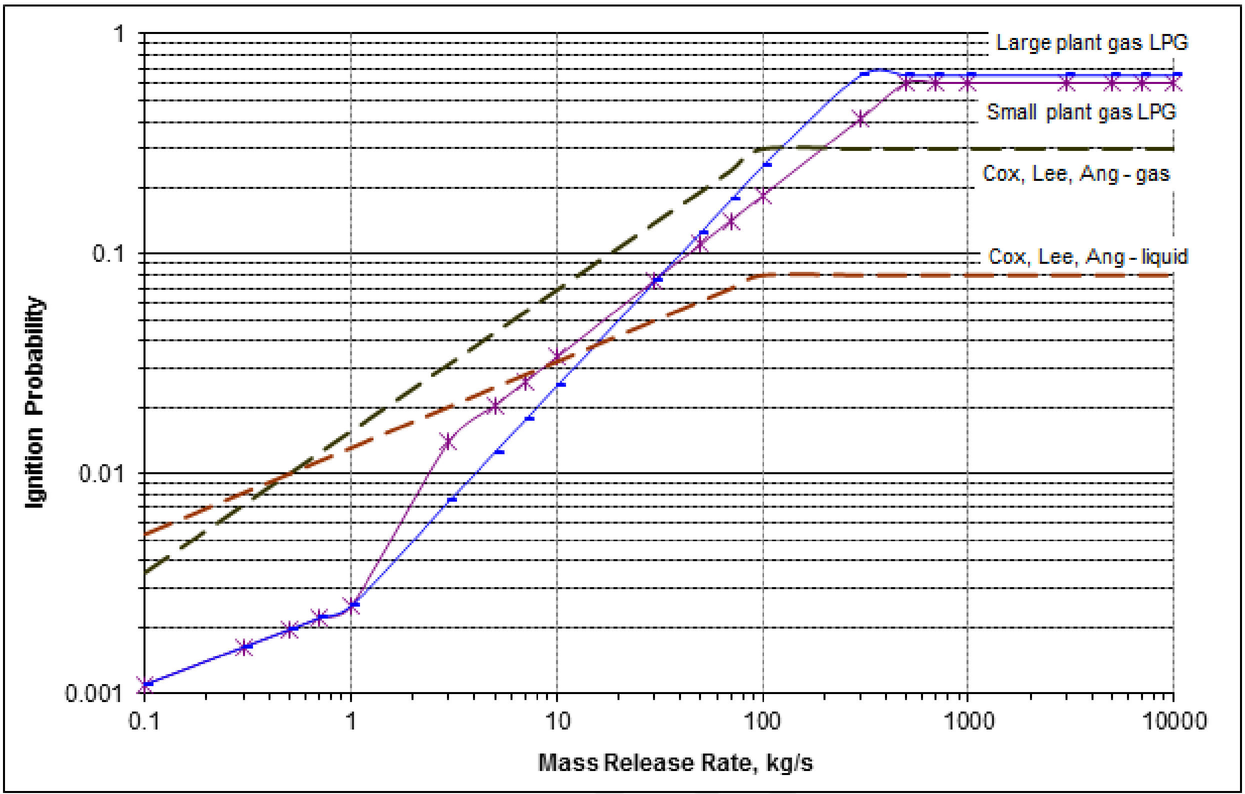


Figure 2-2: Ignition Probability

The graphs represent total ignition probability. An overall distribution for early to delayed ignition ratio of 30:70 to 50:50 split is considered reasonable. For this QRA, a 50:50 split for immediate: delayed ignition probability will be used given the location in an industrial area and the proximity of Chapmans Road.

The timing of ignition is used as a means to predict the nature of the ignited event. Early ignition is taken to indicate a jet fire or pool fire depending on the material concerned. Delayed ignition is taken to indicate that the ignition would initially result in a flash fire or explosion.

2.10 Fatality Criteria

2.10.1 Thermal Radiation

The method of calculating the probability of fatality for an individual, given known exposure duration and thermal heat radiation levels, is undertaken in Phast Risk by using a probit function. The probit function is a general formula which takes the same form, but with various constants used. The probit used for lethality calculations is taken from the TNO Green Book [Ref. 10]. The probit function is defined as follows:

Probit = $-36.38 + 2.56 \ln (t \times q^{4/3})$

Where:

t = exposure duration in seconds

q = thermal radiation level in W/m^2

An exposure duration of 20 seconds has been used as a base case, although it is noted that personnel are likely to find some form of shielding protection within this time frame.

The NSW Hazardous Industry Planning Advisory Paper No. 4 (HIPAP4) [Ref. 11] provides the following broadly qualitative consequences to thermal radiation for information:

- 2.1 kW/m^2 – Minimum to cause pain after 1 minute
- 4.7 kW/m^2 – Will cause pain in 15 – 20 s and injury (at least 2nd degree burns) after 30s exposure. Considered the criterion for injury risk, at a tolerable frequency of 50 chances in a million per year
- 12.6 kW/m^2 – Significant chance of fatality for extended exposure. High chance of injury
- 23 kW/m^2 – Likely fatality for extended exposure, and chance of fatality for instantaneous exposure
- 35 kW/m^2 – Significant chance of fatality for people exposed instantaneously

2.10.2 Flash Fire

If personnel are within the 100% lower flammable limit (LFL) of the gas plume, 100% fatality is assumed.

2.10.3 Boiling Liquid Expanding Vapour Explosion (BLEVE)

BLEVE is an escalation event due to prolonged flame impingement onto pressurised vessels. The probability of BLEVE is dependent on various factors including the types of flammable material and liquid inventory in the vessel, material of construction for the vessel, types and numbers of fire protection systems (e.g. relief valves, cooling systems), mechanism of vessel failure (external impact, jet fire impingement or pool fire impingement), etc. As such, there is no clear guideline or criteria to determine if a BLEVE is credible on a pressure vessel, and the following assumptions will be adapted.

For mounded vessels, escalations to the LPG storage vessels due to flame impingement or mechanical impact are not considered credible due to the protection provided by the mound. In this QRA, mounded vessels BLEVE will not be considered.

For a road tanker, the external impact loss of containment is determined by the local situation. As per TNO Purple Book [Ref. 6], in general, the loss of containment for road tanker accidents do not have to be considered in the QRA model in a location if measures have been taken to reduce road accidents, like speed limits. Drainage will be provided for the truck loading bay, therefore prolonged pool fire impingement onto the truck is not likely. Deluge cages are also provided for the loading bays for cooling of the road tankers. Therefore the probability of BLEVE for a road tanker will be excluded in the QRA.

2.10.4 Vapour Cloud Explosion

VCE are modelled in Phast Risk using Extended Explosion Modelling, which is an extension in Phast Risk. The extended explosion method allows the definition of regions of congestion and confinement. The calculations then consider the interactions between the dispersing cloud and these regions, and calculate the pattern of overpressure across these regions. The relationship between overpressure and fatality probability for different groups of people (e.g. for people in different types of building) can also be defined. The Multi-Energy Method (ME) is selected for the explosion modelling.

A potential congested area has been identified around the piperack area as shown in Figure 2-3.

Figure 2-3: Congested Area on site

The dimensions and other inputs are given in Table 2-6.

Table 2-6: Inputs for Multi-Energy Explosion Congested Area

Congested Area	Dimensions (m)			Multi-Energy Curve	Volume Blockage Ratio
	Width	Length	Height		
1	12	65	2.5	5	0.2

Where:

- Multi-Energy Curve – describes the behaviour of an explosion in terms of the explosion strength. There are ten multi-energy blast curves, between 1 for the weakest explosion and 10 for the strongest. Blast strength number 7 is normally representative of a strong deflagration and blast strength number 10 is normally representative of a detonation.

  The TNO Yellow Book [Ref. 12] provides the guidance in the choice of the source strength base on the three factors: the degree of obstruction by obstacles inside the vapour cloud, ignition energy and degree of confinement. Nonetheless, the Yellow Book also recommends to be conservative in the choice of a source strength for the initial blast.

  For this study, blast strength number 5 is assumed to represent the average explosion strength.

- Volume Blockage Ratio – fraction of the volume of the obstructed region that is occupied by obstructions; or the ratio between volume of all obstacles and total volume of the obstructed region.

  For this study, a blockage ratio of 0.2 is assumed to represent an area of low blockage.

2.11 Risk Criteria

The key deliverable for this study is the location specific individual risk (LSIR) in the form of risk contours. LSIR is the risk of fatality at a point in space to a hypothetical individual at a location for 365 days per year, 24 hours a day, unprotected and unable to escape.

As there are no standard risk criteria which have been developed for the NZ context, this deliverable will be assessed against the suggested risk criteria in the NSW Hazardous Industry Planning Advisory Paper No. 4 (HIPAP4) “Risk Criteria for Land Use Planning” [Ref. 11] as shown in Table 2-7.

Table 2-7: HIPAP4 Individual Fatality Risk criteria

Land Use	Risk Criteria Adopted (per annum)	Interpretation for QRA
Hospitals, schools, childcare facilities, old age housing	0.5×10^{-6} (or 5×10^{-7}) (1 in 2 million)	5×10^{-7} risk contour should not extend to these areas
Residential, hotels, motels, tourist resorts	1×10^{-6} (1 in 1 million)	1×10^{-6} risk contour should not extend to these areas
Commercial developments including retail centres, offices and entertainment centres	5×10^{-6} (1 in 200,000)	5×10^{-6} risk contour should not extend to these areas
Sporting complexes and active open space	10×10^{-6} (or 1×10^{-5}) (1 in 100,000)	1×10^{-5} risk contour should not extend to these areas
Industrial	50×10^{-6} (or 5×10^{-5}) (1 in 20,000)	5×10^{-5} risk contour should, as a target, be contained within the boundaries of the industrial site where applicable

3 REFERENCE

1. WorleyParsons' New Zealand Onshore QRA Method Statement – Using Phast Risk, PCD-473, Rev. A, May 2015.
2. DNV GL Phast Risk software, version 6.7.
3. DNV Failure Frequency Guidance, 'Process Equipment Leak Frequency Data for use in QRA', 2012.
4. Email communication between Y'vette Lee (WorleyParsons NZ) and Les Nelson (Liquigas) dated 30 September 2016.
5. Risk Assessment Data Directory – Storage incident frequencies, Report No. 434-3, International Association of Oil and Gas Producers, March 2010.
6. Guideline for Quantitative Risk Assessment 'TNO Purple Book' (CPR18E), December 2005.
7. Christchurch LPG Depot, Offsite Risk Assessment, 500801-RPT-R0002-R0, June 2008.
8. New Zealand National Climate Database (http://cliflo.niwa.co.nz/).
9. Ignition Probability Review, Model Development and Look-Up Correlations, Research Report published by the Energy Institute, January 2006. ISBN 978 0 85293 54 8.
10. Methods for the Determination of Possible Damage to People and Objects Resulting from Release of Hazardous Materials 'TNO Green Book' (CPR 16E), 1st Ed. 1992.
11. Hazardous Industry Planning Advisory Paper No. 4 (HIPAP4), Risk Criteria for Land Use Safety Planning, January 2011.
12. Methods for the Calculation of Physical Effects – due to releases of hazardous materials (liquids and gases) 'TNO Yellow Book' (CPR 14E), November 2005.

From:	Gary Heaven
To:	Phillis, Damian (New Plymouth); Les Nelson
Cc:	Lee, Yvette (New Plymouth)
Subject:	RE: 503402-TCN-R0001
Date:	Wednesday, 13 September 2017 7:31:51 p.m.
Attachments:	image001.jpg

Thanks Damian, it all looks good to me.

Gary Heaven | Operations & Safety Manager | Liquigas Ltd
84 Liardet St, New Plymouth
P 06 759 0564
M 027 442 9024

From: Phillis, Damian (New Plymouth) [mailto:Damian.Phillis@WorleyParsons.com]
Sent: Wednesday, 13 September 2017 4:04 p.m.
To: Gary Heaven <Gary.Heaven@liquigas.co.nz>; Les Nelson <Les.Nelson@liquigas.co.nz>
Cc: Lee, Yvette (New Plymouth) <Yvette.Lee@WorleyParsons.com>
Subject: FW: 503402-TCN-R0001

Gary/Les,
Can you please review the attached Assumptions Register for the Woolston QRA Update. This is based on information agreed for some previous QRA work at Woolston for Project Gateway; however, a key purpose of this Register is to align these QRA assumptions with those being adopted for the QRA of the Woolston Mobil Terminal so that the basis for the Risk Management Areas in the District Plan are consistent.
Cheers – Damian.

Damian Phillis
Specialist Safety & Risk Engineer, WorleyParsons
25 Gill Street, New Pymouth 4310, New Zealand
T: +64 6 759 6468 M: +64 21 846 308 | GMT + 12:00
www.worleyparsons.com

From:	Les Nelson
To:	Lee, Yvette (New Plymouth)
Cc:	Phillis, Damian (New Plymouth); Gary Heaven
Subject:	RE: 503402-TCN-R0001
Date:	Monday, 18 September 2017 3:58:15 p.m.
Attachments:	image001.jpg image002.jpg

All looks good thanks Y'vette.

Les.

Les Nelson | Depot Supervisor | **Liquigas Ltd**

A 50 Chapmans Road, PO Box 19-715, Woolston, Christchurch 8241
P 03 384 2481 | **M** 027 442 5506

From: Lee, Yvette (New Plymouth) [mailto:Yvette.Lee@WorleyParsons.com]
Sent: Monday, 18 September 2017 1:45 p.m.
To: Les Nelson <Les.Nelson@liquigas.co.nz>
Cc: Phillis, Damian (New Plymouth) <Damian.Phillis@WorleyParsons.com>; Gary Heaven <Gary.Heaven@liquigas.co.nz>
Subject: RE: 503402-TCN-R0001

Hi Les,

Just to follow up with you whether you have any comments on the Assumptions for the Woolston QRA update? The assumptions are basically the same for the previous QRA that we discussed last year.

Please let me know if you need any clarification.

Thank you.

Regards,

Y'vette Lee
Senior Safety and Risk Engineer, WorleyParsons
25 Gill Street, New Plymouth 4310 New Plymouth
T: +64 6 7596783 | GMT + 12:00
www.worleyparsons.com

From: Phillis, Damian (New Plymouth)
Sent: Wednesday, 13 September 2017 4:04 p.m.
To: Gary Heaven (Gary.Heaven@liquigas.co.nz); Les Nelson (Les.Nelson@liquigas.co.nz)
Cc: Lee, Yvette (New Plymouth)
Subject: FW: 503402-TCN-R0001

Gary/Les,
Can you please review the attached Assumptions Register for the Woolston QRA Update. This is based on information agreed for some previous QRA work at Woolston for Project Gateway; however, a key purpose of this Register is to align these QRA assumptions with those being adopted for the QRA of the Woolston Mobil Terminal so that the basis for the Risk Management Areas in the District Plan are consistent.
Cheers – Damian.

Damian Phillis
Specialist Safety & Risk Engineer, WorleyParsons
25 Gill Street, New Pymouth 4310, New Zealand
T: +64 6 759 6468 M: +64 21 846 308 | GMT + 12:00
www.worleyparsons.com

APPENDIX 2 – WOOLSTON OIL TERMINAL QUANTITATIVE RISK ASSESSMENT

MOBIL WOOLSTON TERMINAL

QUANTITATIVE RISK ASSESSMENT

FOR DETERMINATION OF PLANNING OVERLAY

MOBIL OIL NEW ZEALAND LIMITED

PREPARED FOR:	**Christchurch Terminals Manager**
DOCUMENT NO:	**21086-RP-002**
REVISION:	**0**
DATE:	**22-Jun-2018**

Sherpa Consulting Pty Ltd (ABN 40 110 961 898)
Phone: 61 2 9412 4555
Web: www.sherpaconsulting.com

DOCUMENT REVISION RECORD

Rev	Date	Description	Prepared	Checked	Approved	Method of issue
A	06-Oct-17	Draft for discussion	M Braid	J Polich	G Peach	Email PDF
0	22-Jun-2018	Final issue	M Braid	J Polich	G Peach	Email PDF

RELIANCE NOTICE

This report is issued pursuant to an Agreement between SHERPA CONSULTING PTY LTD ('Sherpa Consulting') and Mobil Oil New Zealand Limited which agreement sets forth the entire rights, obligations and liabilities of those parties with respect to the content and use of the report.

Reliance by any other party on the contents of the report shall be at its own risk. Sherpa Consulting makes no warranty or representation, expressed or implied, to any other party with respect to the accuracy, completeness, or usefulness of the information contained in this report and assumes no liabilities with respect to any other party's use of or damages resulting from such use of any information, conclusions or recommendations disclosed in this report.

Title:	**QA verified:**
Mobil Woolston Terminal Quantitative Risk Assessment For Determination of Planning Overlay	R Bush
	Date: 22-Jun-2018

CONTENTS

TABLES

FIGURES

ABBREVIATIONS

AGO	Automotive Gasoline Oil (diesel)
ATG	Automatic Tank Gauging
AWS	Automatic Weather Station
CCC	Christchurch City Council
CCPS	Center for Chemical Process Safety
CDP	Christchurch District Plan
CFD	Computational Fluid Dynamics
DPE	Department of Planning and Environment (NSW)
ESD	Emergency Shutdown
GSQ	George Seymour Quay
HHLA	High High Level Alarm
HIPAP	Hazardous Industry Planning Advisory Paper
IBC	Intermediate Bulk Container
IFR	Internal Floating Roof
LFL	Lower Flammability Limit
LWPL	Lyttelton–Woolston Pipeline
MAPP	Major Accident Protection Policy
MHF	Major Hazard Facility
NB	Nominal Bore
NSW	New South Wales
NZ	New Zealand
OGP	Oil and Gas Producers
PGA	Peak Ground Acceleration
PULP	Premium Unleaded Petroleum
QRA	Quantitative Risk Assessment
SFARP	So Far As Reasonably Practicable
UFL	Upper Flammability Limit
UK HSE	United Kingdom Health and Safety Executive
ULP	Unleaded Petroleum
VCA	Vapour Cloud Assessment
VCE	Vapour Cloud Explosion

TERMINOLOGY

Annual Individual Fatality Risk (natural hazards)	The term “annual individual fatality risk (AIFR)” is commonly used in various natural hazards risk assessments in NZ. This is the risk of fatality to a person at a location including factors for probability of presence/exposure. Note: The natural hazards AIFR has a different basis to the individual fatality risk definition used in land use safety planning in the vicinity of hazardous facilities (as defined below) as the natural hazards AIFR calculation includes factors for probability of exposure/probability of presence. The term AIFR is <u>not</u> used in this QRA report.
Combustible liquid	Any liquid, other than a flammable liquid, that has a flash point, and has a fire point that is less than its boiling point (AS 1940–2004). AGO (i.e. diesel) is an example of a combustible liquid considered in this study.
Consequence	Outcome or impact of a hazardous incident, including the potential for escalation.
Flammable liquid	Liquids [...] which give off a flammable vapour at temperatures of not more than 60.5°C, closed cup test, or not more than 65.6°C, open cup test, normally referred to as the flash point (AS 1940–2004). PMS and RMS (i.e. gasoline) are examples of flammable liquids considered in this study.
Flash fire	The combustion of a flammable vapour and air mixture in which flame passes through that mixture at low velocity, such that negligible overpressure is generated.
Flash point	The lowest temperature, corrected to a barometric pressure of 101.3 kPa, at which application of a test flame causes the vapour of the test portion to ignite under the specified conditions of test (AS 1940–2004).
Gasoline	Synonymous with petrol, gasoline is the common term used in the refining industry to cover all grades of petrol, e.g. premium, regular.
Heat radiation	The propagation of energy in the infra-red region of the radiation electromagnetic spectrum, commonly ‘heat'.
Individual fatality risk	For land use safety planning this is the annual risk of fatality to a notional person at a particular point assuming exposure to the risk 24 hours a day and 365 days per year, i.e. it does not account for probability of presence. Note: This is a different basis to the term AIFR used in natural hazards risk assessment which includes factors for probability of exposure/probability of presence. To avoid confusion with the natural hazards work, the term AIFR is not used in this QRA.
Individual risk	The frequency at which an individual may be expected to sustain a given level of harm from the realization of specified hazards. In this study the level of harm assessed is fatality.
Injury risk	The frequency of injury occurring to a theoretical individual located permanently at a particular location, assuming no mitigating action such as escape can be taken. For fire events this corresponds to a heat radiation level of 4.7 kW/m^2 (HIPAP 4).
Jet/spray fire	An intense directional fire resulting from ignition of a vapour or two phase release with significant momentum (i.e. pressurised) from an orifice (can occur at pressure 2barg or above).

Lower Flammability Limit (LFL)	That concentration in air of a flammable material below which combustion will not propagate.
Offsite	Areas outside the bulk storage sites boundaries. This includes both public and private holdings, roadways, recreational facilities.
Onsite	Within any bulk storage facility site boundary.
Pool fire	The combustion of material evaporating from a layer of liquid at the base of the fire i.e. ignited vapours on the surface of a liquid pool.
Property Damage and Accident Propagation Risk	The frequency of escalation to neighbouring equipment or property occurring assuming no mitigating action such as application of firewater or ESD is undertaken, corresponding to a heat radiation level of 23 kW/m^2 (HIPAP 4).
Risk	The likelihood of a specified undesired event occurring within a specified period or in specified circumstances. It may be either a frequency (the number of specified events occurring in unit time) or a probability (the probability of a specified event following a prior event), depending on the circumstances. In this case, the risk under analysis is the likelihood of fatality per year due to loss of containment of hazardous materials resulting in fire exposure.
Tank top full surface fires	Ignited vapours on the surface of a liquid at liquid surface in tank, covering the full surface area of the tank (i.e. a sunk roof for a floating roof tank)
Vapour Cloud Explosion (VCE)	The combustion of a flammable vapour and air mixture in an environment where factors exist (for example equipment causing congestion or confinement of the flammable cloud) that result in a high flame speed, consequently causing damaging pressure due to the inertia of the unburnt mixture in front of the flame.

1. SUMMARY

1.1. Background

Mobil Oil New Zealand Ltd (Mobil) operates a hydrocarbon fuel storage and handling terminal in Woolston, New Zealand (NZ). The Mobil Woolston Terminal (referred to in this report as 'the Terminal') is currently subject to a planning overlay in the Christchurch District Plan (CDP). The overlay extends 250 m from the fuel storage compound at the Terminal and covers industrial land only. The overlay was a temporary measure to prevent incompatible development occurring in the vicinity of the Terminal. It was based on land use planning guidance published by the UK Health and Safety Executive (UK HSE) for separation distances from fuel terminals handling gasoline. The CDP overlay provisions expire in 2019.

Future protection provisions are subject to completion of a Quantitative Risk Assessment (QRA) to assess the risk from both Current and Future Case operations at the Terminal. The QRA results will be used by Mobil as input to Christchurch City Council (CCC) to drive a Plan Change Process with the aim of producing a revised overlay with rules attached that protect the Terminal from encroachment by incompatible land uses.

Sherpa Consulting Pty Ltd (Sherpa) has been retained by Mobil to undertake a QRA for the Terminal for both a Current and Future Case.

1.2. Objective

The overall objectives of the QRA study were to:

- Determine the offsite fatality risk levels from the Terminal for the Current and Future Cases.
- Assess the risk against the HIPAP 4 risk criteria.
- Provide recommendations regarding the extent of a future overlay. The QRA and proposed overlay will be used by Mobil as an input to the associated planning provisions around the Terminal in the CDP for discussion with CCC.

1.3. Scope

As summarised in Table 1.1, the QRA scope covers both the Current and Future Cases for the Terminal and includes:

- Transfer pipeline: aboveground sections of the Lyttelton–Woolston Pipeline (LWPL) import pipeline from Lyttelton within the site boundary (i.e. from the battery limit valve station).
- Terminal storage and processing: storage tanks, additive storage and handling, pumps, aboveground pipework and manifolds.
- Road tanker loading gantry: tanker filling operations and export of fuels.

Table 1.1: Terminal operations

Activity	Scope
Import of hydrocarbon liquid fuels via pipeline	Receive fuels from Mobil's terminal at George Seymour Quay (GSQ), Lyttelton Port via the Lyttelton–Woolston Pipeline (LWPL). Fuels include gasoline, diesel. The Future Case will also include jet fuel.
Storage of fuels	Storage of fuels in atmospheric storage tanks.
Export of fuels	Export of fuels via road tanker gantries. (There is no export by pipeline).
Miscellaneous	Additive storage and handling.
Exclusions: Only the Terminal and pipelines up to the first battery limit isolation valve are covered. Pipelines outside the site boundary and road transport outside the Terminal gates are excluded from the scope. The QRA does not cover operations of the LWPL outside the Terminal boundary.	

1.4. Method

Hydrocarbon loss of containment scenarios were assessed quantitatively. Scenarios considered were:

- Spills into storage tank bunds, or piping and manifold areas resulting in pool fires or flash fires
- Tank top fires
- Spray fires (pumped liquid systems only)
- Formation of large flammable clouds and potential flashfires or vapour cloud explosions (VCE) resulting from overfills of gasoline from storage tanks ("the Buncefield scenario").

The effect of earthquakes resulting in an elevated frequency and consequence of tank damage was also assessed.

TNO Riskcurves v 9 was used to generate individual fatality risk, injury risk and escalation risk contours.

There are no specific NZ land use safety planning risk criteria, however the decisions version of the CDP (Ref (1), Section 16.2.1.4) suggests that the risk acceptability criteria in the Australian New South Wales Department of Planning and Environment (NSW DPE) Hazardous Industry Planning Advisory Paper (HIPAP) No 4 *Risk Criteria for Land Use Safety Planning*, (HIPAP 4, Ref (2)) should be referred to. Therefore the HIPAP 4 criteria were adopted for this QRA.

Note that identification of any potential additional risk reduction measures is outside the scope of this QRA.

1.5. Conclusions

The study showed that for both the Current and Future Cases, all of the HIPAP 4 risk criteria are met as shown in Table 1.2.

A sensitivity study covering the effect of earthquakes on the overall risk showed very little change to the individual fatality risk results.

Based on these results:

- The existing 250 m overlay in the CDP provides adequate protection from encroachment of incompatible land uses whilst allowing for a future growth scenario at the Terminal and could be retained.
- If the overlay is to be revised, the minimum extent that the planning overlay can be reduced to, whilst still allowing for a credible future increase in throughput at the Terminal, is 170 m from the Terminal boundary. This distance is based on the HIPAP 4 individual fatality risk contour for sensitive land use for the Future Case.

Sensitive or residential uses, and any land uses involving large populations, should not be established within the extent of the overlay.

Table 1.2: QRA results against HIPAP 4 risk criteria

Item assessed	Description and land use	Criteria (per year)	Meets criteria?	
			Current Case	Future Case
Individual fatality risk	Hospitals, child-care facilities and old age housing (sensitive land uses)	0.5×10^{-6}	Yes	Yes
	Residential developments and places of continuous occupancy such as hotels and tourist resorts (residential land use)	1×10^{-6}	Yes	Yes
	Commercial developments, including offices, retail centres and entertainment centres (commercial land use)	5×10^{-6}	Yes	Yes
	Sporting complexes and active open space areas (recreational land use)	10×10^{-6}	Yes	Yes
	Target for site boundary (boundary limit)	50×10^{-6}	Yes	Yes
Injury risk [(a)]	Heat radiation exceeding 4.7 kW/m^2 (residential and sensitive uses)	50×10^{-6}	Yes	Yes
	Explosion overpressures exceeding 7kPa (residential and sensitive uses)	50×10^{-6}	Yes	Yes
Risk of property damage and accident propagation	Heat radiation exceeding 23 kW/m^2 (neighbouring potentially hazardous installations or at land zoned to accommodate such installations)	50×10^{-6}	Yes	Yes
	Explosion overpressures exceeding 14 kPa neighbouring potentially hazardous installations or at land zoned to accommodate such installations)	50×10^{-6}	Yes	Yes

Notes:
(a) HIPAP 4 injury risk criteria due to acute toxic exposure was not assessed in this study as hydrocarbons fuels are not acutely toxic (see Section 4.6).

2. INTRODUCTION

2.1. Background and scope

Mobil operates a hydrocarbon fuel storage and handling terminal in Woolston, NZ. The Terminal is currently subject to a planning overlay in the CDP. The overlay extends 250 m and was a temporary measure based on industry guidance from the United Kingdom Health and Safety Executive (UK HSE) for separation distances from fuel terminals handling gasoline. The distance was selected based on the "Inner Zone" distance given in the UK HSE *Land use planning advice around large scale petrol storage sites*, Ref (3), developed from investigations into the 2005 incident at Buncefield.

Future protection provisions beyond 2019 are subject to completion of a QRA to assess the risk from both Current and Future Case operations at the Terminal.

Sherpa Consulting Pty Ltd (Sherpa) has been retained by Mobil to undertake a QRA for the Terminal for both a Current and Future Case.

The QRA covers Terminal storage and processing, i.e. import into storage tanks, storage of bulk fuels, additive storage and handling, pumps, road tanker export and any pipework and manifolds within the Terminal boundary. Equipment outside the Terminal boundary (e.g. the import pipeline from the Lyttelton Port) is not within the scope of the QRA.

2.2. Exclusions and limitations

Limitations for this study are listed in Table 2.1.

Table 2.1: Study assumptions and limitations

Assumption/ limitation	Comments
1. Future Case operations	Two cases of the risk profile are included: 1. Current Case operations and 2. Future Case operations. The Future Case has been developed based on increased fuel throughputs, and increased pipeline and terminal utilisation advised by Mobil consistent with economic growth over the next 10 years (i.e. to 2027, approximately the same timeframe as the CDP).
2. Transportation risks	The boundary of the risk assessment is the Terminal gate. Transport on public roads is not covered. For pipeline risks, the boundary of the risk assessment is the logical shutoff valve at battery limits of the Terminal. The LWPL outside the Terminal is not covered.
3. Onsite/employee risk	Onsite/employee risk is not covered in the QRA.
4. Environmental risk	Environmental risk is not covered in the QRA.

Assumption/ limitation	Comments
5. Natural hazards risks – sensitivity study	The QRA includes an assessment of the effect of an earthquake event causing a significant loss of containment at the Terminal. This is based on publicly available likelihood of earthquake information sources for Christchurch and industry damage correlations for atmospheric tanks related to peak ground acceleration (PGA). This approach does not include any detailed structural assessment of tank response to earthquakes.
6. Current and future land uses	Sherpa has relied on the information supplied by Mobil and on Council zoning in determining land uses allowable under planning instruments for both the Current and Future Cases.
7. Risk reduction measures	Sensitivity studies around the effect of any risk reduction measures are outside the scope of the QRA report.
8. MHF tasks (Safety Case, MAPP, demonstration of SFARP)	The Terminal is a lower tier Major Hazards Facility under the NZ Health and Safety at Work Act Major Hazards Facilities (MHF) Regulations 2016. The QRA does not include preparation of an MHF Safety Case or Major Accident Prevention Policy (MAPP). The QRA does not cover a demonstration that the controls implemented at the Terminal are adequate and the risk has been reduced So Far As Reasonably Practicable (SFARP). However Mobil may use the QRA results as an input to these processes.
9. Societal risk	Societal risk is not included in this report. The existing populations are low density, associated with industrial land uses and not typically present overnight. The purpose of the overlay is to prevent future encroachment of incompatible populations into the area affected by the fatality risk contours, therefore only the fatality risk contours are required for input to development of the overlay.

