University of Southern Queensland

Faculty of Engineering and Surveying

Optimisation of Pigging Infrastructure in Design

A dissertation submitted by

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Course ENG4111 and 4112 Research Project

towards the degree of

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Abstract

The principle aim of the research was to create a standard, complete with a supporting estimating tool, which will assist in optimising the design of pigging infrastructure in future pipeline projects undertaken by SunWater.

The study involved research into current pigging practices and infrastructure arrangements. Pipelines considered during this research included the majority of pipelines owned by SunWater, as well as several pipelines external to the company. This research involved the operators of the previously mentioned pipelines.

Established during this research were a number of differing levels of infrastructure. The associated costs of these infrastructure levels, both capital and operational, were then analysed. The analysis sought to determine the total cost of the asset over its design life. From this analysis conclusions were drawn as to when a particular level of infrastructure could justifiably be incorporated into a particular pipeline design.

The physical output of the research included general arrangement drawings for the different infrastructure layouts. A document was then prepared linking those arrangements to their associated costs and allowing these outputs to be included in SunWater’s design standards. Finally an estimating tool was developed to supplement the standard, for use in the conceptual and/or preliminary design stages of a pipeline project.

The results of this study will help ensure SunWater makes a justified capital investment in pigging infrastructure on future pipeline designs. It will also aid in streamlining the conceptual and/or preliminary design process of pigging infrastructure.

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Certification

I certify that the ideas, designs and experimental work, results, analyses and conclusions set out in this dissertation are entirely my own effort, except where otherwise indicated and acknowledged.

I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically stated.

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Signature

28-10-2010

Date

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Abbreviations

The flowing abbreviations have been used throughout the text:-

AMPL	– Automatic Multiple Pig Launcher
AOP	– Allowable Operating Pressure
BMA	– BHP Mitsubishi Alliance
BMP	– Burdekin Moranbah Pipeline
CPI	– Consumer Price Index
DICL	– Ductile Iron Cement Lined
DIS	– Drawing Information System
GOC	– Government Owned Corporation
GPS	– Global Positioning System
MSCL	– Mild Steel Concrete Lined
PPE&C	– Personal Protective Equipment and Clothing
PV	– Present Value
SPL	– Sub-sea Pig launcher
WHS	– Workplace Health and Safety
WHSO	– Workplace Health and Safety Officer
WMS	– Work Method Statement
WSS	– Water Supply Scheme

Glossary

The flowing terms have been used throughout the text:-

As Constructed – is representative of what was actually constructed.

Contractor – someone who contracts to supply or do something at a certain price or rate.

Conventional Pig – a pig as described in Section 2.3.

Intelligent Pig – a pig that incorporates various technologies i.e. GPS for tracking etc.

Rubber Ring Jointed Pipe – pipe joined together via a socket and spigot arrangement, sealed by a rubber ring.

Qualitative – relating to or concerned with quality or qualities.

Quantitative – of or relating to the describing or measuring of quantity.

Chapter One – Introduction

‘Pigging is now a consideration of the highest importance in new pipeline planning at every stage and in the service and maintenance programs of every operator.’ (Clark 2003).

1.1 Outline of the Study

This study encompasses the design of pigging infrastructure used in the water industry. It looks into the varying pipe work arrangements that are used in current practice. This includes the varying operational procedures associated with each arrangement.

The main focus of the study is to determine the costs associated with the varying infrastructure arrangements and operational procedures. Taken into account are both capital investment and operational costs. The purpose of the study is to allow some level of financial justification for the inclusion of the infrastructure in a pipeline design. Justification is required at the conceptual and/or preliminary design stage of a pipeline project.

1.2 Introduction

1.2.1 SunWater Ltd

Formed in 2001, SunWater Ltd is a Queensland based Government-Owned Corporation (GOC). Supplying services including infrastructure ownership, water delivery, operation and maintenance of infrastructure and engineering consultancy services, SunWater is a leader in the water industry.

SunWater has an extensive infrastructure base including (SunWater 2010):

- 19 dams;
- 63 weirs and barrages;
- 80 major pumping stations;
- over 2500km of open channel and pipeline.

This extensive infrastructure network is broken up into 23 Water Supply Schemes (WSS) that supply nearly half of Queensland's commercially consumed water (Figure 1.1). SunWater services over 6000 bulk water supply customers and industry clients. The majority of those customers are involved in irrigated agriculture, mining, power generation and industrial and urban development.

SunWater's internal design and drafting resources are located in two design centres. Head office is situated in Brisbane and a regional design office is situated in Ayr, North Queensland. These resources undertake the majority of the design and drafting requirements of the company.

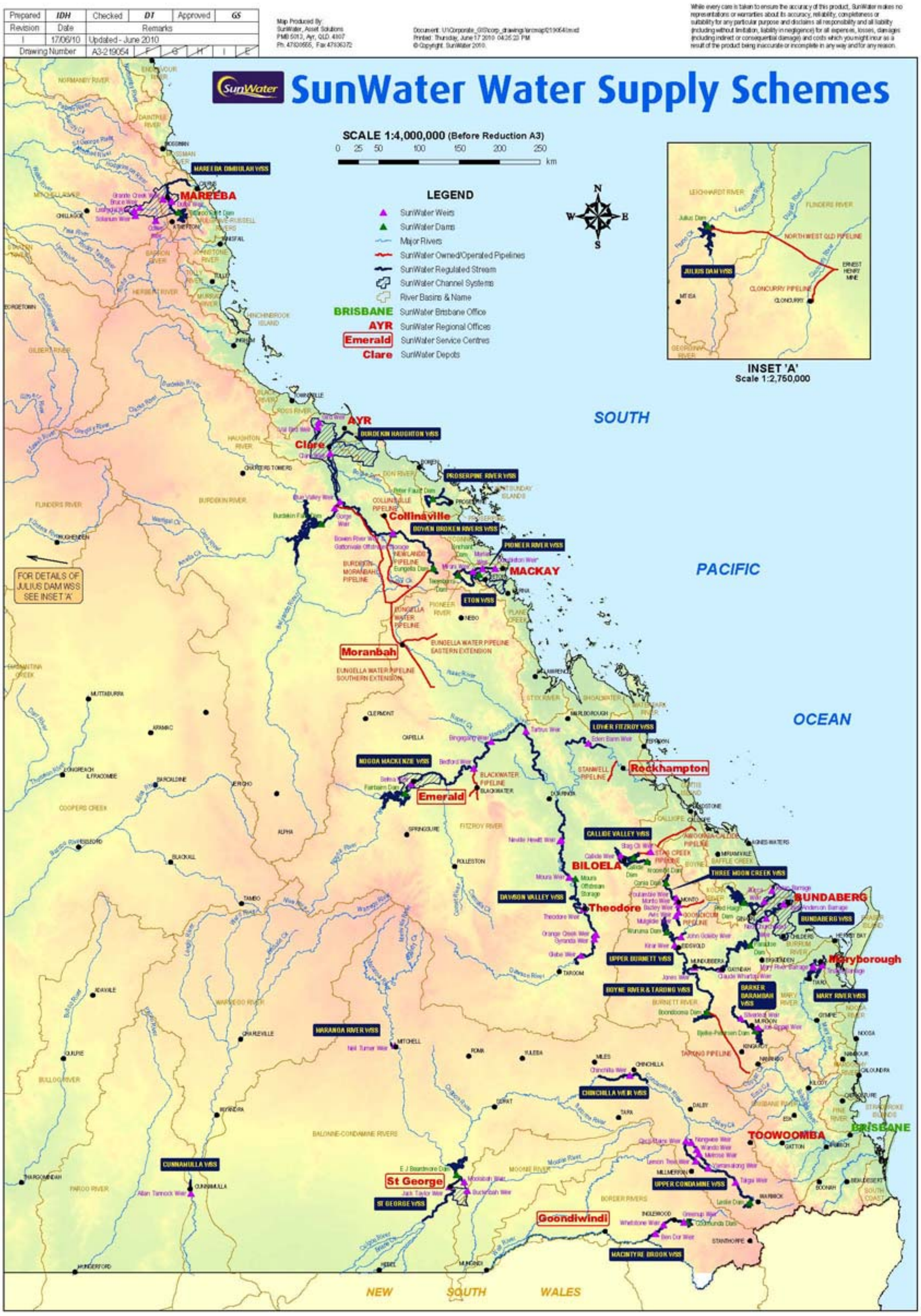


Figure 1.1 – SunWater Water Supply Schemes (SunWater 2003)

1.2.2 Pipeline Pigging

Pipeline pigging is the process by which the internal surface of a pipeline is freed from deposits or growth. Pipeline pigging is also referred to as “pipeline cleaning” or “swabbing”. For the purpose of this study it will be referred to as pipeline pigging. This process is used in pipelines conveying a wide variety of substances. Those substances include but are not limited to gas, petroleum, oil and water. However, this research only focuses on those pipelines that convey water.

Very few sources of water are free from impurities. It is these impurities in the water that promote the growth of algae, moss and other forms of biofilm. This biofilm can form on any surface via which water is conveyed, whether it be the rocks in a river, the bed of a channel or, as far as this research is concerned, the internal walls of a pipeline.

The amount and rate of growth of biofilm that occurs on the internal walls of a pipeline is dependent on a number of factors, including but not limited to:

- the internal lining material;
- the velocity of the water travelling through the pipeline;
- the source water quality.

In any case, over time the biofilm on the internal walls will build up. The build up of biofilm on the internal walls of the pipeline increases the friction experienced by the water as it travels through the pipeline. An increase in the amount of friction experienced by the flowing water will have a consequential effect on the operating efficiency of the pipeline.

The main factor affecting operating efficiency is a reduction in water velocity. A reduction in velocity will in turn create a reduction in the overall flow rate within the system. However, for the purposes of this research the only efficiency that is of concern is that of the pumps.

Pumps are selected as part of a pipeline design. They are selected so that they will operate at, or close to, their peak efficiency under normal operating conditions. As the pumps move away from their peak operating efficiency, they begin to work harder.

As the pumps begin to work harder, the power consumption of the pumps on a pipeline will increase. Resulting from this increase in power consumption is an increase in power costs. It is at this point, when the pumping costs of a pipeline begin to significantly increase, that the pipeline requires pigging. There are other factors that onset the requirement for pigging i.e. water delivery contract stipulations. However, for the purpose of this project these factors are not considered.

The pigging operation aims to remove the build up of biofilm from the internal walls of a pipeline. It is through the removal of the biofilm that the pipeline and hence the pumps are restored to their peak operating efficiency.

1.3 The Problem

In recent times given the extended drought in most parts of Queensland and the boom in mining activities over the last ten years, SunWater has designed, constructed and now operates numerous major pipelines.

The majority of these pipelines are situated in the Central Queensland Bowen Basin (Figure 1.1). These pipelines range in length from 40 km to 220 km and in diameter from 450 mm to 750 mm. They also vary in material, including welded polyethylene, welded and rubber ring jointed mild steel and rubber ring jointed ductile iron.

The design requirement for each of these pipelines varies, as do the infrastructure requirements. All of the pipelines incorporate smaller infrastructure such as air valves, scour outlets and consumer off-takes. Many of them also provide infrastructure for metering, isolation and pumping, as well as the infrastructure to assist in the pigging process i.e. pig insertion and removal structures.

Both above ground and below ground (in a pit) insertion and removal structure designs have been used within the water industry. As well as varying in location (above and below ground) the pipe work arrangements have a number of variations, depending on the pipeline in question. With this varying infrastructure comes varying capital investment. Subsequent to construction, the frequency of use of the infrastructure provided for the pigging process will also vary.

