PHILOSOPHY

PIPELINES

Physical Barrier Selection and Design for Existing Pipelines

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1. Introduction

1.1 Purpose

This philosophy defines APA's design approach and minimum requirements for physical barrier protection of pipelines against mechanical damage from excavation and drilling / augering equipment.

It provides guidance to designers on appropriate barrier selection where protection is required to be retrospectively applied to existing pipelines, for example where a change of land use occurs, or for risk mitigation in high consequence areas.

1.2 Scope

This philosophy has been developed for the purpose of physical barrier selection for the mitigation of 3rd party interference risks to APA pipelines. It is intended for use by APA engineering staff.

This document is not specifically intended for use in the design of new pipelines, where other measures such as increased wall thickness and depth of cover are available. Its primary purpose is to guide the selection of barriers for retrofitting to existing pipelines when required due to land use change.

1.3 Terms & Abbreviations

The specific terms and abbreviations used in this document are listed in Table 1 below.

Table 1 Terms and Abbreviations

Item	Definition
ALARP	As low as reasonably practicable
APA	APA Group
HCA	High consequence area
HDD	Horizontal directional drill
HDPE	High density polyethylene
SMS	Safety Management Study

1.4 References

This Philosophy refers to the documents listed in Table 2.

Table 2 Referenced Documents

Referenced Document	
APA Documents	
320-RP-AM-0078	RBP ALARP Report
36870-RP-C-0001	HDPE Slab Field Trials Report
TBA	Material Lab testing report
320-PL-HEL-0001	Land Management Plan
530-DWG-L-1001, 1002, 1003	Utility Crossing Standard Drawings
Australian Standards	
AS 2885.1-2012	Pipelines – gas and liquid petroleum, Part 1: Design and construction
AS 2885.3-2012	Pipelines – gas and liquid petroleum, Part 3: Operation and maintenance

1.5 Contributors

This Philosophy has been developed with input from the following groups:

- Infrastructure Strategy and Engineering – Mark Fothergill, Craig Bonar, Francis Carroll, Noel Laidlaw
- Infrastructure Development – Construction – Evan White, Raj Kallath, Sudhir Gopisetty

Its initial development was as a result of an ALARP assessment on the Roma Brisbane Pipeline however it is intended to be useful for other pipelines and may be updated in future by other groups.

2. Background

2.1 AS 2885 Requirements

AS 2885 is the governing suite of standards for hydrocarbon pipelines in Australia. It requires protection of pipelines against 3rd party interference / mechanical damage from earthmoving equipment.

For new pipelines, AS 2885.1 specifies depth of cover and penetration resistance requirements based on location class. In HCAs, 2 physical protection measures are required. Because the SMS is part of the design process, a broad range of protection measures are available, such as increased pipeline wall thickness (by specifying heavy wall pipe), increased depth of cover, or re-routing of the pipeline to avoid sensitive areas, as well as barrier protection such as concrete slabs.

2.2 Application to Existing Pipelines

For existing pipelines, where there is a land use change or when the pipeline was constructed prior to AS 2885.1-2007, pipeline segments in HCAs are required to be assessed for compliance with the no rupture and energy release rate requirements and an ALARP analysis carried out to identify appropriate risk mitigation. This is generally triggered by a SMS review which may be the 5-yearly full SMS review or may be a location-specific SMS review for a land use change or encroachment.

For existing pipelines, some of the mitigation measures available for new pipelines are impractical, such as changing the land use to remove the HCA in a metropolitan environment, or fencing/barricading the pipeline corridor in a road reserve. Others are very costly, such as replacing pipe with new pipe throughout HCAs. In many cases, retrofitting of barrier protection may be considered as part of an ALARP analysis and may be a preferred option.

This philosophy is intended to apply to the above scenario where protective barriers are being considered for retrofitting to an existing pipeline.

Other cases for retrofitting of barrier protection may include the introduction of new threats to the pipeline, e.g. roads being constructed or upgraded, or other services or utilities crossing the pipeline such as water or gas pipelines, or power or communications cables.

2.3 Standard Barrier Applications

The standard barrier slab protection described in AS 2885.1 comprises concrete slabs extending 600 mm beyond pipeline edges. Limited detail is provided in AS 2885.1 on requirements or on alternatives to concrete slabbing, however alternatives are permitted if effectiveness is demonstrated by testing. When constructing a new pipeline, such slabs are usually installed during construction at the required locations. Their incremental cost is relatively low, due to the pipeline trench already being excavated and backfilled for pipeline construction purposes.

APA has existing standards for concrete barrier slab construction and these are typically 100mm thick if reinforced, or 150 mm thick if unreinforced.

For retrofitting in built up areas (esp road reserve) these large concrete slabs may not always be acceptable to road authorities and other utilities. Local authorities may allot space within the road reserve to various utilities (water, telecommunications, electricity, gas, etc.) and placement of large concrete slabs overlapping the other utilities' allotted space may not be acceptable to the other utilities.

An example is Brisbane City Council, which allocates utility space as shown in standard drawings such as BSD-1013 (available on BCC internet site).

When applied in significant scale, concrete slabs can be time-consuming and costly to install, and may cause relatively prolonged disruption to the area during excavation, placement and reinstatement.

2.4 Alternative Barrier Types

This philosophy provides details of alternative protection barriers and recommendations for selection of barrier type based on pipeline and land use characteristics.

2.5 Other Factors

When assessing the need for barrier protection a range of pipeline attributes require consideration. These include:

- Wall thickness and grade – this is incorporated in the penetration resistance calculations
- Measurement length and radiation contours – these define the location class and consequences of a failure
- Energy release rates from rupture or leak hole
- Depth of cover – this may count as a physical barrier if the pipeline is deeper than the credible excavation depth for a particular threat.
- Presence of casings, concrete encasement, etc. Typically where pipelines have existing steel or concrete casings the likelihood of 3rd party interference causing significant damage to the pipeline is very low.

2.6 Procedural Measures

SMSs also require procedural protection measures against external interference. The effectiveness of these measures should also be taken into account in ALARP studies and assessment of need for barrier protection.

Typical procedural measures considered include marker signs, patrols, landholder liaison, 3rd party liaison, corridor agreements and similar.