3. SITE DESCRIPTION

3.1. Location

The Terminal is located at 79 Chapmans Road, Woolston, Christchurch, NZ. The Terminal is supplied from the Lyttelton Port via an underground import pipeline from the south-east of the Terminal.

Layouts of the overall Terminal and the hydrocarbon fuel storage areas are shown in Figure 3.1 and Figure 3.2.

3.2. Surrounding land uses

A map showing the surrounding land uses to the Terminal is shown in APPENDIX D, Figure D.1 which is based on the CDP, Ref (4).

3.2.1. Current land use

The land uses surrounding the Terminal are summarised in Table 3.1. The surrounding area is primarily industrial. The nearest residential areas are located approximately 350 m north from the nearest Terminal site boundary. There are no sensitive land uses (as defined in relevant land use safety planning risk criteria given in Table 4.1) within 1 km of the Terminal.

The nearest known surrounding land use with significant quantities of hazardous material is the Liquigas site to the south of the Terminal. However the liquefied petroleum gas (LPG) storage is mounded and at least 350 m from the Terminal storage tanks.

3.2.2. Future land use

The only proposed change in land use that has been identified is the Heathcote Expressway bicycle route along the northern side of the Terminal.

Table 3.1: Surrounding land uses of the Terminal

Direction	Surrounding land use
North	Proposed Heathcote Expressway bicycle route along northern boundary. Heathcote River and industrial areas. Nearest residential areas (350 m from northern boundary).
East	Industrial sites (e.g. caravan servicing facility) Proposed Heathcote Expressway bicycle route along south-west bank of the Heathcote River.
South	Railway line Shipping container storage yard
West	Industrial sites (e.g. chilled food storage warehouse, steel fabrications)

3.3. Operations

The Terminal receives bulk hydrocarbon fuels from the Mobil Lyttelton George Seymour Quay (GSQ) terminal via the LWPL. The fuel is stored in atmospheric storage tanks and distributed by road tanker from the Terminal. Terminal throughputs are shown in the QRA basis in Section 6.

Mobil operates the Terminal which handles gasoline (91 ULP, 95 PULP) and diesel (Automotive gas oil, AGO). There is no jet fuel or ethanol stored or handled at the Terminal.

The Terminal is continuously manned 24 hours/day for seven days a week by a pipeline operator. Day and night operations shifts are 12.5 hours. Office staff are also present for 10.5 hrs/day for five days a week (Monday to Friday).

3.4. Transfer pipeline

All bulk fuel storage tanks at the Terminal are filled via the LWPL. Some fuel is transferred on behalf of the other bulk liquid operators BP and Z Energy, with operations overseen by Mobil. The details of the LWPL are provided in Table 3.2 for completeness although the LWPL outside the Terminal boundary is not covered in the QRA.

Table 3.2: LWPL details

Item	LWPL
Description	Liquid pipeline (multiple types of hydrocarbon fuels). Fully welded main pipeline with flanges at various points may contain screwed small bore fittings (i.e. 25NB and 20NB).
Aboveground/ underground	Combination of aboveground and underground sections between Lyttelton and Woolston. Underground section of pipeline runs into the Woolston terminal inlet manifold.
Service fluids	Current Case: 91 ULP, 95 ULP, AGO. Future Case: 91 ULP, 95 ULP, 98 SPULP, AGO.
Length	Approximately 6.5 km between GSQ and Woolston terminals.
Diameter	Combination of 100NB and 150NB pipeline sections.
Operations	Operational 24 hours/day for seven days a week.
Pipeline shutoff valves	Remote isolation valves at GSQ terminal, Heathcote Valley valve chamber, Harmans Road and Woolston terminal.
Maximum pressure	68.9 barg
Estimated inventory when isolated	59.8 m^3

3.5. Tank storage

A summary of the Terminal fuel storage tanks and the typical materials stored is provided in Table 3.3. All tanks are stored in a single common compound at the northern section of the Terminal.

All tanks are fitted with an automatic tank gauging (ATG) radar (Saab) gauging system with high and high-high level alarms (HHLA) provided through the TankMaster and SCADA system. The tanks also provided with independent high and high-high level indicator probes which are calibrated and tested every six months. High level alarms have a dedicated alarm siren regardless of whether it is activated by the Saab radar gauge or the independent probe.

HHLAs triggered by the Saab radar gauge or the independent probe also trigger Emergency Shutdown (ESD). ESD is interlocked with the HHLA such that the ESD cannot be reset until the tank level is reduced below HHLA level, or the HHLA is bypassed.

Tank to tank transfer between product tanks is not conducted as part of normal operations at the Terminal as the storages are dedicated to particular products.

Interface blending into AGO is undertaken via a controlled dosing unit directly injecting into the pipeline upon receipt at the Terminal manifold.

Additives are stored in horizontal storage tanks as summarised in Table 3.4.

3.6. ESD and fire protection

ESD buttons are provided around the Terminal. ESD disables pump drive units and stops road tanker loading pumps, additives pumps and the LWPL pumps at the GSQ terminal. It also shuts any open tank outlet valves (air operated), and the LWPL control valves at Heathcote Valley, Harmans Road and Woolston will all close.

The Terminal's fire protection is provided by a manually operated fire water ring main which is filled from the town mains. There is no fire water storage onsite and the fire brigade is required to boost the water pressure from the mains. Foam is stored in a warehouse south of the site office.

The bulk liquids tanks at the Terminal are not fitted with in-tank foam pourers. Manually operated fire monitors are located around the exterior of the tank farm.

Heat detection and alarm is provided at the road tanker loading gantry. Foam deluge is currently provided to the loading gantry and must be activated via a manual call point.

3.7. Gantry export

Road tankers filled at the Terminal loading gantry include: rigid trucks, and rigid trucks and trailers. The gantry comprises four loading bays in total but only three are currently in use. All tankers are bottom loaded. Compartments for the different types of road tankers are typically between 3,000-8,000 L depending on the truck configuration.

In the loading gantry, there are dry-break couplings on road tankers which limit spills caused by road tanker drive-away.

The loading gantry is fitted with a scully interlock system which protects against loss of earthing and overfill.

Foam deluge is provided at the loading gantry as discussed in Section 3.6.

Spills in the loading gantry drain to a 30 m^3 underground vessel.

3.8. Future operation

A Future Case is considered for the Terminal which accounts for growth in fuels throughput over the next 10 years up until approximately 2027. In developing the Future Case the following assumptions were made:

- The LWPL is currently almost fully utilised and any increase in overall fuel throughputs would require some increase in pipeline capacity. Note that the feasibility of achieving any increase in import rate via the LWPL has not been assessed in the QRA, i.e. there is no specific LWPL uprate proposal.
- Gasoline will not be not permitted through the Lyttelton road tunnel and it is not desirable to drive through Evans Pass due to the landslip and rock fall risk to the road. Therefore all gasoline will all be transferred to the Terminal via the LWPL.
- Jet fuel will not be permitted through the Lyttelton road tunnel and is not desired to be driven through Evans Pass. Therefore all jet fuel will be transferred to the Terminal via the LWPL.
- Diesel can be driven through either/both the Lyttelton road tunnel and Evans Pass.
- Data tables produced by the Ministry of Business, Innovation & Employment, Ref (5), record fuel demand in NZ each year. Based on data since 2012, an average 2% growth rate per year for all hydrocarbons is anticipated. This corresponds to a 20% increase in the throughput of fuel over a 10 year period. For the purposes of the QRA, a 25% growth in the total volumes of products from all fuel companies in Lyttelton was assumed as this provides a reasonable level of margin over NZ wide prediction. This corresponds to 500,000 m^3/yr of gasoline and 375,000 m^3/yr of jet fuel.
- The LWPL is assumed to be utilised at 90% per year.

To achieve the increased gasoline and jet fuel throughput via the LWPL, the pipeline flow rate would be expected to increase from around 98 m^3/hr to 120 m^3/hr. The practical and economic feasibility of achieving this 22% increase in import rate has not been assessed. (However it would be technically feasible to achieve this, and involve replacing some sections of the pipeline with larger diameter piping and larger pumps at the GSQ site. It is also noted that this is still a low import rate compared to other terminals where pipeline rates typically range from 400 to 800 m^3/hr and ship import rates could exceed 1000 m^3/hr).

Given jet fuel is not transferred via the LWPL currently, two of the out of service tanks (i.e. Tanks 3 and 14) and the bulk AGO storage tank (Tank 1) were assumed to be converted to jet fuel service as per Table 3.3. No changes were assumed to be made to the tank types.

The changes to the operations at the Terminal between the Current and Future Cases are summarised in the QRA basis in Section 6.

Table 3.3: Fuel storage tanks

Tank no.	Diameter (m)	Height (m)	Max. operating volume (m^3)	Max. fill rate (m^3/hr)	Type	Tank overfill safeguards	Class	Typical materials stored	
								Current	Future
Tank 1	18.3	10.2	2,364	82.2	Fixed roof	Gauge, IHHLA	C1	AGO	Jet Fuel
Tank 2	15.2	13.6	2,133	94.8	IFR	Gauge, IHHLA	3	91 ULP	91 ULP
Tank 3	15.2	13.0	966	82.2	Fixed roof	Gauge, IHHLA	-	Out of Service	Jet Fuel
Tank 4	8.3	10.3	480	82.2	Fixed roof	Gauge, IHHLA	C1	AGO	AGO
Tank 5	3.6	9.4	52	94.8	Fixed roof	Gauge, IHHLA	C1	Interface	Interface
Tank 11	21.3	13.8	3,502	94.8	IFR	Gauge, IHHLA	3	91 ULP	91 ULP
Tank 14	9.1	11.2	655	94.8	IFR	Gauge, IHHLA	3	Out of Service	Jet Fuel
Tank 15	16.3	14.7	2,728	94.8	IFR	Gauge, IHHLA	3	95 PULP	95 PULP

Table 3.4: Additive storage tanks

Tank no.	Max. operating volume (m^3)	Average fill rate (m^3/hr) [(a)]	Class	Typical materials stored	
				Current	Future (No changes)
Tank 17	3.1	67.1	3	Additive – Mixing Tank	Additive – Mixing Tank
Tank 18	3.1	67.1	3	Additive – MOA Petrol	Additive – MOA Petrol
Tank 19	3.1	67.1	3	Additive – BP Petrol	Additive – BP Petrol
Tank 20	3.1	67.1	3	Additive – Shell Petrol	Additive – Shell Petrol
Tank 21	3.1	67.1	3	Additive – Caltex Petrol	Additive – Caltex Petrol
Tank 22	3.1	67.1	C1	Additive – Mixing Tank	Additive – Mixing Tank
Tank 23	3.1	67.1	C1	Additive – Mobil AGO	Additive – Mobil AGO
Tank 24	3.4	67.1	C1	Additive – BP AGO	Additive – BP AGO
Tank 25	3.1	67.1	C1	Additive – Shell AGO	Additive – Shell AGO

Notes:

(a) Average fill rate calculated based on time taken for manual procedure of lancing additive from 1,000 L intermediate bulk containers (IBCs) into the tanks.

Figure 3.1: Overall Terminal layout

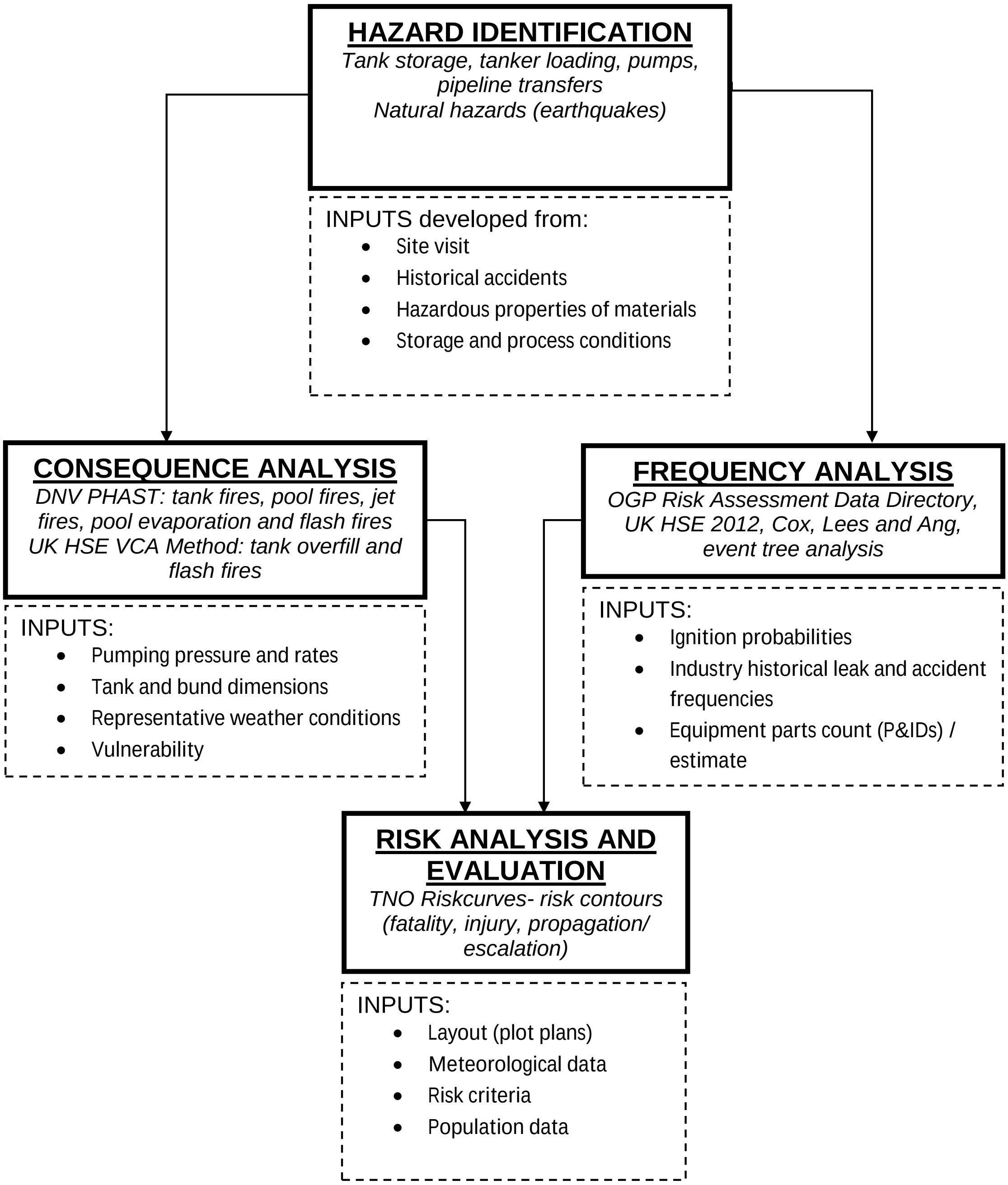
Figure 3.2: Hydrocarbon storage area layout

4. METHODOLOGY

4.1. Overview

An overview of the QRA process, including the steps and inputs for this study is shown in Figure 4.1. The subsequent sections provide further information.

Figure 4.1: Overview of QRA process



4.2. Hazard identification

Hazard identification is the process of identifying hazardous incidents that could result in an adverse impact, together with their causes, consequences and existing safeguards.

Hazard identification was undertaken as a desktop activity based on the consultant's experience with bulk liquids storage and distribution terminals, review of previous risk studies, together with input from the site operator.

The main hazard at the Terminal is the storage and handling of large quantities of flammable and combustible liquids.

Flammable consequences due to a loss of containment of flammable and combustible materials are considered in the QRA.

Toxic consequences (i.e. dispersion of unignited hydrocarbon vapours) are not considered in the QRA for the Terminal as whilst having some toxic properties, hydrocarbon fuels are not acutely toxic by inhalation and so do not have significant toxic offsite effects (refer to Table 5.2).

4.3. Consequence analysis

Consequence modelling of identified scenarios were undertaken to determine the impact area (as heat radiation or as area within a flammable cloud) and the resulting extent of injury or fatality effects. Consequence modelling of identified hazardous events was undertaken using DNV PHAST v7.2 (PHAST).

The overall approach is explained in Section 7.1 and APPENDIX B.

4.4. Frequency analysis

Hazardous scenarios involve loss of containment of hydrocarbon fuels and subsequent ignition. The likelihood of these scenarios was estimated using historical data for both loss of containment and for potential ignition. Loss of containment frequencies were calculated using an estimated count of equipment items ('parts count') combined with historical leak frequency data for each equipment type and adjusted for the proportion of time equipment is in use.

The overall approach is explained in Section 8 and APPENDIX C.

4.5. Risk analysis

Risk analysis was performed using TNO Riskcurves v9 (Riskcurves), which combines the consequences and frequencies to produce contours of equal risk values. The following measures of risk were assessed:

- Individual fatality risk
- Injury risk
- Escalation/propagation risk.

4.5.1. Individual fatality risk

Individual fatality risk represents the probability of some specified level of harm (in this case fatality) occurring to a theoretical individual located permanently at a particular location, assuming no mitigating action such as escape can be taken. This is shown as contours on a map of the area which show the probability of fatality per million per year at a location.

4.5.2. Injury risk

Injury risk represents the probability of injury occurring to a theoretical individual located permanently at a particular location, assuming no mitigating action such as escape can be taken. There are several types of consequences that may result in injury but the most relevant for bulk hydrocarbon liquids storage is from heat radiation.

A heat radiation level of 4.7 kW/m^2 corresponding to the level high enough to result in injury is shown as a contour on a map of the area which shows the probability of injury per million per year at a location.

4.5.3. Propagation/escalation risk

Propagation/escalation risk represents the probability of an escalation to neighbouring equipment or property occurring assuming no mitigating action such as application of firewater or ESD is undertaken. There are several types of consequences that may result in damage or escalation but the most relevant for bulk hydrocarbon liquids storage is from heat radiation. The 23 kW/m^2 heat radiation level, corresponding to the level high enough to result in escalation to neighbouring installations, is shown as a contour on a map of the area which shows the probability of escalation per million per year at a location.

4.6. Risk criteria

4.6.1. HIPAP 4 criteria

There are no specific NZ risk criteria, however the decisions version of the CDP (Ref (1) Section 16.2.1.4) suggests that the risk acceptability criteria in HIPAP 4, Ref (2), should be referred to.

Therefore the HIPAP 4 criteria have been adopted for this assessment. The HIPAP 4 individual risk criteria are shown in Table 4.1.

Note that criteria relating to toxic concentrations resulting in injury were not assessed as the hydrocarbon fuel materials are not acutely toxic by inhalation and hence do not contribute to offsite risk, as discussed in Section 5.1.

Table 4.1: Risk assessment criteria (HIPAP 4, Ref (2))

Description and land use	Criteria (per year)	Assessed in study?
Individual fatality risk		
Hospitals, child-care facilities and old age housing (sensitive land uses)	0.5×10^{-6}	Yes
Residential developments and places of continuous occupancy such as hotels and tourist resorts (residential land use)	1×10^{-6}	Yes
Commercial developments, including offices, retail centres and entertainment centres (commercial land use)	5×10^{-6}	Yes
Sporting complexes and active open space areas (recreational land use)	10×10^{-6}	Yes
Target for site boundary (boundary limit)	50×10^{-6}	Yes
Injury risk		
Heat radiation exceeding 4.7 kW/m^2 (residential and sensitive uses)	50×10^{-6}	Yes
Explosion overpressure exceeding 7 kPa (residential and sensitive uses)	50×10^{-6}	Yes
Toxic concentrations exceeding a level which would be seriously injurious to sensitive members of the community following a relatively short period of exposure (residential and sensitive uses)	10×10^{-6}	No – not applicable as fuels are not acutely toxic
Toxic concentrations exceeding a level which would cause irritation to eyes or throat or other acute physiological responses in sensitive members of the community (residential and sensitive uses)	50×10^{-6}	No– not applicable as fuels are not acutely toxic
Risk of property damage and accident propagation		
Heat radiation exceeding 23 kW/m^2 (neighbouring potentially hazardous installations or at land zoned to accommodate such installations)	50×10^{-6}	Yes
Explosion overpressure exceeding 14 kPa (neighbouring potentially hazardous installations or at land zoned to accommodate such installations)	50×10^{-6}	Yes

4.6.2. Alternative criteria

There is some variation in risk criteria adopted in different jurisdictions. For example, the Victorian (Australia) risk criteria set a more onerous target for land uses other than low density industrial (0.1×10^{-6} per year, see Ref (6)) compared to HIPAP 4 (0.5 to 10×10^{-6} per year for non-industrial land uses).

Individual fatality risk results are presented for alternative criteria as well as the HIPAP 4 criteria (refer to APPENDIX E, Section E2) as an example of how choice of criteria could affect the conclusions of the QRA.

5. HAZARD IDENTIFICATION

5.1. Hazardous materials

The properties of materials stored at the Terminal are summarised in Table 5.2. The explanations of the Hazardous Substances and New Organisms (HSNO) classifications for each material are outlined in Table 5.1.

Table 5.1: HSNO classifications

Classification no.	Hazard description
3.1	Substances that are flammable liquids
6.1	Substances that are acutely toxic
6.3	Substances that are skin irritants
6.7	Substances that are carcinogenic
9.1	Substances that have aquatic ecotoxicity

The flammable consequences due to a loss of containment of any of these materials are considered in the QRA. Toxicity effects are not modelled in the QRA.

Gasoline is the only material with a significant fraction of 'light' components hence the only material where a loss of containment has potential to generate a large flammable vapour cloud. The properties of the different grades of gasoline are very similar.

For the purposes of the QRA, representative materials as shown in Table 5.2 have been used in modelling.

Various additives are handled on-site and are not included in Table 5.2 since they are stored in small quantities. They are assumed have the same properties as gasoline for the purpose of the QRA modelling.

5.2. Hazard identification

Hazard identification for the Terminal was undertaken as a desktop activity based on the consultant's experience with bulk liquids storage and distribution terminals, review of previous risk studies, a site visit and input from the site operations team.

The hazard identification table is shown in Table 5.3.

5.3. External factors

For a specific site, a QRA generally includes a review of external factors that may elevate the likelihood of an incident compared to the statistical failure frequency data.

External factors (e.g. natural hazards) relevant to the Christchurch area and means of inclusion of effect in the QRA for the Terminal are summarised in Table 5.4.

Table 5.2: Material properties

Property	Gasoline (91 ULP, 95 PULP, 98 SPULP)	Diesel (AGO)	Jet Fuel (Future Case only)
HSNO Classification	3.1A, 6.1E, 6.3B, 6.7B, 9.1B	3.1D, 6.1E, 6.3B, 6.7B, 9.1B	3.1C, 6.1E, 6.3A, 9.1B
Boiling Point (atm.) (ºC)	25-210	180-360	140-280
Density (kg/m^3 at 15ºC)	720-775	830	775-840
Vapour pressure (kPa at 20ºC)	30-90	<0.07	<0.1
Auto-ignition temperature (ºC)	>250	230	>220
Flash Point (ºC)	<-40	80	>38
Lower Flammability Limit (LFL) (ppm)	10,000	6,000	10,000
Upper Flammability Limit (UFL) (ppm)	80,000	70,000	60,000
Flammable	Yes	Combustible	Yes
Toxic [(a)]	Yes	Yes	Yes
Representative material used for quantitative modelling	ULP Summer	Dodecane	Decane

Note: (a) In QRA, 'toxic' means a substance that is acutely toxic by inhalation and is in a form where a spill may disperse outside the immediate area of the spill in concentrations capable of causing injury or fatality.

Hydrocarbon fuels are not acutely toxic by inhalation hence do not contribute to offsite fatality risk when unignited. Some hydrocarbons have potential chronic toxicity and carcinogenic health effects. These types of effects are outside the scope of the QRA as they are most relevant to worker hygiene and health, but not offsite risk to the public.

Large black smoke plumes from hydrocarbon fires can occur. These are thermally buoyant and may have respiratory irritation effects if they slump back to ground as may occur under certain meteorological conditions such as inversions. There are numerous examples of tank fires (including Buncefield) which demonstrate that one off exposure to these smoke plumes do not pose a significant injury or fatality hazard, Ref (7). Hence smoke plume effects are not covered in this QRA.

In summary toxicity effects are not modelled in the QRA.

Table 5.3: Hazard scenarios

Area	Hazard scenario	Causes/threats	Consequences	Safeguards	Carried forward to QRA
Tank Farm	Tank overfill	- Human error (incorrect dip prior to start of fill or missed maximum safe fill level)	- Pool fire and potential full-surface bund fire. - Tank roof fire and escalation to adjacent tanks. - Tank vent fire. - Pool evaporation and flammable gas dispersion and flash fire.	- High level alarm and operator shutdown. - Fire fighting (Emergency Services). NOTE: Tank to tank transfer between bulk tanks is not routinely conducted at the Terminal as they are dedicated to particular products.	Yes - Rim seal fires for internal floating roof (IFR) tanks not modelled as the consequence is localised. A scenario is included for escalation of rim seal fires to full surface fires. Vent fires not modelled for all tanks.
		- Level gauge error /failure	- Pool fire and potential full-surface bund fire. - Tank roof fire and escalation to adjacent tanks. - Tank vent fire. - Pool evaporation and flammable gas dispersion and flash fire / VCE (all grades gasoline only).	- Manual dips of tanks (monthly). - Fire fighting (Emergency Services).	
	Leak from tank	- Minor tank leak from mechanical integrity failure - dewatering system leaks - Fitting leak	- Pool fire and potential full-surface bund fire. - Pool evaporation and flammable gas dispersion and flash fire.	- Tank farm operator patrols (daily). - Fire fighting (Emergency Services).	Yes
	Tank roof fire	- Lightning	- Tank roof fire and escalation to adjacent tanks.	- Fire fighting (Emergency Services). Fire water is supplied directly off the town water supply into the ring main.	Yes

Area	Hazard scenario	Causes/threats	Consequences	Safeguards	Carried forward to QRA
	Major mechanical failure of tank	- Metal fatigue - Faulty fabrication - Corrosion of tank base/ weld - Tank explosion due to lightning strike/breach of hazardous area ignition source controls - Adjacent tank on fire - Blocked vent - Fitting leak on tank connection.	- Large spillage of flammable materials in bund. Fire if ignited. - Potential full surface bund fire if rupture of tank or connection. - Flash fire and vapour cloud explosion (gasoline all grades only).	- Remote actuated emergency shutdown valves on tank outlet line. - Daily operational check of the Terminal. - Leaks observed by operator during manual opening and closing of valves during tank filling. - Regular tank inspection and tests. - Ignition source control onsite (tank bunds classified Zone 2 hazardous areas). - Regular maintenance and inspection procedures. - Fire fighting (Emergency Services).	Yes
	Flammable atmosphere in tank vapour space between external dome and IFR	- Damage to floating roof resulting in sinking or partial sinking (e.g. nitrogen blowthrough from clearing import line or pontoon damage). - Vents blocked during filling procedure.	-Ignition by lightning/breach of hazardous area ignition source controls/ hot work on tank/high velocity filling resulting in static during filling tank. Results in: - Initial explosion in tank vapour space - Rim seal fire (floating roof tanks) - leading to a tank full surface area fire. - Potential for spill into the bund with a bund fire. - Boil over possible if water layer exists. - Impact to people (radiant heat and/or exposure to products), property and the environment (products of combustion).	- IFR with mechanical shoe seal minimises vapour egress. - External domed roof protects IFR from rain water accumulation and minimises likelihood of lightning leading to rim seal fires. - Regular tank dewatering minimises water in tanks. - Permit to work controls. - Regular maintenance and inspection procedures. - Level alarms, controlled tank filling. - Filling rate is less than 7 m/s to avoid excessive pipe flow and product entry turbulence. - Site earthing of equipment. - Regular tank inspection and tests including roof inspection.	Yes – Internal explosion and rim seal fires not modelled as the consequence is localised. A scenario is included for escalation of rim seal fires to full surface fires.

Area	Hazard scenario	Causes/threats	Consequences	Safeguards	Carried forward to QRA
	Flammable atmosphere in fixed roof tank vapour space (interface tank only)	- Air ingress to vapour space	- Tank vent fire	- High level alarm and operator shutdown. - PV vent on interface tank. - Fixed fire fighting and Emergency Services. NOTE: Tank to tank transfer between bulk tanks is not routinely conducted at the Terminal as they are dedicated to particular products.	Yes - Vent fires not modelled for all tanks as the consequence is localised. A scenario is included for escalation of vent fires to full surface fires.
	Fire involving additive storage	- Container rupture due to handling error during delivery to site. - Impact by road tanker. - Pump leak during blending.	- Pool fire if ignited.	- All additives delivered in 44 gallon drums, limiting inventory size. Additives are pumped from drums to the additives storage tanks. - Low pump dosing rate. - Location in close proximity to bulk storage tanks	Yes
Tanker Truck Load Rack	Tanker leak during loading	- Hose rupture - Hose, tanker or piping fitting leak.	- Pool fire - Pool evaporation and flammable gas dispersion and flash fire.	- Operator in attendance (activates ESD). - Drained to single interceptor and separator system. - Heat detection. - Foam deluge. - Fixed fire fighting and Emergency Services.	Yes

Area	Hazard scenario	Causes/threats	Consequences	Safeguards	Carried forward to QRA
	Tanker overfill	- Human error	- Pool fire - Pool evaporation and flammable gas dispersion and flash fire.	- Operator in attendance (checks ullage in tanker prior to loading and Scully system stops loading based on metered quantity – invalid barrier since it is not independent of initiating event/cause). - Operator in attendance (activates ESD). - Ignition control. - Foam deluge. - Fire fighting (Emergency Services).	Yes
	Road tanker drive-away incident	- Failure of procedures and hardware interlocks	- Leak of petroleum product in loading area. - Fire if ignited - Impact to people (radiant heat and/or exposure to products), property and the environment (products of combustion).	- Driver training. - Driver not in cab during filling. - "Dry-break" couplings.	Yes
Product Transfer Pumps	Leak from pump during road tanker loading	- Seal leak - Flange leak - Pump rupture	- Pool fire. - Pool evaporation and flammable gas dispersion and flash fire.	- Tank farm operator patrols (daily). - Bunding around pump bay. - Fixed fire fighting and Emergency Services.	Yes
Pipework	Pipework failure (within the Terminal)	- Corrosion - Incorrect maintenance - Overpressure	- Major spillage of flammable/ combustible material.	- Regular maintenance and inspection procedures. - The piping is designed to relevant codes and standards to resist the combined effects on internal pressure due to contents, wind loads, and hydrostatic test loads.	Yes

Table 5.4: External factors

External factors	Damage/outcome	Comments	Inclusion in Terminal QRA
Earthquake	Ground movement damaging/ collapsing tanks	Strength of earthquake and the frequency/return period and probability of significant damage to tanks assessed based on fragility curves. Potential for multiple tank failures simultaneously, or damage to the bunds as well as tanks with larger scale release that is not contained in the bunded areas.	Yes, additional scenario accounting for loss of containment from tanks and bund (see Section B8 for consequence and Section C5 for frequency)
	Liquefaction of ground damaging/collapsing tanks	Liquefaction did occur in the area of the Terminal following the 2011 earthquake, Ref (8).	No adjustment to QRA, as any damage due to liquefaction effects is assumed to be at the same impact scale as earthquake damage due to ground movement/shaking already being accounted for.
Tsunami	Inundation and tank movement/damage	The risk of fatality from a tsunami due directly to inundation is substantially higher than any incremental fatality risk due to secondary effects from a loss of containment of hazardous materials and resulting fire.	No adjustment to QRA.
Strong winds	Loss of containment leading to a fire if ignited (as above) due to equipment damage from strong winds	The tanks are designed to resist the combined effects on internal pressure due to contents, weight of platforms, ladders, live loads, wind loads, and hydrostatic test loads. Operations stopped in adverse weather conditions.	No adjustment to QRA.
Cyclone	High wind speeds	Included in the strong winds component. Christchurch is not identified as a major cyclone area.	No adjustment to QRA.
Storm event/ flood (high rain)	Inundation due to storm surge. High rainfall resulting in flooding impacting tanks.	The terminal boundary is located 20 m from the southern bank of the Heathcote River and is located within the Christchurch Flood Management Area, Ref (4). Inundation due to flooding may lead to asset damage issue if uplifting occurs for empty tanks. Site drainage adequate to prevent onsite flooding.	No adjustment to QRA.
Lightning	Ignition resulting in tank top full surface fire	Christchurch is not identified as a high lightning strike area. LASTFIRE data includes tank top full surface fires started by lightning strikes.	No adjustment to QRA.