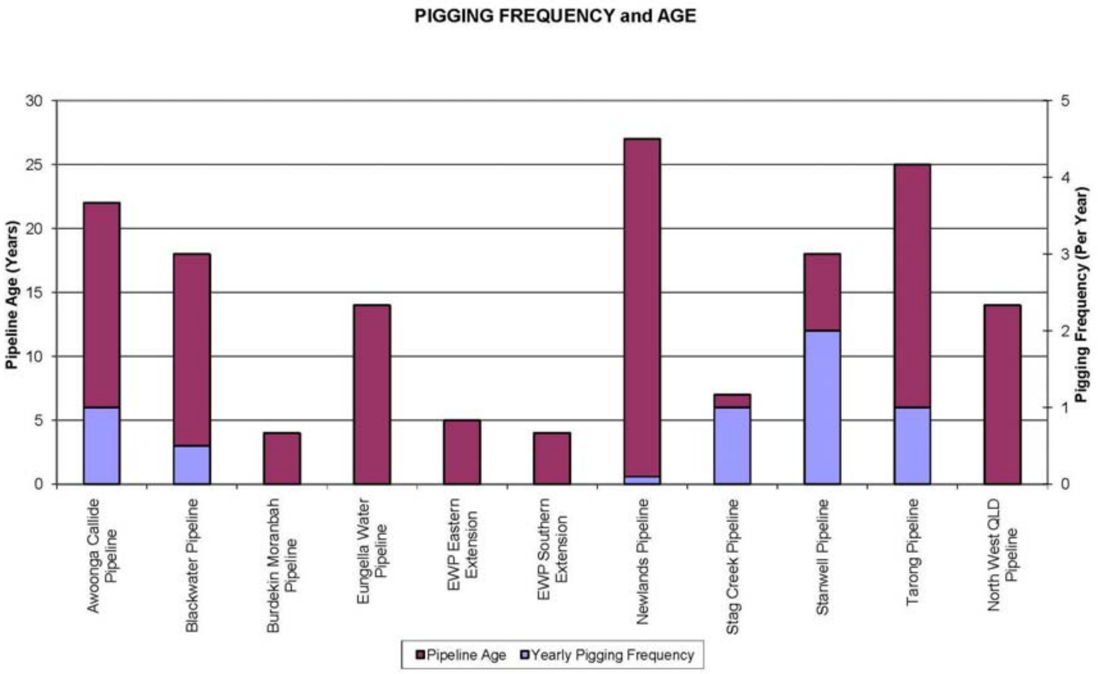


Figure 1.2 – Pigging Frequency and Pipeline Age
(Data sourced from SunWater drawings and operational procedures)

The graph in Figure 1.2 provides a comparison between the age and pigging frequency for a number of SunWater designed, owned and operated pipelines. The red columns represent the age (in years) of each pipeline and the purple columns represent the frequency (in the number of times per year) that each pipeline is pigged.

The graph in Figure 1.3 is based on the same SunWater designed, owned and operated pipelines as that in Figure 1.2. The green columns represent the capital investment (in millions of dollars) associated with the infrastructure provided for the pigging process for each pipeline.

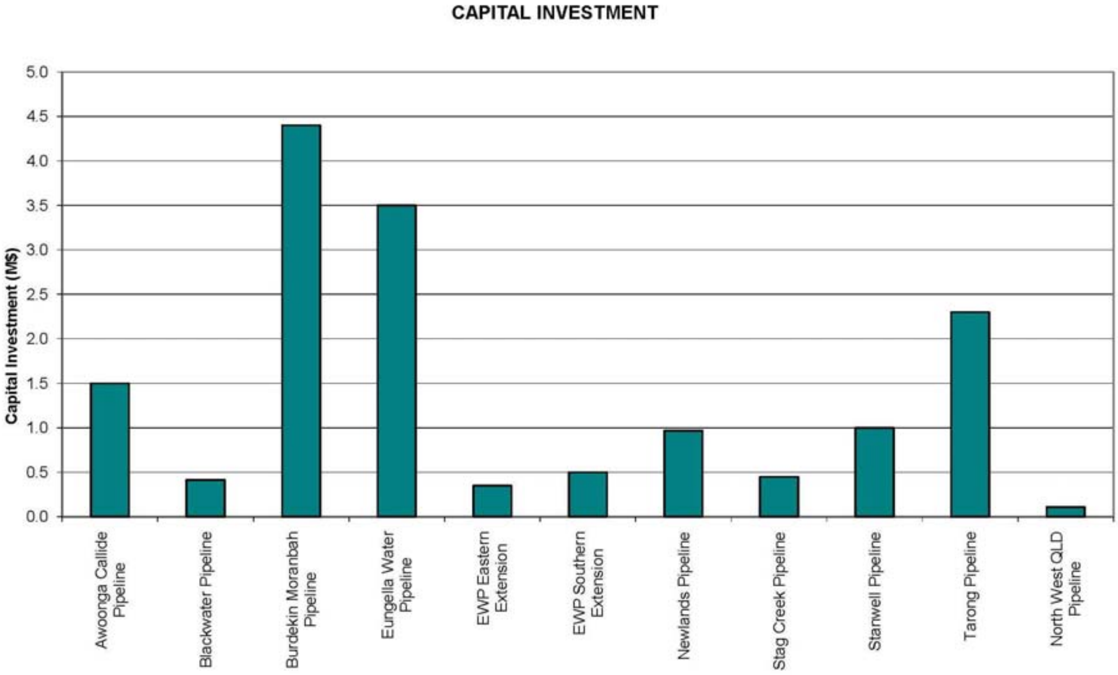


Figure 1.3 – Capital Cost of Pigging Infrastructure

(Data sourced from SunWater SAP system)

From these graphs two conclusions can be made:

- large capital investment is currently made in pigging infrastructure;
- pigging infrastructure is seldom, if at all, used in the majority of cases.

These conclusions lead to the following:

- there is no justification that, on a pipeline by pipeline basis, the pigging process has any benefit (benefits being savings in pumping costs);
- there is no justification that the infrastructure provided, as part of the pipeline design, for the pigging process has been done so considering the benefits that will be derived from the pigging process.

To justify the pigging infrastructure provided for the pigging process in future pipeline designs two investigations need to be undertaken. The results of the two investigations are to be used during future pipeline designs, providing some level of justification for that design:

1 Investigate the benefits derived from the pigging process to determine, on a pipeline by pipeline basis, if and when the process itself and hence the infrastructure should be considered in design.

2 Investigate differing levels of pigging infrastructure and relate those different levels of infrastructure to the benefits derived from the pigging process.

It is the second investigation that forms the basis of this research.

1.4 Research Objectives

The principle aim of this research is to create a standard, complete with a supporting estimating tool that will assist in optimising the design of pigging infrastructure in future pipeline projects undertaken by SunWater.

There are nine objectives associated with this aim (as per the specification, Appendix A):

- research background information relating to the pigging of water pipelines;
- attend the pigging of a water pipeline to gain practical experience and witness a pigging procedure;
- examine the multitude of pigging arrangements for water pipelines in practice at present to establish differing levels of use;
- consult with the operators of various water pipelines that are currently pigged to establish the downfalls and benefits associated with each particular arrangement;
- consider the inherent Workplace Health and Safety (WHS) issues associated with each pigging arrangement. Discuss those issues with the WHS officer/s (WHSO) associated with each pipeline;
- prepare ‘standard’ arrangement drawings for each differing level of use established;
- analyse the current practices, their downfalls, benefits and inherent WHS issues against pipeline particulars and associated capital, operational and maintenance costs;
- develop a standard for swabbing frequency using the above analysis, for differing levels of use;
- create an estimating tool, to be used in the conceptual/preliminary design phase of a pipeline, to assist in determining the optimal arrangement of pigging infrastructure for a particular pipeline.

By meeting each of these objectives, a suitable standard can be created that will help justify SunWater’s capital investment in pigging infrastructure for future pipeline projects.

1.5 Summary

SunWater’s business of bulk water supply requires the design, construction and operation of pipelines. Part of that design, construction and operation involves the pigging process and its associated infrastructure. The pigging process is one that can assist in ensuring pipelines are running at their peak efficiency. However, it is also a process that can draw large capital investments in infrastructure.

To date, SunWater’s current practice for the design of pigging infrastructure does not consider or relate the capital investment in the infrastructure to the benefits derived from the process itself. It is therefore the aim of this study to assist in optimisation the design of pigging infrastructure by relating it to the financial benefits of the pigging process.

Chapter Two – Background Information

2.1 The Pigging Process

At a basic level, pipeline pigging is a fairly simple process. The water supply into the pipeline is shut off and all associated electrical and/or mechanical equipment are isolated. The isolation process is to prevent the water supply into the pipeline from resuming while the ‘pig’ (Section 2.3) is being inserted into the pipeline. Once the water supply is isolated, the ‘pig’ is inserted into the pipeline.

Once the ‘pig’ has been inserted into the pipeline, the line is filled. The isolation is then lifted and the water supply re-started. The hydraulic pressure behind the ‘pig’ pushes it through the pipeline and the rate at which the ‘pig’ travels will vary depending on its type and size. However, the main driver behind the ‘pig’s’ speed is the flow rate within the system.

The ‘pig’ will usually travel no quicker than walking speed, or approximately 1.5 m/s. However the most common speed for a ‘pig’ travelling through a pipeline is 0.5 m/s. This ensures a thorough clean is achieved. The speed of a ‘pig’ can be increased by opening scour outlets ahead of the ‘pig’s’ position in the pipeline and closing the ones behind it. Similarly, the ‘pig’s’ speed can be reduced by opening scour outlets behind the ‘pig’s’ position in the pipeline and closing the ones ahead of it.

As the ‘pig’ travels through the pipeline, its extremities are constantly in contact with the internal walls of the pipeline. The contact between the ‘pig’ and the internal walls is essentially what removes the biofilm from the internal walls of the pipeline (Figure 2.1).

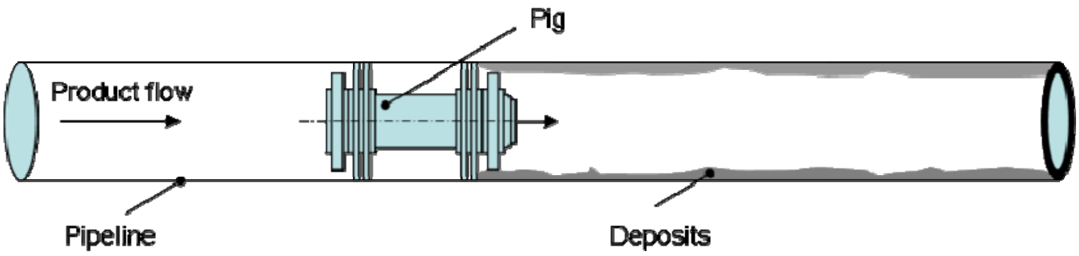


Figure 2.1 – Cleaning Pig in a Pipeline (2008)

The ‘pig’ is tracked through the pipeline, again using the scour outlets. The time it takes for the ‘pig’ to travel from one scour outlet to the next along the pipeline is approximated using the formula:

Time @ Previous Scour + ((Distance Between Scours / Pig Velocity) / 86400)

where time is in hours;
distance is in metres;
velocity is in metres/second.

The scour outlet ahead of the ‘pig’ is opened just before it is due to arrive. As the ‘pig’ approaches the water flowing out of the scour outlet becomes dirty. This indicates the ‘pig’ is nearing the scour. As the ‘pig’ passes the scour there is a short but noticeable pause in the flow of water out of the scour outlet. Shortly after, the water runs clear again. This indicates the ‘pig’ has passed. There is no set requirement on the spacing of scours for this purpose.

The ‘pig’ will continue through the pipeline until it eventually reaches the point where it is to be retrieved. This point can either be the end of the pipeline or some intermediate point along it. The location of the retrieval point will depend on the overall length of the pipeline being pigged. Generally the distance between ‘pig’ insertion and removal points will be no greater than 20-25 km.

If a pipeline is longer than 20-25 km it will generally be pigged in sections. A new ‘pig’ will be used for each section of the pipeline. This is due to the wear experienced by the ‘pig’ as a result of the rubbing effect. At the retrieval point, pushed out ahead of the ‘pig’ will be the remaining dirty water. This dirty water is full of the biofilm the ‘pig’ has removed from the internal walls of the pipeline. The amount of water pushed out ahead of the ‘pig’ is minimised by opening scours along the pipeline in front of the ‘pig’.

2.2 Pigging Infrastructure

An insertion structure is provided at the start of a pipeline or the start of each section of a pipeline. A removal structure is provided at the end of a pipeline or the end of each section of a pipeline. Where the pipeline is broken up into sections for pigging, in most instances the intermediate insertion and removal structures will be one and the same.