In general for existing pipelines, the cost and impact of upgrading procedural measures is small and ALARP studies often require these. This philosophy provides limited guidance on additional procedural measures in the form of pavement/kerb markers for use in urban metropolitan settings.

3. Threats to Pipelines

Typical threats that are considered and evaluated in SMS and ALARP studies are described below. Guidance is provided on evaluation of these threats for SMS and ALARP analysis and mitigation design.

The nature, likelihood and size / severity of threats is assessed through the SMS process for individual pipelines. This document provides only general guidance.

3.1 Excavators

- Excavators are commonly used for trenching or bell hole excavations for other utility installation or maintenance (water, sewer, communications, gas, electricity etc). The maximum credible excavator size should be assessed for each pipeline and location, preferably on the basis of actual sighting records during pipeline patrols. Excavators can cause coating damage, dents/gouges, puncture and leak, or rupture.
- Designers need to assess machine sizes (operating weight), bucket and tooth types. Single point penetration teeth are generally uncommon, except in particular ground conditions.
- The size of credible excavators is limited by transport accessibility (large excavators require large semi-trailer floats which are impractical in suburban streets) and machine accessibility (e.g. overhead power lines)
- It may be that large excavators are only likely where major roadworks or heavy earthworks, such as civil works for a new subdivision or estate, are carried out. Such activities are generally well planned and notified via local councils. If all else fails, pipeline patrols are likely to identify preparatory works, signage and the like prior to major earthworks commencing.
- Single point of tiger tooth scenario – There is some confusion about the Appendix M calculations of AS 2885.1-2012 and this is expected to be clarified in the next revision of AS 2885.1. This philosophy adopts the position that:
  - The general rule is that the maximum tooth length is to be compared with the pipeline's critical defect length to determine its failure mode (leak or rupture) and its 'No Rupture' compliance
  - In the special case that only one of the two points of a tiger tooth can penetrate the pipe wall, consideration may be given to using a lesser maximum defect length for No Rupture calculation.

3.2 Vertical Augers

- Vertical augers are commonly used to bore holes for power poles, sign posts, fence posts and the like.
- This threat is most prevalent in areas with existing power lines, illuminated signs, etc. where poles occasionally require replacement.
- The depth of augered holes for power poles may be 2 to 4 metres.

- If an auger were to contact a steel pipeline, it is likely to meet with significant resistance to drilling, causing noise and vibration which would alert most operators.
- If an auger operator were to persist with drilling in this scenario, it is generally considered possible for the auger pilot bit to penetrate the pipe wall causing a leak, with a hole length up to the diameter of the pilot.
- Full-bore rupture is considered unlikely, as the noise and potential other consequences of a leak from the pilot bit would certainly stop the auger operator from continuing to drill and enlarging the hole.
-

3.3 HDD

- Horizontal directional drills, tunnelling or similar, are used for trenchless cable or pipe installations typically beneath roads or other obstacles. Generally HDD contractors are well aware of the risks of buried asset strikes, due ot the nature of HDD construction compared to excavation type works. HDD contractors are generally likely to follow standard procedures including the use of DBYD.
- HDD equipment for use in non-rock soil materials does not normally have the capability to penetrate steel pipe. Rock drilling heads exist but are normally only used in rock areas; such drilling heads are not effective in soft material as they sink and lose directional control. When such a drill head enters a pipeline trench from adjacent rock the operator would likely stop and investigate.

We should reconsider saying the operator will likely stop. They may not unless the drill profile is not maintained over a number of drill rod lengths. Potentially this comment could be more around the soft material not restraining the drill head allowing it to deflect off the pipeline.

Further commentary on HDD threats is provided in Appendix 1.

3.4 Other Threats

Various other threats may exist in pipeline locations.

Heavy bulldozers and deep rippers are an aggressive threat, generally considered capable of causing a full-bore rupture, but are not common in built up areas.

Specialised heavy equipment such as trenchers may exist in some areas but again are uncommon in built-up urban areas.

The SMS process should identify and assess all credible threats to a pipeline and these should be considered on a case by case basis.

4. Land Use Categorisation

4.1 General

The selection of barrier protection type needs to consider attributes of the land use in the pipeline corridor and likely threats to the pipeline (types of excavation and drilling machinery) that may exist in each land use category.

Typical categorisation of the land use types is set out below, along with indicated threats that are considered credible. Individual SMS or ALARP studies may adopt different categorisation if appropriate.

4.2 Land Use Categories

4.2.1 Parkland

This category refers to parkland or green space within built-up areas, typically classified as 'reserve'. There may be existing, or potential future other utilities sharing the corridor; street and footpath lighting, etc. may also be present. Typical threats may be excavators and augers. HDD rigs are relatively unlikely since there is good access for conventional trenching, but may still exist e.g. to cross watercourses. Less other utility activity than road reserves. Refer to Figure 1.

Figure 1 Parkland category

Green area = parkland or reserve exposed to trenching or pole augering

4.2.2 Road - Parallel

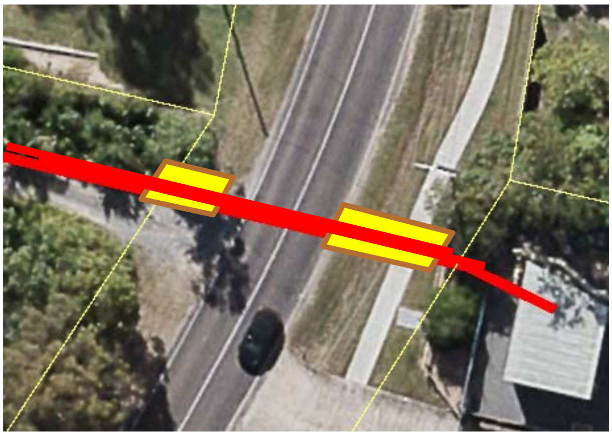
The category includes road reserve where the pipeline is parallel to the road. The pipeline may be under a carriageway or in nature strip. Pipelines in this category may be somewhat exposed to other utility construction or maintenance in the nature strip, which would likely be excavating from above or along the road direction. Third parties are less likely to impact pipeline when it is underneath the road carriageway, due to the more onerous requirements associated with road closure and excavation within the pavement area. This category is generally unlikely to have significant utility construction across road and pipeline if the area is built up; however small property service connections (gas, telecoms, water) may cross the pipeline either by trenching or HDD (small-scale). Where power poles are present, augers may be expected for pole replacement activities. Refer to Figure 2.