External factors	Damage/outcome	Comments	Inclusion in Terminal QRA
Bushfire	External fire escalating to bulk storage tanks	Not relevant – no significant surrounding vegetation	No adjustment to QRA.
Aircraft crash due to pilot error, bad weather or plane fault	Propagation to tank/ bund fires Impact to people (radiant heat and/or exposure to products), property and the environment (products of combustion)	Separation distances to flight path as per aviation standards.	No adjustment to QRA.
Fire/explosion on adjacent site	Escalation to storage tanks	Nearest adjacent sites are industrial warehouses to the east and west of the Terminal. The area has buildings which may be on-site protected places. Fire protection. ERP.	No adjustment to QRA.
Breach of security/ sabotage	Possible release of product with consequences as per above	Security measures include fencing, CCTV, perimeter walks of terminal at night by security guards, operator/driver vigilance (as per MHF security plan). Continuous 24 hr manning by pipeline operator. Process SCADA computer alarms monitored and alarm sounded for urgent operator response.	No adjustment to QRA.

6. QRA BASIS

6.1. Basis

A number of simplifying assumptions need to be made to prepare a QRA and the results are dependent on the assumptions made in defining the input scenarios. This is particularly true of bulk fuel terminals due to the potential variety of products and throughputs. It is therefore important to understand any limiting assumptions in conjunction with the QRA results.

The QRA has been prepared on the following basis:

- Hazardous materials are allocated into representative fuel types (see Table 5.2).
- Existing tanks and infrastructure for the Current and Future Case operations are included with the product allocation shown in Table 3.3. No provision for potential additional tankage is allowed for in the QRA although recommissioning of out of service tanks in the Future Case is provided for.

Terminal throughputs were developed based on 2017 throughput levels for the Current Case, and a future growth case developed by Mobil for to allow for some growth in terminal usage (Future Case).

The operational data used in the QRA is summarised in Table 6.1. Values are defined for both the Current and Future Cases.

6.2. Representative scenarios

Representative scenarios were developed from the hazard identification based on location and materials.

A summary of the scenarios modelled in the QRA is given in Table 6.2.

Table 6.1: Summary of QRA data

Parameter	Current Case	Future Case	Unit	Comments
LWPL import				
Max transfer rate (m^3/hr)	95	120	Gasoline	Provided by Mobil: Current filling rate varies and is 94.8 m^3/hr for gasoline and 82.2 m^3/hr for diesel. A modification is underway to install a modern pump which would increase the filling rates to 99 m^3/hr for gasoline and 88 m^3/hr for diesel, however this change is only minor and does not impact the QRA results.
	82	104	Diesel	
	-	111	Jet Fuel	
Pressure at Woolston inlet manifold	10	10	barg	Provided by NZOSL: 9.65-9.75 barg.
Online time	7,884	7,884	hrs/yr	Provided by Mobil: Pipeline operates 24/7 (i.e. 24 hrs/day x 365 days/yr) with an assumed 90% utilisation.
Annual throughput (m^3/yr)	336,000	500,000	Gasoline	Current Case: calculated based on average monthly totals: 23,000 m^3 (91 ULP), 5,000 m^3 (95 PULP), 26,000 m^3 (AGO). Future Case: based on 22% increase and flammables through pipeline. Annual totals 500,000 m^3 (total gasoline), 22,000 m^3 (AGO), 376,000 m^3.
	312,000	22,000	AGO	
	-	376,000	Jet Fuel	
Road tanker loadout				
Road tanker compartment size	5	5	m^3	Provided by Mobil: There are 6 compartments on average per road tanker, where compartments are likely to be in quantities of 3 m^3, 4 m^3, 6 m^3 or 8 m^3, depending on the configuration. Average size estimate 5m^3.
Max transfer rate (m^3/hr)	115	115	Gasoline	Provided by Mobil
	118	118	Diesel	
	-	115	Jet Fuel	
Max loadout pressure	5	5	barg	Assumed maximum as no online pressure gauge in place.
Total number of road tanker compartments loaded per year	67,200	100,000	Gasoline	Calculated assuming an average road tanker compartment size of 5 m^3.
	62,400	4,400	Diesel	
	-	75,200	Jet Fuel	

Table 6.2: Scenario summary

Scenario	Materials	Main physical inputs	Modelled for:
1. Tank top full surface fire – IFR and fixed roof tanks	Flammables and combustibles	• Tank diameter • Tank height	Each flammable and combustible tank
2. Pool fire – intermediate bund (not applicable at this Terminal as there is a single common bund) or equilibrium pool size if this is smaller than bund	Flammables and combustibles	• intermediate bund dimension (length, width, intermediate bund wall height) • intermediate bund total surface area	Each intermediate bund (tank overfill and minor tank leaks)
3. Pool fire – full bund	Flammables and combustibles	• Bund dimension (length, width, bund wall height) • Bund total surface area	Each full bund (tank rupture)
4. Pool fire – import pipeline, manifold, pumps, pipework, tanker loading bays	Flammables and combustibles	• Total surface area (length, width)	All flammable and combustible areas not inside main storage bund
5. Spray fire – import pipeline, manifold, pumps, pipework, tanker loading bays	Flammables and combustibles	• Operating pressure • Leak/hole size	All flammable and combustible areas not inside main storage bund
6. Flash fire (development of unignited cloud to Lower Flammability Limit (LFL), delayed ignition) – Leaks from process equipment, intermediate/full bund, pipework, tanker loading bays [b]	Relevant to gasoline (any grade) only	• Operating pressure • Leak/hole size • Surface area and evaporation rate from pool	All gasoline areas
7. Overfill – Flashfire/explosion (development of cloud to LFL, delayed ignition in an environment that results in high flame speeds generating overpressure, or a flashfire if there are no factors causing flame acceleration). This is the "Buncefield" scenario.	Flashfire / VCE is relevant to gasoline (any grade) only (Overfill of other materials result in a pool in bund)	• Size of spill (from tank fill rates[a] and bund surface area) • Development of cloud to LFL, ignition in an environment that results in high flame speeds • Degree of confinement • Explosion strength	Gasoline overfill only As per Ref (9), for gasoline tanks where: - vertical height exceeds 5 m - gasoline filling rate exceeds ~75 tonnes/hr

Notes:

(a) The maximum pipeline import rates were used in the modelling to represent tank filling rates.

(b) Overpressures for these type of scenarios from leaks in process equipment, intermediate/full bund, pipework, tanker loading bays are not explicitly modelled due to small flammable cloud sizes and limited congestion / confinement

7. CONSEQUENCE ANALYSIS

7.1. Methodology

Consequence analysis involves qualitative and/or quantitative review of the identified hazardous incidents to estimate the potential to cause injury or fatalities, damage to property or damage to the environment.

The materials are flammable and combustible fuels with minimal acute toxicity issues. Ignited event scenarios only are modelled as follows:

- Pool/bund fires. Ignited vapours on the surface of a liquid pool.
- Tank top full surface fires. Ignited vapours on the surface of a liquid at liquid surface in tank.
- Jet/spray fires. This is an intense directional fire resulting from ignition of a vapour or two phase release with significant momentum (i.e. pressurised).
- Flash fires/vapour cloud explosion. An ignited flammable vapour cloud. Dimensions typically taken to be the extent of the LFL.

The following assumptions relating to the consequences modelled have been made:

- Following a flash fire event a residual pool or jet fire may remain. This is not explicitly modelled as the effect distances are smaller than the flash fire.
- Not all onsite process piping was explicitly considered due to minimal leak points with lower leak frequencies relative to other equipment items. The LWPL import manifold and pipework onsite were quantitatively accounted for. Piping within the bunded areas is assumed to be covered by the statistical leak data for tanks and associated equipment and was not explicitly modelled.
- All scenarios were included in the frequency assessment, i.e. even if the consequence assessment showed that there was no significant impact outside the site boundary (e.g. small leak sizes).

A full set of consequence modelling results for the Terminal is provided in APPENDIX B and additional details of assumptions are provided in the following sections.

7.1.1. Software and models

Consequence modelling of identified hazardous events was undertaken using DNV PHAST v7.2 (PHAST). PHAST is a commercial software package that is widely used in the process and oil and gas industries for calculating the physical effects and consequences of the loss of containment of hazardous materials in hazard analysis.

For gasoline tank overfill scenarios, the extent of the flammable cloud envelope was modelled following the UK HSE Vapour Cloud Assessment (VCA) method, Ref (10), which provides a means of calculating the rate at which the volume of a vapour cloud increases during an overfilling incident, hence predicting the distance to the LFL of the cloud. The distance to LFL is then used as the extent of the flashfire and overpressure impact area if an ignition occurs.

This is an empirical model that can be set up in a spreadsheet and was developed after significant research as part of the incident investigation into the Buncefield incident in 2005. It is regarded as best practice for estimating the effect areas for this type of event without undertaking detailed site specific Computational Fluid Dynamics (CFD) modelling.

The model provides a means of calculating the rate at which the volume of a vapour cloud increases during an overfilling incident, hence predicting the distance to the LFL of the cloud. The model also allows overpressure effect distances from an ignited flammable vapour cloud due to a gasoline tank overfill event to be assessed.

The distance to LFL is then used in the risk model as the extent of the flashfire and overpressure impact area if an ignition occurs. Fatality or property damage effects from overpressure are not explicitly modelled in the risk calculations unless these affect a larger area than the extent of the flammable cloud (refer to Section 7.3.1 for details).

7.1.2. Releases

Loss of containment from equipment was modelled for the representative range of hole sizes in Table 7.1.

The hole size selected for the ranges are the geometric means, which give a weighting towards the lower band, since smaller sized leaks tend to occur more frequently.

The hole sizes were assigned as relevant to specific process equipment as per the data in APPENDIX C, Table C.1.

Table 7.1: Representative hole sizes for modelling loss of containment

Representative hole size used for QRA (mm)	Process equipment hole diameter range (mm), Ref (11)
2	1 to 3
6	3 to 10
22	10 to 50
85	50 to 150
Full bore	>150

The following constraints were applied:

- For loss of containment downstream of a pump, restriction orifice or control valve, the maximum release rate was limited to the normal pumping rate or the process flow rate if predicted flow rate from hole size exceeded the limiting process flow rate.
- For piping with a diameter less than or equal to 100 mm diameter, a full bore rupture case was set equal to the pipe diameter instead of the 85 mm.

- For overfill scenarios the maximum import rate was used. The maximum import rate is set by the Terminal to avoid exceeding a velocity of 7 m/s in the smallest diameter section along the import path.

7.1.3. Scenarios

When released at pressure, a liquid may form an airborne aerosol and/or fall to the ground. The pressure, hole size and fluid properties including vapour pressure all are factors in whether an aerosol, pool or combination of the two will form. Only the light components from gasoline such as C4s and C5s will tend to form a vapour cloud from evaporation or an aerosol release. The formation of a vapour cloud depends on the release characteristics and weather.

For liquid releases at low pressure, such as from a tank leak, an evaporating pool and pool fire (given ignition) were modelled.

For loss of containment within a bund, the size of the pool (whether a pool fire or evaporating pool) is limited by the equilibrium pool diameter.[1] Where the equilibrium pool diameter exceeded the bund diameter, the pool was restricted to the size of the bund.

Loss of containment of gasoline due to tank overfill ('the Buncefield scenario') and the extent of the flammable cloud envelope was modelled following the UK HSE's VCA method, Ref (12), which provides a means of calculating the rate at which the volume of a vapour cloud increases during an overfilling incident, hence predicting the distance to the LFL of the cloud.

The model selected based on the material, scenario and ignition is shown in Table 7.2.

[1] For immediately ignited events (early pool fires), the equilibrium pool diameter is defined as the diameter at which the burn rate of the pool is equal to the release rate. For delayed ignited events (late pool fires and flash fires from pool evaporation), the equilibrium pool diameter is defined as the diameter at which the evaporation rate of the pool is equal to the release rate.

Table 7.2: Scenario rule set for releases

Material	Scenario	Pressure range (barg)	Hole size (mm)	Ignition timing	Consequence modelled
Gasoline (91 ULP, 95 PULP, 98 PULP)	Pumped liquid in pipeline	0-10	2, 6, 22	Immediate	Jet fire
				Delayed	Flash fire
			85, rupture	Immediate	Early pool fire
				Delayed	Flash fire
	Storage tank – mechanical failure	Atmospheric	Rupture	Immediate	Bund fire
				Delayed	Flash fire
	Storage tank – overfill	Atmospheric	Maximum import rate	Immediate	Early pool fire
				Delayed	Flash fire (UK HSE VCA method)
Diesel (AGO)	Pumped liquid in pipeline	0-10	2, 6, 22	Immediate	Early pool fire
				Delayed	Late pool fire
			85, rupture	Immediate	Early pool fire
				Delayed	Late pool fire
	Storage tank – mechanical failure	Atmospheric	Rupture	Immediate	Early pool fire
				Delayed	Bund fire
	Storage tank – overfill	Atmospheric	Maximum import rate	Immediate	Early pool fire
				Delayed	Late pool fire

7.1.4. Weather conditions

Historical meteorological weather data for the Terminal was obtained from the New Zealand National Climate Database CliFlo system, Ref (13) The acquired data set was based on readings from the Automatic Weather Station (AWS) on Kyle St, Christchurch (Station no. 24120) approximately 7 km north-west of the Terminal over the period of May 2012 – May 2017.

From the acquired data sets, representative weather conditions were consolidated for consequence modelling, as outlined in Table 7.3. The analysis of the data, which is an input to the risk model, is included in APPENDIX A.

Jet and pool fires consequences were only modelled under a high wind speed case, D5.0, since they are less influenced by the prevailing wind and weather conditions and higher wind speeds are more conservative as they result in slightly larger effect distances than lower wind speeds.

Table 7.3: Weather conditions for consequence modelling

Name	Pasquill stability class	Wind speed (m/s)	Description
B2.2	B	2.2	Sunny day, low wind speed
D5.0	D	5.0	Cloudy or moderate wind speed
E3.2	E	3.2	Night time and moderate wind speed
F1.4	F	1.4	Night time/early morning, low wind speed

7.1.5. Modelling approaches

A standard set of models and modelling parameters were used in the software as outlined in APPENDIX B.

7.2. Vulnerability

The assessment criteria for exposure to hazardous scenarios (e.g. fires) are given by vulnerability relationships and are summarised in Table 7.4.

For fire scenarios, people are vulnerable to fire through:

- engulfment by fire
- thermal radiation from a fire
- inside buildings exposed to fire.

The vulnerability relationship for heat radiation is from the TNO Green Book, Ref (14), which is defined by the Probit shown below:

$$Pr = -36.38 + 2.56(Q^{4/3}t)$$

where,	Pr	probit corresponding to probability of death	(-)
	Q	heat radiation level	(W/m^2)
	t	exposure time	(s)

There is a range of guidance in industry and regulator advice regarding exposure durations in QRA. For heat radiation exposures this typically ranges from 20 to 60 seconds. TNO (Dutch guidelines) recommends 20 seconds for heat radiation exposures on the basis that the average escape time is 20 seconds which includes 5 seconds reaction time and then escaping at 4 metres per second, Ref (15). This is the default setting in Riskcurves.

The Singapore government recommends that anything less than 30 seconds requires justification, but also sets a minimum fatality threshold of 4 kW/m^2 at 3% fatality probability regardless of exposure duration, Ref (16). HIPAP 4 does not specify but says “The interpretation of ‘fatal’ should not rely on any one dose-effect relationship, but involve a review of available data”, Ref (2).

For this study, 30 seconds has been adopted as the maximum heat radiation exposure duration and used to determine heat radiation levels for consequence modelling.

Table 7.4: Vulnerability criteria for fire scenarios

Event	Level	Probability of fatality assumed in QRA (30 secs exposure)	Other effects	Reference
Spray fire Pool fire	Within fire envelope	100%	Escalation due to direct impingement	OGP Risk Assessment Data Directory, Ref (17)
	23 kW/m^2	95%	Escalation due to heat radiation	HIPAP 4, Ref (2)
	12.5 kW/m^2	33%	Possible fatality indoors if line of sight exposure occurs.	TNO probit, Ref (14)
	7.3 kW/m^2	1%	-	TNO probit, Ref (14)
	4.7 kW/m^2	Injury	Injury only	HIPAP 4, Ref (2)
Flash fire	Within LFL (assumed to be flashfire envelope)	100%	No escalation – very short duration event	UK HSE Research Report 084, Ref (18)

7.3. Results

A full set of consequence modelling results for the Terminal is provided in APPENDIX B.

7.3.1. Tank overfills - overpressure effects from explosions

Overpressure is generally regarded as a function of congestion and confinement with the conventional approach being that high overpressures are sustained only in congested areas. The Terminal area has a relatively open layout with minimal congested areas (limited areas around the tanker loading rack and manifold only). The conventional approach suggests that overpressures are very unlikely at the Terminal.

The UK HSE has also recently published a review of vapour cloud explosion incidents that shows for very large gasoline clouds there is evidence that high overpressures are sustained outside congested areas, Ref (19). This review suggests that there is another factor such as high temperatures or dust resuspension that is involved in generating overpressure in large flammable gasoline clouds. Therefore even though congestion/confinement at the Terminal appears limited, the potential for overpressure effects is still assessed as a potential consequence of a gasoline tank overfill.

As per the findings of the Buncefield investigation, Ref (20), overpressure diminishes very rapidly outside flammable clouds resulting from overfills (large shallow clouds). A correlation for estimating the overpressure from edge of cloud has been published. In this case the overpressure effects causing fatality (14 kPa) are a very similar magnitude as the flashfire extent and hence do not affect the fatality calculations as the probability of fatality within the LFL is assumed to be 100% (as per Table 7.4).

Therefore for this study, all delayed ignition events from tank overfills have been included in the QRA model as flash fires. The overpressure fatality or damage effects have not been explicitly quantified in the QRA model, and the extent of the overpressure footprint that could result in a fatality (or damage to equipment/escalation) was set equal to the LFL envelope of the flash fire.

The modelling results for the Current Case indicated that the combination of filling rates (maximum LWPL import rate is 95 m^3/hr) and tank dimensions were not sufficient for a large flammable cloud to form. This is consistent with guidance from the UK HSE, Ref (3), which defines large gasoline storage facilities (i.e. Buncefield type depots) that land use planning separation distances are applicable to, as vertical tanks of a height greater than 5 m with filling rates for gasoline of more than 100 m^3/hr.

A “Buncefield” type scenario has been considered in the Future Case for the Terminal and the extent of the flammable vapour cloud estimated as per Section B8, with the LFL extending approximately 230 m.

7.3.2. Largest impact distance

The maximum extent of the worst case scenario for the Current Case is the flashfire resulting from a gasoline pool evaporation scenario from the bund after a major rupture of tank 11, with the LFL extending 220 m (as per results in APPENDIX B, Section B5). This extends to the surrounding industrial sites areas but does not extend to any residential areas or sensitive land uses.

For the Future Case, the worst case scenario is the overfill from gasoline tanks, and delayed ignition of a flammable cloud with the LFL extending 230 m (as per results in APPENDIX B, Section B8), extending to the surrounding industrial site areas but not to any residential areas or sensitive land uses.

7.3.3. Potential for escalation to neighbouring sites

The heat radiation level of interest is 23 kW/m^2, at which escalation to equipment in the vicinity of a fire could occur, or rapid escalation to a tank inventory. The maximum extent of the 23 kW/m^2 from a gasoline pool fire is 40 m from the tank top full surface scenario for Tank 11.

There are no neighbouring hazardous industries or facilities in the vicinity within the 23 kW/m^2 effect area hence no escalation events were identified.

8. FREQUENCY ANALYSIS

The frequency of an event is defined as the number of occurrences of the event over a specified time period; with the period in risk analysis generally taken as one year.

The following data was used to estimate frequencies:

- Historical equipment leak frequencies from recently available industry data such as LASTFIRE, Ref (21; 22), and Oil and Gas Producers (OGP), Ref (11; 17).
- Parts count
- Operational error frequencies
- External factors frequencies – earthquakes
- Ignition probability
- Effect of safeguards
- Online time
- Storage tank fire frequencies.

The resulting frequency of each scenario is detailed in APPENDIX C.

9. RISK ASSESSMENT

The risk results are presented as risk contours for both the Current and Future Case operations. Risk contours for individual fatality, injury and property damage and propagation were assessed and presented in the following sections.

9.1. Individual fatality risk

The risk contours for the existing and future increased throughput operations are shown in Figure 9.1 and Figure 9.2, respectively.

Comparison of the risk against the risk criteria is presented in Table 9.1. It shows that all of the individual fatality risk criteria for offsite land uses are complied with for the Current and Future Cases.

A sensitivity study was also completed on the Current and Future Cases to determine the effect of earthquakes on the overall individual fatality risk contours. The results of the assessment, outlined in APPENDIX E, Section E1, show that the effects of earthquakes only has a minor contribution and the results of the assessment against the HIPAP 4 risk criteria in Table 9.1 are unaffected.

Individual fatality risk results are also presented for the Victorian risk criteria as per APPENDIX E, Section E2. The conclusions are the same as against HIPAP 4, i.e. all criteria are met.

Table 9.1: Comparison with individual fatality risk criteria

Description	Risk criteria (per year)	Meets criteria?		Comments
		Current Case	Future Case	
Hospitals, child-care facilities and old age housing (sensitive land uses).	0.5×10^{-6}	Yes	Yes	The risk contours extend up to approximately 155 m (for the Current Case) and 170 m (for the Future Case) from the north-eastern Terminal boundary. However, there are no sensitive land uses in this area.
Residential developments and places of continuous occupancy such as hotels and tourist resorts (residential land use).	1×10^{-6}	Yes	Yes	The risk contours extend up to approximately 90 m (for the Current Case) and 125 m (for the Future Case) from the north-eastern Terminal boundary. However, there are no residential land uses in this area.
Commercial developments, including offices, retail centres and entertainment centres (commercial land use).	5×10^{-6}	Yes	Yes	The risk contours extend up to approximately 40 m (for the Current Case) and 45 m (for the Future Case) from the eastern Terminal boundary. However, there are no commercial land uses in this area.
Sporting complexes and active open space areas.	10×10^{-6}	Yes	Yes	The risk contours extend up to approximately 20 m (for the Current Case) and 35 m (for the Future Case) from the northern and eastern Terminal boundaries. The contour extends to the boundary of an area to the east of the Terminal marked as “Open Space Community Park” in the context of the CDP, Ref (4).
Target for site boundary.	50×10^{-6}	Yes	Yes	The risk contours remain within the site boundary for the Current and Future Cases.

Figure 9.1: Individual fatality risk contour (Current Case)

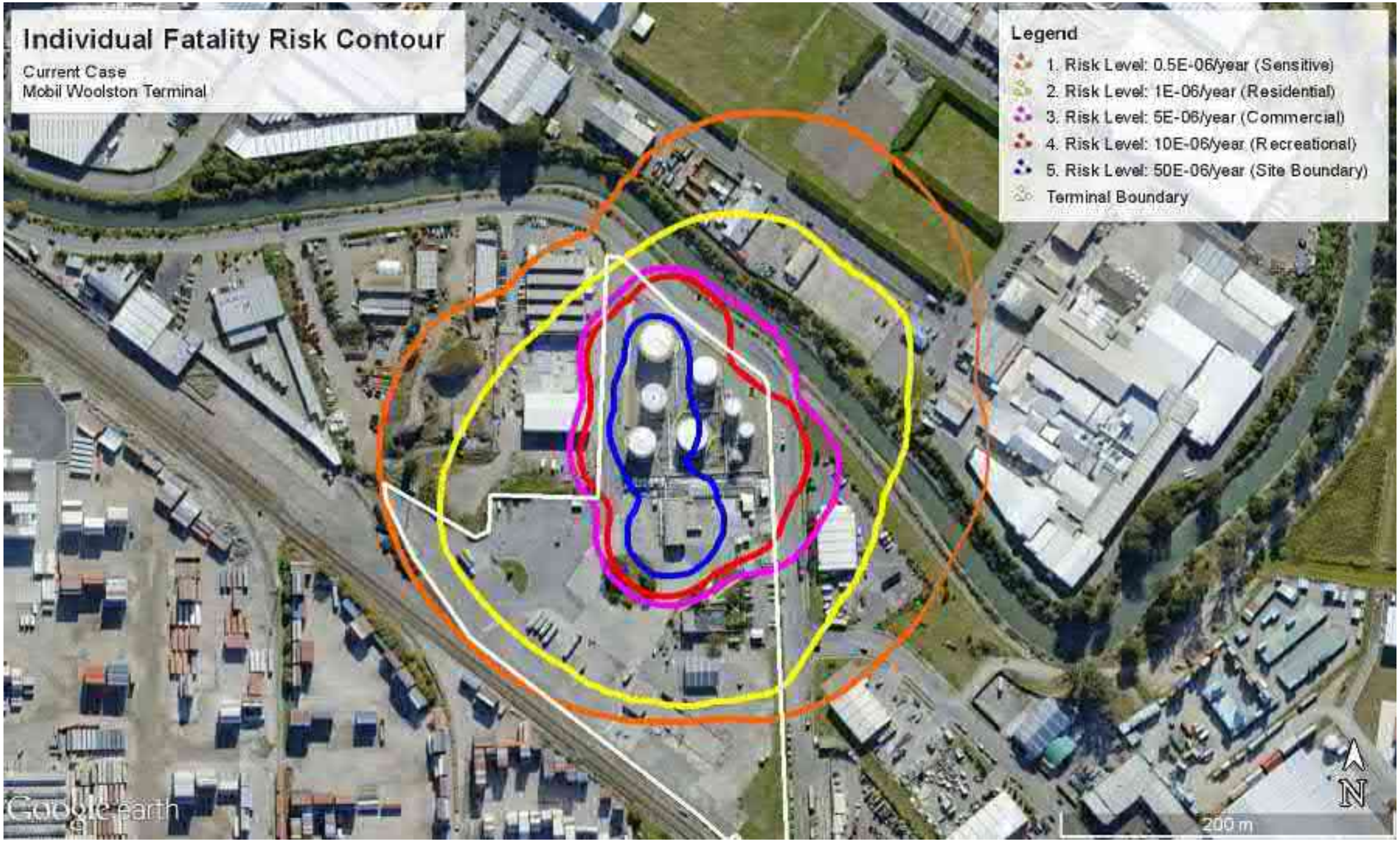
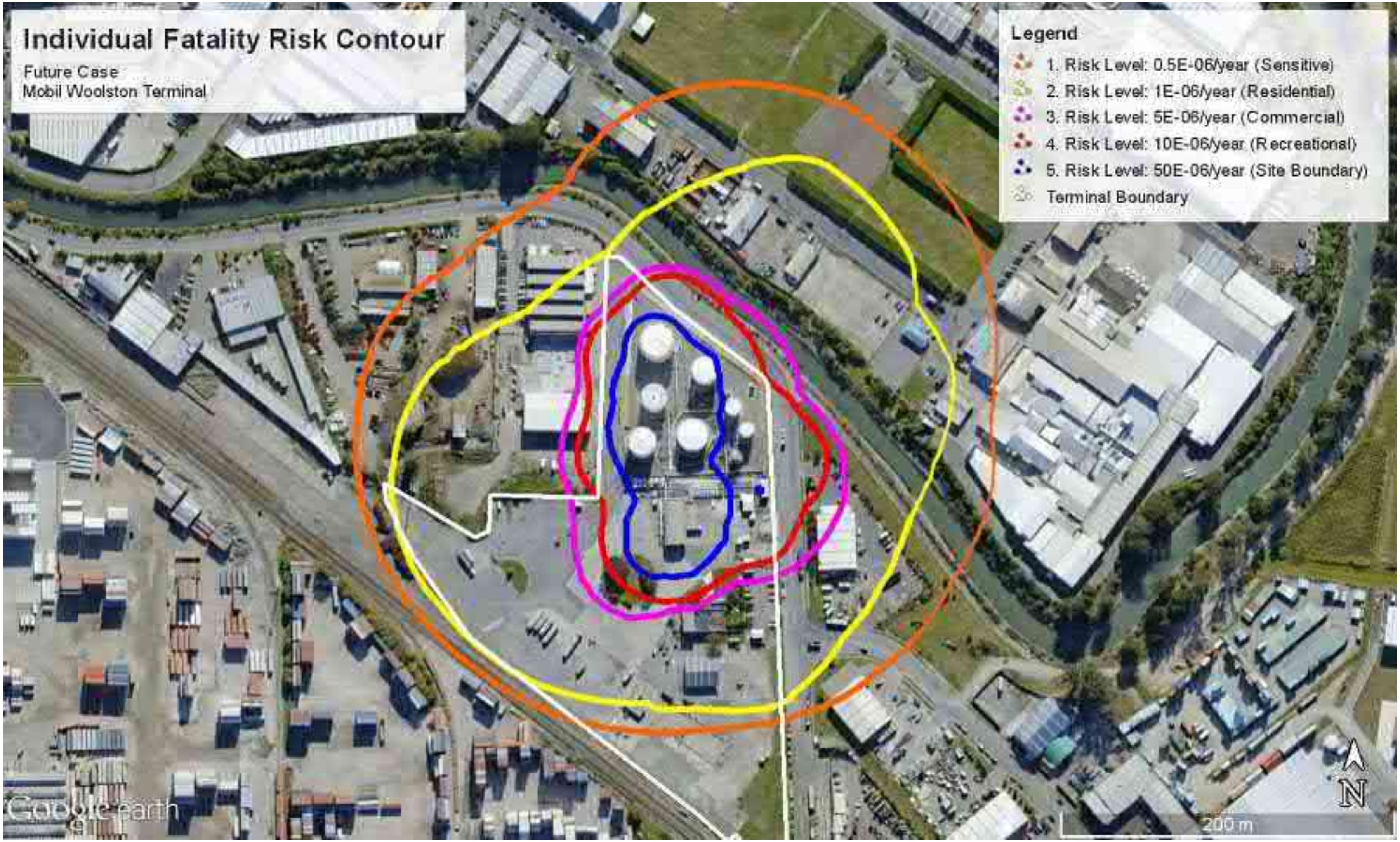


Figure 9.2: Individual fatality risk contour (Future Case)



9.2. Major risk contributors

9.2.1. Current Case

For the current operations, the major risk contributors at three points were extracted from the individual fatality risk model (Current Case) and summarised in Table 9.2. The locations of these analyses points are shown in Figure 9.3.

