DELPHI RISK
MANAGEMENT CONSULTING

SMS ALARP REPORT
ARDEN DRAFT STRUCTURE PLAN
Threats Raised at SMS Workshop

Document No		2020-0005-RPT-0004			
Rev	Date	Status	Originated/Custodian	Checked	Approved
0		Issue For Use	Refer to Document Review and Approval section		

Report and Approval Declaration

Title	SMS ALARP Report -Arden Draft Structure Plan		
Document No	2020-0005-RPT-0004	Revision	0
Declaration	This declaration signifies that the ALARP Review arising from the Safety Management Study review of the Arden Draft Structure Plan has been completed. This notice is to acknowledge that: ▪ The threats identified in the SMS as posing an intermediate risk have been reviewed; ▪ The effectiveness of all controls has been recognised through the review; ▪ The options for further mitigation of the threats have been analysed for effectiveness and practicality; ▪ Where justified, the additional measures have been adopted; and ▪ The resulting risk exposure to the threats is demonstrated to be **ALARP**. The executive summary from the ALARP review is contained within this report document **2020-0005-RPT-0004**. The referenced Safety Management Study Report is 2020-0005-RPT-0003_Arden_SMS_Report_Rev1 facilitated by Mark Harris of Delphi Risk Management Consulting. Review and approval signatures for this declaration and document are placed on the following page.		

Title	SMS ALARP Report - Arden Draft Structure Plan		
Document No	2020-0005-RPT-0004	Revision	0
Role	**Name / Title**	**Signature**	**Date**
Originator	Mark Harris Principal Process Safety & Risk Engineer - DRMC		16/10/2020
Reviewed	Keith Lenghaus Manager Integrity – APA Group		16/10/2020
Approved	Keith Lenghaus Manager Integrity – APA Group		16/10/2020

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1. EXECUTIVE SUMMARY

This report has been undertaken for the Victorian Planning Authority (VPA) and will help inform the Arden Structure Plan to support the area's transition into a world class urban renewal precinct. The purpose of the report is to recommend suitable mitigation measures to reduce 'Intermediate' threats to gas pipelines so that 'Sensitive' land use (AS2885.6 Section 2.4(a)) and High Density land use (AS2885.6 Section 2.3(d)) can reasonably locate within gas measurement length areas adjacent to the APA transmission gas pipelines in the area.

The Arden Draft Structure Plan Safety Management Study (SMS) Workshop held on the 10th of June 2020 identified that the Draft Arden Structure Plan (Arden Plan) posed potential risks to both the community and the existing APA transmission gas pipelines (PL208 and PL66) located within and adjacent to the Arden area.

The SMS workshop identified the following Intermediate risk to pipeline integrity and safety of stakeholders.

The following five (5) Threats were identified as INTERMEDIATE risks to PL208 and PL66 requiring an ALARP assessment.

- Threat ID 2 Excavator causing an ignited hole leading to multiple fatalities
- Threat ID 7 Auger causing an ignited hole leading to a few fatalities
- Threat ID 10 HDD causing an ignited hole leading to multiple fatalities
- Threat ID 15 Installation of utilities by an excavator causing an ignited hole leading to multiple fatalities (Same ALARP assessment as ID2)
- Threat ID 18 Bored crossing causing an ignited hole leading to multiple fatalities

The following additional Threat to the existing network gas pipelines in the area was identified as an INTERMEDIATE risk requiring an ALARP assessment be undertaken. Note that the network pipelines are governed under a different pipeline code (AS4645.1) which follows a similar risk assessment and ALARP methodology but with different consequence and likelihood thresholds.

- Threat ID 43 Excavation over a network pipeline causing a major leak and severely disrupting gas supply to 5000 properties

To comply with AS/NZS 2885.6, AS4645.1 and APA's policy on demonstration of ALARP, further analysis of the risks has been performed.

An independent consultant was engaged to undertake an ALARP assessment of the risks identified above, a DRAFT ALARP assessment was then presented at an ALARP Workshop on the 8th of September 2020 where the findings of the assessment were discussed and agreed.

This report summarises the findings of the ALARP assessment including discussion of the different options for the mitigation of these threats and recommends appropriate actions to reduce the threats to being as low as reasonably practical (ALARP).

Most of these options considered are unjustified as the costs are grossly disproportionate to the level of risk reduction or not considered effective at mitigation.

The ALARP assessment for threats ID2, ID7 & ID15 found that with the existing mitigations in place, the risk of failure was High rather than Intermediate.

Under the Australian Standard we are obliged to consider additional mitigations which can assist in lowering the risk of failure to no higher than Intermediate and ultimately as low as reasonably practical.

This report recommends that the excavator and auger threats (ID2, ID7 & ID15) can be suitably controlled through the use of protective slabbing (such as concrete) on top of the pipeline, marker tape installed above the slab and the replacement of the pipeline coating. Note that the use of slabbing does make the pipeline more difficult to maintain so replacing the 30 year old, brittle, coal tar enamel coating with a current day specification coating helps provide for the long term integrity of the pipeline.

It should be noted that approximately 2168m of APA pipelines are impacted by the Arden Plan however around 218m already have concrete slabbing over them so it is proposed that only ~1950m of pipeline needs to be treated with the proposed mitigations outlined above.

The mitigations proposed are estimated to incur a total one-off cost of ~$19.5M (NOTE: - Cost based on indicative cost of $10,000/m provided by APA).

For Threat ID10 (HDD) and ID18 (Bored Crossing) the use of side slabbing to prevent horizontal impact to the pipeline was considered, however the probability of failure with the existing controls was found to already be in the Hypothetical range. The addition of side slabbing whilst further lowering the probability of failure, could not be justified for the following reasons:

- Side slabbing the full 2168m was considered grossly disproportionate in cost (~$9,000,000) when compared to the benefit of further lowering the already Hypothetical probability of failure.
- Targeted side slabbing is typically considered appropriate at pipeline road crossings however this is where most other utilities will also cross making it very difficult, if not impossible, to retrofit side slabbing in these areas.

For these reasons Threat ID10 & ID18 were determined to be ALARP with the current mitigations and will not require additional mitigation.