Figure 2 Road - parallel category

4.2.3 Road - Crossing

This category includes pipelines within road reserve land but crossing the road either at 90° or at an angle. Pipelines in this category are exposed to other utilities trenching along the road in the nature strip / footpath area, as well as power pole, street light and sign post hole augering. This category is not highly exposed to HDD unless at an intersection. Refer to Figure 3.

Figure 3 Road - crossing category

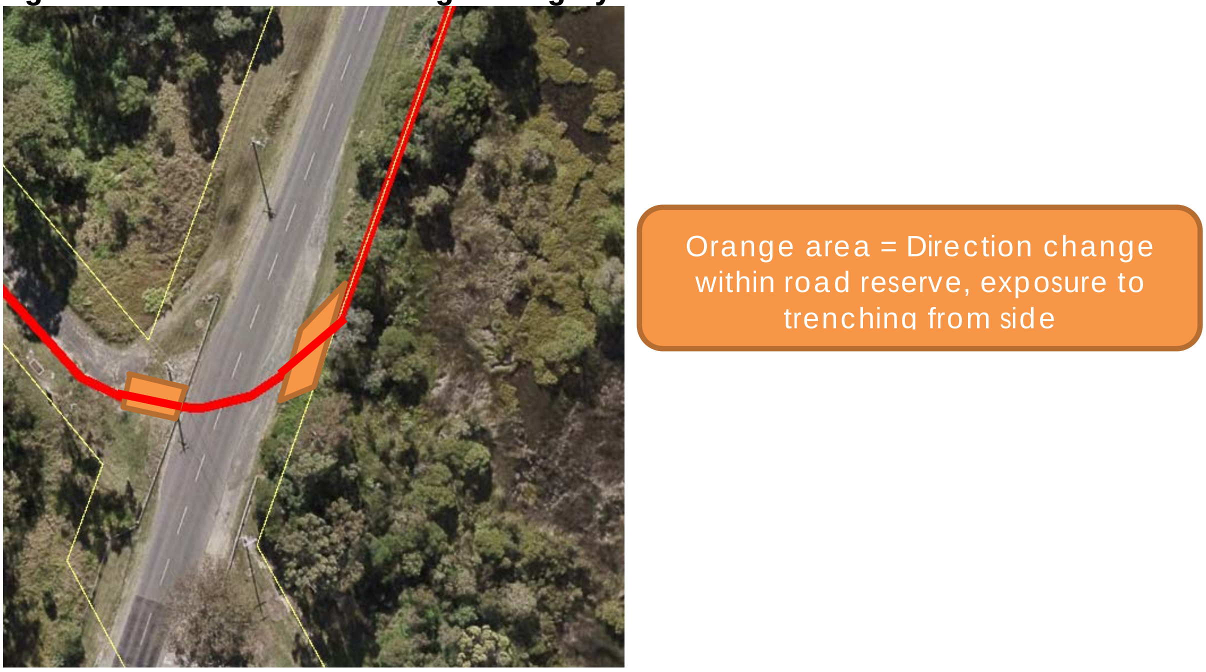


4.2.4 Road – Direction Change

Road reserve – dog leg, branch, acute angle, or other 'special' construction. Most severe exposure due to change of direction / potentially unclear location of pipeline. Exposed to utility trenching along road, power pole, street light and sign post hole augering. Note that if the direction change is underneath a paved road surface, the exposure is lessened. Augering into a paved road carriageway for pole installation is not credible and excavation is more stringently controlled than in the nature strip.

Refer to Figure 4.

Figure 4 Road – direction change category

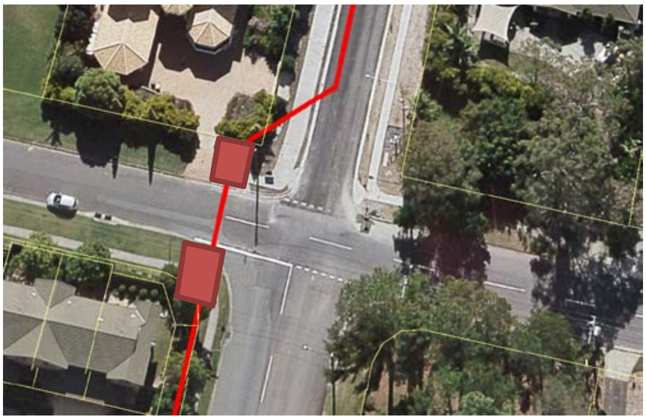


4.2.5 Road – Intersection Crossing

This category refers to pipelines crossing road intersections. In addition to potential utility and roadwork excavations and power pole or sign post augering, this category is considered to be particularly exposed to HDD threats. This is because other utilities such as electricity or communication cables often cross intersections by HDD.

Refer Figure 5.

Figure 5 Road – intersection crossing category



4.2.6 Private Property

Private property land within HCAs is considered in two categories:

- Rural or semi-rural – this land type can exist within a HCA if there are built-up areas within the measurement length.
- Suburban residential or industrial properties in a built-up area. This land type is unlikely to see large excavation or drilling activity unless significant redevelopment.

4.3 Existing Surface Treatments

The type of finished ground surface may vary within each of the land use categories. This refers to the finished surface of the ground above the pipeline.

Typical examples may include:

- Paved bitumen roadway (pipeline located under the road pavement)
- Concrete footpath in road reserve (pipeline may cross or run parallel)
- Paved driveway (where pipeline is in road verge parallel to road, driveways may cross above the pipeline)
- Concrete bikeway in open parkland (pipeline may cross or run parallel)
- Paved footpath/bike path in narrow reserve between house blocks

In some scenarios, concrete pathways and bitumen roads may be considered a protective barrier. Consideration should be given to the presence or absence of marker signs or embedded markers in the pavement surface, as well as the width and effective coverage of the pipeline by the pathway.