The three points were selected to provide an overview of the major contributing scenarios to the offsite risk at the site boundary and at different locations surrounding the Terminal corresponding to a risk level of approximately 1 x 10^{-6} per year.

Risk analyses of major risk contributors at these selected points indicate that:

- Analysis Point 1: Northern boundary of the Terminal.

The pool fire resulting from tank roof fire of Tank 11 is the major risk contributor to the offsite risk at the northern boundary of the Terminal.

- Analysis Point 2: Eastern limit of 1 x 10^{-6} per year contour

Flash fires from the inlet manifold and minor ignited leaks from the gasoline tanks are the major risk contributors to the offsite risk at the 1 x 10^{-6} per year contour to the east of the Terminal.

- Analysis Point 3: Western limit of 1 x 10^{-6} per year contour

Flash fires from minor leaks from the gasoline tanks are the major risk contributors to the offsite risk at the 1 x 10^{-6} per year contour to the west of the Terminal.

Figure 9.3: Analysis point locations (Current Case)

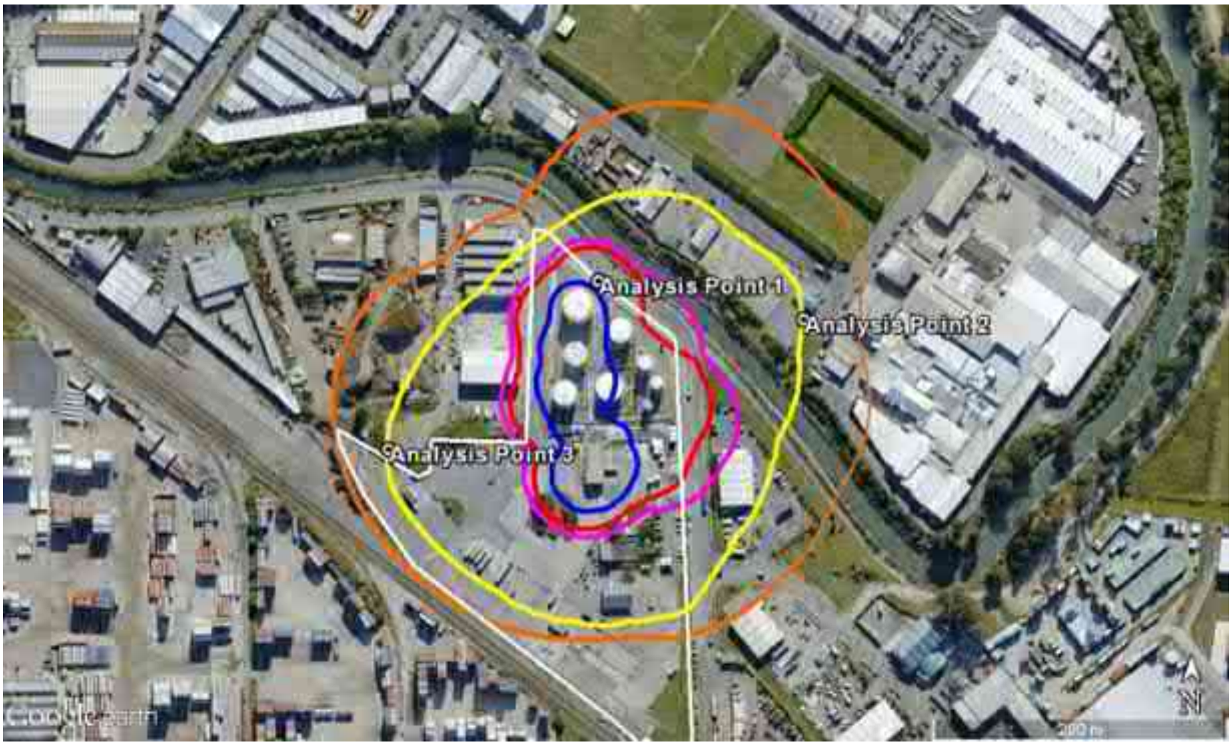


Table 9.2: Major risk contributors at analysis points (Current Case)

Location	Main risk contributors	Contribution at location
Northern Terminal boundary Risk: 3.19 x 10^{-5} per year (Analysis Point 1)	Tank roof fire – Tank 11 (ULP)	62%
	Pool fire – Mechanical failure of tank (ULP) and spill from bund due to ground movement (earthquake)	14%
	Pool fire – Tank 11 (ULP) overfill	8%
	Pool fire – Tank 11 (ULP) minor leak	8%
	Flash fire – Tank 11 (ULP) minor leak	1%
Eastern limit of 1 x 10^{-6} per year contour Risk: 9.89 x 10^{-7} per year (Analysis Point 2)	Flash fire – Inlet manifold 22 mm leak (ULP)	20%
	Flash fire – Tank 11 (ULP) minor leak	17%
	Flash fire – Tank 2 (ULP) minor leak	17%
	Flash fire – Tank 15 (ULP) minor leak	16%
	Flash fire – Tank 11 (ULP) major rupture	9%
Western limit of 1 x 10^{-6} per year contour Risk: 1.02 x 10^{-6} per year (Analysis Point 3)	Flash fire – Tank 11 (ULP) minor leak	22%
	Flash fire – Tank 15 (ULP) minor leak	22%
	Flash fire – Tank 2 (ULP) minor leak	22%
	Flash fire – Tank 11 (ULP) major rupture	13%
	Flash fire – Tank 15 (ULP) major rupture	11%

9.2.2. Future Case

For the future operations, the major risk contributors, at the same three locations considered in the Current Case, were extracted from the individual fatality risk model (Future Case) and summarised in Table 9.3. The locations of these analyses points are the same as the Current Case. The major risk contributors for the Future Case were very similar to the Current Case with the exception of the increase in risk due to overfill of gasoline tanks. This is due to the filling rate of the gasoline tanks increasing to a rate at which Buncefield-type scenario may result.

Figure 9.4: Analysis point locations (Future Case)

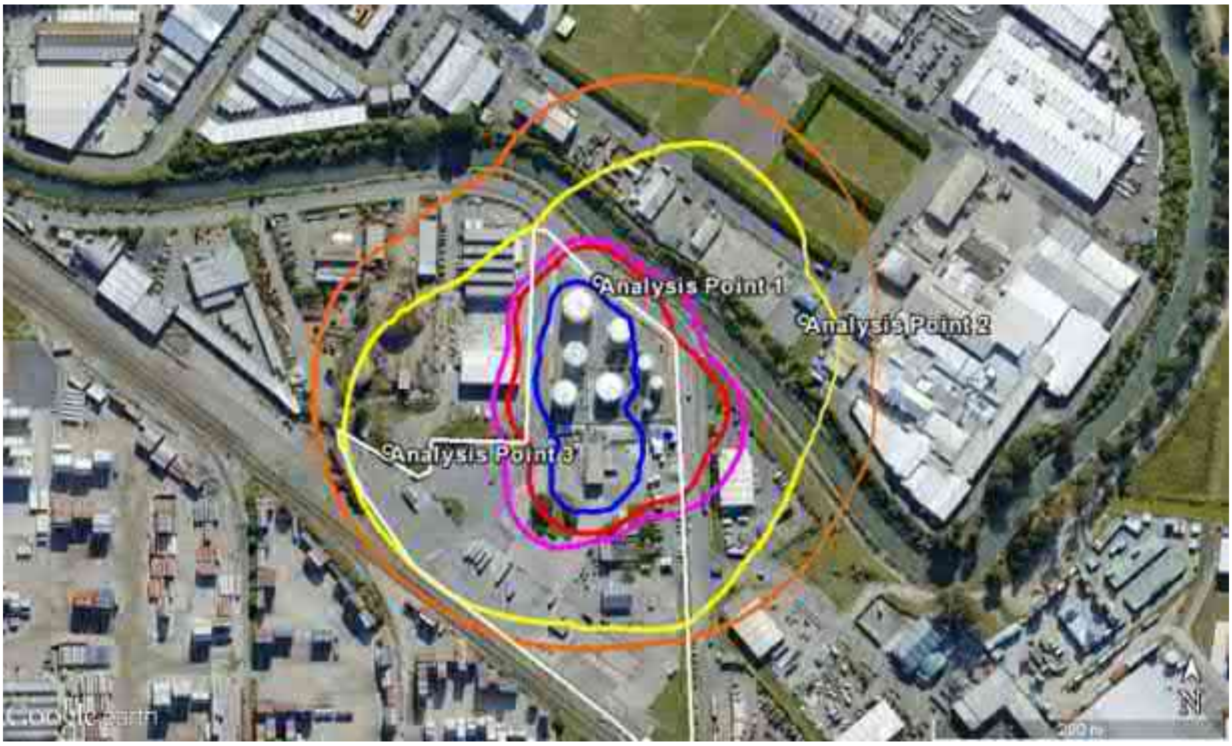


Table 9.3: Major risk contributors at analysis points (Future Case)

Location	Main risk contributors	Contribution at location
Northern Terminal boundary Risk: 3.29 x 10^{-5} per year (Analysis Point 1)	Tank roof fire – Tank 11 (ULP)	62%
	Pool fire – Mechanical failure of tank (ULP) and spill from bund due to ground movement (earthquake)	14%
	Pool fire – Tank 11 (ULP) minor leak	8%
	Pool fire – Tank 11 (ULP) overfill	7%
	Flash fire – Tank 11 (ULP) minor leak	1%
Eastern limit of 1 x 10^{-6} per year contour Risk: 1.25 x 10^{-6} per year (Analysis Point 2)	Flash fire – Inlet manifold 22 mm leak (ULP)	18%
	Flash fire – Tank 11 (ULP) minor leak	13%
	Flash fire – Tank 2 (ULP) minor leak	13%
	Flash fire – Tank 15 (ULP) minor leak	13%
	Flash fire – Tank 11 (ULP) overfill	7%
Western limit of 1 x 10^{-6} per year contour Risk: 1.50 x 10^{-6} per year (Analysis Point 3)	Flash fire – Tank 11 (ULP) minor leak	15%
	Flash fire – Tank 15 (ULP) minor leak	15%
	Flash fire – Tank 2 (ULP) minor leak	15%
	Flash fire – Tank 11 (ULP) overfill	13%
	Flash fire – Tank 15 (ULP) overfill	10%

9.3. Injury risk

Injury risk due to heat radiation impacts were assessed for both Current and Future Case operations. Injury risk contours are shown for the heat radiation impacts only as the frequency of events with any potential to generate an overpressure (i.e. gasoline tank overfills) are well below the relevant frequency criterion.

The injury risk contours (4.7 kW/m^2 heat radiation level) for the Current and Future Case operations are presented in Figure 9.5 and Figure 9.6, respectively.

Comparison of the risk against the risk criteria is presented in Table 9.4.

Table 9.4: Comparison with injury risk criteria

Description	Risk criteria (per year)	Meets criteria?		Comments
		Current Case	Future Case	
Heat radiation of 4.7 kW/m^2 at residential or sensitive land uses.	50×10^{-6}	Yes	Yes	The risk contours extend up to approximately 10 m from the north-eastern and western Terminal boundaries for the Current and Future Cases. However, there are no residential or sensitive land uses in this area.
Overpressure of 7 kPa at residential or sensitive land uses.	50×10^{-6}	Yes	Yes	A risk contour is not generated. The only events with potential overpressures of 7 kPa extending a significant distance are VCEs resulting from gasoline tank overfills. The cumulative frequency (as per APPENDIX C, Section C9.2) of a delayed ignition event is well below 50×10^{-6} per year so a contour cannot be generated and this criteria is met.

Figure 9.5: Injury risk contour (Current Case)

Figure 9.6: Injury risk contour (Future Case)

9.4. Property damage and propagation risk

Damage and propagation risk due to heat radiation impacts were assessed for both Current and Future Case operations. Escalation risk models were prepared only for the heat radiation impacts, as the cumulative frequency of events with the potential to cause explosion overpressures is less than 50×10^{-6} per year hence below the HIPAP 4 acceptability criteria.

The damage and propagation risk contours (23 kW/m^2 heat radiation level) for the Current and Future Case operations are presented in Figure 9.7 and Figure 9.8, respectively.

Comparison of the risk against the risk criteria is presented in Table 9.5.

Table 9.5: Comparison with damage and propagation risk criteria

Description	Risk criteria (per year)	Meets criteria?		Comments
		Current Case	Future Case	
Heat radiation of 23 kW/m^2 at neighbouring potentially hazardous installations or at land zoned to accommodate such installations.	50×10^{-6}	Yes	Yes	The risk contours remain within the site boundary for the Current and Future Cases.
Overpressure of 14 kPa at neighbouring potentially hazardous installations or at land zoned to accommodate such installations.	50×10^{-6}	Yes	Yes	A risk contour is not generated. The only events with potential overpressures of 14 kPa extending a significant distance are VCEs resulting from gasoline tank overfills. The cumulative frequency (as per APPENDIX C, Section C9.2) of a delayed ignition event is well below 50×10^{-6} per year so this criteria is met.

Figure 9.7: Damage and propagation risk contour (Current Case)

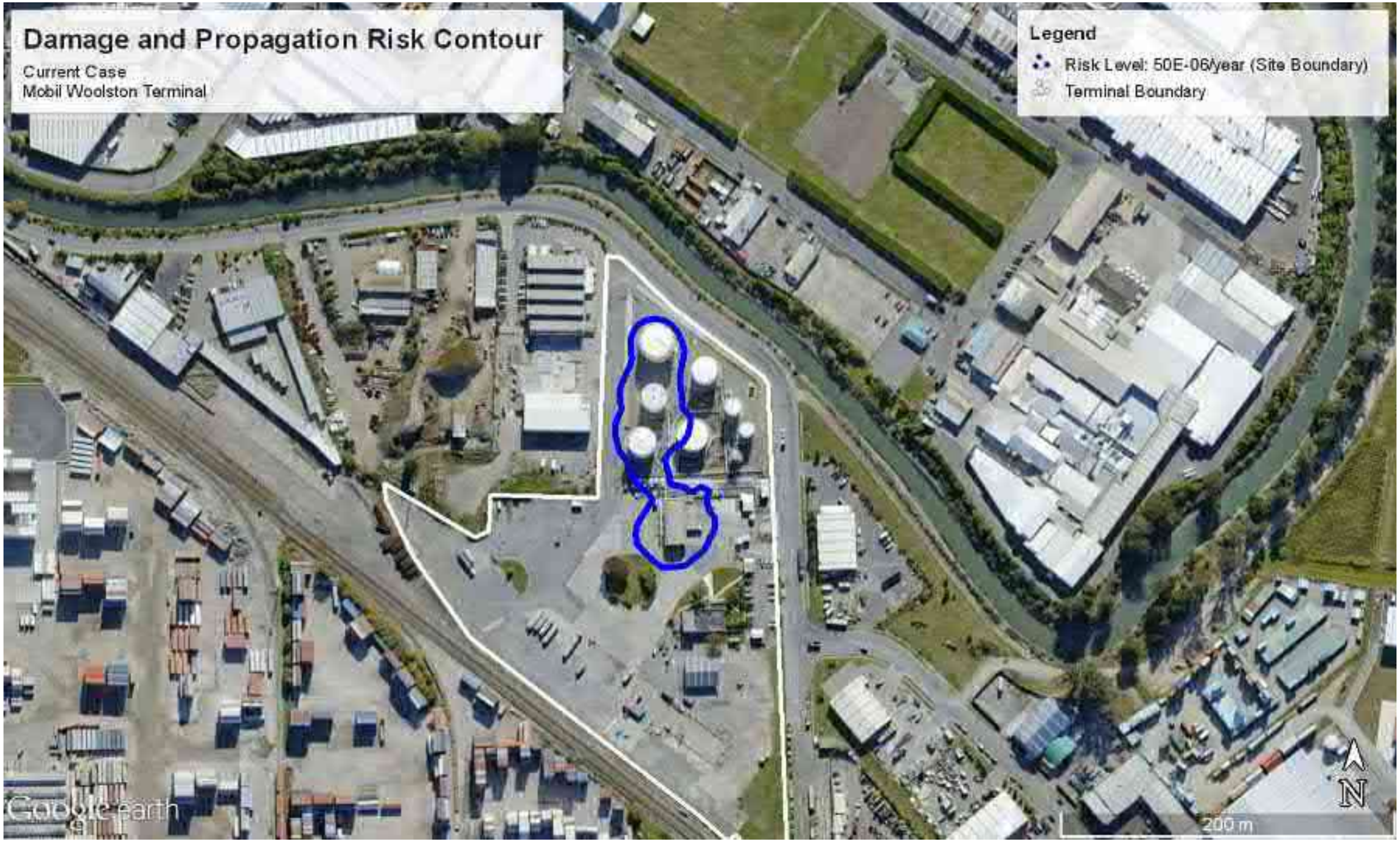
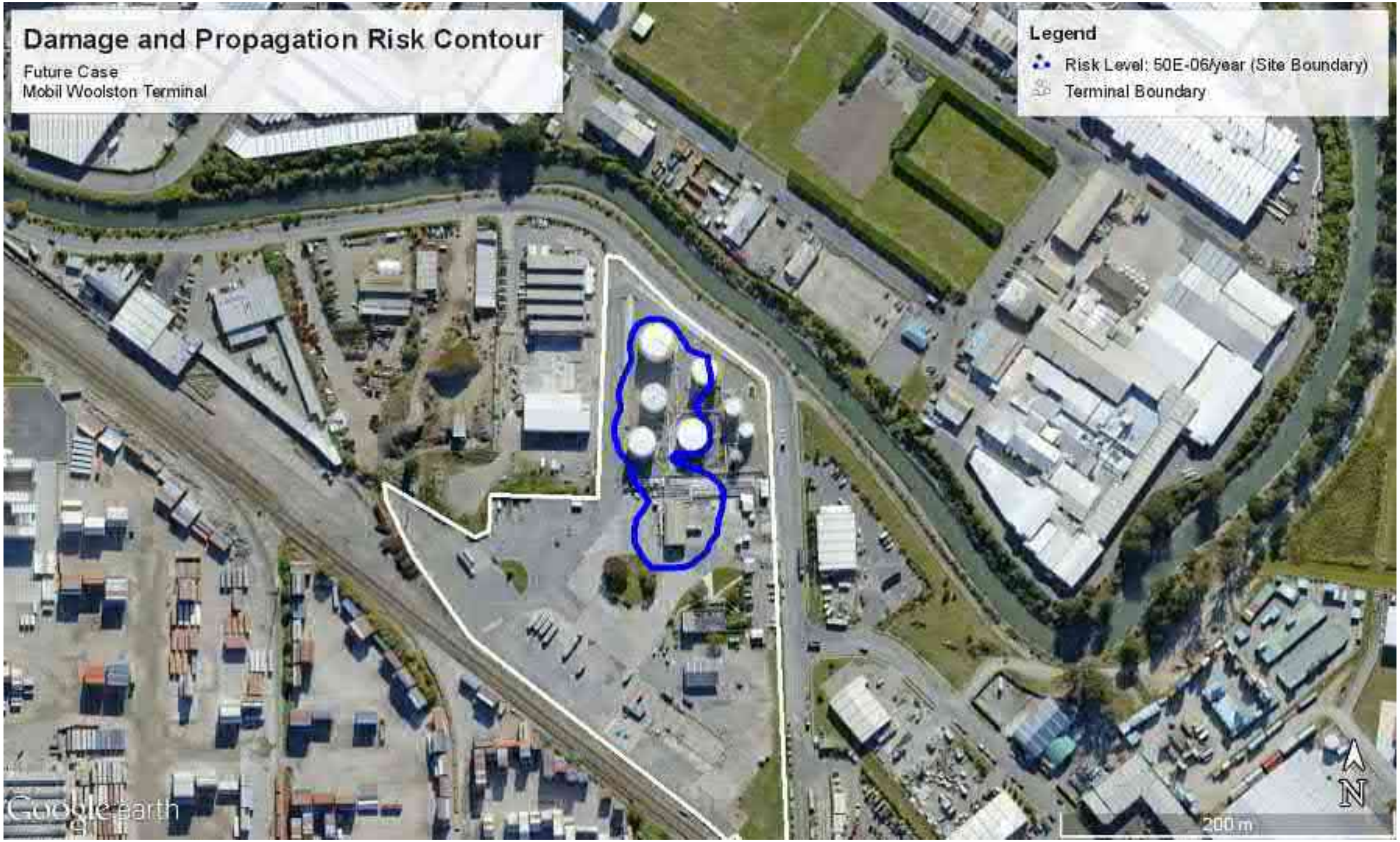


Figure 9.8: Damage and propagation risk contour (Future Case)



9.5. Conclusions

The study showed that for both the Current and Future Cases, all HIPAP 4 individual risk criteria are met as shown in Table 1.2.

A sensitivity study of the effect of earthquakes on the overall risk contours in APPENDIX E, Section E1, showed very little change to the individual fatality risk results if the earthquake contribution is removed.

Based on these results:

- The existing 250 m overlay in the CDP provides adequate protection from encroachment of incompatible land uses whilst allowing for a future growth scenario at the Terminal and could be retained.
- If the overlay is to be revised, the minimum extent that the planning overlay can be reduced to, whilst allowing for a credible future increase in throughput at the Terminal, is 170 m from the Terminal boundary based on the HIPAP 4 sensitive land use contour for the Future Case.

Sensitive or residential uses, and any land uses involving large populations should not be established within the extent of the overlay.

APPENDIX A. METEOROLOGICAL DATA

Historical meteorological weather data for the Terminal was obtained from the New Zealand National Climate Database CliFlo system, Ref (13). The acquired data set was based on readings from the AWS on Kyle St, Christchurch (Station no. 24120) approximately 7 km north-west of the Terminal over the period of May 2012 – May 2017.

Analysis of the data was performed using the methodology outlined in the TNO Purple Book to obtain the representative weather conditions (including wind speed and stability classes) appropriate for the QRA, Ref (23).

As cloud cover data was unavailable, representative weather conditions were determined based on the wind speed and whether occurrence was during the day or at night. An overview of the rule set used to determine the representative weather conditions using the Purple Book approach is shown in Table A.1.

Table A.1: Rule set for representative weather conditions

Time of day	Wind speed range (m/s)	Pasquill stability class	Average wind speed (m/s)
Day	< 4	B	2.2
	> 4	D	5.0
Night	< 2.5	F	1.4
	2.5 – 4	E	3.2
	> 4	D	5.0

For the QRA model, the data were consolidated into five different representative weather conditions which are:

- Pasquill Stability Class: B; wind speed 2.2 m/s (B2.2)
- Pasquill Stability Class: D; wind speed 5.0 m/s (D5.0)
- Pasquill Stability Class: E; wind speed 3.2 m/s (E3.2)
- Pasquill Stability Class: F; wind speed 1.4 m/s (F1.4).

A summary of the meteorological data sets used for the hazard assessment are presented in Table A.2. Additionally, the wind rose map is also provided in Figure A.1.

Note that there are no high wind speeds at this Terminal, as 99% of the data readings are below 7 m/s as shown in Table A.3. Hence, no high wind speed case is defined in the representative weather conditions.

Table A.2: Meteorological data sets used in risk model

Direction wind from (degrees true)	B2.2		D5.0		E3.2		F1.4		Total day	Total night
	Day	Night	Day	Night	Day	Night	Day	Night		
0	5.75	0.00	0.60	0.36	0.00	1.00	0.00	5.37	6.35	6.74
30	14.59	0.00	4.11	2.45	0.00	5.48	0.00	10.17	18.70	18.10
60	16.27	0.00	7.29	4.35	0.00	9.35	0.00	11.04	23.56	24.74
90	3.41	0.00	0.69	0.41	0.00	1.94	0.00	3.41	4.10	5.76
120	0.71	0.00	0.00	0.00	0.00	0.03	0.00	1.15	0.71	1.18
150	0.82	0.00	0.06	0.04	0.00	0.06	0.00	0.81	0.88	0.91
180	4.53	0.00	2.39	1.42	0.00	1.11	0.00	2.28	6.92	4.81
210	11.60	0.00	5.32	3.17	0.00	4.44	0.00	6.89	16.92	14.51
240	8.13	0.00	2.16	1.29	0.00	3.45	0.00	6.20	10.28	10.94
270	2.55	0.00	1.00	0.60	0.00	0.75	0.00	2.67	3.55	4.03
300	2.44	0.00	1.63	0.97	0.00	0.61	0.00	2.42	4.07	4.00
330	3.11	0.00	0.85	0.51	0.00	0.66	0.00	3.13	3.97	4.30
Total	73.89	0.00	26.11	15.57	0.00	28.89	0.00	55.54	100.00	100.00

Figure A.1: Wind rose distribution

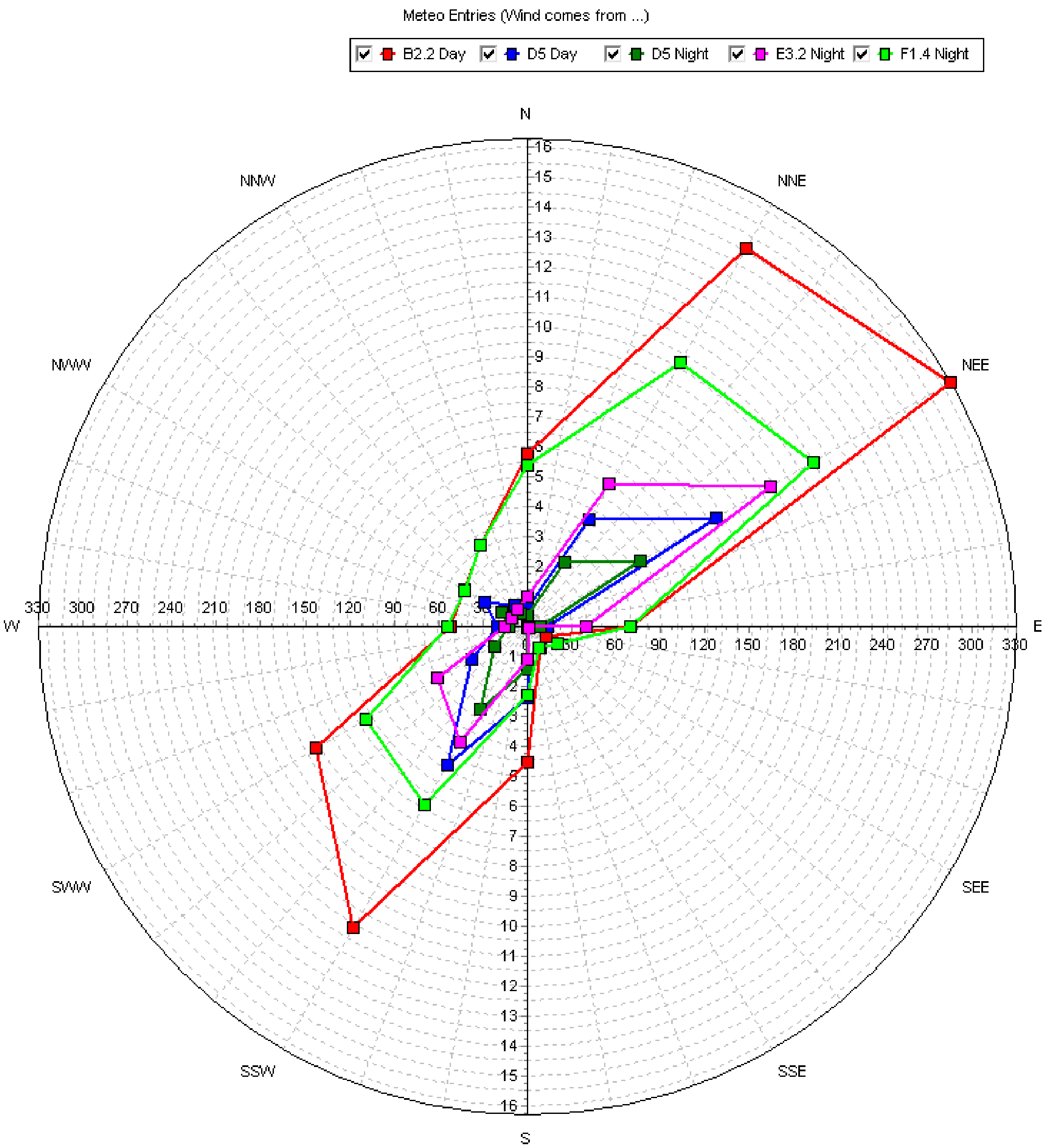


Table A.3: Wind speeds summary table

Wind speed (m/s)	% Individual	% Cumulative total
<0.5	3.4	3.4
0.5-1	11.5	14.9
1-1.5	12.4	27.3
1.5-2	12.3	39.6
2-3	22.1	61.7
3-4	19.0	80.8
4-5	11.5	92.3
5-6	5.1	97.4
6-7	1.9	99.3
7-8	0.6	99.8
8-9	0.1	99.9
>9	0.1	100.0

APPENDIX B. CONSEQUENCE ANALYSIS

B1. Overview

The following types of event were evaluated to determine the effects from hydrocarbon releases at the Terminal:

- Jet/spray fires
- Pool fires
- Flash fires
- Tank top full surface fires
- Tank bund fires
- Tank overfill flash fires (‘Buncefield’ scenario)
- External factors consequences – earthquakes.

Consequence analysis was undertaken for both the current (2017) and projected future operations of the Terminal. The modelling approaches (e.g. parameters and models) and results are presented in the following sections.

The only changes in the consequence assessment and results between the Current and Future Cases, are changes to the overfill consequences of the storage tanks and the tank top full surface fires due to the addition of jet fuel tanks.

B2. Modelling parameters

The modelling parameters used for modelling of consequences are shown in Table B.1 respectively.

For the types of modelling undertaken (i.e. releases involving non-boiling, ambient temperature hydrocarbon liquids) the results are relatively insensitive to most environmental parameters, with the exception of the ground roughness length and the receptor height.

Table B.1: Modelling parameters

Item	Value	Basis
Ambient temperature	13 ˚C	Weather data, average annual temperature.
Soil temperature	13 ˚C	Assumed equal to ambient temperature.
Relative humidity	74%	Weather data, average relative humidity.
Solar radiation	1 kW/m^2	Summer/winter insolation - estimated typical values (0.1 – 1 kW/m^2).
Surface type	Concrete/ gravel	Affects pool spreading calculation.
Ground roughness length	0.1 m	Ground roughness affects turbulent flow properties of wind, hence dispersion of a released material. Terrain effects are taken into account to some degree in dispersion modelling by use of a parameter known as surface roughness length. A surface roughness length of 0.1 m used corresponding to an area with occasional large objects/obstacles and isolated trees and structures such as the area surrounding the terminals.
Averaging time (flammables)	20 seconds	TNO Yellow Book, Ref (24) For a (semi-) continuous source this is the duration over which the concentration will be 'averaged out', to deal with the effect of the meandering of the wind or local atmospheric turbulence. A one-second peak concentration at a given location downwind will be greater than a one-minute averaged peak concentration, which in turn will be greater than a one-hour average concentration, even though the amount released at the source is the same. For flammables a short duration peak is important and 18.75 to 20 sec is typical, for toxics the exposure duration is longer, typically 600 sec to 3600 sec to match the toxic effects being assessed.
Receptor height	1.5 m (1 m for flash fires)	1.5 m around face height. For dispersion to LFL, this is taken at 1 m height as models have been verified against experimental values at this height.