For Threat ID43 (network damage) the risk of failure with the existing mitigations in place found that the risk was intermediate and largely consistent with any other gas networks in a built up area. The use of slabbing to prevent impact to the pipeline was considered, however with approximately 10km of network pipelines in the area, installing any sort of slabbing (recoating not required) would be a grossly disproportionate cost (~$15-$20M) when compared to the possible community impact due to the related loss of supply. As such the risk is considered ALARP with the existing mitigations.

Cost referenced above do not include road resurfacing, traffic management and/or VPA or City of Melbourne (CoM) costs.

All mitigations recommended in this ALARP Report should be implemented before any Arden Plan works are undertaken unless otherwise agreed with APA Group.

2. INTRODUCTION

This document is an ALARP report on the threats arising from the Arden Draft Structure Plan Safety Management Study (SMS) Review carried out in accordance with Australian Standard AS/NZS 2885.6 Pipelines – Gas and Liquid Petroleum – Part 6 Pipeline Safety Management - 2018, for the PL203 and PL66 APA pipelines.

Mark Harris from Delphi Risk Management Consulting (DRMC) was engaged by the Victorian Planning Authority (VPA) to undertake this ALARP assessment. APA have assisted by providing the ALARP Report Template.

2.1 Purpose and Scope

This ALARP report analyses the six (6) intermediate risks in total arising from the SMS listed below.

The following five (5) Threats were identified as INTERMEDIATE risks to PL208 and PL66 requiring an ALARP assessment.

- Threat ID 2 Excavator causing an ignited hole leading to multiple fatalities
- Threat ID 7 Auger causing an ignited hole leading to a few fatalities
- Threat ID 10 HDD causing an ignited hole leading to multiple fatalities
- Threat ID 15 Installation of utilities by an excavator causing an ignited hole leading to multiple fatalities (Same ALARP assessment as ID2)
- Threat ID 18 Bored crossing causing an ignited hole leading to multiple fatalities

The following additional Threat was identified as an INTERMEDIATE risk to the existing network gas pipeline in the area requiring an ALARP assessment be undertaken.

- Threat ID 43 Excavation causing a major leak and severely disrupting gas supply to 5000 properties

2.2 Terms & Abbreviations

The Terms and Abbreviations used in this document are listed below:

Table 1 Terms

Item	Definition
APA	APA Group
DN	Nominal Diameter
Arden	Arden Draft Structure Plan

Table 2 Abbreviations

Item	Definition
ALARP	As Low As Reasonably Practicable

Item	Definition
AS	Australian Standard
AS/NZS	Australian / New Zealand Standard
CP	Cathodic Protection
CTE	Coal Tar Enamel (pipeline coating)
DBYD	Dial Before You Dig
GPT	General Purpose Teeth (used on an excavator bucket)
HDD	Horizontal Directional Drill
LOP	Layer of Protection
LOPA	Layers of Protection Analysis
MAOP	Maximum Allowable Operating Pressure
ML	Measurement Length (heat radiation contour 4.7kw/m2)
MOP	Maximum Operating Pressure
RRF	Risk Reduction Factor
ROW	Right of Way
SMS	Safety Management Study

2.3 References

All work performed in accordance with this Report shall be in conformance with the current issue, including amendments, of those national and international standards, codes of practice, guidelines and APA documents listed in Table 3.

Table 3 Referenced Documents

Referenced Document	
Australian Standards	
AS reference	**Document Name**
AS/NZS 2885.1-2018	Pipelines – Gas and liquid petroleum – Design and construction
AS 2885.3-2012	Pipelines – Gas and liquid petroleum – Operations and Maintenance
AS/NZS 2885.6-2018	Pipelines – Gas and liquid petroleum – Part 6: Pipeline safety management
AS/NZS 4645.1-2018	Gas Distribution Networks - Part 1: Network Management
AS/NZS ISO 31000-2009	Risk Management, Principles and Guidelines
Other References	
Reference	**Document Name**
N/A	Arden Utilities (Arden plan with pipeline overlay)
V2.2	Draft Arden Structure Plan (showing heights)

2.4 Superseded Documents

This Report replaces the previously used document listed in Table 4.

Table 4 Superseded Documents

Superseded Document	
Reference	Document Name
N/A	N/A

3. ALARP METHODOLOGY

3.1 AS2885.6 ALARP Requirements

For in-service transmission pipelines where an SMS Workshop has determined a threat or series of threats present an Intermediate Risk, a formal ALARP assessment is required for each threat under AS2885.6 (Section 4.2). An ALARP assessment shall consider: -

a) the current level of risk (including the effectiveness of current and planned controls) and any additional justification for further risk reduction;
b) additional or improved controls available for further reducing the risk;
c) the reduction in risk resulting from each available control;
d) the cost of each available control;
e) the uncertainty in the analysis including uncertainty in the effectiveness of controls and the consequences and likelihood of failure; and
f) the reasons why any options for additional or improved controls have not been adopted.

3.2 LOPA Assessment

A Layer of Protection Analysis (LOPA) is used to develop a more detailed assessment of the likelihood of failure due to the threat being considered. The LOPA calculation firstly considers the probabilities of certain steps or factors which might lead to a loss of containment event as determined at the original SMS Workshop. The second stage of the LOPA is to determine the effectiveness of known Layers Of Protection (LOP) which provide Risk Reduction Factors that can be applied to the loss of containment event to calculate the overall likelihood (or probability) of the event occurring.

By undertaking this assessment, it can provide a more detailed determination of the likelihood of failure and reconfirm (or otherwise) the Risk Assessment originally determined at the SMS Workshop. The LOPA can then be used as a sensitivity tool to test the effectiveness of new or additional mitigations that can help lower the likelihood of failure with the goal of reaching a level that can be considered ALARP.

AS2885.6 Table F1 Appendix F (below) provides guidance on Frequency (or Likelihood) thresholds, the lower the Frequency, the lower the likelihood of the risk occurring.

Table 5 Frequency of Occurrence for Hazardous Events (AS2885.6 Table 3.2)

Frequency of Occurrence	Description	Numerical Guideline (events/1000 km/year)
Frequent	Expected to occur typically once per year or more.	>/= 1
Occasional	May occur occasionally in the life of the pipeline.	1 to 0.1
Unlikely	Unlikely to occur within the life of the pipeline, but possible.	0.1 to 0.001 (10^{-1} to 10^{-3})
Remote	Not anticipated for this pipeline at this location.	0.001 to 0.00001 (10^{-3} to 10^{-5})
Hypothetical	Theoretically possible, but would only occur under extraordinary circumstances	<0.00001 (<10^{-5})

By comparing the newly calculated Likelihood with the previously considered consequence from the SMS Workshop, an updated Risk Assessment can be determined using the tables below.