5. Barrier Options

5.1 Structural reinforced concrete bridging slabs

This type of slab is load bearing, and typically has compressible f deflection. It typically has strip f over the pipeline, forming an inv

1- Is it worth including stabilised sand as a barrier options for vehicle crossings? sometimes, if the load are marginally excessive, changing the soil type could be an option.
2- How about increasing DOC by building up?

This slab type is typically designe and construction. It is more than adequate to act as a penetration barrier, provided the slabbing extends beyond table drains where maintenance clearing may threaten the pipeline in future.

5.2 Concrete barrier slabs

Standard concrete barrier slabs are routinely used as discussed earlier in this document. They contain either basic mesh or no reinforcement as their purpose is to act as a barrier, not a structural load. They are effective against excavators and augers due to the mass and strength of the concrete slab preventing machinery from reaching the pipeline.

APA standard drawings exist for the installation of standard concrete slabs, reference 530-DWG-L-1001 and 1002. However, in metropolitan areas these can be difficult to obtain local authority approval due to their overlap of other utiltity allotted space in road reserves.

5.3 HDPE slabs

An alternative for pipeline protection against 3rd party interference is the use of solid HDPE slabs. The following sections discuss this material and its use.

5.3.1 Effectiveness

Field trials were carried out by APA in 2016. HDPE slabs were shown to be effective against excavators and small augers. Thicknesses from 20 to 45 mm were trialled, all of solid HDPE. In view of the field trial results, the 20 mm thickness is considered sufficient to prevent normal excavation from proceeding and is suitable to be accepted as a physical barrier. The auger trial resulted in penetration by the pilot bit but refusal when the main auger blade contacted the slab.

Refer to field trial report 36870-RP-C-0001 for further information on the trial method and results. [HOLD – further auger testing yet to be completed].

While the HDPE performed well in APA's trials, it is considered likely to be penetrated by large augers e.g. bored piling construction, or powerful drills e.g. geotechnical sampling. Further testing would be required to establish its performance against these unusual threats.

HDPE lacks the mass and raw strength of concrete slabs, but can be an effective barrier as excavators cannot dig through the 20 mm slabs. They effectively alert an excavator operator by feel and visual indication. They can be removed by a deliberate action, however this is also true of concrete slabs.

Add - As long as the HDPE mat has suitable mechanical properties (toughness and ductility) only the excavator bucket will penetrate the mat. As the full bucket has not penetrated the mat no more earth can be removed from the ground rendering the excavation process ineffective. A significant change to excavation method is required to continue removing earth.

When trenching from the side is considered, HDPE is likely to be slightly less effective than concrete, as HDPE can deflect/bend out of the way. The HDPE is still likely to visually alert the excavator operator. Due to the physical process of trench excavation the HDPE is still considered likely to alert the operator and prevent normal excavation from proceeding without a deliberate action by the excavator (Refer Appendix 2).

Overall APA's requirement is that the presence of the HDPE slab must be sufficient barrier to prevent normal excavation work from proceeding. This means it must take a significant period of time to remove or bypass the slab, such that an excavator operator would not be able to proceed without deliberate action. Based on the field trials conducted, this is true for the tested HDPE slabs provided the joints between slabs are intact and sufficiently strong.

5.3.2 Constructability

HDPE is faster and easier to install than concrete. Many HDPE products are able to be lifted by light machinery or even by hand; no formwork boxing, reinforcement, setting or curing time is required. The typical 20 mm slabs weigh approximately 50 kg each and can be manoeuvred into position by manual means.

Engineering design and specification is required for the manufacture and installation of HDPE slabs and a separate material and installation specification will be developed.

5.3.3 HDPE Slab Width and Installation Depth

The standard HDPE slab dimensions are nominally 1200 wide x 2400 long. Other sizes, such as 1200 wide x 3600 long can also be manufactured, giving extra width and length options. A further option is to rotate the standard slabs 90° to provide a 2400 mm wide protective barrier.

Based on APA's trials and the desktop study referenced in this philosophy, 1200 mm width is considered suitable where the threat is excavation or auger from above.

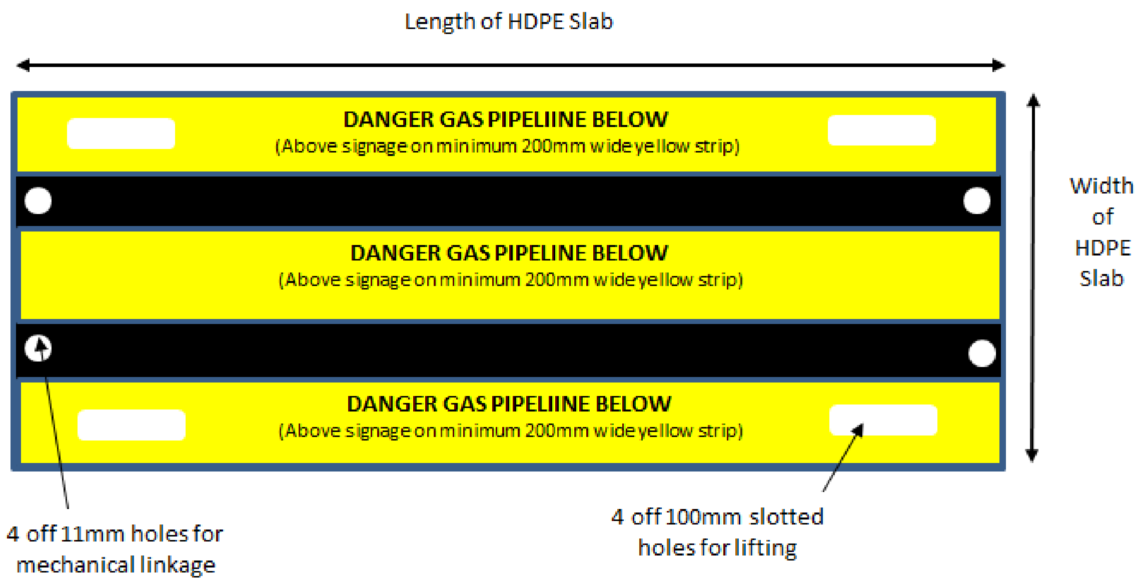
The desktop study component may not pass for pipeline OD >300mm with 1.2m wide slab. A comment on assessing slab widths for diameters greater than 300mm should be made.