B3. Spray fires

Jet/spray fire results for the Current and Future Case operations are summarised in Table B.2. This table provides the dimensions of the spray fires for each identified release condition for gasoline release sizes less than 25 mm, as per rule set outlined in Table 7.2. Additionally, distance to heat radiation levels of interest (as per Table 7.4) is reported. These results represent a continuous release without isolation which represents the worst case scenario for any given leak.

Table B.2: Jet fire consequence results (at 1.5 m receiver height)

Component/ equipment	Scenario ID	Product	Modelled product	Pressure (barg)	Hole size (mm)	Release rate (kg/s)	Jet/spray fire (at D5.0 m/s wind speed)					
							Length (m)	Width (m)	Distance to heat radiation (m)			
									23 kW/m²	12.5 kW/m²	7.3 kW/m²	4.7 kW/m²
Inlet manifold	MAN-01G	91 ULP/ 95 PULP	ULP Summer	10	2	0.08	4	2	5	6	7	8
					6	0.7	9	4	15	16	19	21
					22	9.2	28	12	46	53	61	69
Transfer pipeline	PPL-01G	91 ULP/ 95 PULP	ULP Summer	10	2	0.08	4	2	5	6	7	8
					6	0.7	9	4	15	16	19	21
					22	9.2	28	12	46	53	61	69
LWPL [(a)]	LWP-01G	91 ULP/ 95 PULP	ULP Summer	10	22	9.2	23	10	33	42	52	61
Road tanker loading pumps	PMP-01G	91 ULP/ 95 PULP	ULP Summer	5	2	0.05	3	1	5	5	6	7
					6	0.5	8	4	13	15	16	18
					22	6.5	23	10	37	42	48	55
Road gantry	RTL-01G	91 ULP/ 95 PULP	ULP Summer	5	2	0.05	3	1	5	5	6	7
					6	0.5	8	4	13	15	16	18
					22	6.5	23	10	37	42	48	55

Notes:

(a) Releases from the LWPL underground section within the Terminal boundary were assumed to be orientated at 45° from vertically up as a worst case, as horizontal fires are unlikely due to underground impingement.

B4. Pool fires

Pool fire results are summarised in Table B.3. The reported results include the release rate, equivalent pool diameter and distance to heat radiation levels of interest (as specified in Table 7.4).

In this assessment, spills of a liquid hydrocarbon from a leak were assumed to form a circular pool (spreading in all directions), unless limited by a bund, terrain or drainage. Subsequently, the pool fire dimensions were calculated assuming equilibrium where the burn rate equals the release rate of the material.

Some bunded areas were much longer in one dimension; in these instances the fire was limited to the width of the shorter dimension.

The fire duration and potentially the size of a pool fire is dependent upon the time to detect and stop a leak. These results generally represent continuous release without isolation which represents the worst case scenario for any given leak.

The limiting pool diameters used in the QRA for different release locations were:

- Additive compound: 12 m diameter pool
  - Basis – limited by the bunded area of the additive compound (106 m^2).
- Inlet manifold: 6 m diameter pool
  - Basis – limited by area of the inlet manifold (29 m^2).
- Transfer pipeline: 20 m diameter pool
  - Basis – Assumed bounded by tank compound bund pump slab, foam generator skid and MCC 1 room.
- LWPL: 40 m diameter pool
  - Basis – Restricted by gutter on eastern side of Chapmans Rd.
- Road tanker loadout pumps: 12 m diameter pool
  - Basis – Road tanker loadout pumps are located within bunded area (104 m^2) limiting pool growth for large releases.
- Road gantry: 8 m diameter pool
  - Basis – Gantry is kerbed with drainage limiting pool growth for large releases.

Table B.3: Pool fire consequence results (at 1.5 m receiver height)

Component/ equipment	Scenario ID	Modelled product	Pressure (barg)	Hole size (mm) [(a)]	Release rate (kg/s) [(b)]	Equivalent pool diameter (m)	Pool fire (at D5.0 m/s wind speed) [(c)] Distance to heat radiation from pool centre (m) 23 kW/m²	12.5 kW/m²	7.3 kW/m²	4.7 kW/m²
Additives bund – flammable	-	ULP Summer	0	RUP	-	12	13	26	34	40
Inlet manifold	MAN-01G	ULP Summer	10	85	20	6	13	20	24	28
				RUP	20	6	13	20	24	28
Transfer pipeline	PPL-01G	ULP Summer	10	85	20	20	12	25	37	45
				RUP	20	20	12	25	37	45
LWPL	LWP-01G	ULP Summer	10	85	20	40	12	25	37	45
				RUP	20	40	12	25	37	45
Road tanker loading pumps	PMP-01G	ULP Summer	5	85	24	12	13	26	34	40
				RUP	24	12	13	26	34	40
Road gantry	RTL-01G	ULP Summer	5	85	24	8	13	23	28	33
				RUP	24	8	13	23	28	33
Additives bund – combustible	-	Dodecane	0	RUP	-	12	13	26	37	44
Inlet manifold	MAN-02D	Dodecane	10	2	0.08	0.8	4	6	7	8
				6	0.7	3	9	13	15	18
				22	10	6	13	22	27	32
				85	19	6	13	22	27	32
				RUP	19	6	13	22	27	32
Transfer pipeline	PPL-02D	Dodecane	10	2	0.08	0.8	4	6	7	8
				6	0.7	3	9	13	15	18
				22	10	9	13	26	34	40
				85	19	20	13	24	43	55

Component/ equipment	Scenario ID	Modelled product	Pressure (barg)	Hole size (mm) [a]	Release rate (kg/s) [b]	Equivalent pool diameter (m)	Pool fire (at D5.0 m/s wind speed) [c]			
							Distance to heat radiation from pool centre (m)			
							23 kW/m^2	12.5 kW/m^2	7.3 kW/m^2	4.7 kW/m^2
				RUP	19	20	13	24	43	55
LWPL	LWP-02D	Dodecane	10	22	10	9	13	26	34	40
				85	19	40	NR	30	51	77
				RUP	19	40	NR	30	51	77
Road tanker loading pumps	PMP-02D	Dodecane	5	2	0.06	0.7	4	5	6	7
				6	0.5	2	8	12	14	16
				22	7	8	13	25	31	36
				85	28	12	13	26	37	44
				RUP	28	12	13	26	37	44
Road gantry	RTL-02D	Dodecane	5	2	0.06	0.7	4	5	6	7
				6	0.5	2	8	12	14	16
				22	7	8	13	25	31	36
				85	28	8	13	25	32	37
				RUP	28	8	13	25	32	37

Notes:

(a) “RUP” refers to a full bore rupture.

(b) For loss of containment downstream of a pump, restriction orifice or control valve, the maximum release rate was limited to the normal pumping rate or the process flow rate if predicted flow rate from hole size exceeded the limiting process flow rate. “-“ indicates flow rate is not calculated, relevant parameter for this scenario is pool surface area.

(c) “NR“ indicates heat radiation level was not reached.

B5. Flash fires

Apart from the gasoline tank overfill scenario, vapour clouds result from either:

- evaporation of light components of releases of gasoline which pool on the ground. Similar to pool fires, the maximum size of a pool is limited by bund walls. The limiting sizes are described in Section B4.
- momentum jet pressurised releases.

The rate of evaporation and the dispersion characteristics from a spill are dependent on the weather conditions. The modelling showed that flammable clouds larger than the immediate area of a pool only develop under low wind speed conditions.

Flash fire modelling was only undertaken for gasoline due to the presence of hydrocarbon ‘light ends’ (typically C4-C5), which are not present in significant amounts for heavier fuels such as diesel. Typical vapour clouds from gasoline spills are denser than air.

The results of the flash fires assessment for both the Current and Future Case operations are summarised as follows:

- Leaks from storage tanks resulting in pool evaporation of bund contents resulting in flammable vapour clouds (Table B.4).
- Terminal operations: pressurised small, medium and large releases (Table B.5).

Modelling results for flash fires are reported in terms of fire width and length to 100% LFL concentrations.

Flash fires were modelled for steady state (equilibrium) case assuming a continuous release without isolation or detection, and therefore represent the worst case cloud size. Ignition of the cloud before equilibrium would result in a smaller flash fire.

Table B.4: Flash fire consequence results – storage tanks (pool evaporation) (at 1 m receiver height)

Tank number	Product	Release type	Dimensions of flammable cloud to LFL (m) [a]							
			B2.2		D5.0		E3.2		F1.4	
			Length	Width	Length	Width	Length	Width	Length	Width
Tank 2	91 ULP	Overfill	6	15	NR	NR	5	12	17	149
		Minor leak	79	92	NR	NR	60	74	199	251
		Major rupture	179	138	174	122	161	143	206	257
Tank 11	91 ULP	Overfill	6	15	NR	NR	5	12	17	149
		Minor leak	93	108	NR	NR	74	89	212	256
		Major rupture	194	162	189	142	176	166	223	268
Tank 14	98 SPULP	Overfill	6	15	NR	NR	5	12	17	149
		Minor leak	23	39	NR	NR	4	17	22	215
		Major rupture	187	126	170	104	164	125	201	247
Tank 15	95 PULP	Overfill	6	15	NR	NR	5	12	17	149
		Minor leak	87	100	NR	NR	67	82	207	253
		Major rupture	186	149	181	132	169	154	215	268

Notes:
(a) “NR“ indicates LFL was not reached.

Table B.5: Flash fire consequence results – pressurised releases (at 1 m receiver height)

Component/ equipment	Scenario ID	Pressure (barg)	Hole size (mm) [a]	Release rate (kg/s) [b]	Dimensions of flammable cloud to LFL (m) [c]							
					B2.2		D5.0		E3.2		F1.4	
					Length	Width	Length	Width	Length	Width	Length	Width
Inlet manifold	MAN-01G	10	2	0.08	8	0.7	7	0.5	8	0.9	10	2
			6	0.7	29	5	25	3	27	6	38	22
			22	9	99	35	79	20	89	42	135	220
			85	20	5	5	NR	NR	3	4	13	23
			RUP	20	5	5	NR	NR	3	4	13	23
Transfer pipeline	PPL-01G	10	2	0.08	8	0.7	7	0.5	8	0.9	10	2
			6	0.7	29	5	25	3	27	6	38	22
			22	9	99	35	79	20	89	42	135	220
			85	20	14	14	1	3	9	11	39	99
			RUP	20	14	14	1	3	9	11	39	99
LWPL [d]	LWP-01G	10	22	9	NR	NR	NR	NR	NR	NR	NR	NR
			50	20	20	24	NR	NR	10	17	85	260
			RUP	20	20	24	NR	NR	10	17	85	260
Road tanker loadout pumps	PMP-01G	5	2	0.05	2	0.4	3	0.4	3	0.4	3	0.5
			6	0.5	25	5	20	3	22	6	31	23
			22	6	72	31	51	17	64	35	102	165
			85	24	0.2	1	NR	NR	NR	NR	19	41
			RUP	24	0.2	1	NR	NR	NR	NR	19	41
Road tanker gantry	RTL-01G	5	2	0.05	2	0.4	3	0.4	3	0.4	3	0.5
			6	0.5	25	5	20	3	22	6	31	23

Component/ equipment	Scenario ID	Pressure (barg)	Hole size (mm) [(a)]	Release rate (kg/s) [(b)]	Dimensions of flammable cloud to LFL (m) [(c)]							
					B2.2		D5.0		E3.2		F1.4	
					Length	Width	Length	Width	Length	Width	Length	Width
			22	6	72	31	51	17	64	35	102	165
			85	24	2	4	NR	NR	0.6	2	15	28
			RUP	24	2	4	NR	NR	0.6	2	15	28

Notes:

(a) “RUP” refers to a full bore rupture.

(b) For loss of containment downstream of a pump, restriction orifice or control valve, the maximum release rate was limited to the normal pumping rate or the process flow rate if predicted flow rate from hole size exceeded the limiting process flow rate.

(c) “NR“ indicates LFL was not reached.

(d) Releases from the LWPL were assumed to be orientated at 45° from vertically up as a worst case, as horizontal releases are unlikely due to underground impingement.

B6. Tank top full surface fire

The tank top full surface area fire scenario was assessed for all tank types. For a floating roof tank this scenario represents the collapse of internal floating roof resulting in a full surface roof fire and subsequent collapse of the external roof. Tank top full surface fire consequence results for the current storage tank arrangement are presented in Table B.6. Tank top full surface fire consequence results for the future storage tank arrangement are presented in Table B.7.

B7. Tank bund fire

This scenario was assessed to represent mechanical failure/leaks from storage tank forming a large pool which may cover up to the full bund area (e.g. instantaneous release) and subsequently ignite. The tank bund fire consequence results are presented in Table B.8.

Table B.6: Tank top full surface fire consequence results (Current Case) (maximum distance at any height)

Tank number	Diameter (m)	Height (m)	Product	Distance (m) to heat radiation from tank centre at D5.0 m/s				
				Flame length	23 kW/m^2	12.5 kW/m^2	7.3 kW/m^2	4.7 kW/m^2
Tank 1	18.3	10.2	AGO	42	43	46	51	58
Tank 2	15.2	13.6	91 ULP	32	33	36	41	46
Tank 3	15.2	13.0	Out of Service	-	-	-	-	-
Tank 4	8.3	10.3	AGO	24	27	30	34	38
Tank 5	3.6	9.4	Interface	14	16	18	20	23
Tank 11	21.3	13.8	91 ULP	40	40	44	49	55
Tank 14	9.1	11.2	Out of Service	-	-	-	-	-
Tank 15	16.3	14.7	95 PULP	33	35	38	43	48

Table B.7: Tank top full surface fire consequence results (Future Case) (maximum distance at any height)

Tank number	Diameter (m)	Height (m)	Product	Distance (m) to heat radiation from tank centre at D5.0 m/s				
				Flame length	23 kW/m^2	12.5 kW/m^2	7.3 kW/m^2	4.7 kW/m^2
Tank 1	18.3	10.2	Jet Fuel	29	31	34	39	44
Tank 2	15.2	13.6	91 ULP	32	33	36	41	46
Tank 3	15.2	13.0	Jet Fuel	26	27	31	35	40
Tank 4	8.3	10.3	AGO	24	27	30	34	38
Tank 5	3.6	9.4	Interface	14	16	18	20	23
Tank 11	21.3	13.8	91 ULP	40	40	44	49	55
Tank 14	9.1	11.2	Jet Fuel	18	20	23	26	30
Tank 15	16.3	14.7	95 PULP	33	35	38	43	48

Table B.8: Tank bund fire consequence results (maximum distance at any height)

Compound	Surface area (m^2)	Equivalent diameter (m)	Product	Distance (m) to heat radiation from bund centre at D5.0 m/s [(a)]				
				Flame length	23 kW/m^2	12.5 kW/m^2	7.3 kW/m^2	4.7 kW/m^2
Woolston Tank Compound	6,800	93	ULP	115	NR	123	137	154
Woolston Tank Compound	6,800	93	AGO	130	NR	138	152	170
Woolston Tank Compound	6,800	93	Jet Fuel [(b)]	99	NR	106	119	134

Notes:
(a) “NR“ indicates heat radiation level was not reached, i.e. the model is predicting a very sooty flame with a low radiant heat.
(b) The jet fuel bund fire consequence is applicable to the Future Case only.

B8. Tank overfill – vapour cloud explosion/flash fire

In addition to the tank top full surface and bund fires historically accounted for in hydrocarbon tank farm consequence assessment, flash fire scenarios due to large spills of hydrocarbons (such as those that have occurred in Buncefield UK, CAPECO Puerto Rico and Jaipur, India) have been considered. The industry had previously considered these scenarios to be unlikely.

The investigations into the Buncefield (2005), Jaipur (2009) and Puerto Rico (2009) events identified a number of common factors in the incidents that have occurred including:

- Potential for overfill or other release of hydrocarbon containing volatile material that continues undetected for some time
- Low wind speed, stable atmospheric conditions
- An ignition source in the vicinity
- Factors that may result in localised congestion or confinement of the dispersing flammable vapours.

At Buncefield, a tank was overfilled and the released product (gasoline) subsequently cascaded over the tank edge/girder resulting in large amounts of spray and vapour formation due to vaporisation of volatile components and formation of very fine hydrocarbon droplets. An ignition of the vapour cloud and explosion with overpressures far higher than what would have been predicted by conventional methods at Buncefield.

Extensive work including large scale experiments and CFD modelling were undertaken as part of the Buncefield investigation resulting in further explanation of the severity of the event.

In 2013, the UK HSE and the industry body the Fire and Blast Information Group (FABIG) issued a model for use based on the Health Safety and Laboratory (HSL) paper that can be used to estimate cloud sizes from overfills of volatile materials for zero wind speed conditions, Ref (12). This is primarily dependent on falling droplets drawing in air as they spray, forming a cold, well-mixed flammable cloud that moves due to gravity and local eddies rather than bulk air wind speed. This is known as the UK HSE VCA model.

The technique provides a specific model for assessing the physical behaviour of an overfill from a specific tank geometry and uses empirical correlations to predict a mass addition rate and concentration of hydrocarbon in the initial cloud from a cascading overfill. An extension of this correlation can also be applied to large leaks from tank base/flange failures to estimate the extent of the LFL (for zero wind speeds only).

For this QRA, loss of containment of gasoline due to tank overfill and the extent of the flammable cloud envelope was modelled following the UK HSE's VCA method, which provides a means of calculating the rate at which the volume of a vapour cloud increases during an overfilling incident.

The modelling results for the Current Case indicated that the combination of filling rates (maximum LWPL import rate is 95 m^3/hr) and tank capacities were not sufficient for a flammable cloud to form. As such, delayed ignited events from overfill reverted to flash fires resulting from pool evaporation as covered in Table B.4.

This is consistent with guidance from the UK HSE, Ref (3), which defines large gasoline storage facilities (i.e. Buncefield type depots) and consequent land use planning separation distances as requiring tank filling rates for gasoline of 100 m^3/hr.

For the Future Case, the import rate of gasoline to the Terminal is increased to approximately 120 m^3/hr which results in distances to LFL of around 230 m. The filling rate required to produce a flash fire effect at 1 m receiver height varies depending on the tank dimensions, so the 230 m distance to LFL was assumed applicable for all flash fires resulting from gasoline overfill.

The UK VCA correlation can also be used for estimating the extent of the 14 kPa overpressure level. This predicts a distance smaller but of the same order of magnitude compared to the distance to LFL, e.g. for Tank 2 the distance to 14 kPa overpressure is up to 205 m compared to a distance to LFL of 230 m. This is very similar to the flashfire effect distance hence overpressure fatality effects are not explicitly considered in the risk model, as the LFL envelope is already set to 100% fatality probability.

In calculating the results the following assumptions have been made:

- that the width of the cloud to its LFL is the same as the LFL downwind distance (‘Length’). This is consistent with CFD modelling results undertaken as part of the Buncefield investigation but may be affected by specific bund and building configurations.
- as a worst case it was assumed that both high level alarm and operator initiated shutdown have failed and that overfill of the tank occurs for 30 min duration.

B9. External factors consequences – earthquakes

Earthquakes result in different damage levels according to the Peak Ground Acceleration (PGA) experienced. No differentiation is made between vertical and horizontal PGA. Both can cause damage but the mode of damage may be different. Only extensive loss of containment scenarios (e.g. multiple tank failures simultaneously, or damage to the bunds as well as tanks with larger scale release that are not contained in the bunded areas) are considered in the QRA. Lower levels of damage (e.g. damage to connected piping, tank nozzle failure) are considered to be similar (i.e. no worse consequence) to scenarios already covered in the QRA, and so are not specifically considered.

For a catastrophic mechanical failure scenario of a single or multiple tanks where the bund is damaged and fails to adequately contain the spilled material, the following assumptions are made:

- No attempt is made to estimate specific hole sizes or rates of release due to earthquake damage. The assumption is that severe buckling or vertical uplift causes catastrophic failure of a tank wall or floor and the entire contents are rapidly lost.
- Each main spill area is assumed to be broadly constrained by roads and associated stormwater drainage channels.
- The minimum pool depth is assumed to be 300 mm which corresponds to a very uneven surface which would likely be the case following an earthquake resulting in cracking/deformation of ground.

The consequence distances corresponding to a spill from the largest capacity Class 3 tank (Tank 11) is shown in Table B.9.

Table B.9: Tank bund fire consequence results (at 1.5 m receiver height)

Modelled product	Release inventory (m^3)	Equivalent diameter (m)	Distance (m) to heat radiation from bund centre at D5.0 m/s [(a)]			
			23 kW/m^2	12.5 kW/m^2	7.3 kW/m^2	4.7 kW/m^2
ULP Summer	3,500	122	NR	79	125	170

Notes:
(a) "NR" indicates heat radiation level was not reached.

APPENDIX C. FREQUENCY ANALYSIS

C1. Overview

The following data were evaluated to determine the overall event frequencies for the Terminal:

- Historical equipment leak frequencies
- Parts count
- Operational error frequencies
- External factors frequencies – earthquakes
- Ignition probability
- Effect of safeguards
- Online time
- Storage tank fire frequencies (including tank overfill).

The details for each of the data selected are outlined in the following sections.

C2. Historical equipment leak frequencies

The main source of historical leak frequencies used is the OGP's Risk Assessment Data Directory Process release frequencies, Ref (11). The data and sources are included in Table C.1.

Tank top full surface fire frequencies were estimated from the LASTFIRE project, Ref (22), based on the storage tank type.

OGP and LASTFIRE data were selected as they are specific to the oil and gas industry and are updated relatively frequently based on industry incident reporting.

The frequency of tank overfill was estimated using layer of protection/event tree analysis since this is dependent on instrument failures and safeguards specific to each site.

Mechanical failures of atmospheric storage tanks (both bulk vertical tanks and smaller additives tanks) are obtained based on the UK HSE's Failure rate and event data for use within land use planning risk assessments report, Ref (25).

For the underground section of the LWPL within the Terminal boundary, leak frequencies were obtained based on CONCAWE's Performance of European cross-country oil pipelines report, Ref (26).

Table C.1: Equipment leak frequencies

Equipment type and size	Frequency (per year) by hole size					Source
	2 mm	6 mm	22 mm	85 mm	Full bore/ rupture	
Instrument fitting	1.8E-04	6.8E-05	2.5E-05			OGP
Pressure vessel (storage)	2.3E-05	1.2E-05	7.1E-06	4.3E-06	4.7E-07	OGP
Pump (centrifugal)	5.1E-03	1.8E-03	5.9E-04	9.7E-05	4.8E-05	OGP
Pump (reciprocating)	3.3E-03	1.9E-03	1.2E-03	3.7E-04	4.3E-04	OGP
Filter	1.3E-03	5.1E-04	1.9E-04	3.5E-05	2.0E-05	OGP
Flanges ANSI Raised Face - 50mm	2.6E-06	7.6E-07	1.2E-06			OGP
Flanges ANSI Raised Face - 150mm	3.7E-06	1.1E-06	9.0E-07	6.0E-07		OGP
Flanges ANSI Raised Face - 300mm	5.9E-06	1.7E-06	1.4E-06	1.8E-07	3.4E-07	OGP
Flanges ANSI Raised Face - 450mm	8.3E-06	2.4E-06	2.0E-06	2.6E-07	3.6E-07	OGP
Flanges ANSI Raised Face - 600mm	1.1E-05	3.2E-06	2.6E-06	3.3E-07	3.8E-07	OGP
Flanges ANSI Raised Face - 900mm	1.7E-05	4.9E-06	4.2E-06	5.4E-07	4.4E-07	OGP
Valve (manual) - 50mm	2.0E-05	7.7E-06	4.9E-06			OGP
Valve (manual) - 150mm	3.1E-05	1.2E-05	4.7E-06	2.4E-06		OGP
Valve (manual) - 300mm	4.3E-05	1.7E-05	6.5E-06	1.2E-06	1.7E-06	OGP
Valve (manual) - 450mm	5.3E-05	2.1E-05	8.0E-06	1.5E-06	1.9E-06	OGP
Valve (manual) - 600mm	6.2E-05	2.4E-05	9.4E-06	1.8E-06	2.1E-06	OGP
Valve (manual) - 900mm	7.8E-05	3.0E-05	1.2E-05	2.2E-05	2.3E-06	OGP
Process piping - 50mm [a]	5.5E-05	1.8E-05	7.0E-06	0.0E+00	0.0E+00	OGP
Process piping - 150mm [a]	2.6E-05	8.5E-06	2.7E-06	6.0E-07	0.0E+00	OGP
Process piping - 300mm [a]	2.3E-05	7.6E-06	2.4E-06	3.7E-07	1.7E-07	OGP
Process piping - 450mm [a]	2.3E-05	7.5E-06	2.4E-06	3.6E-07	1.7E-07	OGP
Process piping - 600mm [a]	2.3E-05	7.4E-06	2.4E-06	3.6E-07	1.6E-07	OGP
Process piping - 900mm [a]	2.3E-05	7.4E-06	2.3E-06	3.6E-07	1.6E-07	OGP
Pipeline (underground)			5.0E-08	4.0E-08	4.3E-08	CONCAWE
Tank rupture (atmospheric storage – vertical bulk)					5.0E-06	UK HSE 2012
Tank rupture (atmospheric storage – small/medium)					1.0E-04	UK HSE 2012
Loading arm (Road tanker) [b]			3.0E-07 (per hour)		3.0E-08 (per hour)	TNO Purple Book

Notes:

(a) Process piping and pipeline release frequencies are per metre-year.

(b) Hole sizes are 10% of diameter up to a max of 50 mm & full bore – basis is per hour (not per year as for all other items in table).

C3. Parts count

A parts count was completed for the terminal areas and operations type where a potential for hydrocarbon release was identified.

The Terminal was rationalised into six systems, including:

- MAN (Manifold)
- PMP (Pumps)
- RTL (Road Tanker Loading Gantry)
- LWP (Lyttelton-Woolston Pipeline)
- PPW (Transfer Pipework).

These systems were further expanded for parts count based on the product handled and the type of operation (e.g. import or export). These sections are summarised in Table C.2.

Table C.2: Sections defined for the QRA

ID	Scenario description	Area description
MAN-01G	Inlet Manifold - Gasoline	Manifold
MAN-02D	Inlet Manifold - Diesel	Manifold
PMP-01G	Road Tanker Loadout Pump - Gasoline	Transfer Pump
PMP-02D	Road Tanker Loadout Pump - Diesel	Transfer Pump
RTL-01G	Road Tanker Loading - Gasoline	Road Tanker Gantry
RTL-02D	Road Tanker Loading - Diesel	Road Tanker Gantry
LWP-01G	Lyttelton-Woolston Transfer Line - Gasoline	Import Pipeline
LWP-02D	Lyttelton-Woolston Transfer Line - Diesel	Import Pipeline
PPL-01G	Inlet Transfer Pipework - Gasoline	Transfer Pipework
PPL-02D	Inlet Transfer Pipework - Diesel	Transfer Pipework

Parts count and line length calculations were estimated for the process based on site layout diagrams. A sample parts count sheet used for the QRA is presented in Figure C.1. The example below applies for a single bay within the Terminal road tanker loading gantry. The complete parts count sheets for all the sections are not reproduced in this report.

Figure C.1: Sample parts count sheet

Parts Count Sheet

CLIENT	Mobil Oil NZ Ltd
JOB DESC	Lyttelton Port QRA
Area Code	RTL
Area Desc	Road Tanker Gantry
Section No	01G
Initiating Event ID	RTL-01G
Event Description	Road Tanker Loading - Gasoline
Release Type	L
Detectors provided?	Yes
ESD equipment provided?	Yes
Congestion/confinement?	Yes
Impingement possible?	Yes
Fire fighting equipment provided?	Yes
Toxic material present?	No

Equipment Item	**Tag**	**Number**	**Move-ments per year**	**Op. Hrs per year**	**Leak Frequency per Hole Size in mm (Leaks/Year)** 002	006	022	085	RUP
Loading Arm (Road Tanker & Ships)	LOA_ART	1		2917			8.75E-04		8.75E-05
Valve (manual) - 150mm	VLM_150	1		2917	1.03E-05	4.00E-06	1.57E-06	7.99E-07	
Flanges ANSI Raised Face - 150mm	FLG_RF_150	2		2917	2.46E-06	7.33E-07	5.99E-07	4.00E-07	
Valve (manual) - 50mm	VLM_050	1		2917	6.66E-06	2.56E-06	1.63E-06		
Flanges ANSI Raised Face - 50mm	FLG_RF_050	2		2917	1.73E-06	5.06E-07	7.99E-07		

C4. Operational error frequencies

The frequency of operational errors from incorrect coupling was determined for the Terminal based on Mobil operational data. As there have been no coupling errors over at least the past 10 years of operation at the Terminal, the upper bound frequency of an error was determined based on an assumed error during the next operation.

For the Terminal, the frequency of coupling errors was determined as 7.54 x 10^{-7} per operation for road tanker loadouts at the gantry for the Current and Future Cases.

C5. External factors frequencies – earthquakes

To estimate the effect of earthquake risk in the QRA it is assumed that:

- An earthquake with the PGA (>2 g) required to cause a high probability of significant damage to either partially full or full tanks will occur at an average frequency of 1 x 10^{-4} per year. This is on the basis that the 1.3 g earthquake PGA experienced at Lyttelton Port in 2011 caused no tank damage resulting in loss of containment (whereas tank fragility correlations predict a 50% probability of significant damage level at 1.3 g, therefore a more severe PGA event would be needed to cause a significant probability of damage.
- Full tanks have a 0.75 probability of significant damage to an earthquake of this size.
- There is at least one full tank per compound (full tanks are at greater risk than partially full tanks). The highest hazard product (gasoline) tank is assumed to spill and the probability is adjusted accordingly.

- The frequency is applied to each main storage bunded area and an ignition probability applied to estimate the total fire frequency in each area (as per the general QRA ignition rule set for spillages in flammable storage areas).

The calculation for the Terminal is shown below:

Frequency of earthquake risk resulting in large spill and ignition

= Probability of peak ground acceleration (>2 g) x probability of tank damage x fraction of large tanks that are gasoline x ignition probability

= 1 x 10^{-4} x 0.75 x (3/4) x 0.08

= 4.5 x 10^{-6} per year

C6. Ignition probability

The ignition probability values used in this study were based on the assessment by Cox, Lees and Ang, Ref (27). The probabilities are based on the release rate and the phase of the fluid assessed. The ignition probability values to be used in the QRA are provided in Table C.3.

Using the values described in Table C.3, further analysis was undertaken to calculate the ignition probabilities of the assessed flammable substances that result into fires. These values are presented in Table C.4.

Releases of combustible liquids such as diesel are more difficult to ignite due to their high flash point. In this study, diesel is stored in common bunds with flammable liquids and tank product allocations may also be changed from time to time. Hence to ensure a fire scenario was included for all tanks and to take into account possible escalation from a flammable liquid fire, the ignition probability for diesel was assumed to be one-tenth that of flammable liquids such as gasoline, Ref (28).

No additional fixed ignition sources were identified for this Terminal.