Table 6 Approved Severity Classes for Transmission Pipelines (AS2885.6 Table 3.1)

	Severity Class				
	Catastrophic	**Major**	**Severe**	**Minor**	**Trivial**
Dimension	***Measures of Severity***				
People	Multiple fatalities result	One or two fatalities or several people with life-threatening injuries	Injury or illness requiring hospital treatment	Injuries requiring first aid treatment	Minimal impact on health and safety
Supply	Widespread or significant societal impact, such as complete loss of supply to a major city for an extended time (more than a few days)	Widespread societal impact such as loss of supply to a major city for a short time (hours to days) or to a localized area for a longer time	Localised societal impact or short-term supply interruption (hours)	Interruption or restriction of supply but shortfall met from other sources	No impact or restriction of pipeline supply
Environment	Impact widespread; viability of ecosystems or species affected or permanent major changes	Major impact well outside PIPELINE CORRIDOR or site; or long-term severe effects; or rectification difficult	localised impact substantially rectified within a year or so	Impact very localized and very short-term (weeks), minimal rectification	No effect; minor impact rectified rapidly (days) with negligible residual effect

Table 7 Risk Matrix (AS2885.6 Table3.3)

Frequency of Occurrence	**Risk Class**				
	Severity Class				
	Catastrophic	**Major**	**Severe**	**Minor**	**Trivial**
Frequent	**E**	**E**	**H**	**I**	**L**
Occasional	**E**	**H**	**I**	**L**	**L**
Unlikely	**H**	**H**	**I**	**L**	**N**
Remote	**H**	**I**	**L**	**N**	**N**
Hypothetical	**I**	**L**	**N**	**N**	**N**

3.3 ALARP Assessment

The ALARP assessment seeks to find any additional mitigations (e.g. those listed above or any other credible mitigations like slabbing or more patrolling etc…) which have a material effect of lowering the likelihood of failure whilst not being grossly disproportionate in cost to the additional benefit they bring.

An ALARP assessment needs to provide clear justification for why certain additional mitigations are applied or not applied.

The risk controls listed below are required to be considered as part of any formal ALARP assessment:

A. Imposition of RESTRICTED OPERATING PRESSURE or reduction of MAOP (to a level where RUPTURE is non-credible, or the consequence of failure can be sufficiently reduced).
B. Pipe replacement (with NO-RUPTURE pipe).
C. Pipeline relocation (to a location where the consequence is eliminated).
D. Modification of land use (to separate the people from the pipeline).
E. Implementing controls that are effective in controlling THREATS to the pipeline from the Intermediate risks under consideration.

Without pre-empting the findings of the ALARP assessments, some comments with respect to the above are warranted.

3.3.1 ALARP Option A

Restricting or lowering the MAOP of a transmission pipeline (TP) would reduce the influence/size of the ML in the event of a loss of containment however it also reduces the capacity of the TP to deliver gas and it is unlikely this will be possible given that broader gas demand will continue to rise in the surrounding areas. This also only partially reduces the credible threat of a fatality so the threat will remain to an extent, noting rupture is already not credible.

3.3.2 ALARP Option B

Pipeline replacement with a higher strength pipe in situ will all but eliminate the likelihood of a leak and is an option however cost is significant.

3.3.3 ALARP Option C

Pipeline relocation could be possible by moving the pipeline to the western side of the structure plan area subject to existing infrastructure along the railway and Moonee Ponds Creek but again very expensive, requiring new easements and would only really move the problem rather than solve it.

3.3.4 ALARP Option D

Modifying the land use means not building the "High Density" development which I suggest is not practical against the wider societal benefit.

3.3.5 ALARP Option E

As the main risks to the pipeline are from above with an excavator or an auger the pipeline industry regularly mandates the use of concrete slabbing (along with marker tape) over the pipeline along with increased signage and or increased patrolling. The ALARP assessment will determine if this option is justified.

3.4 ALARP Assessment for Network Pipelines (AS4645.1)

The ALARP assessment under AS4645.1 for Gas Distribution Networks is similar to AS2885.6 in methodology however the Frequency Table and Severity Table in AS4645.1 is different (shown below). Obviously, the types of mitigations can be different but the methodology in making the ALARP assessment is the same with mitigations being credible and effective without being grossly disproportionate in cost in comparison to the benefit they bring.

Table 8 Approved Likelihood Classes for Network Pipelines (AS4645.1 Table B2)

Frequency of Occurrence	Description	Numerical Guideline (events/1000 km/year)
Frequent	Expected to occur once per year or more typically 1 or more times PA.	>/= 1
Occasional	May occur occasionally in the life of the gas distribution network typically 0.1 to 0.2 times PA	every 5 to 10 years
Unlikely	Unlikely to occur within the life of the gas distribution network, but possible typically 0.01-0.02 times PA	every 50 to 100 years
Remote	Not anticipated for this gas distribution network at this location typically 10^{-3} to 10^{-5} times PA.	1 in 1000 to 100000 years
Hypothetical	Theoretically possible, but would only occur under extraordinary circumstances	<0.00001 (<10^{-5})
	NOTES. Extreme care should be exercised when determining the likelihood as hypothetical, especially for event where the severity is major or above. The validation of this likelihood places a great reliance on the availability of information which may not be in the public domain.	