Figure 2.2 – Swab Structure on the Burdekin Moranbah Pipeline (SunWater 2005)

There are many variations in the infrastructure provided for the insertion and removal of the ‘pig’ into and out of a pipeline. The infrastructure can be provided above ground, as in Figure 2.2. It can also be provided below ground, usually in a pit. The pipe work and valving arrangement will also vary, depending on the design characteristics of the pipeline. Operational procedures for the pigging process will also vary based on the type of infrastructure provided.

2.3 The ‘Pig’

‘Pig’ is the term given to the object that actually does the cleaning within the pipeline. Pigs are available in many forms (Knapp Polly Pig Inc 2001):

- Urethane Foam Pigs;
- Solid Cast Urethane Foam Pigs;
- Sphere Pigs;
- Metal Mandrel Pigs;
- Urethane Cups and Discs;
- Custom Designed Pigs.

In the water industry, the most common forms of pig used are the Urethane Foam and Metal Mandrel pig. Both types of pig have their advantages and disadvantages.

The type of pig used will depend on the pipeline that is to be pigged. There are a number of pipeline related factors that will determine the most appropriate pig. Some of those factors include:

- acuteness of the pipeline bends;
- type of pipeline joints (welded, rubber ring etc.);
- pressure in the pipeline;
- the extent of biofilm on the internal walls of the pipeline.

The Urethane Foam Pig (Figure 2.3) as its name suggests, has a urethane foam body. The external coating varies based on the application, but is generally a urethane elastomer. These pigs have a bullet shape, which assists with launching the pig and in traversing pipelines that change diameter. Urethane Foam Pigs are, in most cases, a throw away item. They are used to pig a pipeline, or in some cases a section of pipeline, only once.

Figure 2.3 – Urethane Foam Pig (Knapp Polly Pig Inc 2001)

The Metal Mandrel (Figure 2.4) pig consists of a metal body, with replaceable urethane discs. These pigs are built such that the urethane discs can be unbolted and replaced as necessary (usually before each pigging operation). Metal Mandrel pigs are not suited to pipelines that are rubber ring jointed as it has the potential to dislodge the joints as it passes.

Figure 2.4 – Metal Mandrel Pig (Knapp Polly Pig Inc 2001)

There are two factors that determine the size of a pig. The first is the internal diameter of the pipeline to be pigged. The pig needs to be larger in external diameter than the internal diameter of the pipeline. This allows the pig to constantly be in 360 degree contact with the internal wall of the pipeline. The relative size of the pig compared to the pipe diameter is dependent on the type of pig being used.

The second factor in determining the size of a pig is the configuration of bends on the pipeline being pigged. The length of the pig will vary depending on the acuteness of the bends in the pipeline. A short pig will be used on a pipeline consisting of tight bends. As the tightness of the bends on a pipeline reduces the pig length can increase.

Chapter Three – Literature Review

The following literature review looks at past articles that have been written relating to the process of pipeline pigging. In particular, the review focuses on the varying arrangements of pigging infrastructure and the theories behind their design. The articles considered cover a range of industries, not just the water industry.

3.1 Manually Operated Pigging Infrastructure

The original method for launching and receiving pigs in a pipeline was via manual handling. This involved physically inserting the pig into the pipeline before it could be launched. Similarly, it involved manually removing the pig from the pipeline once it had been received. There are a number of aspects to be considered in the design of pigging infrastructure that will require manual launching and/or receiving of the pig. Figure 3.1 gives an example of a manually operated pig launcher.

Figure 3.1 – Example of a Manually Operated Pig Insertion Structure

3.1.1 Pig Insertion

To insert a pig into a pipeline, the pipeline itself has to be opened in some way. The opening in the pipeline needs to be large enough to be able to accommodate the particular pig to be inserted. This is done via a localised enlargement in the pipeline (Section 3.1.2).

The internals of a pipeline can be exposed or opened in a number of ways. Several factors affect the way in which a pipeline will be opened. These factors include, among others:

- ease of operator use;
- frequency of the pigging process;
- diameter of the main pipeline.

Fisher (1998) discusses quick opening closures and the various forms they are available in. Two of the forms discussed are the threaded or screwed type, and yoke type. Fisher (1998) also discusses the safety aspects of these quick opening closures and the need for them to have pressure warning devices fitted. This allows the pressure inside the pig chamber to be equalised before it is opened.

Warriner (2008) discusses a simple method of opening a pipeline using a flange. However, reference is also made to a quick opening closure in the form of a door. This door is said to include some form of safe bleeding device as part of a locking mechanism. The purpose of which is to provide a safe environment for the operator when opening the door.

Both Fisher (1998) and Warriner (2008) offer a number of varying methods for opening a pipeline. However, their over arching argument is towards quick opening closures, relating it to ease of access for operators. This is consistent with the general perception of the industry that money can be saved by spending less time on operation. However, this doesn't take into consideration the capital investment. While money is being saved in operation, capital costs are potentially increasing. Some kind of justification should correlate capital investment and operational savings.

Neither Fisher (1998) nor Warriner (2008) consider a spool piece for pig insertion. A spool piece is an easily removable section of pipe, held in place during normal operation via some form of coupling. During the pigging operation the entire spool piece is removed for pig insertion. This method of pig insertion is fairly common practice within the water industry in Queensland.

Quarini and Shire (2007) discuss the complexity that pigging infrastructure can add to a pipeline design. In doing so, they offer an alternative; an innovative solution. Quarini and Shire (2007) mention a ball valve designed with a side cavity to insert and/or remove a pig.

Quarini and Shire (2007) add another dimension to the aspect of manual pig launching and receiving. They do this by considering specially designed valves to insert or remove pigs from a pipeline. This eliminates the need for any form of opening as such. However, it would not remove the need for an enlargement in the pipeline.

Quarini and Shire (2007) describe how their solution reduces the complexity of the pipeline, which again relates back to ease of operator use. The same issue arises in that capital costs are being increased to reduce operational costs. Again, justification is required in this situation to correlate between capital investment and operational savings.

Another limiting factor when using this type of manual insertion would be the diameter of the pipeline. The article by Quarini and Shire (2007) does not describe the diameters up to which this type of valve is available. Previous experience would suggest that a valve of this type would not be fabricated for larger diameter pipelines i.e. 500mm diameters and above.

3.1.2 Launch Chamber

The whole pigging process relies on the pig being in constant 360 degree contact with the internal wall of the pipeline. To achieve this, pigs are designed to have an outside diameter slightly larger than the internal diameter of the pipeline. Therefore, as previously stated, for a pig to be inserted into a pipeline there usually needs to be an enlargement in the pipeline.

There are three design considerations for this enlargement in the pipeline. They are:

- the size of the enlarged diameter;
- the length of pipeline that has to be enlarged;
- the transition from the main pipeline diameter to the enlarged diameter.

Size of the increase in diameter:

Fisher (1998) describes the following enlargements in his article:

- for a main line diameter of 250 mm or less, an increase of one pipe size or a minimum of 50 mm;
- for a main line diameter between 300 mm and 600 mm, an increase of two pipe sizes or a minimum of 100 mm;
- for a main line diameter of 750 mm or larger, an increase of three pipe sizes or a minimum of 150 mm.

Quarini and Shire (2007) describe how the pig is inserted into a chamber that is slightly bigger in diameter than that of the main pipeline.

Warriner (2008) gives two circumstances. When pigging is to be completed using conventional pigs an increase in pipe diameter from the main line of 50 mm is warranted. Whereas when pigging is undertaken using intelligent pigs an increase in pipe diameter from the main line of 100 mm is required.

Quarini and Shire (2007), Fisher (1998) and Warriner (2008) all acknowledge that there is a requirement for an enlarged section of pipe within pig launching and receiving infrastructure. The enlargement discussed is an allowance for insertion/launching or receiving/removal of the pig as part of the pigging process. However, each article presents different opinions on the size of that enlargement.

Quarini and Shire (2007) do not give exact, or in fact any, dimensions as to the size of the enlargement. They do little more than acknowledge the fact that it is required.

There are conflicting opinions between the articles written by Fisher (1998) and Warriner (2008). Warriner (2008) suggests that the enlargement should be uniform regardless of the main pipeline diameter. He bases the size of the enlargement purely on the type of pig to be used. Further to that, his basis only considers two broad types of pig, the conventional pig or an intelligent pig. The main pipeline size is not considered by Warriner (2008).

Fisher (1998), on the other hand, suggests that the enlargement should be relative to the main pipeline diameter. He groups various main pipeline diameters into three categories and then describes the enlargement pertaining to that category of main pipeline diameters. The enlargement he suggests is based on a certain number of pipe sizes larger than that of the main pipeline. Unlike Warriner (2008), Fisher (1998) does not consider the type of pig to be used in the pigging process as a factor in determining the extent of the enlargement.

Although each author bases size of the enlargement on completely different factors, the actual enlargements they suggest aren't that dissimilar. Fisher (1998) uses an enlargement of between 50 mm and 150 mm and Warriner (2008) uses and enlargement of between 50 mm and 100 mm.

Even though the suggestions of both articles end up in the same region, the size of enlarged section of an insertion and/or removal structure should be based on a collaboration of a number of factors. Among those factors are:

- main pipeline diameter;
- pipe diameter increments;
- type of pigs to be used in the pigging process.

Length of pipeline to be enlarged:

Warriner (2008) lists a number of criteria that the length of the enlargement should be based on:

- operating procedures of the pipeline;
- the service being provided;
- the type of pigs to be run;
- available space for the structure.

Warriner (2008) then goes on to say the length of enlarged pipe in the launcher is different to that of the receiver. The two lengths discussed being twice the pig length and three and a half times the pig length respectively.

Fisher (1998) describes how the enlarged section of a pig launcher/receiver should be one and a half times the length of the longest pig expected to be used.

Both authors, Warriner (2008) and Fisher (1998), perceive that the main factor in determining the length of the pipeline enlargement is the type of pig. Although Warriner (2008) does list a number of contributing factors, his final word highlights the type of pig to be used.

There is quite a large difference, however, in the ratio of pig length to enlargement length between the two articles. Warriner (2008) specifies a length almost three times that of Fisher (1998).

Generally, both authors align with practice today in adopting the type of pigs to be used as the major determining factor in the length of enlargement required. However, Fisher's (1998) ratio of pig length to enlargement length would seem to align closer with current practices in the water industry in Queensland. Having said that, there are a number of factors, other than the type of pig to be used, that will affect the enlargement length. Warriner (2008) has covered the extent of these factors quite well in his article.

Transition from the main pipeline diameter to the enlarged diameter:

Quarini and Shire (2007) simply state that the transition from the main pipeline diameter to the enlarged diameter should be 'connected to the line at a shallow angle by a flared pipe' (Quarini & Shire 2007).

Warriner (2008) describes how the transition to and/or from the enlarged pipe can be either an eccentric or concentric taper. Elaborating on this, Warriner (2008) specifies the use of eccentric tapers on horizontal launchers. Concentric tapers are then to be used on horizontal receivers and all vertical systems.

Fisher (1998) discusses how an eccentric taper should be used to reduce from the enlarged section of pipe to the main pipeline diameter. The reason is to ensure a good seal when the pig is pushed into the line as well as ensuring the pig will launch.

Again, Quarini and Shire (2007) do not elaborate any more on the matter other than to say there is a reduction to the main pipeline diameter after the enlarged section of pipe.

Warriner (2008) and Fisher (1998) give semi-conflicting theories. They both make use of a taper to reduce from the enlarged section of pipe to the main pipeline diameter. The conflict is in the type of taper being used. Where Warriner (2008) specifies different tapers for different applications, Fisher (1998) simply specifies the same taper to be used in all cases.

The consensus from previous experience has current practice lying with Fisher’s (2008) theory, especially within the water industry in Queensland. Although like the other parts of the enlargement pipe work, it can vary from case to case for different reasons.