Table C.3: Total ignition probabilities (Cox, Lees and Ang, Ref (27))

Mass flow rate (kg/s)	Total ignition probability of a gas or mixture	Total ignition probability of a liquid	Fraction of explosions given ignition of a gas, liquid or mixture	Explosion probability of a gas or mixture	Explosion probability of a liquid
< 1	0.01	0.01	0.04	0.0004	0.0004
1 - 50	0.07	0.03	0.12	0.0084	0.0036
> 50	0.3	0.08	0.3	0.09	0.024

Table C.4: Calculated ignition probabilities for fires

Mass flow rate (kg/s)	Immediate ignition of gas/ mixture resulting in fire	Delayed ignition of gas/mixture resulting in fire	Immediate ignition of liquid resulting in fire	Delayed ignition of liquid resulting in fire
< 1	0.0096	0.0004	0.0096	0.0004
1 - 50	0.0616	0.0084	0.0264	0.0036
> 50	0.21	0.09	0.056	0.024

C7. Effect of safeguards

Manually initiated shutdown is also allowed in the situation where:

- there are personnel present and shutdown functionality is available
- the event can be readily detected and isolated, particularly if continuous monitoring occurs.

Manual shutdown activation is useful in limiting the duration and inventory released. However, depending on the scenario and inventory between any block valves an un-isolated and isolated release may have similar consequences.

Safeguards relating to fire protection (e.g. foam deluge in the road tanker loading gantry) are not accounted for in estimating the initial event likelihood. They can be used to estimate the likelihood of escalation to other equipment (as they do not prevent the initial event, but limit the consequences) or to reduce the likelihood of a small event escalating to a larger event (e.g. rim seal fire escalating to a full tank surface fire).

C8. Online time

An online factor was applied to the leak frequencies of each identified sections provided in Table C.2. The online time factor reduces the leak frequency based on the proportion of time that the equipment is used.

The online time factor for each of these sections assessed in the QRA are summarised in Table C.5.

Table C.5: Online times assumed by section

Scenario	Online time (hours/year)		Comments on online time calculation
	Current Case	Future Case	
MAN-01G	3,807	4,271	Hours LWPL import: Gasoline (91 ULP, 95 PULP, 98 SPULP)
MAN-02D	4,077	212	Hours LWPL import: Diesel (AGO)
MAN-03J	-	3,402	Hours LWPL import: Jet Fuel
PMP-01G	2,922	4,348	Hours road tanker export: Gasoline (91 ULP, 95 PULP, 98 SPULP)
PMP-02D	2,644	186	Hours road tanker export: Diesel (AGO)
PMP-03J	-	3,270	Hours road tanker export: Jet Fuel
RTL-01G	2,922	4,348	Hours road tanker export: Gasoline (91 ULP, 95 PULP, 98 SPULP) **Current Case:** = (336,000) m^3/yr / (115.2) m^3/hr = 2,917 hr/yr
RTL-02D	2,644	186	Hours road tanker export: Diesel (AGO)
RTL-03J	-	3,270	Hours road tanker export: Jet Fuel
LWP-01G	3,807	4,271	Hours LWPL import: Gasoline (91 ULP, 95 PULP, 98 SPULP)
LWP-02D	4,077	212	Hours LWPL import: Diesel (AGO)
LWP-03J	-	3,402	Hours LWPL import: Jet Fuel
PPL-01G	3,807	4,271	Hours LWPL import: Gasoline (91 ULP, 95 PULP, 98 SPULP)
PPL-02D	4,077	212	Hours LWPL import: Diesel (AGO)
PPL-03J	-	3,402	Hours LWPL import: Jet Fuel

C9. Storage tank incident frequencies

The types of incident considered for the bulk storage tanks area are:

- tank top full surface fire
- tank overfill leading to pool fire in the bund and flash fire
- tank major rupture leading to pool fire in the bund and pool evaporation leading to flash fire
- tank minor leak leading to pool fire in the bund and pool evaporation leading to flash fire.

C9.1. Tank top full surface fire

The tank top full surface fire frequencies used in the QRA study were obtained from the most recent LASTFIRE Project Update 2012, Ref (22).

LASTFIRE Project Update 2012 indicates that the tank top full surface fire frequency for fixed roof tanks (all causes including lightning, hot work etc.) is given as 2.1×10^{-5} per year. The LASTFIRE data includes all types of hydrocarbon fuel tanks. For gasoline, the frequency is taken from the data directly, while for diesel, an additional reduction factor of 10% has been applied to the reported data as the vapour space is not within the flammable range under normal circumstances.

LASTFIRE Project Update 2012 indicates that there has been no tank top full surface fires recorded for Internal Floating Roof (IFR) tanks. The rim seal fire frequency for IFR tanks is given as 4.4×10^{-5} per year. The bulk tanks at the Terminal are not provided with rim seal fire detection or tank top foam pourers that would cover the floating blanket/pan and the rim seals with foam upon activation, and a manual foam attack could take some time to arrange. Hence, the probability of a tank top full surface fire on an IFR tank was also taken as 4.4×10^{-5} per year.

As all the tanks are located in a common compound bund without fixed spray cooling water, escalation between tanks at the Terminal is accounted for. For tank top fires where the 23 kW/m^2 heat radiation level can reach other tanks, escalation is considered possible. An adjustment factor of 0.25 is applied to account for the probability of the wind blowing in the direction of the neighbouring tank.

A summary of the tank top full surface fire frequencies used for each tank is shown in Table C.6.

Table C.6: Tank top full surface fire frequencies Current Case

Tank number	Product	Tank type	LASTFIRE 2012 base frequency (per year)	Frequency due to escalation (per year)	Total frequency (per year)
Tank 1	AGO	Fixed	2.10E-06	2.25E-05	2.46E-05
Tank 2	91 ULP	IFR	4.40E-05	2.25E-05	6.65E-05
Tank 3	Out of Service	-	-	-	-
Tank 4	AGO	Fixed	2.10E-06	1.05E-06	3.15E-06
Tank 5	Interface	Fixed	2.10E-06	1.05E-06	3.15E-06
Tank 11	91 ULP	IFR	4.40E-05	1.10E-05	5.50E-05
Tank 14	Out of Service	-	-	-	-
Tank 15	95 PULP	IFR	4.40E-05	1.15E-05	5.55E-05

C9.2. Tank overfill

For this study, the frequency of an extended duration tank overfill was calculated as a function of tank level gauging failure and failure of operator during stock reconciliation.

Basis:

Failure rate of gauging system = once every 10 years, Ref (29)

Failure of stock reconciliation = 0.1 (estimated based on Center for Chemical Process Safety (CCPS) guidelines, Ref (30). This is a fairly conservative approach.)

Using the event tree analysis, the frequency of pool fire in bund (immediate ignition) due to tank overfill was determined to be 1.14 x 10^{-4} per tank-year and the flash fires/VCE (delayed ignition) due to tank overfill was determined to be 3.8 x 10^{-5} per tank-year, as shown in Figure C.2.

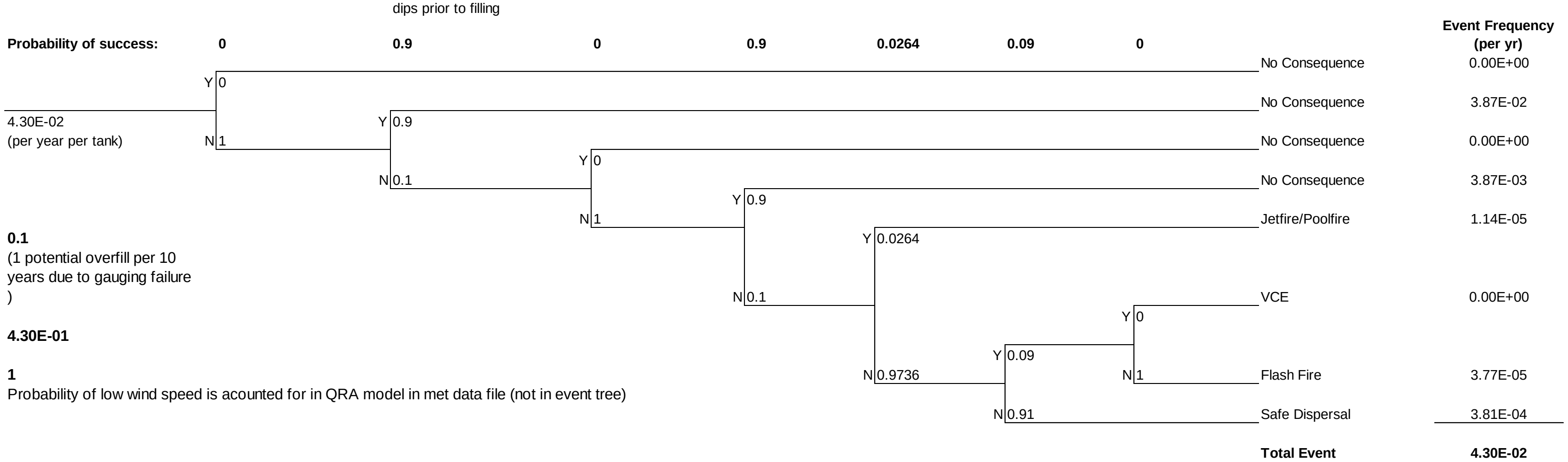
Where the tanks are contained in an intermediate bund, a tank overfill leading to pool fire in bund frequency is associated with the consequence of the intermediate bund fire. Otherwise, if there is no intermediate bund, the pool is assumed to cover the bund full surface area and potentially lead to the consequence of the full bund fire.

This value was then adjusted by the proportion of time that the tank is in filling mode (CCPS enabling condition for overfill).

Figure C.2: Example tank overfill event tree (Future Case)

Values to be entered by user

	A. Initiating Event Frequency	B. Sufficient Ullage available in receiving tank to prevent overfill	C. Manual Detection and Operator Response	D. High Level Alarm and Operator Response	E. Independent LSHH and Shutdown	F. Immediate Ignition	G. Delayed Ignition	H. VCE/Flash Fire
Site specific comments		For import via the LWPL, there will virtually always be sufficient inventory available to overfill a tank	Allow for operator to notice that level is not increasing at expected rate (i.e. stock reconciliation checks occur over filling period). No discrepancy alarm but hourly logging and dips prior to filling	Not independent of gauging failure	Independent high-high level probe with alarm and shutdown.	Cox Lees and Ang (liquid, 1-50 kg/s)	Cox Lees and Ang (vapour / mixed phase, 1-50kg/s)	Set to 0 for VCE - all modelled a LFL as distance to 14kPa very simliar to LFL
Probability of success:		**0**	**0.9**	**0**	**0.9**	**0.0264**	**0.09**	**0**



Tank Overfill Frequency (per year): **0.1** (1 potential overfill per 10 years due to gauging failure)

In Filling Mode: (Enabling condition) **4.30E-01**

Low wind speed (<2m/s) (Enabling condition) **1** Probability of low wind speed is acounted for in QRA model in met data file (not in event tree)

Definitions of factors used in Event Tree

A. Initiating Event Frequency	Calculated by the frequency of tank overfill (eg. due to gauging failure) multiplied by the proportion of time the tank is in filling mode. If the tank is continuously being filled or information has not been supplied, a conservative approach is to set the "in filling mode" factor to 1.
B. Sufficient Ullage available in receiving tank to prevent overfill	This factor is that there is sufficient ullage in the tank to prevent overfill. This factor is normally set to "0" for imports via ship or via pipeline from another terminal as there is normally never sufficient ullage. However this may be altered for tank-to-tank transfer or import from road tanker.
C. Manual Detection and Operator Response	This factor represents the probability that an operator would be able to successfully detect gauging failure (eg. due to stock reconciliation, or discrepancy alarm) and take action to prevent overfill.
D. High Level Alarm and Operator Response	This factor represents the probability that an operator would be able to successfully respond to a high level alarm and take action to prevent overfill. This factor should not be taken into account for overfill caused by gauging failure as it is not independent of the initiating event.
E. Independent LSHH and Shutdown	This factor represents the probability that an indendent LSHH would successfully shutdown the import line to the tank to prevent overfill. Equal to 1 - PFD (Probability of Failure on Demand)
F. Immediate Ignition	Probability that an overfill event is ignited immediately resulting in a jetfire/poolfire.
G. Delayed Ignition	Probability that an overfill event is ignited after a delay resulting in a VCE/flash fire.
H. VCE/Flash Fire	Ratio of delayed ignition events between VCE and flash fire. If area is confined and would typically result in a vapour cloud explosion then factor is closer to "1". If area is unconfined and would typically result in a flash fire then factor is closer to "0".

C9.3. Tank major rupture and minor leak

Tank major ruptures and minor leaks could lead to pool fires in bund and pool evaporation resulting in flash fire.

The tank bund fire frequencies were calculated using the event tree analyses. Derivation of these frequencies is provided below.

Tank rupture (major)

This frequency was applied for all full bund fire events due to tank rupture. An event tree was developed for tank rupture frequency where 5.0 x 10^{-6} per tank-year is used based on DNV Buncefield Report, Ref (10).

This is appropriate for large bund fires as these failures are difficult to isolate depending on the leak source location and may result in large pool size (restricted by the bund area).

Allocation is made between bund fires and flash fires (based on immediate and delayed ignition probability), with the frequencies reported in Table C.7.

Leaks from tank (minor)

This frequency was applied for the full bund fire events due to tank minor leak.

The tank minor leak frequency was estimated based on the data in LASTFIRE, Ref (22), where the frequency of spills into bund at 3.97 x 10^{-4} per tank-year was divided into the number of releases resulting from a minor leak. This gives a total leak frequency of 2.36 x 10^{-4} per tank-year which is used for the QRA.

This is covers bund fires where the applicable cause of failure could be due to human error, leak from pipework, flanges and valves, drain failure, shell corrosion and other. This excludes tank rupture and overfill as these have already been accounted for in previous sections.

Allocation is made between bund fires and flash fires (based on immediate and delayed ignition probability), with the frequencies reported in Table C.7.

C10. Current Case frequencies

The frequencies for scenarios included in the current Case QRA model are summarised in Table C.7, Table C.8 and Table C.9.

C11. Future Case frequencies

The frequencies for scenarios included in the Future Case QRA model have been developed using the same approach as the Current Case.

Resulting Future Case frequencies are summarised in Table C 10, Table C.11 and Table C.12.

Table C.7: Tank fire frequencies (Current Case)

Tank number	Product	Tank top full surface fire frequency (per year)	Tank overfill		Tank major rupture		Tank minor leak	
			Bund fire frequency (per year)	Flash fire frequency (per year)	Bund fire frequency (per year)	Flash fire frequency (per year)	Bund fire frequency (per year)	Flash fire frequency (per year)
Tank 1	AGO	2.46E-05	1.13E-06	-	2.80E-08	-	6.23E-07	-
Tank 2	91 ULP	6.65E-05	3.96E-06	1.23E-06	2.80E-07	4.25E-07	6.23E-06	1.93E-06
Tank 3	Out of Service	-	-	-	-	-	-	-
Tank 4	AGO	3.15E-06	2.30E-07	-	2.80E-08	-	6.23E-07	-
Tank 5	Interface	3.15E-06	-	-	2.80E-08	-	6.23E-07	-
Tank 11	91 ULP	5.50E-05	6.51E-06	2.02E-06	2.80E-07	4.25E-07	6.23E-06	1.93E-06
Tank 14	Out of Service	-	-	-	-	-	-	-
Tank 15	95 PULP	5.55E-05	2.28E-06	7.05E-07	2.80E-07	4.25E-07	6.23E-06	1.93E-06

Table C.8: QRA location frequencies summary (Current Case)

Scenario ID	Total release frequency (per year)	Jet fire/pool fire frequency (per year)	Flash fire frequency (per year)	Total event frequency (per year)
ADD_01G_RUP	5.00E-04	2.80E-05	1.20E-05	4.00E-05
ADD_02D_RUP	4.00E-04	2.24E-06	9.60E-07	3.20E-06
MAN-01G_002	2.33E-03	2.23E-05	9.22E-07	2.33E-05
MAN-01G_006	8.24E-04	7.91E-06	3.26E-07	8.24E-06
MAN-01G_022	2.73E-04	1.68E-05	2.15E-06	1.90E-05
MAN-01G_085	4.53E-05	2.79E-06	3.57E-07	3.15E-06
MAN-01G_RUP	2.09E-05	1.29E-06	1.64E-07	1.45E-06
MAN-02D_002	2.49E-03	2.39E-06	9.96E-08	2.49E-06
MAN-02D_006	8.83E-04	8.47E-07	3.53E-08	8.83E-07
MAN-02D_022	2.92E-04	1.80E-06	2.44E-07	2.04E-06
MAN-02D_085	4.85E-05	2.99E-07	4.05E-08	3.39E-07
MAN-02D_RUP	2.23E-05	1.38E-07	1.86E-08	1.56E-07
PMP-01G_002	1.79E-03	1.72E-05	7.08E-07	1.79E-05
PMP-01G_006	6.33E-04	6.07E-06	2.51E-07	6.32E-06
PMP-01G_022	2.09E-04	1.29E-05	1.65E-06	1.46E-05
PMP-01G_085	3.48E-05	2.14E-06	2.74E-07	2.41E-06
PMP-01G_RUP	1.60E-05	9.86E-07	1.26E-07	1.11E-06
PMP-02D_002	1.62E-03	1.55E-06	6.46E-08	1.62E-06
PMP-02D_006	5.72E-04	5.50E-07	2.29E-08	5.72E-07
PMP-02D_022	1.90E-04	1.17E-06	1.58E-07	1.33E-06
PMP-02D_085	3.15E-05	1.94E-07	2.63E-08	2.20E-07
PMP-02D_RUP	1.45E-05	8.92E-08	1.21E-08	1.01E-07
RTL-01G_002	2.12E-05	2.04E-07	8.40E-09	2.12E-07
RTL-01G_006	7.81E-06	7.50E-08	3.09E-09	7.81E-08
RTL-01G_022	8.81E-04	5.43E-05	6.95E-06	6.12E-05
RTL-01G_085	5.19E-02	3.19E-03	4.09E-04	3.60E-03
RTL-01G_RUP	8.77E-05	5.40E-06	6.91E-07	6.09E-06
RTL-02D_002	1.92E-05	1.84E-08	7.67E-10	1.92E-08
RTL-02D_006	7.07E-06	6.79E-09	2.82E-10	7.07E-09
RTL-02D_022	7.97E-04	4.91E-06	6.66E-07	5.58E-06
RTL-02D_085	4.81E-02	2.97E-04	4.02E-05	3.37E-04
RTL-02D_RUP	7.93E-05	4.89E-07	6.62E-08	5.55E-07

Table C.9: QRA pipeline frequencies summary (Current Case)

Scenario ID	Total release frequency (per km-year)	Jet fire/pool fire frequency (per km-year)	Flash fire frequency (per km-year)	Total event frequency (per km-year)
LWP-01G_022	2.17E-05	1.34E-06	1.71E-07	1.51E-06
LWP-01G_085	1.74E-05	1.07E-06	1.37E-07	1.21E-06
LWP-01G_RUP	1.87E-05	1.15E-06	1.47E-07	1.30E-06
LWP-02D_022	2.33E-05	1.43E-07	1.94E-08	1.63E-07
LWP-02D_085	1.86E-05	1.15E-07	1.55E-08	1.30E-07
LWP-02D_RUP	2.00E-05	1.23E-07	1.67E-08	1.40E-07
PPL-01G_002	1.13E-02	1.08E-04	4.48E-06	1.13E-04
PPL-01G_006	3.69E-03	3.55E-05	1.46E-06	3.69E-05
PPL-01G_022	1.17E-03	7.23E-05	9.25E-06	8.15E-05
PPL-01G_085	2.61E-04	1.61E-05	2.06E-06	1.81E-05
PPL-02D_002	1.21E-02	1.16E-05	4.84E-07	1.21E-05
PPL-02D_006	3.96E-03	3.80E-06	1.58E-07	3.96E-06
PPL-02D_022	1.26E-03	7.74E-06	1.05E-06	8.79E-06
PPL-02D_085	2.79E-04	1.72E-06	2.33E-07	1.95E-06

Table C 10: Tank fire frequencies (Future Case)

Tank number	Product	Total Tank top full surface fire frequency [a] (per year)	Tank overfill		Tank major rupture		Tank minor leak	
			Bund fire frequency (per year)	Flash fire frequency (per year)	Bund fire frequency (per year)	Flash fire frequency (per year)	Bund fire frequency (per year)	Flash fire frequency (per year)
Tank 1	Jet Fuel	3.21E-05	1.82E-06	-	8.40E-08	-	1.87E-06	-
Tank 2	91 ULP	6.92E-05	3.28E-06	1.02E-06	2.80E-07	4.25E-07	6.23E-06	1.93E-06
Tank 3	Jet Fuel	3.32E-05	7.46E-07	-	8.40E-08	-	1.87E-06	-
Tank 4	AGO	7.50E-06	6.38E-08	-	2.80E-08	-	6.23E-07	-
Tank 5	Interface	4.20E-06	-	-	2.80E-08	-	6.23E-07	-
Tank 11	91 ULP	5.66E-05	5.39E-06	1.67E-06	2.80E-07	4.25E-07	6.23E-06	1.93E-06
Tank 14	Jet Fuel	1.69E-05	5.05E-07	-	8.40E-08	-	1.87E-06	-
Tank 15	95 PULP	5.66E-05	4.20E-06	1.30E-06	2.80E-07	4.25E-07	6.23E-06	1.93E-06

Notes:
(a). total frequency includes escalation from neighbouring tanks

Table C.11: QRA location frequencies summary (Future Case)

Scenario ID	Total release frequency (per year)	Jet fire/pool fire frequency (per year)	Flash fire frequency (per year)	Total event frequency (per year)
ADD_01G_RUP	5.00E-04	2.80E-05	1.20E-05	4.00E-05
ADD_02D_RUP	4.00E-04	2.24E-06	9.60E-07	3.20E-06
MAN-01G_002	2.61E-03	2.51E-05	1.03E-06	2.61E-05
MAN-01G_006	9.25E-04	8.88E-06	3.66E-07	9.24E-06
MAN-01G_022	3.06E-04	1.89E-05	2.41E-06	2.13E-05
MAN-01G_085	5.08E-05	3.13E-06	4.00E-07	3.53E-06
MAN-01G_RUP	2.34E-05	1.44E-06	1.84E-07	1.63E-06
MAN-02D_002	1.29E-04	1.24E-07	5.17E-09	1.29E-07
MAN-02D_006	4.58E-05	4.40E-08	1.83E-09	4.58E-08
MAN-02D_022	1.52E-05	9.34E-08	1.27E-08	1.06E-07
MAN-02D_085	2.52E-06	1.55E-08	2.10E-09	1.76E-08
MAN-02D_RUP	1.16E-06	7.14E-09	9.68E-10	8.11E-09
MAN-03J_002	2.08E-03	5.99E-06	2.49E-07	6.24E-06
MAN-03J_006	7.36E-04	2.12E-06	8.81E-08	2.21E-06
MAN-03J_022	2.44E-04	4.51E-06	6.03E-07	5.11E-06
MAN-03J_085	4.05E-05	7.48E-07	1.00E-07	8.48E-07
MAN-03J_RUP	1.86E-05	3.44E-07	4.61E-08	3.91E-07
PMP-01G_002	2.66E-03	2.55E-05	1.05E-06	2.66E-05
PMP-01G_006	9.41E-04	9.04E-06	3.73E-07	9.41E-06
PMP-01G_022	3.12E-04	1.92E-05	2.46E-06	2.17E-05
PMP-01G_085	5.17E-05	3.19E-06	4.08E-07	3.59E-06
PMP-01G_RUP	2.38E-05	1.47E-06	1.88E-07	1.66E-06
PMP-02D_002	1.14E-04	1.09E-07	4.56E-09	1.14E-07
PMP-02D_006	4.04E-05	3.87E-08	1.61E-09	4.04E-08
PMP-02D_022	1.34E-05	8.23E-08	1.12E-08	9.35E-08
PMP-02D_085	2.22E-06	1.37E-08	1.85E-09	1.55E-08
PMP-02D_RUP	1.02E-06	6.29E-09	8.53E-10	7.15E-09
PMP-03J_002	2.00E-03	5.76E-06	2.39E-07	6.00E-06
PMP-03J_006	7.08E-04	2.04E-06	8.47E-08	2.12E-06
PMP-03J_022	2.34E-04	4.33E-06	5.80E-07	4.91E-06
PMP-03J_085	3.89E-05	7.19E-07	9.62E-08	8.15E-07
PMP-03J_RUP	1.79E-05	3.31E-07	4.43E-08	3.75E-07
RTL-01G_002	3.16E-05	3.03E-07	1.25E-08	3.16E-07
RTL-01G_006	1.16E-05	1.12E-07	4.60E-09	1.16E-07
RTL-01G_022	1.31E-03	8.08E-05	1.03E-05	9.11E-05
RTL-01G_085	7.72E-02	4.75E-03	6.08E-04	5.36E-03
RTL-01G_RUP	1.30E-04	8.03E-06	1.03E-06	9.06E-06
RTL-02D_002	1.35E-06	1.30E-09	5.41E-11	1.35E-09

Scenario ID	Total release frequency (per year)	Jet fire/pool fire frequency (per year)	Flash fire frequency (per year)	Total event frequency (per year)
RTL-02D_006	4.98E-07	4.79E-10	1.99E-11	4.98E-10
RTL-02D_022	5.62E-05	3.46E-07	4.69E-08	3.93E-07
RTL-02D_085	3.40E-03	2.09E-05	2.83E-06	2.37E-05
RTL-02D_RUP	5.59E-06	3.45E-08	4.67E-09	3.91E-08
RTL-03J_002	2.37E-05	6.84E-08	2.84E-09	7.12E-08
RTL-03J_006	8.74E-06	2.52E-08	1.05E-09	2.62E-08
RTL-03J_022	9.86E-04	1.82E-05	2.44E-06	2.07E-05
RTL-03J_085	5.80E-02	1.07E-03	1.44E-04	1.22E-03
RTL-03J_RUP	9.81E-05	1.81E-06	2.43E-07	2.06E-06

Table C.12: QRA pipeline frequencies summary (Future Case)

Scenario ID	Total release frequency (per km-year)	Jet fire/pool fire frequency (per km-year)	Flash fire frequency (per km-year)	Total event frequency (per km-year)
LWP-01G_022	2.44E-05	1.50E-06	1.92E-07	1.69E-06
LWP-01G_085	1.95E-05	1.20E-06	1.54E-07	1.35E-06
LWP-01G_RUP	2.10E-05	1.29E-06	1.65E-07	1.46E-06
LWP-02D_022	1.21E-06	7.44E-09	1.01E-09	8.45E-09
LWP-02D_085	9.66E-07	5.95E-09	8.06E-10	6.76E-09
LWP-02D_RUP	1.04E-06	6.40E-09	8.67E-10	7.26E-09
LWP-03J_022	1.94E-05	3.59E-07	4.80E-08	4.07E-07
LWP-03J_085	1.55E-05	2.87E-07	3.84E-08	3.25E-07
LWP-03J_RUP	1.67E-05	3.09E-07	4.13E-08	3.50E-07
PPL-01G_002	1.27E-02	1.22E-04	5.02E-06	1.27E-04
PPL-01G_006	4.14E-03	3.98E-05	1.64E-06	4.14E-05
PPL-01G_022	1.32E-03	8.11E-05	1.04E-05	9.15E-05
PPL-01G_085	2.93E-04	1.80E-05	2.31E-06	2.03E-05
PPL-02D_002	6.28E-04	6.03E-07	2.51E-08	6.28E-07
PPL-02D_006	2.05E-04	1.97E-07	8.20E-09	2.05E-07
PPL-02D_022	6.52E-05	4.02E-07	5.44E-08	4.56E-07
PPL-02D_085	1.45E-05	8.93E-08	1.21E-08	1.01E-07
PPL-03J_002	1.01E-02	2.91E-05	1.21E-06	3.03E-05
PPL-03J_006	3.30E-03	9.51E-06	3.95E-07	9.90E-06
PPL-03J_022	1.05E-03	1.94E-05	2.59E-06	2.20E-05
PPL-03J_085	2.33E-04	4.31E-06	5.76E-07	4.88E-06

APPENDIX D. LAND USES

A map showing the surrounding land uses to the Terminal is shown in Figure D.1, based on the CDP Map, Ref (4).

A comparison was made against the proposed Christchurch Replacement District Plan, Ref (31), which showed that no changes were proposed for the area surrounding the Terminal. Hence, it was assumed that there will be no significant change in the land use zoning between the Current and Future Case operations.

The only change identified is a bike path is planned to route along Cumnor Terrace close to the northern boundary of the Terminal for the Future Case.

Figure D.1: Surrounding land uses map (approximate areas only)

APPENDIX E. SENSITIVITY STUDIES

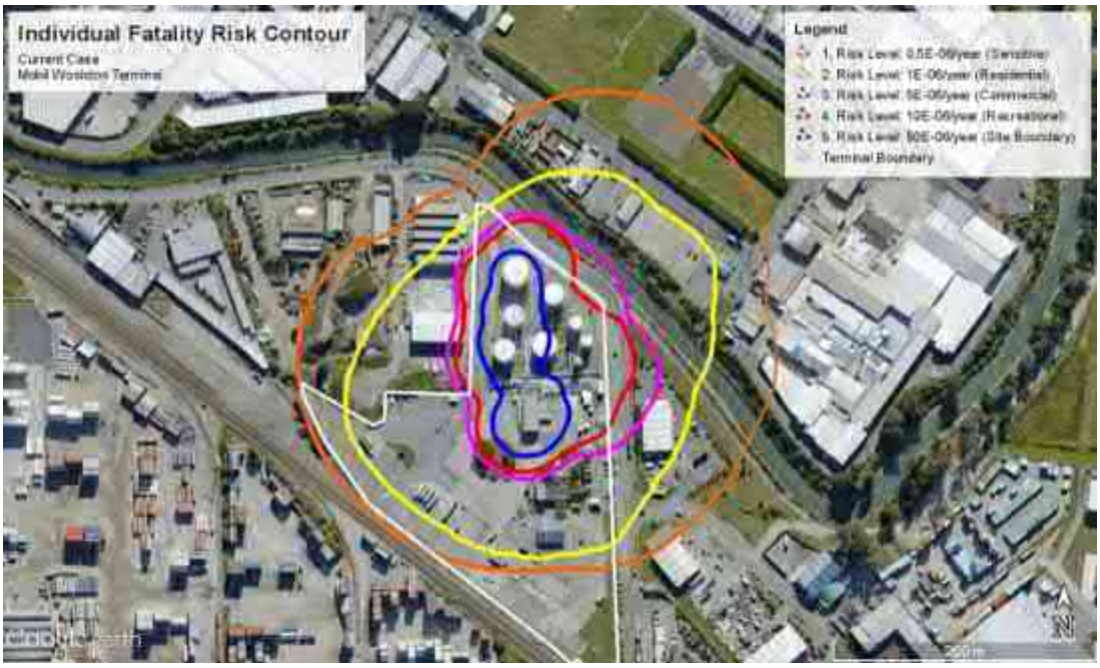
E1. Earthquake effects

A sensitivity study of the Current and Future Cases was completed to determine the effect of accounting for earthquakes on the overall individual fatality risk contours. The results of the assessment are illustrated in Figure E.1 and Figure E.2.

The comparison shows a small reduction of up to 25 m in the extent of some of the risk contours, with the largest changes at the northern section of the Terminal. The reduction in the contours extent does not however change the results of the assessment against the HIPAP 4 risk criteria (i.e. all individual fatality risk criteria are met).