Table 9 Approved Severity Classes for Network Pipelines (AS4645.1 Table B1)

	Severity Class				
	Catastrophic	**Major**	**Severe**	**Minor**	**Trivial**
Dimension	***Measures of Severity***				
People	Multiple (more. than 3) fatalities result	Few fatalities, (1 to 3) or several people with life-threatening injuries	Injury or illness requiring hospital treatment	Injuries requiring first aid treatment	Minimal impact on health and safety
Supply	Interruption >100 000 consumer weeks	Interruption >50 000 consumer weeks	Interruption >2000 consumer weeks, or >1000 consumers	Interruption >20 consumer weeks, or >100 consumers	Interruption >2 consumer weeks, or >5 consumers
Environment	Effects widespread, viability of ecosystems or species affected permanent major changes	Major off-site impact or long-term severe effects or rectification difficult	localised (< ha) and short-term (<10 year) effects, rectification moderate	Effect localized (<0.1 ha) and short term (<1 year), minimal rectification and very short-term (weeks), minimal rectification	No effect or minor on-site effects rectified rapidly with negligible residual effect
	NOTES. 1. Significant environmental consequences may occur in locations which are relatively small and isolated. 2. Consequences for significant consumers, e.g. hospitals, aged care facilities may require inclusion in the severity Table in the supply dimension. 3. The environmental effects listed are the result of the actions of the network operator 4. Consumer weeks are the product of number of consumers by the number of weeks that this group of consumers has no gas supply				

4. SMS TREATMENT OF EXCAVATOR THREATS (ID2 & ID15)

4.1 Threat Scenario

It is recognised in the pipeline industry, and the Australian Standard for transmission pipelines that external interference by third parties is the greatest risk to the containment of product in the pipeline and as such to the safety of stakeholders and the public, supply, and the environment. As such AS/NZS2885.6 requires various controls to be in place to prevent loss of product caused by external interference.

The Arden SMS review found an ALARP assessment was required which is related to the excavator threats listed in the Table below.

Table 10 Original SMS Assessment for Excavators (Threat ID2 & ID15).

Threat ID	Location Classification	Description	Deemed Credible?	Failure Assessment	Risk Assessment Result L – Likelihood R – Risk C -Consequence
2	T2/ClC/I	**Excavator use over easement (up to 30T). Pipe Damage resulting in a hole causing loss of containment. Hole is less than critical defect length or max credible hole size (whichever is the smaller) 80-90mm hole leading to a ML 65-70m.**	Yes	Consequence - Catastrophic as potential work crew and onlookers could be seriously injured or killed (multiple fatalities) (Supply consequence considered Severe not Major); Likelihood - Hypothetical as would only occur under extraordinary circumstances	L: Hypothetical C: Catastrophic R: Intermediate
15	T2/ClC/I	**Excavator use over easement (up to 30T) Open cut Utilities installation (Water/Power/Comms) over or under the pipeline. Pipe impacted during utility installation resulting in damage or a hole causing loss of containment. Hole is less than critical defect length or max credible hole size (whichever is the smaller) Maximum credible hole size for a 30T excavator 80-90mm hole leading to a ML 65-70m.**	Yes	Consequence - Catastrophic as potential work crew and onlookers could be seriously injured or killed (multiple fatalities) (Supply consequence considered Severe not Major); Likelihood - Hypothetical as would only occur under extraordinary circumstances	L: Hypothetical C: Catastrophic R: Intermediate

During the SMS Workshop the threat of excavation by a third party was considered with respect to utility installation. The activity was found to be credible in all areas.

4.2 Threat Description

The threat under consideration is unauthorised excavation on top of the pipeline to install a utility or similar activity causing the pipeline to be punctured by an excavator (>5 up to 30T) with a tiger tooth or penetration tooth. The resulting leak could ignite causing multiple fatalities of those undertaking excavation and possibly the public in the built-up Arden plan area.

4.3 Event Consequence

The SMS workshop deemed the threats would result in pipeline penetration causing a hole with ignition leading to a risk assessment of **Catastrophic** in the event of multiple fatalities to people undertaking the activities and the significant public presence.

4.4 Event Likelihood

The SMS concluded there is a **Hypothetical** likelihood of failure and an **Intermediate** risk to People from this threat, and a **Severe** risk of an affect upon the supply arising from the event.

The controls currently in place to mitigate this risk and their effectiveness and weaknesses are listed in the table below.

Table 11 Current Controls - Excavators.

Control Measure	Frequency	Effectiveness	Weaknesses
Wall thickness	24/7	Partially effective with excavators as penetration by the tiger/penetration teeth may occur before operator is aware.	Excavators >5T with tiger/penetration teeth can penetrate the pipeline.
Depth of Cover (minimum of 1200mm)	24/7	Only effective if excavation is shallower than pipeline depth, this may not always be the case.	Not effective for deep installations.
Protective Slabbing	Generally effective 24/7 where it is installed	Mostly effective for these threats as operators will recognise that they have struck something and investigate.	Slabbing only installed at some road crossing points, estimated length 218m of slabbing currently. .
DBYD	24/7	Effective for utility companies, council services, and developers.	DBYD request information may not pinpoint exact location. Dependent upon use.
Marker Posts / Right of Way Signs	24/7	Partially effective.	Relies on line of sight being maintained and awareness of machinery operator. Signage clutter in a built-up area makes signage less obvious and somewhat less effective
Liaison Activities	As per procedures	Some contact with utility companies and landholders. Awareness programs with local councils. Partially effective.	Could be more effective with targeted programs.
Inspection of works near pipeline	On site during known development	Effective if known development	Development must be known
Permit Issuing Officer	On site during known development	Effective if known development	Development must be known
ROW/Easement Patrol	Weekday patrol	Partially effective for this threat.	Not fully effective as activities can occur at any time when a patrol person is not present.

4.5 LOPA Assessment - Excavators

The ALARP workshop reviewed the draft excavator LOPA and found that with existing mitigations, the likelihood of an event resulting in multiple fatalities was **Remote** leading to a **High** risk requiring additional mitigations to lower the risk to at least Intermediate.

Excavator Threat ID2 & ID15 LOPA found the likelihood of failure was Remote at $9.29x10^{-5}$ events per 1000km per year with existing mitigations. The pipeline standard AS2885.6 requires that due to the Catastrophic consequence of failure considered, a Hypothetical Likelihood below $1x10^{-5}$ events per 1000km per year should be achieved.

An additional LOPA calc was undertaken to assess the effectiveness of additional concrete slabbing and marker tape over the pipelines which found that the likelihood of failure was lowered to $1.39x10^{-6}$ thus lowering the risk to **Intermediate**.

A separate LOPA also considered pipeline replacement finding that the likelihood of failure was lowered to $4.18x10^{-9}$ thus lowering the risk to **Intermediate**.

A Layers of Protection Analysis (LOPA) for these existing controls at the locations of concern in this ALARP report is presented in Appendix A.

4.6 ALARP Assessment - Excavators

The following additional controls (refer table below) have been considered for this Threat including the main forms of mitigation referenced by AS2885.6 Section 4.2.

It can be seen from the table below that protective slabbing (such as concrete) with marker tape is expected to be the most cost-effective way to lower the likelihood of failure sufficiently to achieve ALARP.