3.1.3 Infrastructure Valving

To be able to open the pipeline and insert a pig into the enlargement, the product flow has to be isolated. Once the pig has been inserted into the pipeline it then needs to be launched. These aspects of the pigging process are undertaken using some form of valve. The main valves associated with pigging infrastructure are:

- isolation valves;
- drain valves;
- bypass valves.

‘The main line valve should always be a full port, through-conduit valve. The bypass or kicker valve can be a reduced port valve. The line bringing the product into the main line can be a reduced port valve.’ ‘The kicker or bypass line will be 1/4 to 1/3 of the pipeline diameter.’ ‘The drain and vent connection size will vary depending on application’ (Fisher 1998)

Warriner (2008) only briefly speaks on valves. The article specifies a drain valve size of 50 mm or greater for pigging infrastructure up to 350 mm in diameter. Pigging infrastructure greater in diameter than 350 mm is to have a drain valve size of 100 mm.

Warriner (2008) does not talk about the size or type of valves used in pigging infrastructure. He implies that the drain valve size will vary according to the particular situation it is to be used in, which agrees with what Fisher (1998) says.

Fisher (1998) goes into more detail about all three types of valves. The main line valve or isolation valve he describes is similar to a gate valve which is commonly used in practice today. Fisher’s (1998) one third sizing for a bypass valve is closer to what is used in the water industry today.

Finally, there are other innovations in valving with the pigging industry. As previously stated, Quarini and Shire (2007) discuss the development of a special ball valve. The valve incorporates a cavity in the side to allow for the pig to be launched and/or received. This would effectively reduce the number of valves, as discussed above, required for the pigging process.

3.2 Automated Pigging Infrastructure

As technology improves new methods for launching and receiving pigs into a pipeline are being developed. A large development in the pigging industry was the incorporation of automatic pig launching/receiving facilities into pipelines. These automatic pig launchers are more common in sub-sea, oil and gas pipelines. Figure 3.2 is an example of an automated pig launcher.

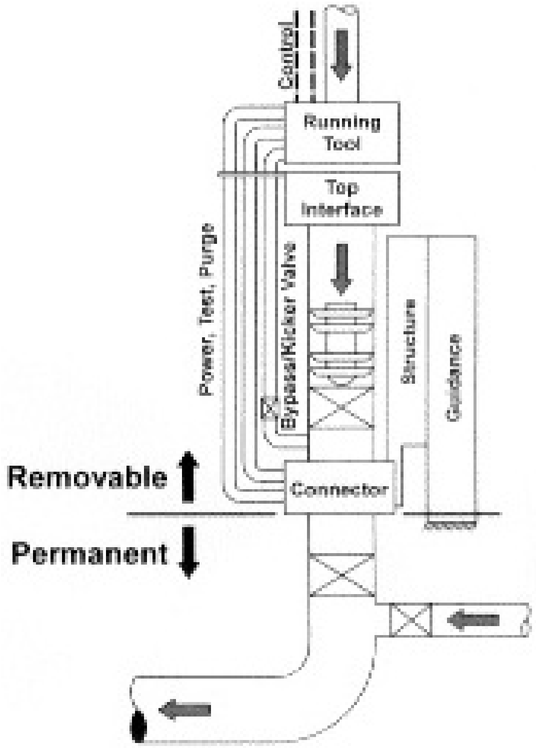


Figure 3.2 – Block Diagram of SPL with Surface Kicker Line (Kozel 1997)

3.2.1 Sub-Sea Launchers

Kozel (1997) describes the main purpose or reason for using a sub-sea pig launcher (SPL). That purpose being to launch or receive pigs in a sub-sea pipeline that has no access on the surface.

Due to the depths of some sub-sea pipelines, some being greater than 100 metres below sea level, the launching or receiving of pigs via surface launchers is not possible. Sub-sea pig launchers are designed to allow for retrofitting to existing sub-sea pipelines.

According to Kozel (1997) the functions of an SPL are the same as those of the infrastructure used for pigging on the surface. The main difference between the two is in their implementation.

The processes used in surface launching are also required in sub-sea launching. Such processes include:

- main line isolation;
- bypass pipe work;
- drain/vent points.

3.2.2 Surface Launchers

Quarini and Shire (2007) describe a recent development in automated pig launching systems for pipelines that are regularly pigged. A pig launcher has been developed that will launch five pigs without manual intervention.

Like their other references to infrastructure provided for the pigging process, Quarini and Shire (2007) merely acknowledge the fact that automatic launchers are available. They do however imply one important fact, in that the multiple pig launchers are for pipelines requiring frequent pigging. These types of launchers would not be economical on pipelines that are only occasionally pigged.

The article by Warriner (2008) also touches on automatic pig launchers. His paper describes a number of systems available, including:

- valve type multiple pig launcher;
- vertical multiple pig launcher;
- automatic multiple pig launcher (AMPL).

In describing the valve type multiple pig launcher, Warriner (2008) discusses how the infrastructure incorporates a set of valves for launching each pig in the system. This effectively allows the pressure from the main line to launch each pig individually as it is needed.

In describing the vertical multiple pig launcher, Warriner (2008) discusses the addition of launch pins, hydraulically operated, to what otherwise would be standard infrastructure. Each launch pin holds one pig in place ready to be launched.

In describing the AMPL, Warriner (2008) discusses the use of cassettes. A number of pigs are preloaded into a specially designed or fitted cassette, which is then loaded into the pigging infrastructure.

Again, each of these systems has their place. There is no indication within the article of the diameter range that these launchers can be adapted to. They would only be economical in situations where the frequency of pigging was high. In the majority of water pipeline instances the cost of these automated launchers could not be justified. Mainly due to the infrequent intervals with which water pipelines are pigged.

3.3 Siphon Pigging

Siphon pipelines form part of open channels or canals. The pigging of these follows the same principle, but is executed differently.

Steinke and Drain (2004) describe how a dragline or crane is used to launch and/or retrieve a pig into a canal. The machinery places the pig in the canal upstream of the siphon and releases it. Similarly, another piece of machinery retrieves the pig once it exits the siphon.

No permanent pig launching or receiving devices are incorporated into these canals. Hence, as Steinke and Drain (2004) describe, the process is as simple as a piece of machinery placing the pig into or retrieving the pig from the product flow in the canal.

3.4 Summary

There are many different perspectives when it comes to pigging infrastructure. With manual launching, the arrangement or process that is gone through is basically the same in most cases. It is the pipe work and valving arrangements provided that can and do vary.

There are also a number of different technologies available for the automatic launching and receiving of pigs. Although most automated systems are designed for sub-sea, gas or oil pipeline applications. Finally, in the case of canals, launching and/or retrieving pigs can simply involve a piece of machinery.

Chapter Four – Qualitative Research

The first part of the research focuses on the qualitative side of the problem (Figure 4.1). The figure shows the contributing factors to this side of the problem. Each of these factors had to be investigated before the quantitative side of the problem could be considered. The investigation involved looking into current pigging practices that are in use today. The purpose of the investigation was to set out a number of differing levels of pigging infrastructure. These differing levels of infrastructure would form the base for the remainder of the research.

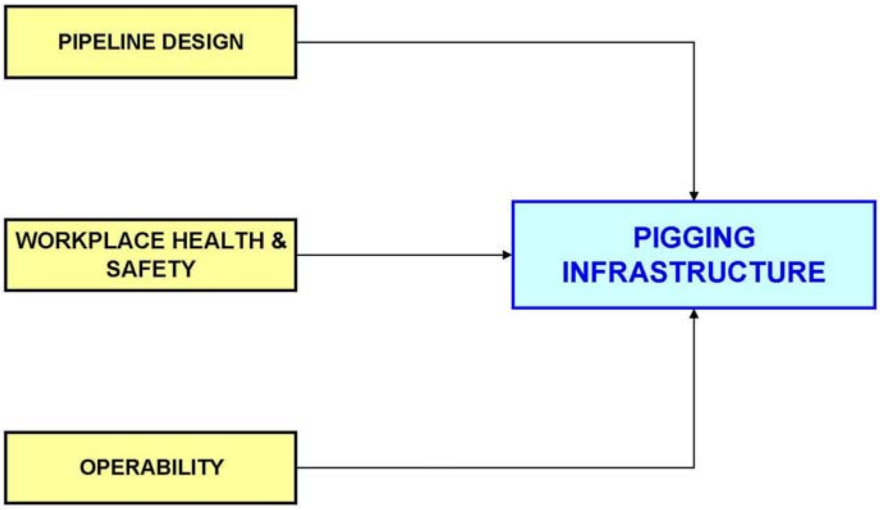


Figure 4.1 – Qualitative Factors to be Considered

The investigation was undertaken in four stages, each stage being dependant on the last. The four stages are listed below and discussed in the following sections:

- existing arrangements;
- questionnaire development;
- operator survey;
- standard arrangement development.

4.1 Existing Arrangements

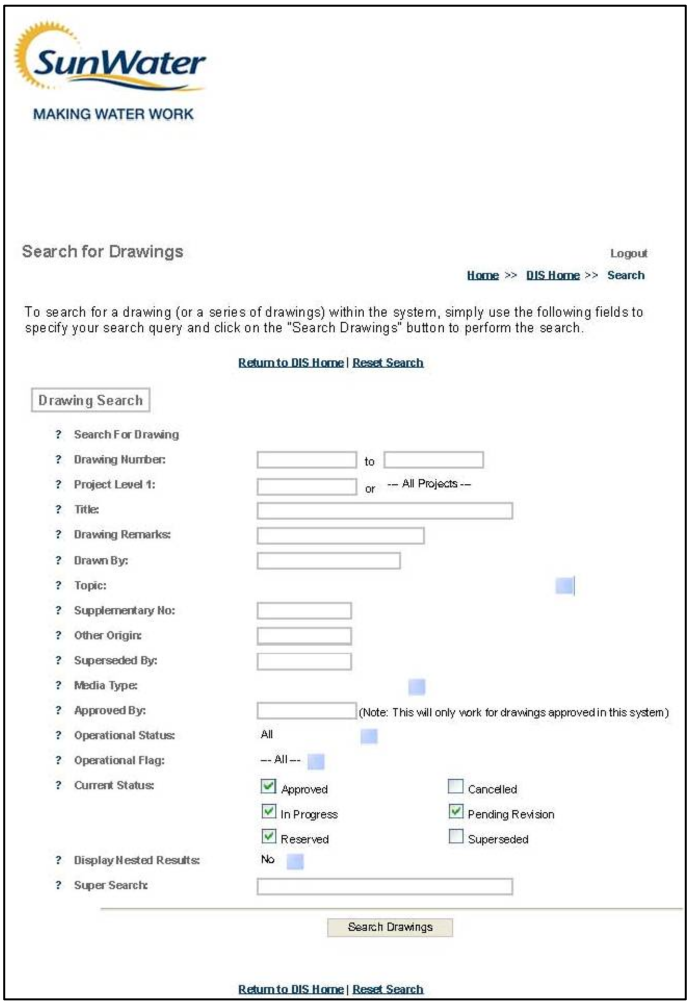
Before any analysis could be undertaken the existing pigging infrastructure arrangements in current practice were researched. To achieve this, two directions were taken. The first was to research the existing pigging arrangements and operational procedures for pipelines owned and operated by SunWater. The second was to research the existing pigging arrangements and operational procedures for pipelines that are external to SunWater.

This research involved obtaining a number of drawings for each pipeline that contained some form of pigging infrastructure. The drawings sought included:

- overall pipeline layout plans;
- pipeline operational layout plans;
- pipeline hydraulic summaries;
- pipeline longitudinal sections;
- pigging infrastructure general arrangements.

Not all of these drawings were available for every pipeline researched. The majority only had three to four of these drawings available. Where possible, the ‘As Constructed’ versions of the drawings were obtained.

Locating these drawings for all pipelines owned and operated by SunWater was a lengthy but simple process. Within SunWater there is a utility that contains all drawings produced by SunWater. This utility is called the Drawing Information System (DIS). The utility is an intranet based system that provides an extensive search facility (Figure 4.2).



Search for Drawings

To search for a drawing (or a series of drawings) within the system, simply use the following fields to specify your search query and click on the "Search Drawings" button to perform the search.