Figure E.1: Comparison of earthquake effects on Current Case

Individual fatality risk contours – Current Case



Individual fatality risk contours – Current Case without earthquake effects

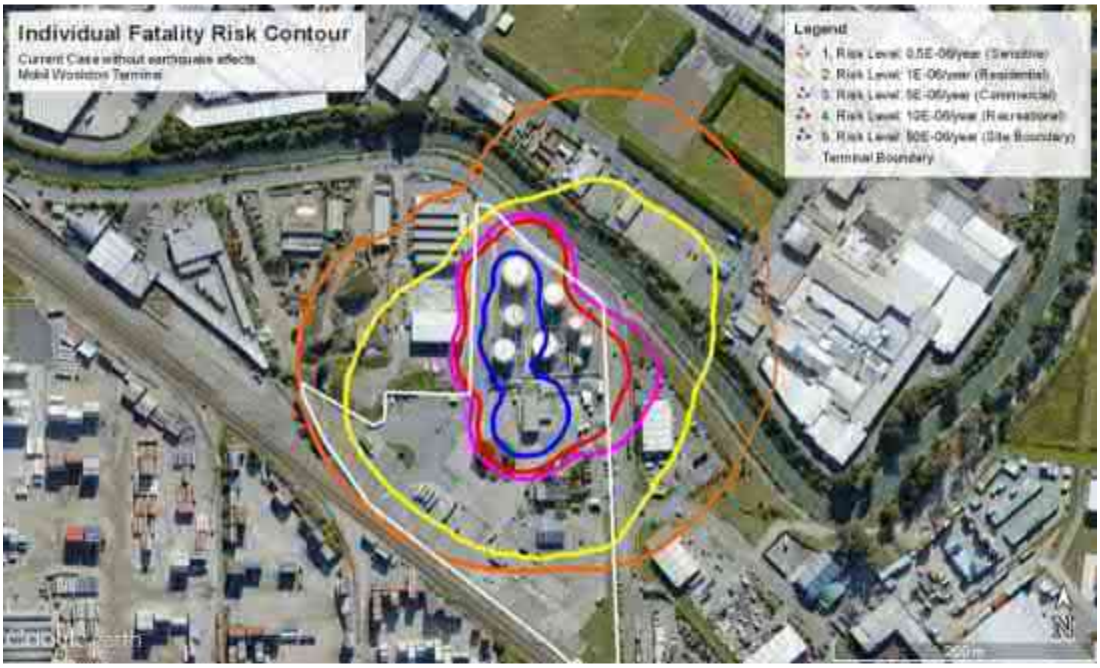
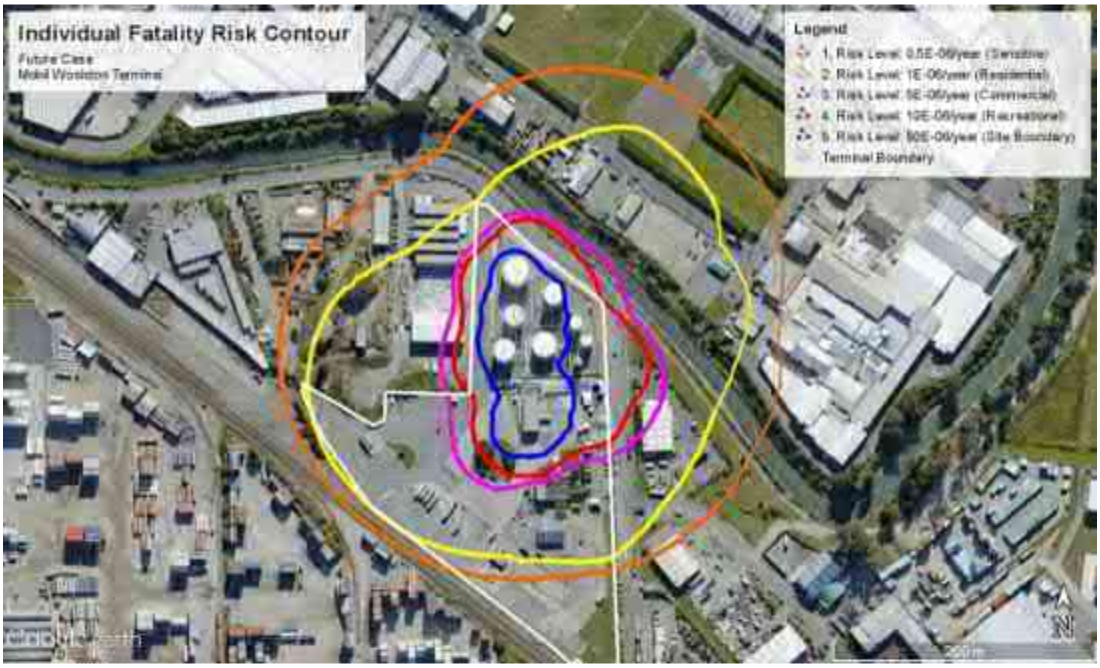
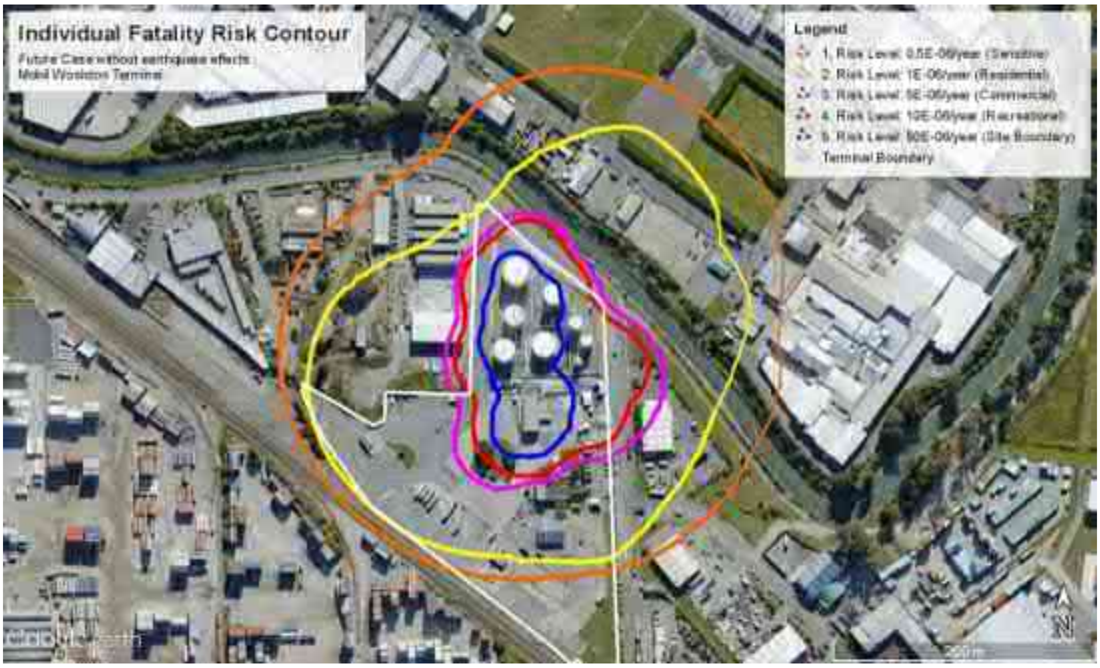


Figure E.2: Comparison of earthquake effects on Future Case

Individual fatality risk contours – Future Case



Individual fatality risk contours – Future Case without earthquake effects



E2. Alternative risk criteria

Worksafe Victoria guidance (Ref (6) suggests that planning consider:

- An *inner planning advisory area* – where the individual risk of fatality from potential foreseeable incidents is greater than or equal to 1×10^{-7} per year (equivalent to one chance in 10 million years or 0.1×10^{-6} per year).

And that Worksafe generally advises against the following proposed land use or developments:

- land use or developments within the inner area, apart from low density industrial uses such as non-retail warehousing or other low employee density business or industrial use. This minimises the numbers of people that might be affected by a low frequency-high consequence incident and maximises the likelihood of people safely responding to an emergency.

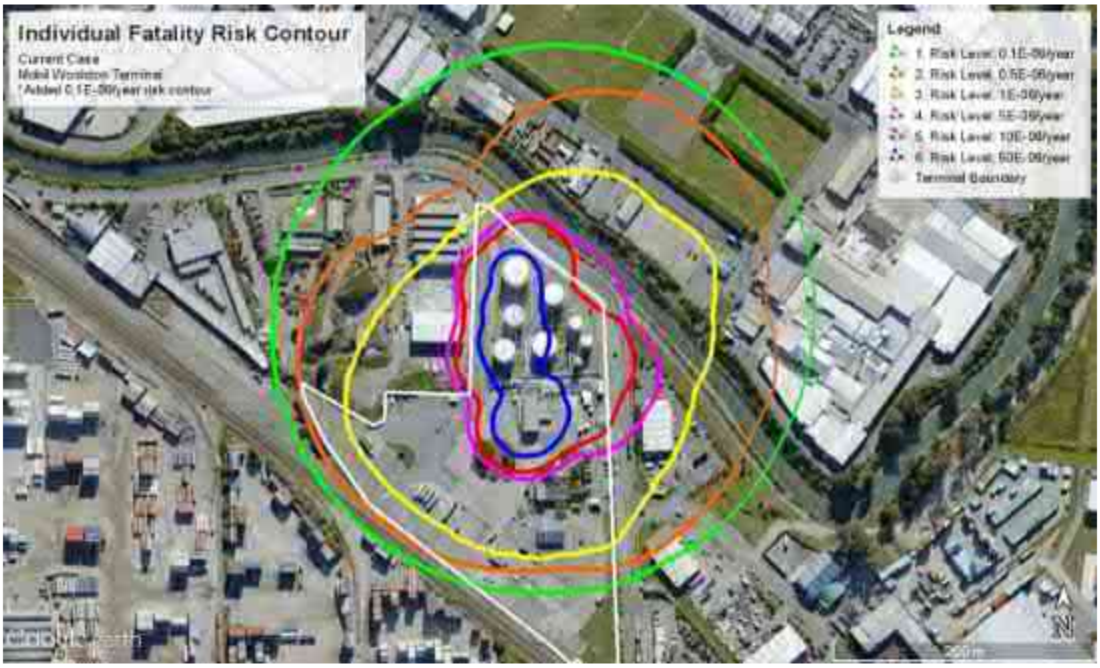
Figure E.3 and E.4 show the additional risk contour as well the HIPAP 4 contours for the Current and Future Cases.

If the Worksafe Victoria criterion 0.1×10^{-6} per year was applied instead of the HIPAP 4 sensitive land use criterion (of 0.5×10^{-6} per year), the effect would be to:

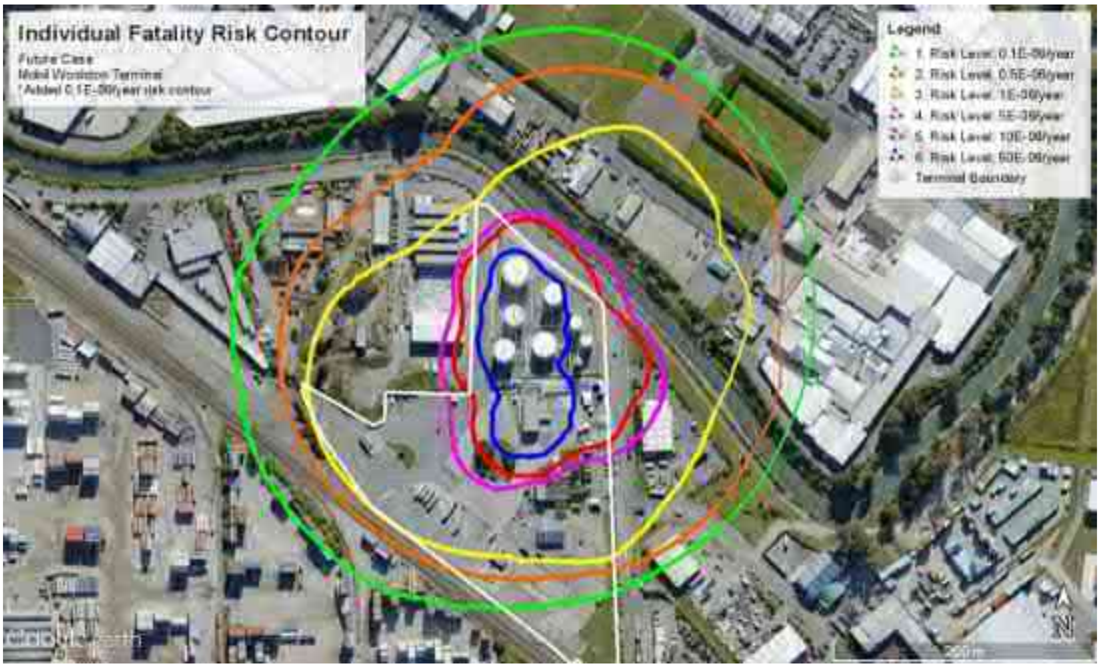
- confirm that the 250m current overlay in the CDP would remain adequate
- increase the <u>minimum</u> recommended extent of the overlay from around 170 m to 190 m.
- further restrict allowable development to "*low density industrial uses such as non-retail warehousing or other low employee density business or industrial use"* rather than the suggested interpretation based on HIPAP 4 that "*sensitive or residential uses, and any land uses involving large populations should not establish within the extent of the overlay*"*.*

Figure E.3: Alternative individual fatality risk contours

Individual fatality risk contours – 0.1 x 10^{-6}/year contour added (Current Case)



Individual fatality risk contours – 0.1 x 10^{-6}/year contour added (Future Case)



APPENDIX F. REFERENCES

1. http://proposeddistrictplan1.ccc.govt.nz/. *The Proposed Christchurch Replacement District Plan.* [Online] [Cited: 7 June 2017.]

2. **NSW Department of Planning.** *Hazardous Industry Planning Advisory Paper No.4 - Risk Criteria for Land Use Safety Planning.* 2011.

3. **UK HSE.** Land use planning advice around large scale petrol storage sites SPC/TECH/GENERAL/43. [Online] [Cited: 8 May 2015.] http://www.hse.gov.uk/foi/internalops/hid_circs/technical_general/spc_tech_gen_43/index.htm.

4. **Christchurch City Council.** Planning Maps. *Christchurch District Plan.* [Online] 7 April 2017. [Cited: 22 May 2017.] https://districtplan.ccc.govt.nz/pages/plan/book.aspx?exhibit=DistrictPlan.

5. **Ministry of Business, Innovation & Employment.** Data tables for oil.xlsx. [Online] 2017. [Cited: 10 July 2017.] http://www.mbie.govt.nz/info-services/sectors-industries/energy/energy-data-modelling/statistics/oil.

6. **Victoria, Worksafe.** Major hazard facilities Land use planning near a major hazard facility. 2010. Vol. WSV1331/01/03.10.

7. **LASTFire Project Update.** *Large Atmospheric Storage Tank Fire Project, Incident Survey for 1984-2011.* 2012 Edition.

8. **Brackley, H. L.** *Review of liquefaction hazard information in eastern Canterbury, including Christchurch City and parts of Selwyn, Waimakariri and Hurunui Districts.* 2012. Report No. R12/83.

9. *Safety and environmental standards for fuel storage sites Process Safety Leadership Group Final report.* s.l. : UK HSE, 2009.

10. **UK HSE.** *The Buncefield Incident 11 December 2005: The final report of the Major Incident Investigation Board Volumes 1, 2A, 2B.* 2008.

11. **International Association of Oil & Gas Producers (OGP).** *Risk Assessment Data Directory: Process Release Frequencies, Report No. 434-1 OGP Process Release.* 2010. 434-1.

12. **Fire and Blast Information Group.** *Technical Note 12 – Vapour Cloud Development in over-filling Incidents.* April 2013.

13. **National Institute of Water and Atmospheric Research Ltd (NIWA).** New Zealand National Climate Database. [Online] 2017. [Cited: 10 May 2017.] https://cliflo.niwa.co.nz/.

14. **TNO Institute of Environmental Sciences.** *Green Book: Method of determination for possible damage to people and objects resulting from the release of hazardous materials.* 2nd. 2005.

15. **VROM.** *Besluit Externe Veiligheid Inrichtingen (External Safety (Establishments) Decree).* 2014.

16. **Singapore Major Hazards Department.** *Revised Quantitative Risk Assessment Guidelines - QRA Technical Guidance Rev No. 2.* 2016.

17. **International Association of Oil & Gas Producers (OGP).** *Risk Assessment Data Directory: Report No. 14.1 Vulnerability of Humans.* 2010. 14.1.

18. **WS Atkins Consultants Ltd.** *UK HSE Research Report 084: Effects of flashfires on building occupants.* 2003.

19. *RR1113 Review of Vapour Cloud Explosion Incidents.* **HSE, UK.** 2017.

20. **Joint Industry Panel.** *Buncefield Investigation Dispersion & Explosion Characteristics of Large Vapour Clouds Volume 1: Summary Report SCI DOCUMENT ED024.* 2014.

21. **LASTFIRE.** *Large Atmospheric Storage Tank Fires Study, consortium of oil companies.* 2010. http://www.lastfire.org.uk/.

22. **LASTFIRE Project Update.** *Large Atmospheric Storage Tank Fire Project, Incident Survey for 1984-2011.* 2012 Edition.

23. **TNO Institute of Environmental Sciences.** *Purple Book: Guidelines for quantitative risk assessment.* 2005. First Edition.

24. —. *Yellow Book: Methods for the calculation of physical effects due to releases of hazardous materials (liquids and gases).* 2005. Third Edition Second revised print.

25. **UK HSE.** *Failure Rate and Event Data for use within Land Use Planning Risk Assessments.* 2012.

26. **CONCAWE.** *Performance of European cross-country oil pipelines: Statistical summary of reported spillages in 2013 and since 1971, Report No. 4/15.* 2015.

27. **Cox, Lees and Ang.** *Classification of Hazardous Areas.* 1992.

28. **Mannan.** *Lees' Loss Prevention in the Process Industries, Fourth Edition.* 2012.

29. **Standards Australia.** *AS IEC 61511 Functional safety - Safety instrumented systems for the process industry sector; Part 3: Guidance for the determination of the required safety integrity level.* 2004.

30. **Center for Chemical Process Safety (CCPS).** *Guidelines for Initiating Events and Independent Protection Layers in Layer of Protection Analysis.* s.l. : American Institute of Chemical Engineers, Inc, 2015.

31. **Christchurch City Council.** Planning Maps. *The proposed Christchurch Replacement District Plan.* [Online] 7 April 2017. [Cited: 22 May 2017.] http://proposeddistrictplan.ccc.govt.nz/Pages/Plan/Book.aspx?hid=36201&exhibit=ProposedDistrictPlan.

32. **Rankin, Jenny.** Email: 2017-05-08 JR-AM MCR Heathcote Expressway - Cumnor Terrace - From: Jenny Rankin, To: Andrew McCormack. 2017.

APPENDIX 3 – COMBINED SUMMARY OF QUANTITATIVE RISK ASSESSMENT

TECHNICAL NOTE

CHRISTCHURCH DISTRICT PLAN - RISK OVERLAY FOR DISCUSSION

BURTON PLANNING LTD

Rev	Date	Description	Prepared	Reviewed	Method of issue
A	14 Dec 2017	Issued to Client for comments	J Polich, Sherpa	D Phillis, Worley	Email PDF
B	22 June 2018	Updated to address CCC comments	J Polich, Sherpa	D Phillis, Worley	Email PDF
0	26 June 2018	Final Issue	J Polich, Sherpa	D Phillis, Worley	Email PDF
1	21 Sep 2018	Shape file details added in Section 3.2 and legend shown on Figure 2.3	J Polich, Sherpa	D Phillis, Worley	Email PDF

QA verified	**-**
Date	**-**

Sherpa Consulting Pty Ltd (ABN 40 110 961 898)
Phone: 61 2 9412 4555
Web: www.sherpaconsulting.com

CONTENTS

TABLES

FIGURES

1. INTRODUCTION

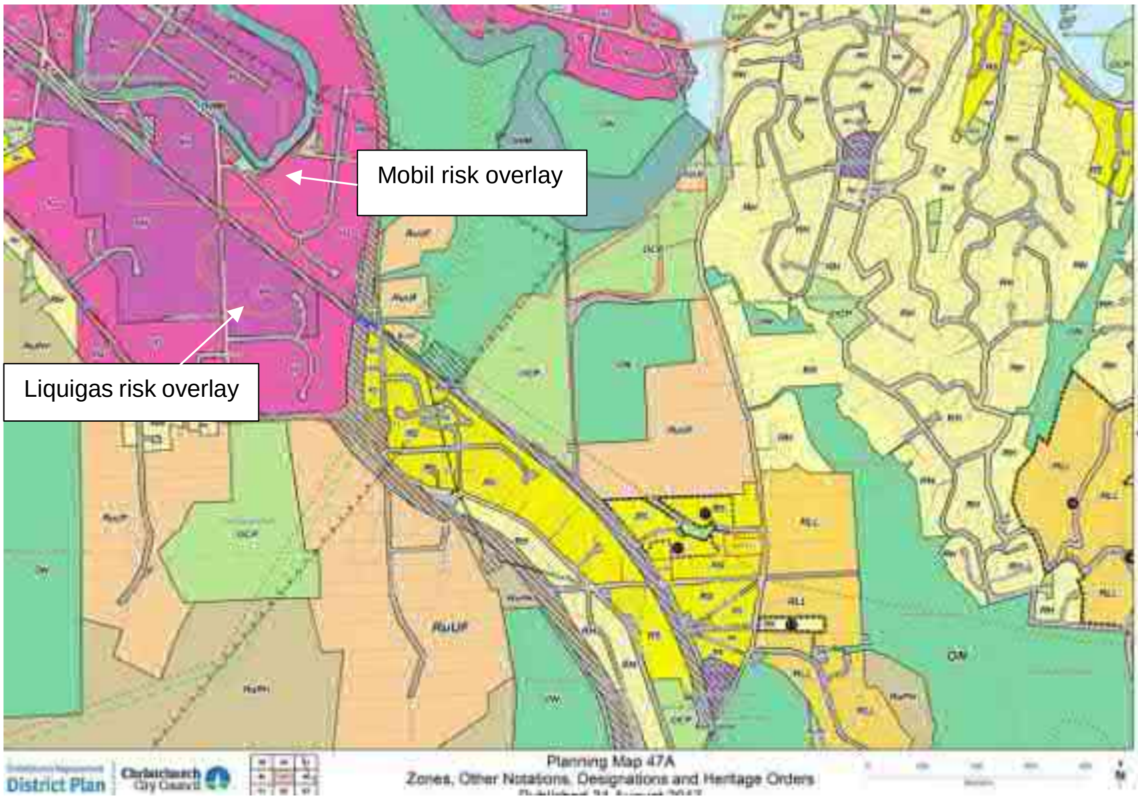
1.1. Background

The Christchurch District Plan (CDP) currently includes a risk management overlay provision around the Liquigas (LPG) and Mobil (hydrocarbon fuel) facilities in Woolston Christchurch, New Zealand (NZ). This is reproduced in Figure 1.1.

The overlay extends around 100m to 250m from the sites and covers industrially zoned land along with a small local pocket park, Heathcote River and margins, and road and rail networks. The overlay was a temporary measure to prevent incompatible development occurring in the vicinity of the facilities which are potentially hazardous due to the flammable materials handled. It was based on land use planning guidance published by the UK Health and Safety Executive (UK HSE) for separation distances from fuel terminals (Ref 1) in the case of the Mobil terminal and a seven year old Quantitative Risk Assessment (QRA) for the Liquigas terminal. The CDP risk overlay provisions expire in 2019.

Future protection provisions are subject to completion of a QRA to assess the site specific risk from the Liquigas and Mobil facilities. The QRA results are necessary to inform and provide the basis for a Plan Change Process with the aim of producing a revised overlay with rules attached, that continues to protect the facilities from encroachment by incompatible land uses.

Figure 1.1: CDP risk overlay (expires 2019)



1.2. QRA status

QRA reports have been completed over 2017- 2018 for both facilities to assess the offsite individual fatality risk levels as follows:

1. Mobil Woolston Terminal QRA completed by Sherpa Consulting Pty Ltd (Sherpa), document: *Mobil Woolston Terminal Quantitative Risk Assessment For Determination Of Planning Overlay Mobil Oil New Zealand Limited* Doc No 21086-RP-002 Rev 0, 22-Jun-2018 (Ref 2).
2. Liquigas Woolston LPG Depot QRA completed by Worley Parsons New Zealand Pty Ltd (Worley Parsons) document: *LIQUIGAS Woolston LPG Depot Quantitative Risk Assessment* Doc No 503402-RPT-R0001-R1 May 2018 (Ref 3).

Worley and Sherpa have peer reviewed the assumptions and methodology for the QRA undertaken by the other party. Both consultants consider that the methodologies are consistent with the typical approaches used within industry to prepare land use safety planning risk assessments.

Whilst there are some technical differences in approach (for example choice of software) the authors agree that:

- The approach in each QRA is appropriate for the specific facilities.
- Both QRAs have been prepared to account for a reasonable future growth case hence should be representative of risk levels for each site operation over the next 10 years (up to 2028) which is consistent with a timeframe for a District Plan.
- The QRA results are presented and assessed in a consistent manner, ie both QRAs use individual fatality risk as the basis for assessment hence can be used cumulatively.

Overall, it is agreed by the consultants that any differences in approach with respect to the assumptions for the specific facilities, the overall QRA methodology and reporting styles, are not significant in the context of using the results for preparing a combined risk overlay to replace the existing CDP overlay provisions.

1.3. Scope and objectives

The purpose of this report is to:

- present the individual fatality risk contours for both the facilities
- propose a combined overlay for review by CCC
- explain the basis for the proposed overlay.

The overall approach and assumptions for the QRAs are not covered as these are contained in the individual QRA reports.

1.4. Risk assessment

Land use safety planning QRAs typically assess the following risk measures:

1. Individual fatality risk. Individual fatality risk represents the probability of some specified level of harm (in this case fatality) occurring to a theoretical individual located permanently at a particular location, assuming no mitigating action such as escape can be taken. This is shown as contours on a map of the area which show the probability of fatality per million per year at a location.
2. Societal risk. Societal risk is a measure of the probability of incidents affecting an actual population (rather than a theoretical individual as in individual risk), i.e. takes into account the number of people exposed to risk. Probability of presence is accounted for, and mitigating effects such as whether people are located inside or outside, or effective emergency response can also be accounted for where relevant.

Individual fatality risk is a function of the source of risk (ie the potentially hazardous facility), not the receptors or persons exposed to a risk, and is typically the main basis for assessing risk acceptability from a potentially hazardous facility to surrounding land uses. Different risk criteria apply to different land uses, with a lower risk level applicable to more sensitive land uses (eg schools, housing) and a higher risk level applicable to less sensitive (ie industrial) land uses.

Societal risk is a potential issue when there are large populations (commercial offices, shopping centres etc), residential (present overnight) or sensitive (more vulnerable or difficult to evacuate) populations within the area affected by the individual fatality risk contours. Societal risk is generally assessed only when these types of population occur within or in close proximity to the fatality risk contours, or when a significant change in population is proposed in the vicinity of a hazardous facility.

Given that such populations or sensitive activities do not currently occur near the two Woolston facilities, the use of individual fatality risk is an appropriate basis for future planning.

1.4.1. Risk criteria

There are no specific NZ risk criteria, however the decisions version of the CDP (Ref 4 Section 16.2.1.4) suggests that the risk acceptability criteria in NSW Department of Planning. *Hazardous Industry Planning Advisory Paper No.4 - Risk Criteria for Land Use Safety Planning* (known as HIPAP 4, Ref 5) should be referred to.

1.4.2. Adopted criteria

HIPAP 4 contains criteria for both individual fatality risk and societal risk.

The HIPAP 4 individual fatality risk criteria as shown in Table 1.1 have been adopted for both the Liquigas and Mobil QRAs and are used as the basis for setting the extent of the combined risk overlay.

In the Woolston area around Mobil and Liquigas, the populations are associated with low density industrial land uses and are not typically present overnight apart from shift workers employed in industrial activities.

The purpose of the overlay approach is to prevent encroachment of incompatible populations (eg due to a change in land use) into risk affected areas and also to avoid an unacceptable increase in societal risk due to large populations encroaching. Therefore only the individual fatality risk contours are required to provide input to setting the extent of an overlay. An assessment of the existing societal risk is not required for this purpose.

Table 1.1: HIPAP 4 individual fatality risk criteria

HIPAP 4 description and land use	HIPAP 4 criteria (per year)
Hospitals, child-care facilities and old age housing (sensitive land uses)	0.5×10^{-6}
Residential developments and places of continuous occupancy such as hotels and tourist resorts (residential land use)	1×10^{-6}
Commercial developments, including offices, retail centres and entertainment centres (commercial land use)	5×10^{-6}
Sporting complexes and active open space areas (recreational land use)	10×10^{-6}
Target for site boundary (boundary limit)	50×10^{-6}

1.4.3. Land uses

It should be noted that the land use categories defined in the HIPAP 4 risk criteria do not always directly align with a specific land use category in a planning instrument such as the CDP.

Commercial land uses include office spaces used by the general working public for non-industrial activities, ie sales, call centres, general business activities.

Offices that are directly associated with industrial facilities or retail facilities servicing an industrial surrounding (e.g. control rooms, offices on an industrial site, lunch bars used by people such as truck drivers or operators already working in the industrial area) and that have relatively low numbers of people, minimal overnight populations and do not attract large numbers of the general public unrelated to the industry, are classified as an industrial land use.

The actual land uses located around the Woolston facilities are industrial in the context of HIPAP 4, which is consistent with the industrial zoning in the CDP (ie Industrial General (IG) and Industrial Heavy (IH) zones).

2. INDIVIDUAL FATALITY RISK CONTOURS

2.1. Contours

The individual fatality risk contours for the Mobil future growth case are shown in Figure 2.2 (from Ref 2) and for the Liquigas growth case in Figure 2.3 (from Ref 3).

2.2. Potential interaction between sites

Whilst the boundaries between the two sites are close, there is a large separation distance between the main hazardous inventories (around 450m as per Figure 2.1). As per Figure 2.2 the risk contours from the Mobil site do not extend into the Liquigas site. The risk contours from the Liquigas site do extend into the Mobil site, but they do not reach the gasoline inventories.

Therefore there is no significant risk of escalation between the two sites.