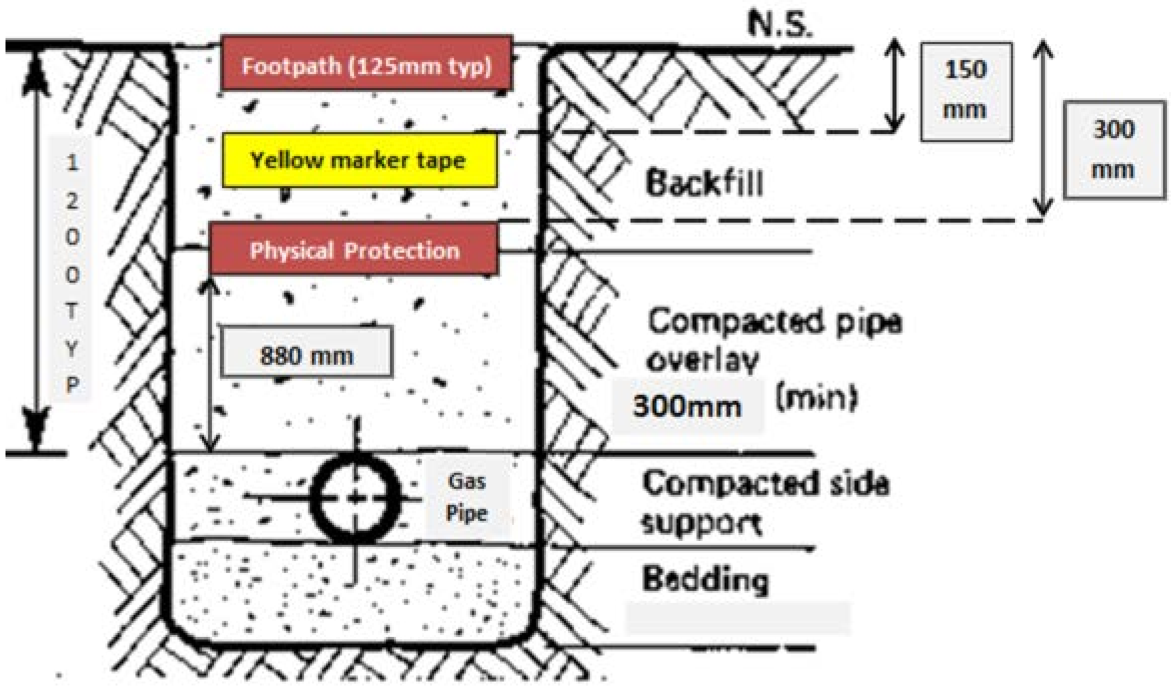
Where trenching may cross the pipeline, in all likely scenarios, 1200 mm slab at 300 mm cover is considered sufficient that the excavator would contact the slab prior to the pipeline. Refer Appendix 2.

In the unlikely scenario of commencing a branch excavation from a trench pre-dug trench adjacent to the pipeline and slab, and as deep as the pipeline, 1200 mm slabs may permit large excavator buckets to contact the pipeline before disturbing the slab in certain geometrical arrangements. Where this mode of attack is considered likely, 1800 or 2400 mm wide slabs are recommended.

Depth of installation is important for constructability and for effectiveness. Cover below surface is important to resist pull-out, due to the mass of soil above the slab. If connectors between slabs are sufficiently strong, 300 mm cover is considered satisfactory.

Other considerations include clearance above the pipeline to allow excavation for slab installation without onerous proving / sighting requirements.





Physical Protection Installation in High Consequence Areas

5.3.4 Joints between HDPE Slabs

Joints between adjacent slabs are important. Joiners between adjacent units are required as the resistance to pull-out by excavators is greatly increased by the extra length and weight of soil on top of the slabs.

Effective joints between slabs is important as the pull-out resistance is considered to be most significant in affecting the time and effort required to remove or bypass the slab.

Durability of joining systems needs to be considered and a design life established for the selected components.

5.4 Side wall slabs

In some circumstances, vertical concrete or HDPE slabs may be utilised to protect against HDD threats approaching from the side of the pipeline. However, these will significantly increase construction cost and complexity due to depth and size of excavation. Side barriers are recommended for use only where HDD threats are considered likely enough to warrant special protection.

5.5 Other

Users of this philosophy should always weigh up costs and risks of the barrier installation against other options as required by AS 2885.1 in the ALARP process.

6. Recommended Barrier Selection

6.1 General

This section sets out APA's recommended effective barrier protection for various categories of land use around the pipeline.

6.2 Barriers for Land Use Change or HCA Risk Mitigation

For land use change or HCA ALARP upgrade, suitable barrier types are identified in Table 3. This table is provided as a guide for barrier selection for retrospective application. In general, both HDPE and concrete slabs are acceptable and may be used.

The table correlates the threats and land use categories with the barrier types identified as effective against those interference threats. Structural bridging slabs are not included in the table as these are not required for land use change or HCA applications.

X = recommended

- = not required

not recommended- use only if required by SMS

X* = only if required by site-sp

Table 3 Barrier Selection for Land Use Change or HCA Risk Mitigation

Land Use Category	Barrier concrete slab or 2400 mm HDPE	Concrete foot/bike path or 1200 mm HDPE	Side walls
Parkland	-	X	-
Road – parallel	-	X	-
Road – crossing	X	-	-
Road – direction change	X	-	-
Road – intersection crossing	X	-	X*
Private property – acreage/rural	-	X*	-
private property – suburban	-	-	-

Notes on Table 3:

1. In all of the road categories, barriers should be located between the kerb and channel (carriageway edge) and the property boundary. Retrospective barrier installation is not recommended beneath paved road surfaces.

2. Users may select other arrangements. For example, if depth of cover exceeds the credible threat depth then barrier protection may not be justified.
3. Individual HCAs should be assessed in SMS and ALARP studies. For example, T2 and S location classes may be given an increased level of protection than T1 and I location classes.

6.3 Effect of Surface Treatments

The recommendations in Table 4 apply to the various surface treatments, when considering retrofitting barrier slab protection in high consequence areas.