Drawing Search

? Search For Drawing
? Drawing Number: to
? Project Level 1: or -- All Projects --
? Title:
? Drawing Remarks:
? Drawn By:
? Topic:
? Supplementary No:
? Other Origin:
? Superseded By:
? Media Type:
? Approved By: (Note: This will only work for drawings approved in this system)
? Operational Status: All
? Operational Flag: -- All --
? Current Status: ☑ Approved ☐ Cancelled
☑ In Progress ☑ Pending Revision
☑ Reserved ☐ Superseded
? Display Nested Results: No
? Super Search:

Figure 4.2 – DIS Search Facility (SunWater 2010)

Initially, a global search was performed on ‘pig’ and ‘swab’ using the ‘Title’ search facility. This returned a list of all pipelines that contained drawings with titles incorporating the search words. Using the system, each pipeline was analysed, on a number of levels, to search for the required drawings. Once this search parameter had been exhausted, another search was carried out using the DIS.

This time the search was for every pipeline owned by SunWater within the system, regardless of whether or not it had pigging infrastructure. A stock take was undertaken, eliminating all pipelines in the search results that had been previously evaluated. From here, each remaining pipeline was analysed, on a number of levels, to ensure that no pipeline containing any form of pigging infrastructure was missed. If the result was positive, i.e. pigging infrastructure was found, the appropriate drawings were obtained.

Obtaining the drawings for pipelines that are external to SunWater was a different process. Before any search could be conducted, the pipelines to be examined had to be determined. This was done via consultation with senior members of SunWater's design team. A number of organisations were identified that own and operate water delivery pipelines. SunWater has and/or continues to have a working relationship with each of the selected organisations. Through these working relationships, drawings for some of the pipelines had already been obtained from the relevant organisation and included in the DIS.

For these particular pipelines a search was conducted in much the same way as that for the SunWater owned and operated pipelines. For collection of drawings for the remaining externally owned and operated pipelines, communication lines were established with each particular organisation. It is through these lines of communication that the required drawings were sought.

At the end of the search a total of 16 pipelines were investigated from five different organisations. The names of those organisations and their associated pipelines are as follows:

SunWater (and its subsidiaries)

- Awoonga Callide Pipeline (Inc. Duplication)
- Blackwater Pipeline
- Burdekin Moranbah Pipeline
- Eungella Water Pipeline
- EWP Eastern Extension
- EWP Southern Extension
- Newlands Pipeline

- Stag Creek Pipeline
- Stanwell Pipeline
- Tarong Pipeline
- North West QLD Water Pipeline

BHP Mitsubishi Alliance (BMA)

- Bingegang Pipeline

WA Water

- Perth Collector Bore Main
- Perth to Kalgoorlie Pipeline

Goulburn Murray Water

- Sugarloaf Line

Coliban Water

- WWMC to Bendigo Line

As previously stated, not all of the desired drawings could be obtained for every pipeline. Several of the pipelines in fact yielded none of the required drawings. The majority of these pipelines being the ones owned and operated externally to SunWater. However, although not all of the desired drawings could be obtained, enough were obtained to give a reliable cross section of current pigging infrastructure arrangements.

4.2 Questionnaire Development

The second stage involved the development of a questionnaire. The questionnaire was developed for use in the operator survey (Section 4.3). It was developed to use as a guide in the survey stage of the investigation. This was to ensure that the information being gathered was uniform across the board.

The format adopted for the questionnaire was based on a template from SunWater's standard forms and templates. The template was easily adapted to better suit the requirements of the survey. Extra prompts for details were added and the existing core topics were altered to suit. Also provided within the original template was room to record answers to the questions during the survey.

The questionnaire was structured so that the questions would follow on from one question to the next. In depth or lengthy questions were avoided. The aim being to focus on a small number of key areas directly related to the project objectives.

The questions themselves focused on a number of aspects of pipeline pigging. Those aspects included:

- frequency of the pigging process;
- operational procedures for the pigging process;
- the infrastructure provided for the pigging process.

As well as these specific pipeline pigging related questions, some general questions were also included in the questionnaire. These questions were to do with pipeline details (diameter, length etc.), the interviewee's details and experience in the industry and the source water quality. A copy of the final questionnaire is included as Appendix B.

4.3 Operator Survey

Given the development of a questionnaire, the next stage was to conduct a survey. The survey sought to gather information pertaining to the opinions of operations staff about the pigging process they are involved in and more importantly the infrastructure they are required to use. The survey entailed interviewing a range of people involved in pigging operations. The people interviewed included:

- pipeline operators;

- operations supervisors;
- pigging contractors.

Again the pipelines involved in the survey came from both within SunWater's network as well as several external to SunWater's operations. The range of organisations and number of pipelines included as part of the survey was similar to that for which drawings were sought.

Each interview was either undertaken via a face-to-face meeting or a phone conversation. Although a face-to-face meeting was preferential, the majority of cases were a phone conversation. There were a number of reasons for this:

- limited amount of time;
- limited budget;
- long distances between operational areas.

In either case, face-to-face or over the phone, each interview followed through the questions on the questionnaire. Where necessary the interviews diverged from the formal set of written questions. As the interview was conducted, the responses of the interviewees were recorded straight onto the questionnaire itself.

Within SunWater the participation in the survey was reasonable. Of the 11 pipelines incorporating pigging infrastructure that SunWater owns and operates, questionnaires were completed for six. In addition, one of the pigging contractors regularly used by SunWater also participated in the survey. Their insight was invaluable given the experience they had and variety of infrastructure they had worked with.

Willingness to participate in the survey by the organisations outside of SunWater was also reasonable. All but two of the companies made time to answer and discuss the survey questions. Table 4.1 summarises the information gathered via the survey.

Table 4.1 – Survey Results Summary

ORGANISATION	PIPELINE	INFRASTRUCTURE DESCRIPTION	OPERABILITY	WHS RISKS
SunWater	Burdekin Moranbah	Above Ground	N/A	N/A
	Eungella Water	In a Pit	N/A	N/A
	EWP Eastern	Above Ground	N/A	N/A
	EWP Southern	Semi Pit	N/A	N/A
	Newlands	In a Pit	Poor	High
	Stanwell	In a Pit	Satisfactory	High
BMA	Bingegang	In a Pit	Satisfactory	High
WA Water	Perth Collector	In a Pit	Satisfactory	High
	Perth to Kalgoorlie	N/A	N/A	N/A

The operability rating provided in the table has been determined based on the comments received in the survey. WHS risk ratings provided in the table associated with each pipeline's infrastructure have also been based on comments received in the survey.

Four of the six pipelines owned and operated by SunWater that participated in the survey have never been pigged. Three of these four pipelines were constructed in the last five years, while the remaining pipeline is approximately 15 years old. Operability and WHS ratings have not been given to these pipelines as the infrastructure has never been used.

Of the two remaining SunWater owned and operated pipelines one is regularly pigged, while the other is infrequent. Both pipelines contain pigging infrastructure housed in a pit and both have inherent WHS issues. Operation of the two arrangements varies. One requires the unbolting of several flanges, which is very time consuming. The other incorporates couplings that are easily removed and reinstated. The pipeline frequently pigged is done so internally by SunWater staff while the other is undertaken by a contractor.

The particular contractor used by SunWater was also contacted and participated in the survey. They provided details of the particular pigging operation undertaken on the SunWater owned and operated pipeline. Also discussed were their thoughts on other pigging operations they have undertaken, specifically the different infrastructure types they have encountered.

Of the three pipelines external to SunWater's operation that participated in the survey, two were regularly pigged while one had never been pigged. The pipeline that had never been pigged was not given an operability or WHS rating, similar to that for the SunWater pipelines that had not been pigged.

Both of the externally owned pipelines that are regularly pigged contain infrastructure housed within a pit. Like that for the SunWater owned and operated pipelines there were inherent WHS issues. The completed questionnaires for each interview undertaken are included as Appendix C.

4.4 Standard Arrangement Development

The purpose of the preceding three activities was to gather information on current pigging practices and the infrastructure used as part of those practices. All of that information was then to be used to develop a number of 'standard' arrangements for pig insertion and/or removal structures. The differing 'standard' arrangements were to cater for differing levels of use of the infrastructure.

To determine the different 'standard' arrangements to be adopted for the project the existing infrastructure arrangements had to be grouped. This grouping or categorising was done according to the infrastructure's general arrangement drawing. The infrastructure arrangements that were similar were grouped together. This would eventually lead to a small number of conceptually different infrastructure layouts. These layouts formed the basis for the adopted ‘standard’ general arrangements.

Within each group or category of infrastructure, variations existed in the detail or delivery of the concept. For the purpose of this project, a single general arrangement had to be established for each group. This was achieved using the comments from the survey previously conducted (Section 4.3).

Each existing infrastructure arrangement contained specific comments from the survey. These comments were sorted into the same groups as the infrastructure they relate to. That information was then collated within each group. The end result was a number of categories or groups of infrastructure, each with several slightly varying infrastructure arrangements and their associated benefits or downfalls as described by the operators of the pipelines themselves.

For each of these groups, taking into consideration the existing arrangements and associated benefits or downfalls of each, a single arrangement was decided upon. This arrangement was then drafted as a ‘standard’ drawing for inclusion in the ‘Pigging Infrastructure Design Standard’ to be developed later in this thesis (Section 7.1).

The ‘standard’ drawings developed are not detailed design drawings ready for construction. They are general arrangement drawings, showing the arrangement and labelling significant features. The ‘standard’ drawings have been drafted for use in the conceptual and/or preliminary design stages of a pipeline project only. The ‘standard’ arrangement drawings should be detailed according to the pipeline design, at the detailed design stage of a pipeline project.

There were three distinct groups of existing infrastructure established. Those three groups were defined, for the purposes of this project, as:

- level one (add on);
- level two (below ground or a pit);
- level three (above ground).

4.4.1 Level One Infrastructure

Level one infrastructure is not specifically designed for the pigging process. It is designed as an 'add-on' for another piece of infrastructure in the pipeline design. It consists of two isolation valves and a dismantling joint. The arrangement itself will depend upon the infrastructure it is being 'added' to. The only requirement is that the dismantling joint is between the two isolation valves. Common infrastructure that this arrangement could be 'added' to include; isolation structures, non return structures, or as shown on the 'standard' general arrangement drawing, flow meter structures. The 'standard' general arrangement drawing is included as Appendix D.

The basic operational procedure requires the two isolation valves to be closed. The dismantling joint is then removed, after the section of pipe work between the two valves has been de-pressurised. The pig is then inserted into the pipeline and the dismantling joint is reinstated. The two isolation valves are then opened ready to launch the pig into the pipeline. There is no enlargement in the pipe work to insert the pig. There exists a requirement for the pig to be vacuum packed before it is inserted into the pipeline. As a consequence only urethane foams pigs can be used. The packaging is then broken before the pig is launched, eventually being eroded as the pig travels through the pipeline.

The general arrangement drawing also consists of an alternate arrangement. This is a slightly more dedicated arrangement for the pigging process; however it is still designed to be an 'add-on' for another piece of infrastructure. The basic operational procedure varies from that described above.

During normal operation the main line isolation valve is open and the remaining two are closed. The pig launcher is de-pressurised before removing the end cap. The pig is inserted and the cap is reinstated. Upstream of the pig launcher, the isolation valve is opened to fill the launch chamber. Once full, both the valves upstream and downstream of the pig launcher are fully opened. The main line isolating valve is then slowly closed to redirect the majority of flow through the pig launcher. As the flow through the launcher increases the pig is launched into the pipeline. The infrastructure valving is then returned to its configuration for normal operation.

This arrangement has been included to offer another option at this level of infrastructure for consideration during detailed design. For costing and analysis purposes of this project, the alternate arrangement is not considered.

4.4.2 Level Two Infrastructure

Level two infrastructure is specifically designed for the pigging process. It consists of a series of pipe fittings and valves. This particular arrangement is located in a pit below the natural surface level. The ‘standard’ general arrangement drawing is included as Appendix E.