These mitigations are largely effective for this type of threat as operators will recognise that they have struck something and investigate. It is a major exercise to remove an engineered protective slab. It should be noted that installing such slabbing may disturb the soil near the pipeline and as the CTE pipeline coating is brittle and much more difficult to access once the concrete slabs are in place, the pipeline coating will need to be replaced as part of the works prior to the slabbing being installed.

Pipeline replacement, relocation and even MOP reduction would all required much higher costs for new infrastructure as described in the table below.

The costs included below are indicative only based on APA advice. It is recommended that budget pricing be sort from reputable pipeline contractors to provide reliable input to cost planning.

Table 12 Additional Controls Cost Summary - Excavators.

No	Mitigation	Effectiveness	Practical	Cost	ALARP Considerations	Level of Risk Reduction	Action
1	MOP reduction	Partially effective for this threat. Reduces radiation zone but may still cause fatalities. Also, reduction in pressure would lead to reduction in capacity leading to limited supply to large parts of Melbourne	Not practical	Significant cost required to provide an alternate gas supply to compensate for the reduced gas pressure within the piping running through the Arden Plan area. Alternatively, societal cost significant due to loss of gas capacity in the network	Not Justified because full capacity is required in the pipe network. Cost of a new supply would be similar to Number 3 below	N/A	No action
2	Pipe Relocation	Not practical - the wider area near the Arden Precinct will also be subject to future development over time just moving the problem into the future. Availability of new pipeline easement in the built-up area would be extremely difficult and costly.	Not practical	~$30M+ for 2.17km 4 stopples, and tie-ins, new pipeline design, supply and installation on other side of the road. Traffic management, excavation management. Abandonment Plan. Plus, land negotiation/procurement	Not Justified or effective	N/A	No action
3	Pipeline Replacement	Effective but major disruption to traffic during works and a major activity to keep gas flowing whilst new pipeline is installed	Practical	~$30M+ for 2.17km 4 stopples, and tie-ins, new pipeline design, supply and installation on other side of the road. Traffic management, excavation management. Pipeline Abandonment Plan	Effective but significantly more expensive than Slabbing (No.5 below)	Significant reduction in Excavator risk and all but eliminate HDD/Bored crossing risk. Frequency decrease of $9.29x10^{-5}$ to $4.18x10^{-9}$	No action
4	Modification of Land Use (to separate the people from the pipeline)	Not possible as economic benefit and societal benefit significantly outweigh the risk to the population and the pipelines	Not practical	N/A	Not Justified	N/A	No action
5	Install protective slabbing and marker tape over pipeline. Re-coat CTE coating	Effective reduction in likelihood as per LOPA assessment	Practical	1750m of DN450 less the existing 218m of slabbing + 430m of DN250 pipeline to be protected. **TOTAL - Slabbing, Marker Tape and Re-coating 1952m.** Prefab concrete slabs with recoating and marker tape ~($10,000/m) ~$19.5M. Not including road restoration or traffic management costs	Justified for excavator and auger risk	Frequency decrease of $9.3x10^{-5}$ to $1.4x10^{-6}$	Install protective slabbing with marker tape where the pipelines ML are over the Arden Plan. Recoating required as existing coating is fragile and slabbing disrupts future access to pipeline.
6	Liaison activities targeting, including telecommunication , large developers, excavation companies, and landholders likely to install power poles in the area.	Partially effective in ensuring notification is undertaken.	Practical	Nominal within existing budgets	Already part of the current PIMP for the area.	Nominal	Opportunity to re-engage with third parties as the Arden Precinct proceeds
7	Ensure pipeline signage is in compliance with AS/NZS2885.1	Signage already compliant with AS2885 as Location Class does not change	Practical	Nominal within existing budgets	Signage already in place	Nominal	Opportunity to ensure signage is not destroyed during works and remains properly and regularly visible as required under AS2885.1

5. SMS TREATMENT OF AUGER THREAT (ID7)

5.1 Threat Scenario

The Arden SMS review found an ALARP assessment was required which is related to the auger threats (ID7) listed in the Table below.

Table 13 Original SMS Assessment for Augers (Threat ID7).

Threat ID	Location Classification	Description	Deemed Credible?	Failure Assessment	Risk Assessment Result L – Likelihood R – Risk C -Consequence
7	T2/CIC/I	**Augering of Piles for streetlight pole footings or fences** Auger impacts pipeline causing a hole in the pipe (~50mm) which would require replacement of a section. Potential loss of supply and serious injury to auger operator if gas ignited (5-10% chance for a large gas leak)	Yes	Consequence - Major as potential work crew or an onlooker could be seriously injured or killed (Supply consequence considered Severe not Major); Likelihood - Remote as relatively frequent installation or replacement of lighting in the footpaths where the pipelines resides when not in the middle of the road. Use of an auger is more likely than the requirement for excavation over the life of the pipelines	L: Remote C: Major R: Intermediate

5.2 Threat Description

The threat under consideration is unauthorised augering on top of the pipeline to install a power pole or similar activity causing the pipeline to be punctured by the pilot drill on the auger. The resulting leak could ignite causing 1-2 fatalities of those undertaking excavation and possibly the public given the built-up area.

Whilst most of the pipelines under review are "in the road" there are sections in Dryburgh street which run in the footpath and given the current street scape, is likely to be redeveloped as part of the Arden Plan so this threat was considered credible by the SMS Workshop.

5.3 Event Consequence

The SMS workshop deemed the threats would result in pipeline penetration causing a 50mm hole with ignition leading to a risk assessment of **Major** in the event of 1-2 fatalities to people undertaking the activities. Supply consequence considered Severe not Major.

5.4 Event Likelihood

The SMS Workshop concluded there is a **Remote** likelihood of failure and thus an **Intermediate** risk to People from this threat. With respect to Supply a **Low** risk of an affect upon the supply was considered arising from this threat.

The controls currently in place designed to mitigate the Auger threat are listed in the table below.

Table 14 Current Controls - Augers.