Figure 2.1: Distance between hazardous material inventories

Figure 2.2: Individual fatality risk contours, Mobil site, Future Case

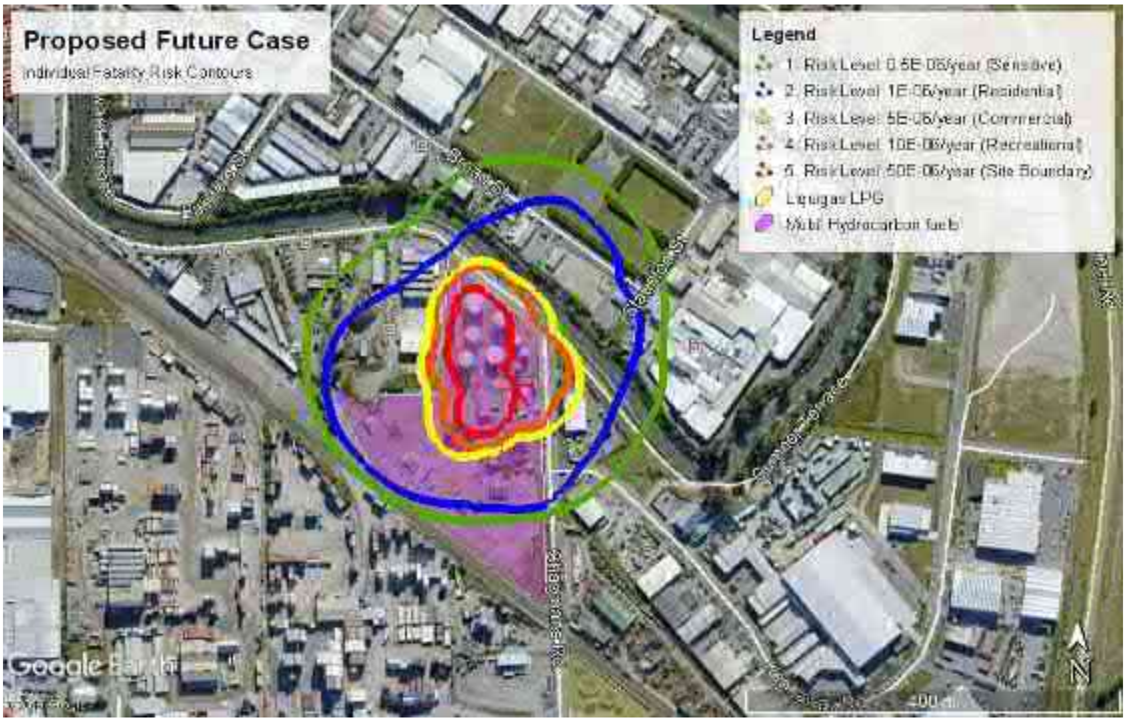
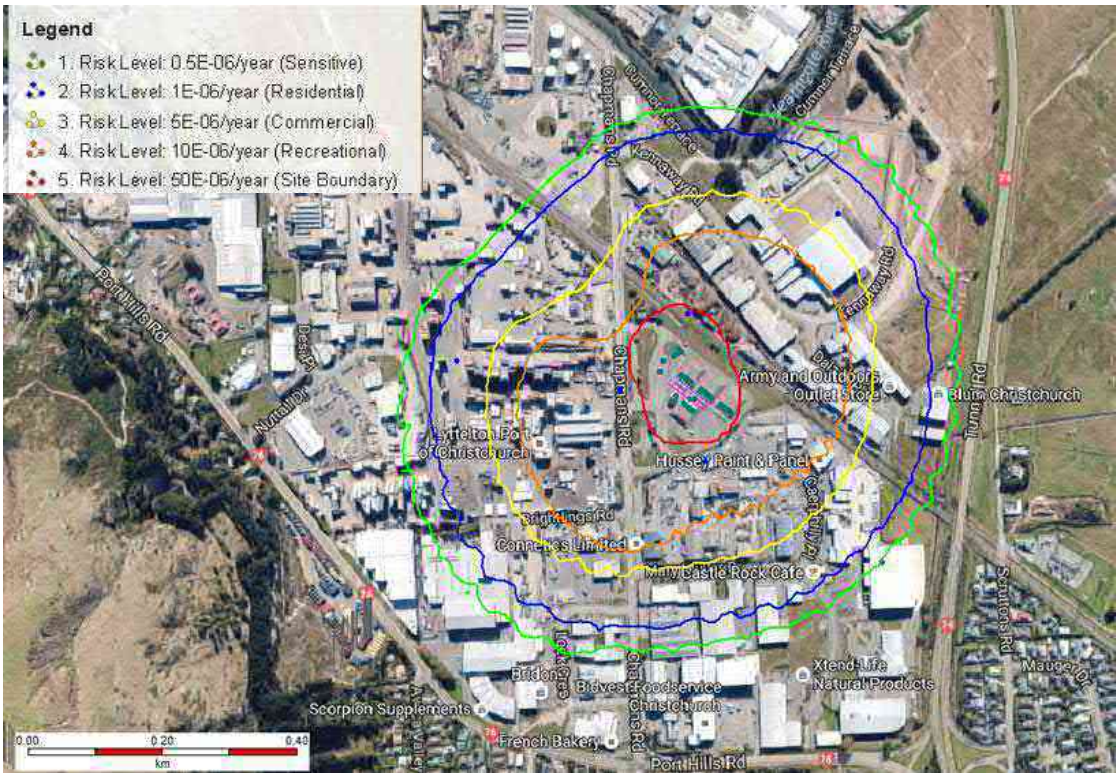


Figure 2.3: Individual fatality risk contours, Liquigas site, Future Case



3. SUGGESTED OVERLAY

3.1. Proposed overlay

An overlay is proposed based on combining the sensitive land use contours (0.5 $\times 10^{-6}$ per year) from both sites.

The sensitive land use contour is selected as the intent is to prevent encroachment on the existing facilities by sensitive land uses ('sensitive' includes residential in this case) and also to use the overlay as a de-facto means of preventing large or high density non-industrial populations, hence limiting societal risk increases.

The merged contours are shown in Figure 3.1.

Another option (as was done in Auckland Unitary Plan around the WOSL site) would be to use property boundaries that the contour cuts through for ease of application in a planning context. An example of this type of overlay (boundaries are approximate only) is shown in Figure 3.2.

3.2. Digital map file

A shape file meeting CCC's digital data supply requirements has been supplied for the merged contour shown in Figure 3.1. (Note that shape files are not provided for the alternative overlay option shown in Figure 3.2).

The Figure 3.1 shape file dataset filenames are :

Merged Mobil + Liquigas (0.5E-06year).prj

Merged Mobil + Liquigas (0.5E-06year)Poly.cpg

Merged Mobil + Liquigas (0.5E-06year)Poly.dbf

Merged Mobil + Liquigas (0.5E-06year)Poly.prj

Merged Mobil + Liquigas (0.5E-06year)Poly.shp

Merged Mobil + Liquigas (0.5E-06year)Poly.shp.gsr2

Merged Mobil + Liquigas (0.5E-06year)Poly.shx

The files have been provided as a single zipped file:

Merged Mobil+Liquigas 0.5e-6year SHP files.ZIP

As required by CCC, these files provide the merged contour as a polygon in the NZGD2000 co-ordinate system (as per the screen shot shown in Figure 3.3).

3.3. Comparison to existing CDP risk overlay

Based on the site specific QRAs the extent of the overlay (which currently extends around 100m to 250m from the sites) has changed as follows:

1. Reduced to approximately 170m around the Mobil site (measured from the main bund).
2. Increased to approximately 300m for the Liquigas site.

Figure 3.1: Proposed overlay – contours merged

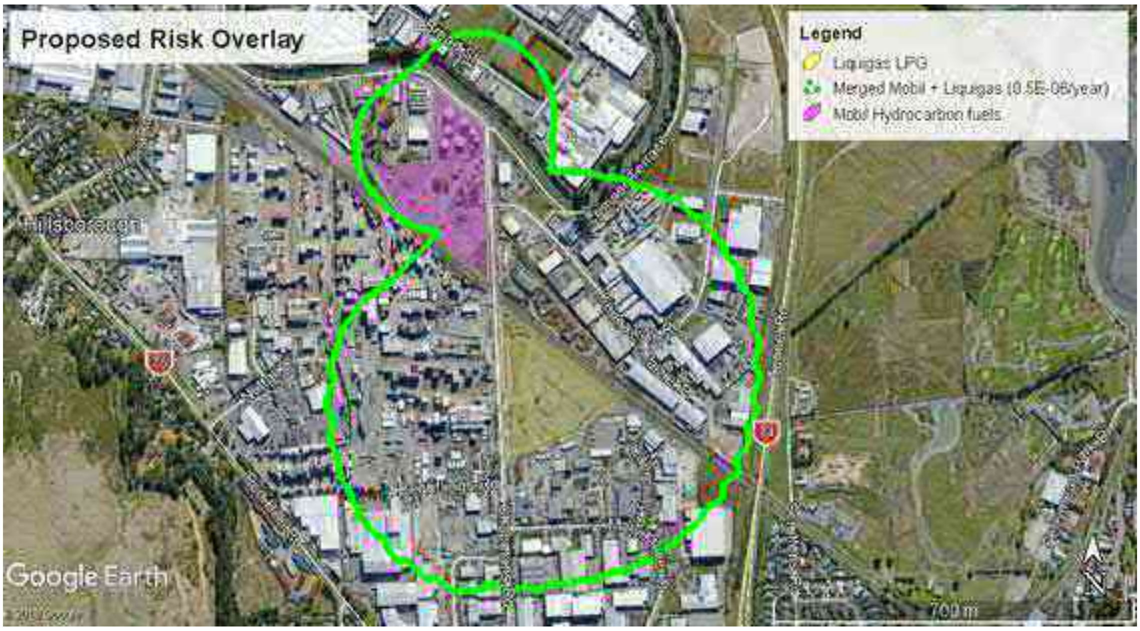


Figure 3.2: Alternative overlay – property boundary example (approximation only)

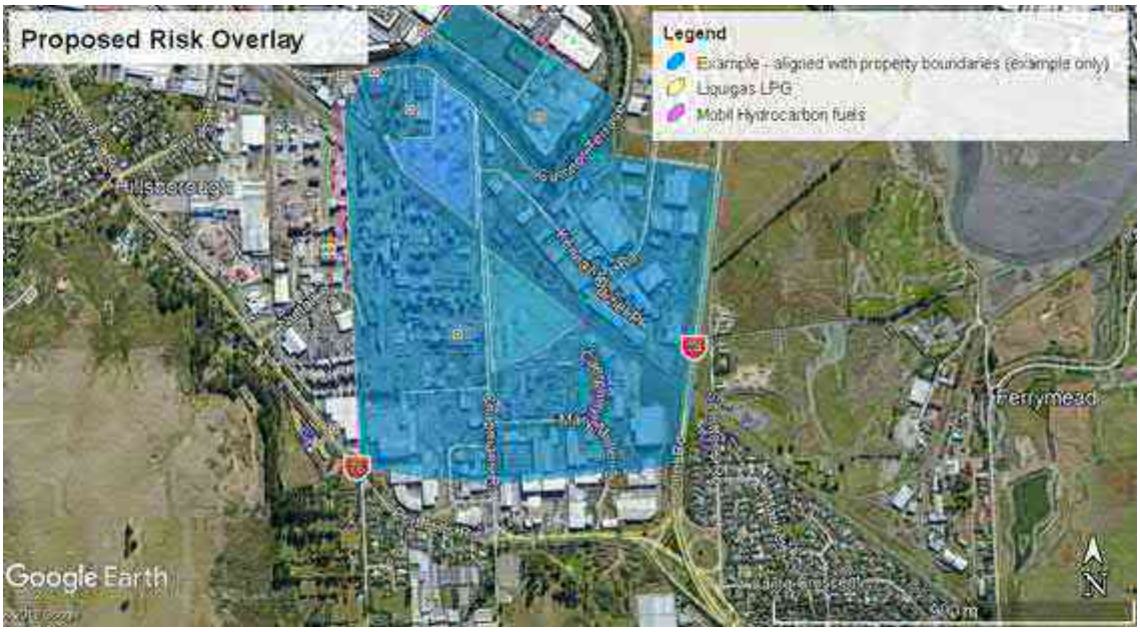
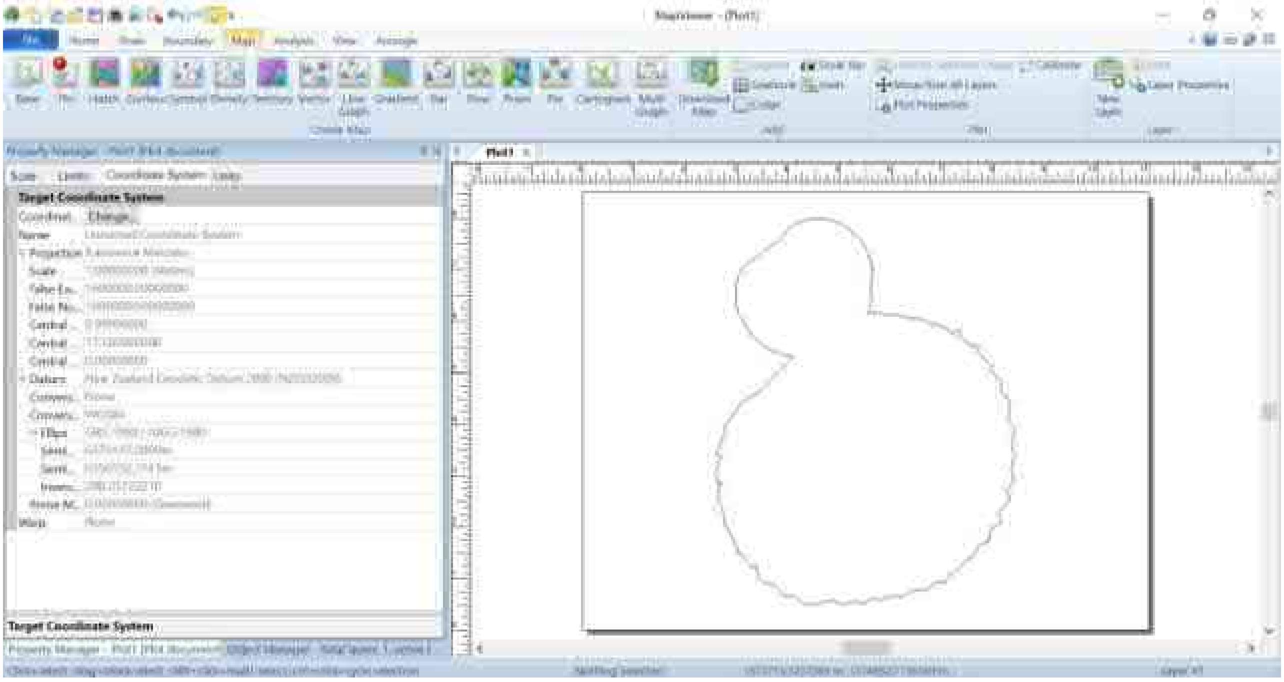


Figure 3.3: Screen shot of Figure 3.1 as shape file for CCC


Target Coordinate System
Target Coordinate System

4. REFERENCES

1 UK HSE. *Land use planning advice around large scale petrol storage sites* SPC/TECH/GENERAL/43. [Online] [Cited: 8 May 2015.] http://www.hse.gov.uk/foi/internalops/hid_circs/technical_general/spc_tech_gen_43/index.htm

2 Sherpa Consulting Pty Ltd *Mobil Woolston Terminal Quantitative Risk Assessment for Determination of Planning Overlay Mobil Oil New Zealand Limited* Doc No 21086-RP-002 Rev 0, 22-Jun-2018

3 WorleyParsons New Zealand Pty Ltd *LIQUIGAS Woolston LPG Depot Quantitative Risk Assessment* Doc No 503402-RPT-R0001-R1 May 2018

4 http://proposeddistrictplan1.ccc.govt.nz/. *Proposed Christchurch Replacement District Plan.* [Online] [Cited: 7 June 2017

5 NSW Department of Planning. *Hazardous Industry Planning Advisory Paper No.4 - Risk Criteria for Land Use Safety Planning.* 2011

APPENDIX 4 – COPY OF PLAN CHANGE TEXT AMENDMENTS

DISTRICT PLAN AMENDMENTS

Note: For the purposes of this plan change:
Any text proposed to be added by the plan change is shown as bold underlined and text to be deleted as ~~bold strikethrough~~.
Text in green are defined terms to be linked to their respective definition in Definitions Chapter.
Text in blue are cross references to be linked to external and/or other provision within the Plan.

Amend the District Plan as follows:

Chapter 4 Hazardous substances and contaminated land, 4.1 Hazardous substances, 4.1.2 Objectives and Policies

4.1.2.2.2 Policy - Woolston Risk Management Area~~s~~

a. Avoid sensitive activities locating within the Woolston Risk Management Area~~s~~ where these have the potential to be exposed to unacceptable risk and/or may otherwise constrain the development, operation, upgrading or maintenance of bulk fuel and gas terminals.

Advice note:
1. The Woolston Risk Management Area~~s are~~ is shown on Planning Map 47A. ~~The geographic extent of these areas may be subject to a future plan change to have effect by 31st March 2019 and any such plan change would need to be based on the findings of a Quantitative Risk Assessment.~~

Chapter 4 Hazardous substances and contaminated land, 4.1 Hazardous substances, 4.1.4 Rules – Hazardous substances

4.1.4.1.5 Non-complying activities

Activity	
NC2	a. Any sensitive activity located within ~~a~~ the Woolston Risk Management Area. ~~This rule shall cease to have effect by 31 March 2019.~~ Advice note: 1. The Woolston Risk Management Area~~s are~~ is shown on Planning Map 47A. ~~The geographic extent of these areas may be subject to a future plan change to have effect by 31st March 2019 and any such plan change would need to be based on the findings of a Quantitative Risk Assessment.~~

16.2.1.4 Policy – Activities in industrial zones

a. ...

b. Avoid any activity in industrial zones with the potential to hinder or constrain the establishment or ongoing operation or development of industrial activities and strategic infrastructure, or by being exposed to unacceptable risk. This includes but is not limited to avoiding:

   i. sensitive activities located within the 50dB Ldn Air Noise Contour, the Lyttelton Port Influences Overlay Area, the Woolston Risk Management Area and in proximity to the National Grid;

   ii. discretionary or non-complying activities in the Woolston Risk Management Area ~~close proximity to bulk fuel storage facilities~~ unless ~~a quantitative risk assessment establishes that~~ the proposed activity in its location meets risk acceptability criteria appropriate to the applicable land use.

c. ...

d. ...

Advice note for Clause b~~.ii~~:

1. The Woolston Risk Management Area is shown on Planning Map 47A. ~~As at June 2015, bulk fuel storage facilities in industrial zones are limited to the LPG and oil depots in Chapmans Road, Woolston.~~

~~2. The quantitative risk assessment shall consider the vulnerability of activities to hazardous events from a bulk fuel storage facility, such as fires and vapour cloud explosions, and the ability of the proposed activity to enact timely and effective emergency action and evacuation. This will require consideration of factors including:~~

   ~~a. Site and building occupancy, and the ability to easily evacuate;~~

   ~~b. Building type and siting; and~~

   ~~c. The effects of structures and landscaping on the propagation of vapour cloud explosions.~~

~~3.~~2. ~~The identification of appropriate~~ Appropriate risk acceptability criteria ~~and guidance on preparing a quantitative risk assessment shall refer to guidance~~ include those in the Planning NSW Hazardous Industry Planning Advisory Papers No. 3 and 4 Risk Criteria for Land Use Safety Planning. Those criteria were used in determining the geographic extent of the Woolston Risk Management Area. ~~, or similar guidance suitable to the content of the site and activity that the risk assessment is for.~~ Early consultation with the companies responsible for the LPG and oil depots is encouraged for any proposed activity within the Woolston Risk Management Area ~~300 metres of the depots~~, as the companies will be able to assist with the identification of ~~appropriate~~ risk issues relating to any proposed development. ~~acceptability criteria and the extent to which a quantitative risk assessment is necessary.~~

3. Council holds and will make freely available to the public, the Quantitative Risk Assessments prepared by the LPG and oil depot companies for the Woolston Risk Management Area.

4. For the avoidance of doubt, the relevant discretionary and non-complying activities are only those the subject of Rule 16.4.1.4 D1, Rule 16.5.1.4, and Rule 16.5.1.5 NC1.

Chapter 16 Industrial, 16.4 Rules – Industrial General Zone

16.4.1.1 Permitted activities

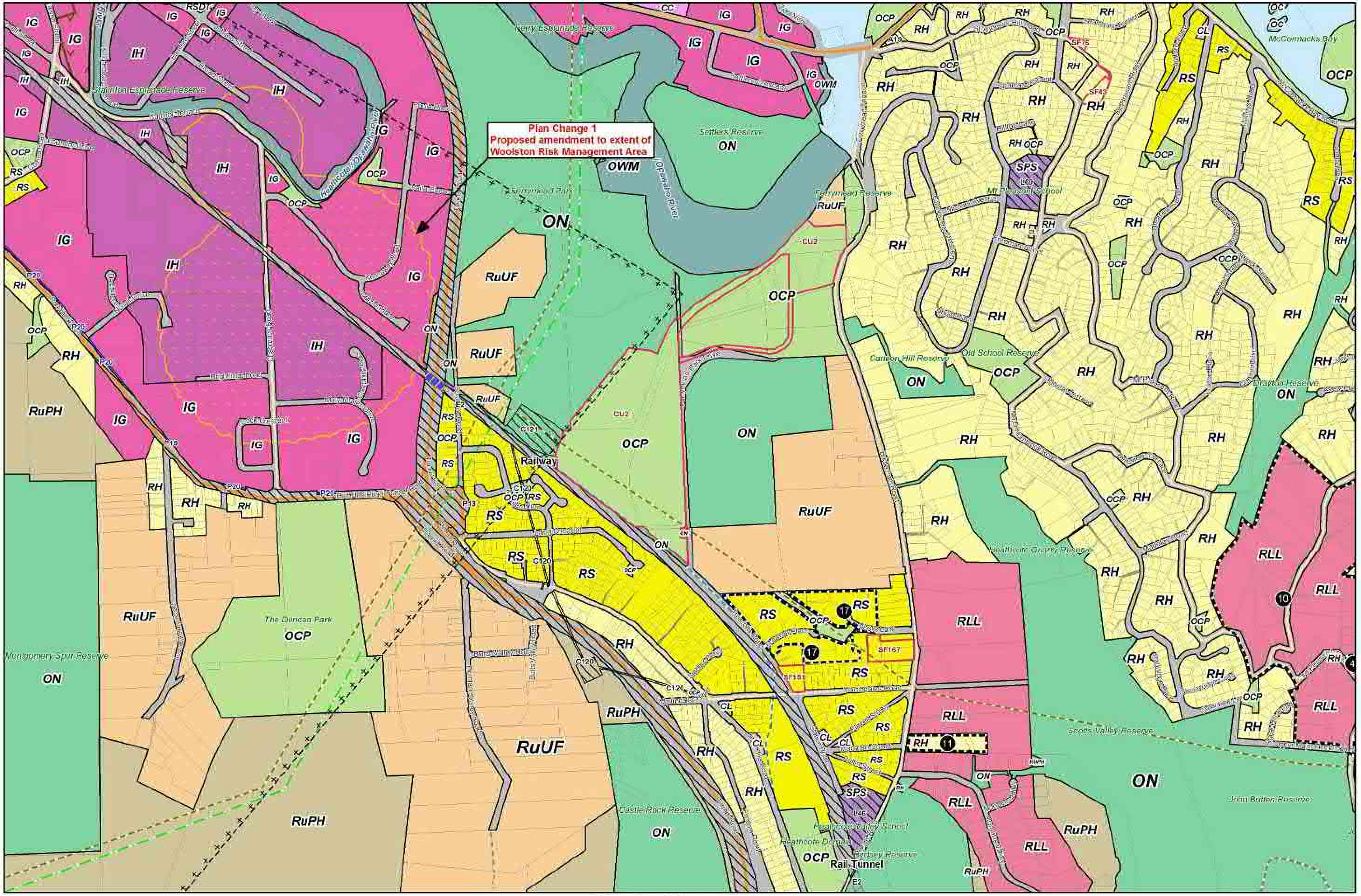
Activity		Activity specific standards
P18	Preschool a. outside the 50 dB L_{dn} Air Noise Contour; b. in Lyttelton, outside the Lyttelton Port Influences Overlay Area as defined on the planning maps; c. outside the Woolston Risk Management Area as defined on the planning maps	a. Any preschool activity shall be: i. located more than 100 metres from the boundary of an Industrial Heavy Zone; and ii. any habitable space must be designed and constructed to achieve an external to internal noise reduction of not less than 25 dB $D_{tr,2m,nT,w}+C_{tr}$; and; and iii. any bedroom or sleeping area must be designed and constructed to achieve an external to internal noise reduction of not less than 30 dB $D_{tr,2m,nT,w}+C_{tr}$.

16.4.1.5 Non-complying activities

	Activity
NC2	Sensitive activity within the 50 dB L_{dn} Air Noise Contour, the Woolston Risk Management Area or within the Lyttelton Port Influences Overlay Area as defined on the planning maps.

Amend Planning Map 47A by removing the existing Risk Management Areas and replacing it with the new Woolston Risk Management Area, as shown on the attachment.

Amend Planning Map Legend **by renaming "Risk Management Areas" to "Woolston Risk Management Area" and removing the text under "Risk Management Areas", as shown on the** attachment.



Christchurch District Plan

Christchurch City Council

Planning Map 47A
Zones, Other Notations, Designations and Heritage Orders
Published 19 December 2017

GIS & Analytics Team
Christchurch City Council

Proposed Plan Change 1

PC_01.gws
Date:25/09/2018

Land Use Zones

CBP	Commercial Banks Peninsula
CC	Commercial Core
CL	Commercial Local
CMU	Commercial Mixed Use
CO	Commercial Office
CRP	Commercial Retail Park
IG	Industrial General
IH	Industrial Heavy
IP	Industrial Park
OC	Open Space Coastal
OCP	Open Space Community Parks
OCP or RuQ(T)	Open Space Community Parks or Rural Quarry (Templeton)
OMI	Open Space McLeans Island
OMF	Open Space Metropolitan Facilities
ON	Open Space Natural
OWM	Open Space Water and Margins
PA	Pāpakāinga/Kāinga Nohoanga
RBP	Residential Banks Peninsula
RGA	Residential Guest Accommodation
RH	Residential Hills
RLL	Residential Large Lot
RMD	Residential Medium Density
RNN	Residential New Neighbourhood
RSS	Residential Small Settlement
RS	Residential Suburban
RSDT	Residential Suburban Density Transition
RuBP	Rural Banks Peninsula
RuPH	Rural Port Hills
RuQ	Rural Quarry
RuQ or OCP(T)	Rural Quarry or Open Space Community Parks (Templeton)
RuT	Rural Templeton
RuUF	Rural Urban Fringe
RuW	Rural Waimakariri
SPA	Specific Purpose (Airport)
SPB	Specific Purpose (Burwood Landfill and Resource Recovery Park)
SPC	Specific Purpose (Cemetery)
SPW	Specific Purpose (Defence Wigram)
SPLR	Specific Purpose (Flat Land Recovery)
SPR	Specific Purpose (Golf Resort)
SPH	Specific Purpose (Hospital)
SPLP	Specific Purpose (Lyttelton Port)
SPN	Specific Purpose (Ngā Hau e Whā)
SPRa	Specific Purpose (Ruapuna Motorsport)
SPS	Specific Purpose (School)
SPST	Specific Purpose (Styx Mill Road Transfer Station)
SPT	Specific Purpose (Tertiary Education)
	Transport
	Transport over Open Space Water and Margins Zone

All new roads are deemed to be part of the Transport Zone, from the date of vesting in Council or Crown. When roads are legally stopped and any relevant designations removed they are deemed to be subject to the provisions of the adjoining zone(s).

Other Notations

	220kV National Grid
	110kV National Grid
	66kV National Grid
	66kV Electricity Distribution Lines
	33kV Electricity Distribution Lines
	11kV Heathcote to Lyttelton Electricity Distribution Lines
	Air Noise Boundary and Air Noise Contours
	On-Aircraft Engine Testing Contours
	Christchurch International Airport Protection Surfaces
	Amenity Tree Planting 1.8m Contour Buffer
	Key Pedestrian Frontage
	Major Arterial Road
	Minor Arterial Road
	Collector Road
	160m Contour Line (applies only to Rural Banks Peninsula zone)
	Accommodation and Community Facilities Overlay
	Brownfield Overlay Area
CA	Character Area Overlay
	Coastal Bach Overlay
	Community Housing Redevelopment Mechanism
1	Kainga Overlay Area 1
2	Kainga Overlay Area 2
3	Spencerville Overlay
4	Moncks Spur/Mt Pleasant Density Overlay
5	Shalamar Drive Density Overlay
6	Upper Kennedys Bush Density Overlay
7	Akaroa Hillslopes Density Overlay
8	Allandale Density Overlay
9	Samarang Bay Density Overlay
10	Residential Large Lot Density Overlay
11	Residential Mixed Density Overlay - 86 Bridle Path Road
12	Residential Mixed Density Overlay - Redmund Spur
13	Residential Medium Density Lower Height Limit Overlay
14	Diamond Harbour Density Overlay
15	Existing Rural Hamlet Overlay
16	Medium Density (Higher Height Limit) Overlay
17	Peat Ground Condition Constraint Overlay
18	Riccarton Wastewater Interceptor Catchment Overlay
19	Stormwater Capacity Constraint Overlay
	Lyttelton Port Influences Overlay Area
	Meadowlands Exemplar Overlay
	Prestons Road Retirement Village Overlay
	Ruapuna Inner Noise Boundary
	Ruapuna Outer Noise Boundary
	Salvation Army Addington Overlay
A	Scheduled Activity
	St Georges Heaton Overlay
	Woolston Risk Management Area

~~Risk Management Area (refer Rule 4.4.1.1.6). The geographic extent of these areas may be subject to a future plan change to have effect by 31st March 2019 and any such plan change would need to be based on the findings of a Quantitative Risk Assessment.~~

Plan Change 1
Text to be amended

Designations and Heritage Orders

A	Chorus New Zealand Limited
B	Chorus New Zealand Limited / Telecom New Zealand Limited
C	Christchurch City Council
D	Christchurch International Airport Limited
E	KiwiRail Holdings Limited
F	Kordia Limited
G	Meterological Service of New Zealand Limited
H	Minister supporting Greater Christchurch Regeneration
I	Minister of Corrections
J	Minister for Courts
K	Minister of Defence
L	Minister of Education
M	Minister of Health
N	Minister of Police
O	Minister for Social Development
P	New Zealand Transport Agency (Operational Corridor)
P	New Zealand Transport Agency (Future Works)
Q	Orion New Zealand Limited
R	Radio New Zealand Limited
S	Spark New Zealand Trading Limited
U	Transpower New Zealand Limited
V	Ōtākaro Limited
	Lyttelton Tunnel Designation
	Land Subject to two Designations: Primary - Railway Designation, Secondary - Roading Designation
	Land Subject to two Designations: Primary - Roading Designation, Secondary - Railway Designation
	Heritage Order

Information Only

	District Boundary
	Lyttelton Tunnel Road
	Summit Road Protection Act Overlay

The cadastre and coastline shown on the planning maps is not part of the information in the District Plan. It has been provided on the planning maps as an additional function to enhance navigability and search capability. District Plan rules do not apply for overlays extending into the Coastal Marine Area. The Coastal Marine Area is as defined in the Resource Management Act. The cadastre was based on the most recent information held by the Council at the date the map was produced. Establishing compliance or otherwise with the plan may require a formal survey.

The District boundary is as defined in the Resource Management Act, which uses the definition from the Local Government Act. The line on these maps representing the District boundary is indicative and for information purposes only. The actual boundary is as defined in the legislation. Determining rights and obligations under the District Plan where the District boundary is relevant may require a formal survey.

The District Plan planning maps are at a scale of 1:10000 and 1:50000. Use at any other scale than specified on each map is for information purposes only, and does not form part of the District Plan.

For information, acknowledgements and disclaimers relating to external data sources used in the planning maps please see the Data Sources page (https://ccc.govt.nz/the-council/plans-strategies-policies-and-bylaws/plans/christchurch-district-plan/additional-information/data-sources)

Christchurch District Plan | Christchurch City Council

Legend
Zones, Other Notations, Designations and Heritage Orders
Published 19 December 2017

GIS & Analytics Team
Christchurch City Council

Proposed Plan Change 1

Legend_A_PC1.gws
Date:24/09/2018