The basic operational procedure requires the two isolation valves to be closed. The two couplings on either end of the pipe spool piece are loosened and pushed to the sides after de-pressurisation. The pipe spool piece is then removed. This arrangement does not include the facilities to roll the pipe spool piece to one side. It requires a crane to be on site to lift the pipe spool piece out of the pit. The pig is then inserted into the pipe spool piece, which is then reinstated. The two couplings are also then reinstated. Bypass pipe work around the two isolation valves is used to fill the small section of line containing the pipe spool piece. Once the line is full the two isolation valves are opened ready to launch the pig into the pipeline.

The pipe work arrangement itself could also be altered during detailed design. The extent of the alteration would depend on the location of the pigging infrastructure in relation to other infrastructure. Possibilities exist for the elimination of one of the isolating valves along with associated pipe work.

This arrangement, being a pit, has a number of inherent WHS issues. The first issue relates to access. Should a vertical ladder be included, as in the 'standard' general arrangement drawing, some form of fall arrest system will be required. The second issue relates to confined spaces, namely rescue of an injured person from the pit. Given the only access is a vertical ladder, rescue would be difficult. The issue of limited access is solved by having a crane (already on site to remove the pipe spool piece) and rescue gear (harness, stretcher etc.) on site during operation. An alternative to having a crane on site would be to install some form of permanent davit arm. Both of these issues will require further consideration during detailed design. For the purpose of this project an options analysis, completed as part of this research, proved the most economical option was the use of a crane.

4.4.3 Level Three Infrastructure

Level three infrastructure is also specifically designed for the pigging process. It too consists of a series of pipe fittings and valves. This particular arrangement, however, is located above ground. The 'standard' general arrangement drawing is included as Appendix F.

The basic operational procedure is almost identical to that of the level two infrastructure. It requires the two isolation valves to be closed. Once closed the isolated section of pipe work is de-pressurised. The coupling on one end of the pipe spool piece is loosened and pushed to the side and the flange on the other end is unbolted. The pipe spool piece is then removed. Unlike the level two infrastructure, this arrangement does include the facilities to roll the pipe spool piece to one side. The pig is then inserted into the pipe spool piece, which is then reinstated. The coupling is also then reinstated. Bypass pipe work around the two isolation valves are again used to fill the small section of line containing the pipe spool piece. Once the line is full the two isolation valves are opened ready to launch the pig down the pipeline.

The pipe work arrangement itself, like the level two infrastructure, could also be altered during detailed design. The extent of the alteration would again depend on the location of the pigging infrastructure in relation to other infrastructure. Possibilities also exist in this arrangement for the elimination of one of the isolating valves and its associated pipe work.

The main driver behind this arrangement is the elimination of the inherent WHS issues associated with the level two infrastructure. This is achieved by bringing the pipe work above ground. However, in doing this the issue of thrust is greatly increased. Thrust issues are solved by way of large concrete thrust blocks. Thrust block design has been considered as part of this research. Further design will be required at the detailed design stage of a project.

4.4.4 Thrust Block Design

To be able to do a complete analysis on level three infrastructure some form of thrust block design had to be undertaken. Thrust block design was only required on level three infrastructure. Thrust issues associated with level one infrastructure would be part of the design of the infrastructure it is being ‘added’ to. In level two infrastructure thrust issues are solved using the pit itself as the thrust block. For the purpose of this project a thicker, deeper wall on the upstream side of the pit was incorporated into the concrete volume calculation. Detailed design of the pit will require thrust issues to be considered further.

As part of this project, design of thrust blocks on level three infrastructure was purely to determine relative sizes for costing. SunWater's design library includes a spreadsheet that provides thrust block sizes based on a set of design criteria. The spreadsheet is designed for use in determining thrust block sizes for both horizontal and vertical bends along a pipeline. It is not specifically focused on the particular type of thrust block design encountered in the level three infrastructure, but for the purpose of this project it will provide adequate results. A copy of the completed thrust bock design spreadsheet is included as Appendix G.

The spreadsheet requires the input of the following pipeline parameters:

- soil bearing capacity (adopted as 100kPa);
- test head (m);
- invert elevation (m);
- nominal pipe diameter (mm);
- angle of the bend (°);
- height and width of the proposed thrust block.

Where thrust blocks were required to be designed they were done so based on the class of pipe being used. This meant that the test head adopted was the Allowable Operating Pressure (AOP) of the particular pipe class being used, as described in the Ductile Iron Pipeline Systems Design Manual (Tyco Flow Control Asia Pacific Group 2008). An invert elevation of 0.0 m was adopted in all design cases. This meant that the thrust blocks were being designed based on the pipeline operating at the maximum pressure that the pipe class being used could sustain. Effectively the thrust blocks have been very conservatively designed for the purpose of this project.

Pipe diameter varied throughout the analysis; however the angle of the bend in question was always 45 degrees, as per the 'standard' general arrangement drawing for level three infrastructure. Finally, the height and width adopted for the thrust blocks were:

Height = pipe diameter (mm) + 900 mm + 300 mm
Width = pipe diameter (mm) + 1000 mm

Height calculations were a sum of the pipe diameter, cover to natural surface (900 mm) and a set depth below the pipe (300 mm). The width calculation was a sum of the pipe diameter and a set distance either side of the pipe (500 mm).

Resultant thrust forces are calculated in the spreadsheet using the following formula, set out in Hardie's Textbook of Pipeline Design (James Hardie & Coy. Pty. Limited 1985):

$$\mathbf{R^1 = 1.541 \times 10^{-5} \times H \times D^2 \times \sin\theta/2}$$

where R^1 is the resultant thrust (kN);
H is the total head (m);
D is the pipe external diameter (mm);
θ is the angle of the bend (°).

This formula does not take into account the velocity of flow within the pipeline. It considers it as a small enough number to be negligible. Results of the design gave thrust block sizes ranging from 4.5 m^3 to 40.4 m^3. As previously stated, thrust block designs for the purpose of this project have been done so conservatively. Further consideration needs to be given to thrust issues at the detailed design stage of any pipeline project.

4.4.5 Workplace Health and Safety

With any project in this current age, design for WHS is essential and needs to be given careful consideration. Within SunWater a WHS Management System exists for use in all designs. As part of that management system, a flow chart of the design process for design for construction and end users is provided. This flow chart sets out the responsibilities of the different contributors to the design i.e. project manager, designer and end user. It shows what reviews are required, what part of the design process they should occur in and who should take part in the reviews.

There is also a hierarchy of controls that should be considered during design:

- Elimination;
- Substitution;
- engineering controls;
- administrative controls;
- protective equipment (PPE&C).

This hierarchy of controls should always be applied starting from the top (elimination) and working down to the bottom (protective equipment). A combination of these controls may be required.

For all work involved in this research project, both desktop and field related, a comprehensive risk assessment was undertaken. Resulting from that risk assessment was the development of a Work Method Statement (WMS). Both the risk assessment and WMS were developed using SunWater's WHS Policy (SunWater 2010). Copies of the risk assessment and WMS are included as Appendix H.

There are WHS issues associated with each infrastructure arrangement established as part of this project. The level two infrastructure is the most prone to WHS issues, and several of those have already been discussed (Section 4.4.2). One issue that is of concern for each level of infrastructure is access to the isolation valves for opening and/or closing. They are too high to access from floor level. In any level of infrastructure a platform could be constructed allowing appropriate access to the top of the valves. In the case of level two infrastructure, a spindle could be extended to the side of the pit.

A solution to this problem has not been incorporated onto the 'standard' arrangement drawings, it has merely been noted that there is a requirement for access to the top of the valves. For the purposes of this project this issue is common to all levels of infrastructure and the costs of negation of the issue would also be common. Therefore those costs have not been included as part of the analysis and would be another issue for detailed design.

An individual safe design review has been undertaken incorporating all levels of infrastructure as part of this project (Appendix H). However, due to recent re-structuring within the organisation, gaining access to a WHSO to assist with a safe design review was difficult. Regardless of this, incorporation of any level of infrastructure into a detailed design will require a full WHS risk assessment. That risk assessment will need to include a safe design review and will also require the input of not only a WHSO but operations and maintenance staff as well.

4.5 Summary

The qualitative side of the project was broken up into four parts; existing arrangements, questionnaire, survey and standard arrangement development. Infrastructure arrangements used in current practice were established. Those arrangements were then subjected to critical evaluation by way of a questionnaire based survey. The existing infrastructure were categorised based on their arrangement. A single standard arrangement was then developed from each of these categories.

In total three differing levels of infrastructure were established. For each arrangement a 'standard' general arrangement drawing was drafted. Basic operational procedures have also been outlined. All of the standard arrangements are conceptual only. The final infrastructure arrangement for construction will require detailed design.

Chapter Five - Stanwell Pipeline Pigging

One of the project objectives was to attend the pigging of a pipeline. The purpose of this objective was to gain practical experience in all aspects of the pigging process; ultimately leading to a better understanding of the process itself and the requirements of the infrastructure from an operations point of view.

At the beginning of July the opportunity arose to attend the pigging of Stanwell Pipeline. Stanwell Pipeline is one of SunWater's owned and operated pipelines. The pipeline is approximately 28 km in length and is located 20 minutes west of Rockhampton in Central Queensland. The pipeline's primary customer is the Stanwell Power Station.

Stanwell Pipeline is one of the more regularly pigged pipelines within SunWater's network. On average, this pipeline is pigged twice every year. As this is the case, the operations crew working on Stanwell Pipeline are one of the more experienced in the pigging process within SunWater. It is for this reason that Stanwell Pipeline was chosen as the best to attend as far as gaining a practical understanding of the pigging process is concerned.

The whole process took approximately three days. The first day involved travel to site and completing the necessary approvals and paper work to allow the pigging operation to happen. Customers also had to be contacted and made aware of the operation. Preparation of the pig also occurred on the first day. The pig used was a Metal Mandrel pig (Figure 5.1). Preparation of the pig involved replacing the four urethane discs on the pig and loading it onto a trailer for transport to site.

Figure 5.1 – Metal Mandrel Pig Used at Stanwell Pipeline

The second day was when the pigging process was undertaken. The process itself was very similar to that described in Section 2.1, with some minor variations to suit this particular pipeline. There were six operators involved in this particular pigging operation. Usually only four operators are required, but on this occasion there were two additional people who were there for training purposes. The pipeline was pigged as a single section and the entire operation ran smoothly with minimal interruptions. Figure 5.2 shows the pig exiting the pipeline.

Figure 5.2 – Pig Exiting Stanwell Pipeline

The third and final day included debriefing and analysis. The previous day's operation was discussed to identify any issues for future reference. The flow rate data was also checked to quantify the improvement in the pipeline's efficiency. Finally all photos were documented and saved and reports completed before travelling home.

The experience of witnessing a pigging operation was extremely beneficial. It reinforced existing knowledge of the process as well as identifying other minor but important aspects of the process not previously considered. It provided the opportunity to discuss the pigging process and its associated infrastructure with not only operational staff, but their supervisors as well. The experience gave an understanding of what is required out the infrastructure provided for the pigging process.

Chapter Six – Quantitative Research

The second part of the research focuses on the quantitative side of the problem (Figure 6.1). It involved a detailed analysis of the costs associated with each level of infrastructure developed in the first part of the research. The purpose of the analysis was to determine the total cost of each level of infrastructure over its design life. The total cost then being a direct link to the benefits, or savings, required from the pigging process for that level of infrastructure to be justified.

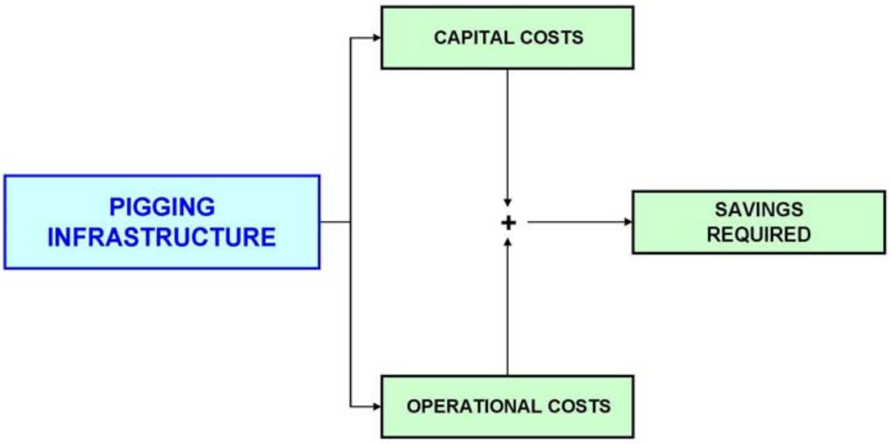


Figure 6.1 – Quantitative Aspects to be Considered

The analysis had three contributing factors. All three factors were used to develop a model (Section 6.4) for use in determining the total costs of the infrastructure over its design life. The three contributing factors are listed below and discussed in the following sections:

- capital costs;
- operational costs;
- an options analysis into various WHS & operational issues.