Control Measure	Frequency	Effectiveness	Weaknesses
Wall thickness	24/7	Partially effective with augers as penetration by the auger "bit" may occur before operator is aware.	Augers can penetrate the pipeline.
Depth of Cover (minimum of 1200mm)	24/7	Only effective if excavation is shallower than pipeline depth, this may not always be the case.	Not effective for installation of power poles or similar with a large auger.
Protective Slabbing	Generally effective 24/7 where it is installed	Mostly effective for these threats as operators will recognise that they have struck something and investigate.	Slabbing only installed at some road crossing points, (estimated length 218m of slabbing currently). .
DBYD	24/7	Effective for utility companies, council services, and developers.	DBYD request information may not pinpoint exact location. Dependent upon use.
Marker Posts / Right of Way Signs	24/7	Partially effective.	Relies on line of sight being maintained and awareness of machinery operator. Signage clutter in a built-up area makes signage less obvious and somewhat less effective
Liaison Activities	As per procedures	Some contact with utility companies and landholders. Awareness programs with local councils. Partially effective.	Could be more effective with targeted programs.
Inspection of works near pipeline	On site during known development	Effective if known development	Development must be known
Permit Issuing Officer	On site during known development	Effective if known development	Development must be known
ROW/Easement Patrol	Weekday patrol	Partially effective for this threat.	Not fully effective as activities can occur at any time when a patrol person is not present.

5.5 LOPA Assessment - Auger

The ALARP workshop reviewed the draft auger LOPA and found that with existing mitigations, the likelihood of a **Major** event resulting in 1-2 fatalities was **Unlikely** leading to a **High** risk requiring additional mitigations to lower the risk to at least Intermediate.

Auger Threat ID7 LOPA found the likelihood of failure was Unlikely at 7.43×10^{-3} events per 1000km per year with existing mitigations.

An additional LOPA calc was undertaken to assess the effectiveness of additional protective slabbing (such as concrete) over the pipelines which found that the likelihood of failure was lowered to 7.43×10^{-5} being **Remote** thus lowering the risk to **Intermediate**.

A Layers of Protection Analysis (LOPA) for the Auger Threat is included in Appendix B.

5.6 ALARP Assessment - Augers

The same additional mitigations referenced in Section 3.6 above for excavators also applies to augers. The use of protective slabbing (such as concrete) over the pipelines will significantly lower the likelihood of failure and achieve ALARP for this threat in the Arden area.

6. SMS TREATMENT OF HDD OR BORED CROSSING THREATS (ID10 & ID18)

6.1 Threat Scenario

The Arden SMS Workshop found that the threat of an HDD or Bored crossing by a third party with respect to utility/sewer installation was considered credible and determined that an ALARP assessment was required relating to both threats as listed in the table below.

Table 15 Original SMS Assessment for HDD & Bored Crossings (Threat ID10 & ID18).

Threat ID	Location Classification	Description	Deemed Credible?	Failure Assessment	Risk Assessment Result L – Likelihood R – Risk C -Consequence
10	T2/CIC/I	**Use of HDD to install Utilities across pipeline easement Pipe Damage resulting in a hole causing loss of containment. Hole is less than critical defect length or max credible hole size (2/3rds CDL is 190mm, resulting ML ~175m)**	Yes	Consequence - Catastrophic as potential work crew and multiple onlookers could be killed due to ML of ~175m) (Supply consequence considered Major); Likelihood - Hypothetical as would only occur under extraordinary circumstances	L: Hypothetical C: Catastrophic R: Intermediate
18	T2/CIC/I	**Use of Bored or Jacked crossing to install Utilities under pipeline easement (e.g. Sewer pipe) Damage to coating, or gouge or a hole or rupture of the pipeline requiring dig up and repair and significant loss of supply.**	Yes	Consequence - Catastrophic as potential work crew and multiple onlookers could be killed due to ML of ~175m) (Supply consequence considered Major); Likelihood - Hypothetical as would only occur under extraordinary circumstances	L: Hypothetical C: Catastrophic R: Intermediate

6.2 Threat Description

The threat under consideration is unauthorised Boring or HDD under the pipelines causing the pipeline to be punctured with a sizeable hole. The pipelines themselves cannot rupture but given the power of the equipment in question a significant hole in the pipeline is a possibility. The resulting loss of containment could ignite causing multiple fatalities of those undertaking excavation and possibly the public given the built-up Arden area.

6.3 Event Consequence

The SMS workshop deemed the threats would result in pipeline penetration causing a hole with ignition resulting in multiple fatalities to people undertaking the activities and the public leading to a risk consequence of **Catastrophic**. Whilst a hole of any size could occur the workshop used the CDL of 190mm as a worst case resulting in a ML of up to 170m in the event of ignition. From a Supply perspective the consequence was considered a **Major** risk given there would be significant societal impact due to a short-term loss of supply.

6.4 Event Likelihood

The SMS Workshop concluded there is a **Hypothetical** likelihood of multiple fatalities and thus an **Intermediate** risk to People from this threat.

Threats raised from SMS Workshop

The ALARP workshop found the likelihood of an event resulting in multiple fatalities was indeed **Hypothetical** based on the calculated Likelihood in the LOPA assessment assuming existing controls for both HDD and Bored Crossings.

The controls currently in place designed to mitigate risk and their effectiveness and weaknesses are listed in the table below.

Table 16 Current Controls – HDD & Bored Crossings.

Control Measure	Frequency	Effectiveness	Weaknesses
Wall thickness	24/7	Partially effective with HDD and Bored crossings as penetration may not occur before operator is aware.	Large equipment may penetrate the pipeline.
Depth of Cover (minimum of 1200mm)	24/7	HDD and Bored crossings would typically go below the underside of the pipeline (>1.65m deep).	Not effective for shallow installations.
Existing top Protective Slabbing (in Road Reserves)	Top slabbing not effective	None	Provided no protection to HDD or Bored Crossings.
DBYD	24/7	Effective for utility companies, council services, and developers.	DBYD request information may not pinpoint exact location. Dependent upon use.
Marker Posts / Right of Way Signs	24/7	Partially effective.	Relies on line of sight being maintained and awareness of machinery operator. Signage clutter in a built-up area makes signage less obvious and somewhat less effective
Liaison Activities	As per procedures	Some contact with utility companies and landholders. Awareness programs with local councils. Partially effective.	Currently some liaison is undertaken but could be more effective with targeted programs.
Inspection of works near pipeline	On site during known development	Effective if known development	Development must be known
Permit Issuing Officer	On site during known development	Effective if known development	Development must be known
ROW/Easement Patrol	Weekday patrol	Partially effective for this threat. Can identify long term projects only. Takes significant time to set up and is more likely to be spotted by patrolling	Not fully effective as activities can occur at any time.