Table 4 Effect of Surface Treatment

Land Use Category	Surface Treatment	Barrier (HDPE Slab) Recommended
Parkland – Open Space	Grass or unmade	Yes
	Concrete Bikeway (Effective Markers)	No
Road Reserve	Bitumen road carriageway	No
	Grass, gravel or dirt verge	Yes
	Concrete footpath	Yes*
	Driveway crossing	No

Surface treatments will need to be assessed for each slabbing project, e.g. the interface between HDPE slab extents and bitumen/concrete pavement extents.

Note * - slabbing beneath footpaths should be considered when there is a risk of 3rd party construction removing the footpath, but may not be required in all cases.

6.4 Barriers for Encroachments or Infrastructure Crossings

For encroachment or new crossing of existing pipeline, a different range of barriers are applicable. Guidelines are set out in Table 5.

Table 5 Barrier Selection for Encroachment or Infrastructure Crossing

Circumstance	Structural bridging slab	Barrier concrete slab	HDPE slab 2400 mm	HDPE slab 1200 mm	Side walls
New major road, highway or railway (pipeline not designed as a highway or railway crossing)	X	-	-	-	X*
New or upgraded local or rural road crossing	X*	X	-	-	-
Pipeline or cable crossing	-	X	X*	X	-

X = recommended

- = not required

X* = only if required by site-specific assessment

6.5 Path and Kerbside Markers – Procedural Measure

In addition to physical barriers, special embedded markers may be permanently applied to pavements, kerbs and road surfaces as a warning to excavators.

These should be considered in conjunction with physical barriers, for example at a bikeway or similar path crossing. Barrier slabs could be installed either side of the pathway, up to the path edge. Instead of demolishing and replacing the pathway to install a barrier slab beneath, credit may be given to the use of the pathway pavement itself as a barrier. Additional surface markers on the pavement may increase its effectiveness.

Such markers are typically of stainless steel construction and anchored into the concrete surface. For transmission pipelines the words ‘DANGER’ and ‘GAS PIPELINE’ are recommended to be engraved or stamped on the markers.

Sufficient markers should be installed to give any observer a clear indication of the location and direction of the pipeline. Conventional marker signs should also be located nearby including the appropriate AS 2885 content and telephone number to contact APA.

Appendix 1 – HDD Commentary

This Appendix provides commentary on HDD threats that may occur perpendicular to the pipeline with different drill heads based on soil conditions.

Hard Material

Hard Material in HDD terminology refers to ground conditions such as rock (strength of 40MPa to 200 MPa+). In these conditions the HDD contractor tends to use the drill bits such as Rotary Rock Bits and Percussive Bits.

Drill bits of these types are designed for penetrating hard materials and must be assumed to be capable of penetrating the pipe. The hole that results is likely to be equivalent to 50 – 100 mm, but this will vary with the drill size, the angle and location of contact, and with the ability of the soil to control the direction of the drill when it is confronted with the steel pipe.

Soft Material

Soft Material in HDD terminology refers to ground conditions such as sand, organic soils and clay. In these situations the HDD Contractor tends to use flat and bent spade for aggressive steering.

With the steering operation in this type of soil, the cutting motion of the head will quickly remove adjacent material allow the head to sink and lose direction control. Hence, the likelihood of this equipment being used in normal conditions is low.

Commentary on Perpendicular crossings:

The hole is likely to result in a horizontal puncture, and immediately gas is released it will flow along the drill hole, discharging the drilling fluid and other debris at the machine (and for the smaller machines, the operator). At this stage, the Operator will be warned and will stop the machine, limiting further damage and investigate.

Commentary on Parallel installations:

There is at least one case reported where a pipeline was ruptured because the HDD ran parallel with an installed pipe and was effectively guided by it. In this situation, the drill makes a continuous gouge along the pipeline length, weakening it to the point of rupture.

Discussions with HDD operators were that structure (in this case, it will be pipe) will be evident to the operator and the operator indicated that if confronted with a similar reaction from the machine, he would stop and investigate.

Common industry practices for HDD activities which are widely by prudent operators

Perpendicular crossings:

- All existing pipelines / services will be vacuum excavated and detailed on a surveyed drawing (by client) and provided to Pipeline Drillers. A bore profile will then be designed with the suitable distances plotted, once approved this will be utilised by the Pipeline Drillers steering personnel on site.

Soft Material - I'm not sure this reads properly. Is the intent the flat and bent spade tools are not capable of puncturing the pipeline.

- The depths of existing pipelines/services shall be verified by HDD superintendent, prior to the commencement of any drilling activities. The validation/ witness holes (excavated by client) will also be inspected to ensure appropriate depth and distance from the existing pipeline.
- The drill head/steering tool will be calibrated on site prior to the pilot hole commencing and verified by the HDD superintendent.
- Prior to approaching the witness point, all relevant personnel i.e. client representatives, permit holders, will need to be on site as the drill head approaches the validation/ witness point. Visual monitoring and depth of head measurements to be taken every metre from 2 metres (minimum) outside of the validation point. Once it is confirmed that the drill head is at the required distance from the existing pipeline, the pilot hole will be continued as normal.

Parallel installations:

- For existing gas facilities, a typical suggestion is to excavate a test hole every 15.24mts and minimum of 3.6mts deeper to positively locate and inspect the facility if the drill path is within 1.5mts of a distribution gas pipeline.
- If an existing gas pipeline that is being paralleled crosses under pavement, the pipeline should be exposed at each curb for monitoring. The intervals for the test holes will be dependent on the proximity of the existing pipeline to the drill path, as well as the type of gas pipeline in operation.

Conclusion on HDD risk:

in place?

Based on the above illustrated industry practices and other industry practices I place e.g. DBYD, project HDD drill path tolerances, and daily monitoring of the drill data by the qualified drill engineer, it can be said that the chance of HDD drill coming in contact with gas pipeline is low.

Appendix 2 – HDPE Slab Depth and Width

This section provides supporting information on the suitability of HDPE slabs at proposed depth and width combinations, and the effectiveness of this protection against excavator trenching.