6.1 Capital Costs

The capital costs associated with pigging infrastructure are those costs involved in constructing the infrastructure in the first instance. There are a number of separate costs that when combined, will form the total capital investment:

- pipe work costs;
- valve costs;
- concrete and reinforcement costs;
- metal item fabrication costs;
- construction costs.

6.1.1 Pipe Work Costs

The pipe work costs include the costs associated with each and every piece of pipe work contained within a particular level of infrastructure. Not only are 'off the shelf' pipe fittings included, any pipe specials that are required are also included. This is the case for both the mainline diameter pipe work and any smaller pipe work involved in the arrangement, such as bypass pipe work.

'Off the shelf' pipe fitting costs were obtained directly from a supplier. Two Ductile Iron Cement Lined (DICL) pipe suppliers were contacted and both provided budget prices for the particular pipe fittings requested. The first supplier provided costs for both the PN20 and PN35 pipe work. The second only provided costs for the PN20 pipe work. Of the two, the prices the second supplier provided were deemed to be the most accurate. As they did not provide costs for the PN35 pipe work some form of interpolation was required. The costs provided by the first supplier, showed on average a ten percent increase in price between the PN20 and PN35 pipe work. This percentage increase was adopted and applied to the PN20 pipe work costs provided by the second supplier to obtain P35 pipe work costs.

Other costs, such as air valve arrangement and pipe special fabrication costs were extracted directly from previous project actual costs (projects undertaken by SunWater). Where direct costs could not be obtained they were interpolated from the costs of the same pipe work of a different diameter. The interpolation was undertaken using the ‘trend line’ feature contained within Microsoft Excel. Known costs were plotted against pipeline diameter and a trend line fitted to the curve. The trend line used was either linear or polynomial. The equation for that line was then used to determine the unknown costs. An example of such is shown in Figure 6.2. All pipe fitting costs include the costs of associated bolt and gasket sets.

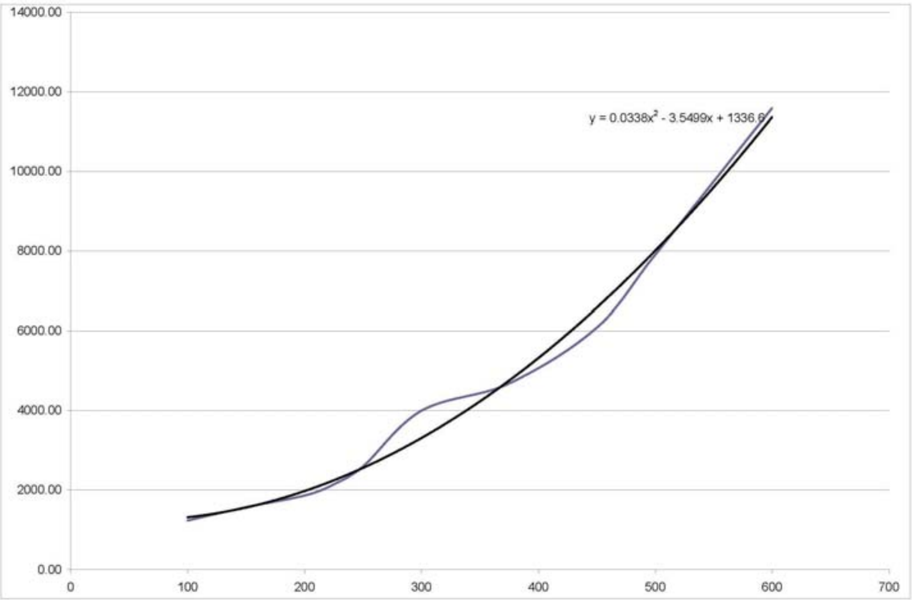


Figure 6.2 – Pipe Fitting Costs Interpolation

6.1.2 Valve Costs

Valve costs are simply the total cost of all valves within the arrangement. This includes all main line isolation valves, bypass valves, drain valves and any other valves associated with operation of the infrastructure. This does not include air valves which are factored into the pipe work costs.

Valve costs were determined in the same way as the 'off the shelf' pipe fitting costs; they were obtained directly from a supplier. Where interpolation was required it was done so in the same manner as that for the pipe work costs. The valve costs, as with the pipe fittings costs, include the cost of all necessary bolt and gasket sets.

6.1.3 Concrete and Reinforcement Costs

All concrete and reinforcement costs were based on a per cubic metre rate. The concrete and reinforcement costs do not include costs associated with thrust blocks. Costs associated with thrust blocks have been included in the construction costs. The cubic metre rate accounts for all costs associated with the construction of a reinforced concrete structure, including:

- Excavation;
- form work material and erection;
- reinforcement supply and tying;
- concrete supply and pouring;
- all other miscellaneous costs associated with a concrete structure itself.

The rate adopted for this analysis was $2,500.00 per cubic metre. This figure has been adopted within SunWater for use in cost estimates. Outside of this project, an analysis was undertaken by one of SunWater's internal construction supervisors. The analysis revealed the adopted rate to be quite accurate and hence sufficient for use in cost estimates. Provided the same unit rate is applied consistently, a credible cost comparison will be achieved.

6.1.4 Metal Item Fabrication Costs

The costs associated with metal item fabrication vary depending on the amount and type of metal fabrication that is required for a particular arrangement. Metal items that are common on pipeline pigging infrastructure include:

- ladders;
- handrails;
- pipe supports;
- pipe spool roll out arrangements.

The costs associated with fabrication of these metal items have been determined in one of two ways. The preferred method was to extract fabrication costs directly from previous project actual costs (projects undertaken by SunWater). Where applicable, the extracted costs were turned into a per metre rate and applied to the metal items of the various pipe diameters. This approach was adopted for ladders and handrails. Where direct costs could not be obtained a conservative lump sum figure was applied. This approach was adopted for pipe supports and pipe spool roll out arrangements. Costs associated with these two items are generally constant regardless of diameter. The following illustrates the rates and lump sum values adopted:

- ladders = \$500.00/m;
- handrails = \$105.00/m;
- supports = \$1000.00 each;
- roll out rail arrangement = \$1000.00 each.

6.1.5 Construction Costs

Construction costs encompass any other costs associated with the construction of the infrastructure not yet already considered. The following is a list of those costs:

- labour;
- plant/machinery;
- miscellaneous items;
- thrust blocks.

Both labour costs and plant/machinery costs were considered as a daily rate. The constituents of that daily rate were simply an hourly rate multiplied by the number of hours worked in a day. For the purpose of this project both labour and plant/machinery daily rates were based on a ten hour day.

Individual items of plant/machinery were allocated hourly rates. The hourly rates came directly from the relevant plant/machinery operators that are used by SunWater. The labour consisted of three items:

- four labourers @ $100/hr/person;
- one supervisor @ $125/hr;
- accommodation and meals @ $200/night/person.

Both the labour and supervisor rates are based on SunWater's existing internal charge out rates. The accommodation and meal allowance was based on rates provided in SunWater's Travel Allowance Policy (SunWater 2010).

The miscellaneous costs are made up of a number of small items that are required during the construction process. They are generally items that can be purchased at a local hardware store. The rate adopted for this aspect was a lump sum based purely on previous experience.

Thrust block costs are similar to the concrete and reinforcement costs in that they are also based on a per cubic metre rate. Like the concrete and reinforcement rate it accounts for all materials, plant/machinery and labour required for construction. The rate adopted was $1,500.00 per cubic metre. A lower rate has been adopted for thrust blocks than structural concrete due to thrust blocks being primarily mass concrete. The reinforcing in thrust blocks is minimal compared to that of structural concrete.

6.2 Operational Costs

The operational costs are costs associated with the undertaking of the pigging process itself. These are purely a summation of resource costs. The only material cost incurred is the cost of the pig itself. There are two resources used in the pigging process:

- Labour;
- plant/machinery.

Both labour costs and plant/machinery costs were considered as a daily rate. The constituents of that daily rate were simply an hourly rate multiplied by the number of hours worked in a day. Again, for the purpose of this project both labour and plant/machinery daily rates were based on a ten hour day.

There is only a small amount of plant/machinery required for the pigging process. Where it was required it was allocated an hourly rate that came directly from the relevant plant/machinery operators that are used by SunWater.

The labour costs for the purpose of this project were based on the process requiring four people. An electrician for all isolations and operating the pumps, one person tracking the pig, one person ahead of the pig closing off-takes and another person behind the pig reopening off-takes.

The daily rate for the labour consisted of:

- four labourers @ $100/hr/person;
- accommodation and meals @ $200/night/person.

The labour rate is again based on SunWater's existing internal charge out rates. The accommodation and meal allowance was also again based on rates provided in SunWater's Travel Allowance Policy (SunWater 2010).

The cost of the pig used in the pigging process will also vary depending on the type of pig used. However, for the purpose of this project the cost of the pig was taken as being common to all infrastructure levels and therefore not included as part of the analysis.

6.2.1 Present Value

In calculating the total operational costs over the design life of a pipeline, the Present Value (PV) of those operational costs has been used. To determine the PV of the operational costs the PV function within Microsoft Excel has been used.

The PV function works on a number of variables:

- interest rate;
- number of payment periods;
- the payment value;
- the expected future value (at end of last payment period);
- either payment at the beginning of end of the period.

For the purposes of this project an interest rate of six percent has been adopted. The number of payment periods is 20, based on the design life of the pipeline (20 years) with only one payment per period. Payment value varied depending on the analysis being undertaken. The expected future value was always considered to be \$0 and the payment was always made at the end of the payment period.

The formula the PV function within Excel uses in the calculation is as follows:

$$\mathbf{pv\ (1 + rate)^{nper} + pmt\ (1 + rate + type) \times \{[(1 + rate)^{nper} - 1]/rate\} + fv = 0}$$

where pv is present value;
rate is the interest rate (%);
nper is the number of payment periods;
pmt is the payment per period (\$);
type is either 1 for the beginning of the period or 0 for the end;
fv is the future value (\$).

6.3 Options Analysis

During the ‘standard’ arrangement development there were a number of operational and WHS issues to be considered. As such, the solutions to these issues had the potential to impact upon one another. To ensure that there was no duplication in the solutions to these issues, an options analysis was undertaken. This options analysis determined the most economical solution for these issues.

The overlapping issues involved the access and egress of the infrastructure and the method in which dismantled pipes could be removed. The different solutions to the problems were costed using information sought from suppliers. These costs were then compared for a number of scenarios to determine the most economical method of solving the issue.

The options analysis only applied to the level two and three infrastructure. Due to the arrangement being completely different, the level one infrastructure did not have the same issues as the other two levels of infrastructure. To begin the analysis, the different issues were considered and all possible solutions to the individual issues were then recorded. Against each solution, its associated costs (over the design life of the pipeline) were determined, as shown below:

Level Two Infrastructure

• Access	Stairs	$48,000.00
	Vertical Ladder (Inc. Fall Arrest)	$12,800.00
• Confined Space – Rescue	Davit Arm or Similar	$20,000.00
	Crane (PV)	$9,800.00
	Stairs	As Above
• Spool Removal	Crane (PV)	As Above
	Roll Out Arrangement	$1,000.00

The level three infrastructure was only concerned with the pipe spool removal for which the options and associated costs are shown above. Once all individual costs had been determined, the various solution combinations were established and total costs calculated. Table 6.1 summarises those combinations and their associated total costs. The complete options analysis is included as Appendix I.