6.5 LOPA Assessment – HDD & Bored Crossing

The ALARP workshop reviewed the draft HDD & Bored LOPA's and found that with existing mitigations, the likelihood of a **Catastrophic** event resulting in multiple fatalities was **Hypothetical** leading to an **Intermediate** risk.

HDD Threat ID10 LOPA found the likelihood of failure was Hypothetical at $6x10^{-6}$ events per 1000km per year with existing mitigations.

Bored Crossing Threat ID18 LOPA found the likelihood of failure was Hypothetical at $3.46x10^{-7}$ events per 1000km per year with existing mitigations.

There was significant discussion with respect to frequency of HDD and Bored Crossings in the area. It was agreed that HDD could be expected once every 10 years in the area. Regarding bored crossings the council representative suggested that the use of Bored Crossings is increasing as the preferred form of utility installation and anticipated that there could be a bored crossing every 2 years.

A Layers of Protection Analysis (LOPA) for the HDD and Bored Crossing Threats are included in Appendix C & D.

6.6 ALARP Assessment – HDD & Bored Crossings

From the LOPA assessment both the HDD and Bored Crossings threat meet the Hypothetical failure likelihood tolerance level defined in AS2885.6 of less than $1x10^{-5}$ events per 1000km per year.

The ALARP Workshop considered the use of Protective Side Slabbing with embedded 20mm thick steel plate installed on either side of the pipeline to provide an effective barrier to HDD or Bored penetration. This is a design APA has used in specific locations where a new road is crossing an existing pipeline in an area known for possible future development and or when the road crossing is at an acute angle to the pipeline.

This additional mitigation was considered fully effective for these threats as it would be almost impossible to penetrate the slab. Equipment operators would recognise that they have struck something and investigate. It is also a major exercise to remove an engineered slab that is already installed. It should be noted that this solution it is costly and a major exercise to install such slabbing, in addition the soil next to the pipeline would be disturbed and as such the brittle CTE pipeline coating would need to be replaced.

Unless the entire pipeline is protected it would also be difficult to identify where exactly side slabbing would be best located. It would most likely be installed at road crossings but as the entire pipeline is in the road, an HDD in particular, could be undertaken anywhere within or adjacent to the Arden plan.

It was noted that setting up for an HDD or Bored Crossing will likely be undertaken by an experienced contractor familiar with DBYD requirements. The act of setting up is a major exercise (particularly boring) and as such patrolling is typically a more effective mitigation for these activities. As such the Risk Reduction Factors used for DBYD and Patrolling were increased in the LOPA assessments to reflect this fact.

The following table of additional controls have been considered for these particular Threats in addition to those already identified for excavators in Section 3.6 Table 7.

On its own, side slabbing is not considered justified as the existing risk is already below the Hypothetical level. Installing side slabbing along the full 2.17km of transmission pipeline effected by the Arden plan would be ~$8.5M plus re-coating. This costing is based on advice from APA for side slabbing only at ~$4,000/m, if recoating is required this cost would likely more than double and does not include the cost of road resurfacing and traffic management.

It is considered that the **existing mitigations achieve ALARP** and the cost of full side slabbing would be grossly disproportionate to the benefit achieved to lower the likelihood of failure below its current level.

Table 17 Additional Controls Cost Summary – HDD & Bored Crossings.

No	Mitigation	Effectiveness	Practical	Cost	ALARP Considerations	Level of Risk Reduction	Action
1	Install Side Slabbing to protect from HDD/Bored Crossing (concrete slabs with embedded 20mm steel plate installed vertically either side of the pipeline at road crossings	Effective	Practical	For a 50m crossing at $4k per m (slabbing both sides) a crossing costs $200k, assuming 10 crossings leads to a total cost of $2M plus costs of road resurfacing and traffic management. Recoating of the pipeline in these areas would also need to be added to the total cost.	Marginal for HDD & Bored Crossing subject to knowing where HDD may be required in the future	Frequency improvement for HDD risk is $6.x10^{-6}$ to $3.x10^{-7}$ for Bored risk is $6.9.x10^{-6}$ to $3.5.x10^{-7}$ As existing mitigations achieve Hypothetical likelihood, additional expenditure is grossly disproportionate to the additional benefit achieved	APA and Council to consider if localised side slabbing in known risk areas is justified as part of the top slabbing mitigation.

7. SMS TREATMENT OF NETWORK PIPELINE THREAT (ID43)

7.1 Threat Scenario

Whilst the local gas network in the area is not covered by AS2885.6 the Arden SMS review found an ALARP assessment was required which is related to the threat of any excavation over the network pipelines in the Arden Plan listed in the table below.

Table 18 Original SMS Assessment for Network Pipelines (Threat ID43)

Threat ID	Location Classification	Description	Deemed Credible?	Failure Assessment	Risk Assessment Result L – Likelihood R – Risk C -Consequence
43	N/A	**Network Gas Pipelines within the Development area PE and Cast-Iron network pipelines are fragile to any significant impact causing a loss of containment, loss of supply to the immediate area and a potential source for an explosive environment leading to injury. The Cast Iron pipe is particularly difficult to weld and repair**	Yes	Likelihood is Unlikely as pipelines are shallow, low strength and prone to failure if impacted, general excavation across development is a regular occurrence. Severity for Supply is Severe because of a loss of containment may affect more than 5000 customers. Safety - There is no expectation that there would be any injuries or fatalities as a result of a loss of containment	L: Unlikely C: Severe R: Intermediate

It is recognised in the network pipeline industry, and the Australian Standard for gas distribution networks that external interference by third parties is the greatest risk to the containment of product in the pipeline and as such to the safety of stakeholders and the public, supply, and the environment. As such AS/NZS4645.1 requires various controls to be in place to prevent loss of product caused by external interference.

During the SMS Workshop the threat of excavation impact by a third party was considered with respect to utility installation. The activity was found to be credible in all areas within the Arden plan.

7.2 Threat Description

The threat under consideration is unauthorised excavation on top of the pipeline to install a third party utility or similar activity causing the pipeline to be punctured. Due to the relatively low operating pressure of the network the resulting leak is unlikely to ignite or lead to any injury but it could disrupt a significant number of customers, APA advised that it could be more than 5000 customers.

7.3 Event Consequence

The SMS workshop deemed the threats would result in pipeline penetration causing a hole leading to a risk consequence of **Severe** with respect to supply.