Excavator and Slab Combinations

Considering the excavator sizes (20 & 35 tonne) and corresponding bucket sizes (general purpose and tiger teeth) which have been identified as credible threats in the Safety Management Study, a desktop study was conducted to determine whether the excavator bucket may miss the protective slab and come in contact with the pipeline while excavating perpendicular to the pipeline axis. The scenarios considered for this study include;

- Pipeline diameter 300mm
- Pipeline depth of burial, 1,200mm and 900mm
- Protecting slab depth of burial 300mm
- Protecting slab width, 1,200mm and 2,400mm
- Excavator bucket swing radius (bucket knuckle to tooth tip), 1,473mm for 20 tonne and 1,600mm for 30 tonne.

Excavation Process Model

Considerations were made on the movement paths for excavator buckets during typical excavation practices. Excavation path curvature was sourced from excavator manufacturer data on working ranges of excavators. It should be noted that the curvature of movement becomes increasingly steep as excavation depth increases.

For the purposes of the study it has been assumed that earth will be excavated progressively by the excavator bucket in progressive layers. An excavator bucket has a finite volume and earth is an incompressible material. Therefore it has been deemed as not credible to assess scenarios where the bucket is fully submerged in earth and then commences to excavate.

Excavation Diagrams

Figure 6 20 t Excavator, Partial Bucket Load

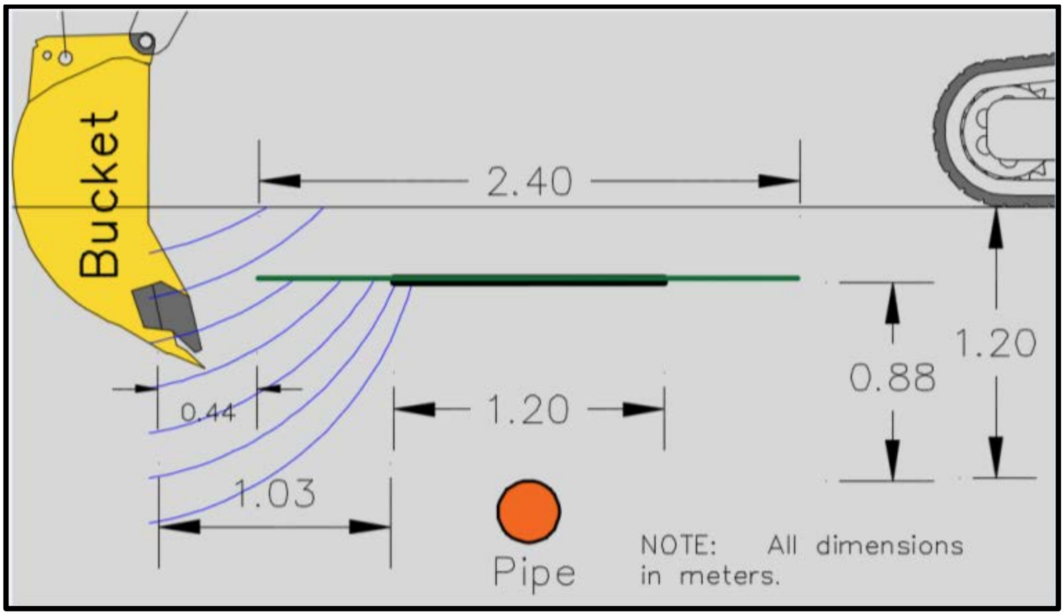


Figure 7 35t Excavator, Partial Bucket Load

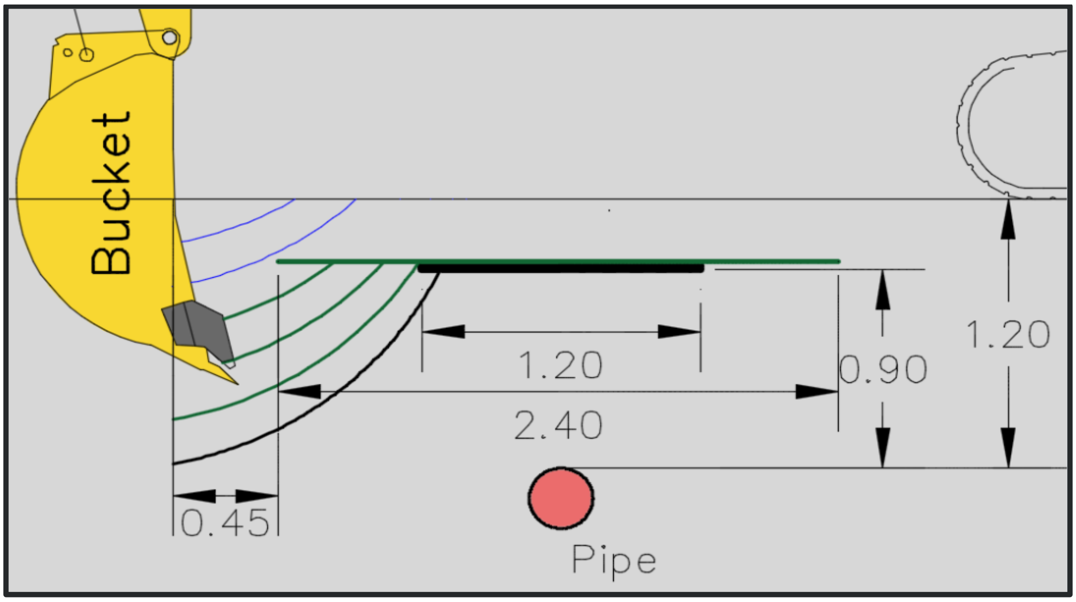


Figure 8 zzzzz Figure titles missing. Seems to be missing a diagram or two. The scenario that does not pass is not shown.