7.4 Event Likelihood

The SMS Workshop concluded there is an **Unlikely** likelihood of failure and thus an **Intermediate** risk to supply from this threat.

Threats raised from SMS Workshop

The controls currently in place designed to mitigate risk and their effectiveness and weaknesses are listed in the table below.

Table 19 Current Controls – Network Pipelines.

Control Measure	Frequency	Effectiveness	Weaknesses
Wall thickness	24/7	Partially effective with against excavators. The pipe network is either plastic or cast iron which both are not nearly as strong as a properly design transmission pipeline.	any type of equipment could hole these pipes.
Depth of Cover (minimum of 1200mm)	24/7	Only effective if excavation is more shallow than 600mm, this is unlikely to be the case most of the time.	Not effective for any significant excavation.
ROW/Easement Patrol	Adhoc inspection only	Intermittent effectiveness	Not partially effective for this threat.
DBYD	24/7	Effective for utility companies, council services, and developers.	DBYD request information may not pinpoint exact location. Dependent upon use.
Marker Posts / Right of Way Signs	24/7	Partially effective.	Relies on signs being maintained and awareness of machinery operator
Liaison Activities	As per procedures	Some contact with utility companies and landholders. Awareness programs with local councils. Partially effective.	Currently some liaison is undertaken but could be more effective with targeted programs.
Inspection of works near pipeline	On site during known development	Effective if known development	Development must be known
Permit Issuing Officer	On site during known development	Effective if known development	Development must be known

7.5 LOPA Assessment – Network Pipelines

The ALARP workshop did not get an opportunity to review the LOPA for this Threat during the workshop however the attendees were asked to review, and pass comment post the workshop. The LOPA found that assuming there is 10km of network piping in the Arden area that there is an **Occasional** (rather than Unlikely) Likelihood for a **Severe** consequence with the existing mitigations. There were no specific comments or changes to the LOPA from the attendees thus confirming that the risk is **Intermediate**.

Threat ID43 LOPA found the likelihood of failure was Occasional at 3.15×10^{-1} events per 1000km per year with existing mitigations.

By considering plastic slabbing Threat ID43 LOPA found the likelihood of failure was lowered to **Unlikely** at 1.58×10^{-2} events per 1000km per year with plastic slabbing installed.

Both Occasional and Unlikely matched with a Severe consequence give an Intermediate risk under AS4645.1 Gas Distribution Network Standard.

A Layers of Protection Analysis (LOPA) for these existing controls at the locations of concern in this ALARP report is presented in Appendix E.

7.6 ALARP Assessment – Network Pipelines

The proposed installation of plastic slabbing over the top of up to 10km of network piping in the Arden area would be a major exercise, it is estimated that installed cost would be $1000-$2000/m giving an indicative total cost of $10-$20M. Given the risk impacts only on supply and not safety, it is considered that plastic slabbing is not justified for use.

The ALARP workshop attendees did not get an opportunity to review the LOPA for this Threat during the ALARP workshop however the attendees were asked to review and pass comment post the workshop. There were no specific comments or changes from the attendees to the LOPA, as such the **Occasional** likelihood with existing mitigations was accepted thus confirming that the risk is **Intermediate** and considered **ALARP**.

8. CONCLUSIONS

External Interference activities pose a potential risk to the transmission pipelines in and adjacent to the Arden structure plan area. The Safety Management Study workshop identified six (6) threats to be of **Intermediate** risk and requiring an ALARP assessment.

To comply with AS/NZS2885.6 and APA's policy on demonstration of ALARP, further analysis of the risk has been performed.

The ALARP analysis identified a range of options for the further mitigation of the threats. Most of these options are unjustified as the costs are grossly disproportionate to the level of risk reduction.

The following mitigations were identified as justified and did offer benefits in lowering the likelihood of failure due to the threats. These were:

1. For the locations where the pipeline currently does not have top slabbing, new engineered protective slabbing such as concrete (fabricated to APA design requirements) and pipeline marker tape will be installed over the pipeline(s) to protect from excavator and auger impact. Re-coating of the pipeline(s) will also be required It is anticipated that there is about 1950m of additional protective slabbing required, representing an indicative cost of approx. $19,500,000. These costs do not include road resurfacing, or traffic management. (Note:- The costings included in this ALARP Report are indicative only and it is strongly recommended that Council engage APA Group directly to confirm budget pricing for the proposed mitigations to provide more certainty.
2. Liaison activities targeting telecommunication & utility companies, large developers, excavation companies, and landholders in areas shall continue to be undertaken. This activity should be completed as part of APA's regular pipeline management plan.
3. Ensure pipeline signage is maintained in compliance with AS/NZS2885.6 as the Arden plan is developed. Pipeline signage should be maintained in good condition and to APA and AS/NZS2885.6 standards. This activity should be completed as part of APA's regular pipeline management plan.

Used together, these mitigations will reduce the frequency significantly for those areas at risk from the excavation and auger threats in particular. With these measure in place the frequency of the excavation and auger threats (Threat ID2, 7 & 15) are reduced to ALARP and in compliance with AS/NZS2885.6.

Threat ID10 (HDD), Threat ID18 (Bored Crossing) and Threat ID43 (Excavation damage to Network pipelines) were assessed as ALARP with no further mitigations.

9. RECOMENDATIONS

The following actions are recommended to reduce the threats identified at the SMS workshop to **ALARP**:

1. For the locations where the pipeline currently does not have top slabbing(~1950m), new engineered protective slabbing such as concrete(fabricated to APA design requirements) and pipeline marker tape will be installed over the pipeline(s) to protect from excavator and auger impact. Re-coating of the pipeline(s) will also be required.
2. APA to confirm exactly what length of transmission pipeline must be slabbed.
3. Council to consider engaging with APA directly to confirm exactly how much slabbing and coating treatment is required and at what indicative cost to provide more certainty.
4. All mitigations recommended in this ALARP Report should be implemented before any Arden Plan works are undertaken unless otherwise agreed with APA Group.

Appendix A LOPA FOR EXCAVATORS (ID2 &15)

Appendix B LOPA FOR AUGER (ID7)

Appendix C LOPA FOR HDD (ID10)

Appendix D LOPA FOR BORED CROSSING (ID18)

Appendix E LOPA FOR NETWORK PIPELINES (ID43)