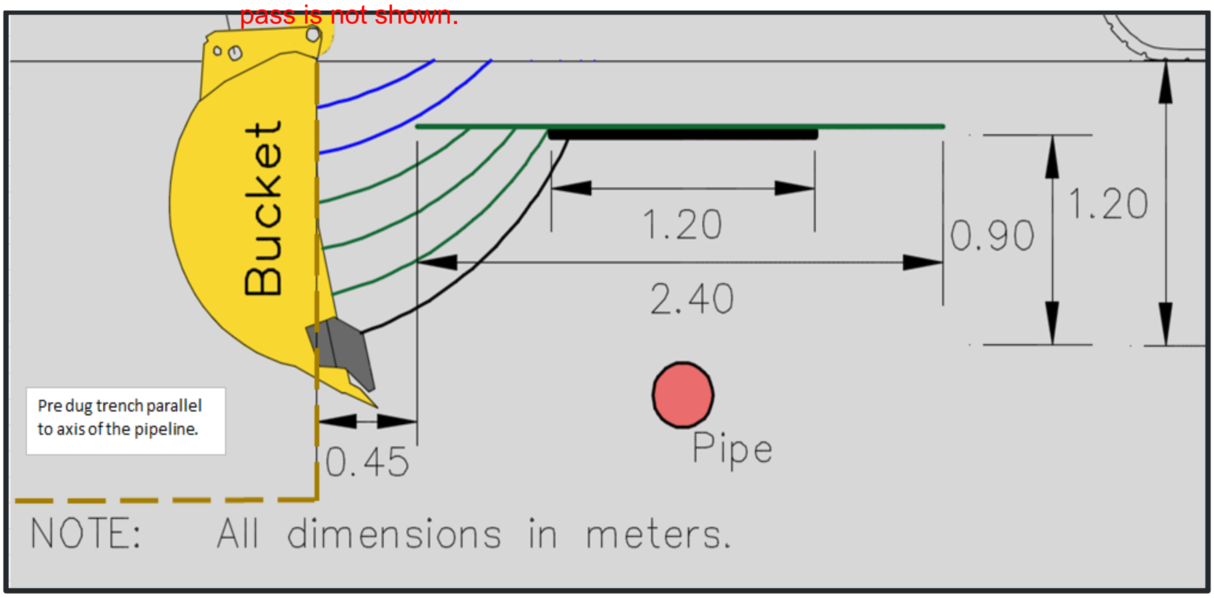
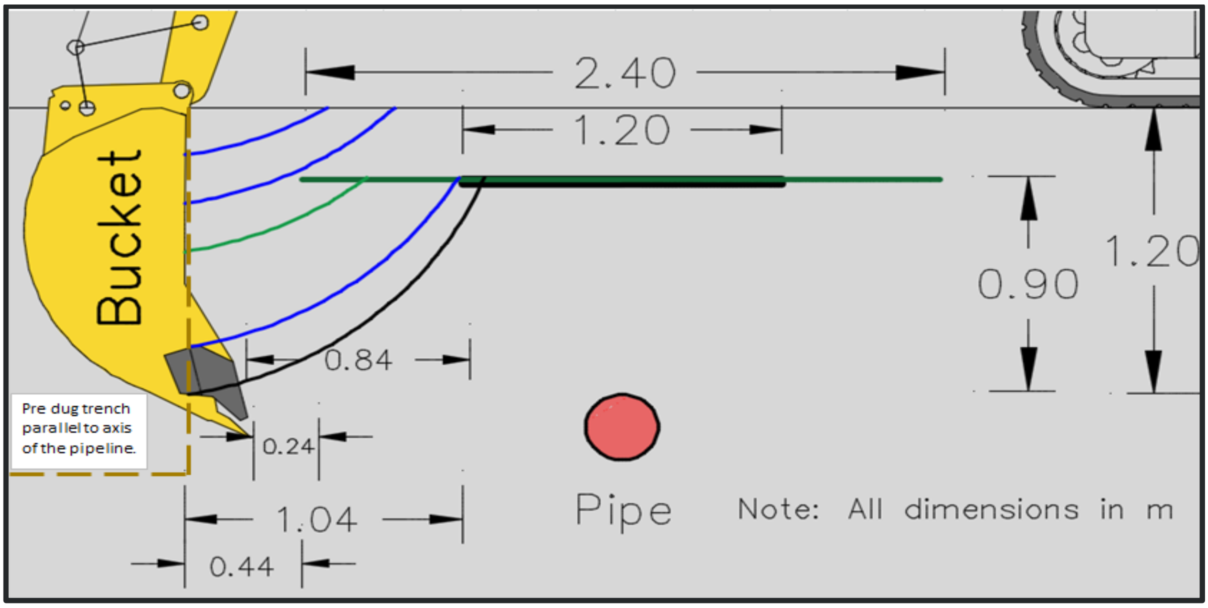


Figure 9 zzzzz



Study Results and Discussion

The following is a summary of conclusions from the desktop study:

- In all scenarios reviewed with a slab width of 2.4m, the slab will be struck by the excavator bucket and provide a visual warning to the excavator operator of a buried structure prior to the excavator coming in contact with the pipeline. Numerous layers of earth would need to be removed prior to the excavator coming in contact with the pipeline. As a result the operator would strike the slab on multiple occasions with the slab tending to lift, heaving earth on top of the slab giving a visual warning to the excavator operator and work crew.

- For all scenarios except one with a slab width of 1.2m, the slab will be struck by the excavator bucket and provide a visual warning to the excavator operator of a buried structure prior to the excavator coming in contact with the pipeline. Numerous layers of earth would need to be removed prior to the excavator coming in contact with the pipeline. As a result the operator would strike the slab on multiple occasions with the slab tending to lift, heaving earth on top of the slab giving a visual warning to the excavator operator and work crew.
- For the scenario where a prior trench has been excavated parallel to the pipeline which abuts the 1.2m wide slab, and excavation then commences on a perpendicular branch in the direction crossing the pipeline, there is the possibility that the excavator bucket could come in contact with the pipeline without hitting the slab first.

  This scenario although possible is considered very unlikely. Digging a prior parallel trench would require working in close proximity to the pipeline for some time within the permit to work area. All procedural controls would need to fail for the operator to not be aware of the pipeline adjacent to the trench. In addition for this scenario to eventuate the excavator operator would need to attempt to commence digging the perpendicular trench with the excavator bucket at fully submerged depth, rather than progressive layers which is normal practice. Implementing a normal practice of digging in layers would result in the slab being struck and the operator warner prior to striking the pipeline.

  Therefore although this scenario is possible it has been assessed as very unlikely as all three factors including failure of procedural controls, a parallel trench with a branch trench and non-standard excavation procedures are required for the protective slabbing to be missed. However to mitigate against this potential risk, slabbing locations for the project should be assessed on a location by location basis and where it is determined there is a possibility of parallel trench with branch connections at a particular location a 2,400mm slab width should be installed.