Table 6.1 – Options Analysis Summary

Infrastructure Level	Option	Total Cost (Over Design Life)
Level Two	Stairs/Crane	$58,000.00
	Stairs/Roll Out	$49,000.00
	Ladder/Davit/Roll Out	$34,000.00
	Ladder/Crane	$23,000.00
Level Three	Roll Out	$1,000.00
	Crane	$10,000.00

Under the level two infrastructure, the first option uses stairs for access and egress and a crane to remove the pipe spool piece. The second option again uses stairs for access and egress, but a roll out arrangement for pipe spool removal. The third option adopts a vertical ladder (complete with fall arrest system) for access and egress. It incorporates a davit arm for confined space rescue and the roll out arrangement for the pipe spool. The final option again uses the vertical ladder and fall arrest system, but adopts a crane for both pipe spool removal and confined space rescue. The level three infrastructure options are simply a comparison between the roll out arrangement and the use of a crane for pipe spool removal.

In all options that use a crane, the costs shown represent the PV of the costs associated with that crane over the 20 year design life. For more detail on the PV calculation refer to Section 6.2.1.

For the pipe spool removal in the level three infrastructure, adopting the crane approach is extremely expensive compared to the roll out arrangement. The roll out arrangement is by far the most cost effective option and was adopted. However, this is not the case for the level two infrastructure. Together with the installation of vertical ladders (complete with fall arrest systems), using a crane for the removal of the pipe spool is the most cost effective option. It is more cost effective in this instance than the roll out arrangement as the crane can perform two duties. It can be used for removal of the pipe spool piece, as well as a rescue device given the confined space. This in turn eliminates the requirement for a davit arm and hence the costs associated with it. Not having a pipe spool roll out feature will also allow the pit size to be reduced, with resulting savings in concrete and construction costs.

The option of installing stairs instead of a ladder eliminates the requirement for any form of rescue device. However the cost of the stairs, as shown, is significantly higher than that of the ladder. This is due to the stairs requiring the pit to be much wider. Therefore, there is not only the cost of the stairs themselves to consider, but the cost of the extra pit width.

Options presented above enable the calculation of the capital and operational costs of each level of infrastructure for the purpose of this project. There are a number of different issues to be considered regarding WHS in the design of any infrastructure. These options should be considered in depth as part of detailed design and its associated risk assessments. The hierarchy of controls for WHS (Section 4.4.5) should be followed i.e. the primary solution should be elimination. If the most appropriate control is an engineering control, as discussed above, administrative and PPE&C controls should also be put in place during operation i.e. WMS.

6.4 Modelling

A model was developed in order to process all of the costing information. This model was used to determine the total capital investment and the operational costs of a particular level of infrastructure, for a particular pipe class, over the pipelines design life. The model itself was a Microsoft Excel based system. A copy of the bare model is included as Appendix J.

Throughout the model, the spreadsheet cells are colour coded. Green cells represent rates or costs that have been manually added. Red cells are cells that require information to be entered depending on the type of infrastructure being assessed. Blue cells contain formulas that automatically populate once all of the red cells have been populated. In total the model consists of 11 workbooks or sheets within Excel:

- Interface;
- Capital Costs;
- Operational Costs;
- Total Costs;
- Working;
- PN20 Pipe Costs;
- PN35 Pipe Costs;
- Pipe Dimensions;
- Concrete-Metal;
- Construction;
- Operation.

The Interface is the results sheet of the model. It shows the capital and operational costs of the infrastructure over the pipe diameter range, as well as the total costs of the infrastructure over the pipeline's design life. Due to the way the model has been constructed, some manipulation of data is required each time the model is used. The amount of manipulation required depends on the type of infrastructure being assessed.

The Capital, Operational and Total Costs sheets contain graphs showing the results from the Interface sheet. The results are graphed using an XY plot over the pipe diameter range. The Capital and Operational graphs show the capital and operational cost results respectively. The Total Costs graph shows the combined capital and operational cost results. These sheets are set to populate automatically and require no manipulation.

The Working sheet is used to calculate the concrete volumes (excluding thrust blocks) associated with each type of infrastructure. Volumes are determined automatically using formulas and take into consideration the pipe work in the arrangement and the main pipe diameter. Again there is no manipulation required in this sheet. The concrete volume calculations assume several dimensions (where applicable):

- a clear width between the pipe and concrete wall of 800 mm;
- wall thicknesses of 500 mm (thrust bearing wall) and 300 mm (all other);
- floor thickness of 300 mm;
- pipe cover of 900 mm;
- a clear height between the pipe and floor of 300 mm;
- a finished height above natural surface of 200 mm or 50 mm (depending on the infrastructure).

The PN20 Pipe Costs and PN35 Pipe Costs sheets, as their names suggest, contain the all of the individual pipe fitting costs. They also contain the respective valve costs. Again, as the name suggests, the Pipe Dimensions sheet contains all of the necessary dimensions of the individual pipe fittings. All of the dimensions have been sourced directly from the Ductile Iron Pipeline Systems Design Manual (Tyco Flow Control Asia Pacific Group 2008). No manipulation is required in any of these sheets.

The Concrete-Metal sheet contains the cubic metre rate for reinforced concrete (excluding thrust blocks). It also contains all of the metal item costing information. The metal items cells contain both rates and formulas, however, again there is no manipulation required.

Contained within the Construction sheet are all of the construction costs. The majority of this sheet contains formulas and rates. The units of the rates do vary. Unlike most of the other sheets in the model, this sheet does require manipulation during the modelling process. The manipulation required pertains to the population of quantities depending on the infrastructure level being modelled.

The final sheet in the model, Operation, contains all of the costs associated with the pigging process, or operational costs. This sheet is very similar to the Construction sheet. It contains mainly formulas and rates. Manipulation is also required within this sheet when modelling. Again that manipulation involves the population of quantity cells.

The model could not take into account every possible variable. It is for this reason a number of assumptions were required, and have been based on previous knowledge and common practice in the design of water pipelines within SunWater. Assumptions made relating to the modelling of the infrastructure costs were as follows:

- all infrastructure pipe work is DICL;
- a pigging frequency of one event per year;
- a pipeline length of less than 25km*;
- a design life of 20 years;
- design costs associated with the infrastructure have not been considered;
- drainage of the infrastructure has not been considered.

* Pipelines greater in length than 25km are pigged in sections, thus requiring more infrastructure. In essence, this assumption only allows for one insertion structure and one removal structure per pipeline.

6.4.1 Level One Infrastructure (PN20 Pipe Class)

The construction costs for the level one infrastructure (PN20 pipe class) were based on the quantities illustrated in Figure 6.3.

					375	450	500	600	750
		Rate	Unit	Quantity	Total				
Labour									
	Four Men	$ 4,000.00	day	1	$ 4,000.00	$ 5,540.00	$ 6,600.00	$ 8,720.00	$ 12,000.00
	Supervisor	$ 1,250.00	day	1	$ 1,250.00	$ 1,731.25	$ 2,062.50	$ 2,725.00	$ 3,750.00
	Accomodation/Meals etc.	$ 1,000.00	day	1	$ 1,000.00	$ 1,385.00	$ 1,650.00	$ 2,180.00	$ 3,000.00
Plant									
	Franna Crane	$ 2,500.00	day	1	$ 2,500.00	$ 3,462.50	$ 4,125.00	$ 5,450.00	$ 7,500.00
Materials									
	Miscellaneous	$ 200.00	lump sum	1.00	$ 200.00	$ 277.00	$ 330.00	$ 436.00	$ 600.00
Thrust Blocks		$ 1,500.00	m^3		$ -	$ -	$ -	$ -	$ -

Figure 6.3 – Construction of Level One Infrastructure (PN20)

Based on a ten hour working day, as discussed in Section 6.1.5, it was determined that a total of one day would be required to construct this level of infrastructure for a 375 mm diameter pipeline. Through consultation with senior design and construction staff within SunWater it was determined that for a 750 mm diameter pipeline, it would take three times as long to construct the infrastructure. The multiplication factor for the intermediate pipeline diameters was then determined using interpolation. The interpolation was based on a linear trend line of the following equation:

$$\mathbf{y = 0.005x - 0.75}$$

where y is the multiplication factor;
x is the pipe diameter (mm).

The miscellaneous costs, as discussed in Section 6.1.5, have been assigned a lump sum value. This value has been adopted using previous experience in construction. The same interpolation has been used over the full pipe diameter range. Finally, no thrust block costs have been included. Costs associated with any thrust issues will have been accounted for in the design of the infrastructure that the level one pigging arrangement is being 'added' to.

To put it another way, the issue of thrust on the piece of infrastructure that the level one arrangement is being 'added' to would still exist even if the level one arrangement was not 'added' to it. Therefore the costs associated in solving any thrust issues are part of the piece of infrastructure the level one arrangement is being ‘added’ to and not the level one infrastructure itself.

The operational costs for the level one infrastructure (PN20 pipe class) were based on the quantities illustrated in Figure 6.4.

					750	375	450	500	600
		Rate	Unit	Quantity	Total				
Labour									
	Four Men	$ 4,000.00	day	3	$ 12,000.00	$ 9,600.00	$ 10,200.00	$ 10,800.00	$ 11,400.00
	Accomodation/Meals etc.	$ 800.00	day	2	$ 1,600.00	$ 1,280.00	$ 1,360.00	$ 1,440.00	$ 1,520.00
Plant									
	Franna Crane	$ 2,500.00	day	1	$ 2,500.00	$ 2,000.00	$ 2,125.00	$ 2,250.00	$ 2,375.00

Figure 6.4 – Operation of Level One Infrastructure (PN20)

Also based on a ten hour working day, it was determined that for a 750 mm diameter pipeline using level one infrastructure, the pigging process would take three days. It was concluded that the operational costs would only slightly vary over the diameter range. The only difference would be in the time taken to remove and reinstate the extra bolts in each flange set. It was therefore decided to base the operational costs for the remainder of the diameter range on a five percent decrease i.e. each time the diameter reduced the operational costs would reduce by a factor of 0.05.

The three days allowed for the pigging process includes the time taken to complete everything from the development of work method statements and other related paperwork, the pigging operation itself through to the final reporting at the end of the process.

Of the three levels, it has been determined that the level one infrastructure requires the most time to undertake the pigging process. This is due to a number of factors:

- there is no specialised launch chamber;
- to insert the pig a dismantling joint has to be removed. This involves removing and reinstating the bolts from two sets of flanges;

- no enlargement is provided in the arrangement. Therefore the pig has to be vacuum packed (Section 4.4.1) to be able to be inserted it into the pipeline.

The crane is required for only one day. Its sole job is to lift the dismantling joint out of and back into place. The crane does not have to be on site while the pig is travelling through the pipeline. Two nights of accommodation and meals assumes that all personnel travel to site on the first morning and return home on the third afternoon. Thus there is only a requirement for two nights.

The results of the model created for level one infrastructure using a pipe class of PN20 are contained within Table 6.2. The full model is included as Appendix K.

Table 6.2 – Level One (PN20) Analysis Results

Costs	Diameter (mm)				
	375	450	500	600	750
Capital	$51,000	$76,000	$97,000	$121,000	$188,000
Operational	$163,000	$173,000	$183,000	$193,000	$203,000
Total	$214,000	$249,000	$280,000	$314,000	$391,000

In determining the total capital costs two pieces of infrastructure have been included, a pig insertion structure and a pig removal structure. The total operational cost accounts for all of the operational costs over the entire design life of the pipeline. The PV of those operational costs has been calculated and adopted. It was determined on an interest rate of six percent over the 20 year design life. A ten precent contingency has also been added to both the capital cost and the operational cost of the infrastructure.

The results show quite a large increase in total costs from the lower end of the diameter range to the upper. Of the three levels of infrastructure, level one has the lowest capital investment over the entire diameter range. Given the minimal amount of material and construction effort required this comes as no surprise. On the other hand, as previously discussed, level one infrastructure requires the largest effort operationally. Consequently it also has the largest costs associated with operation of the three levels.

6.4.2 Level Two Infrastructure (PN20 Pipe Class)

The construction costs for the level two infrastructure (PN20 pipe class) were based on the quantities illustrated in Figure 6.5.

					375	450	500	600	750
		Rate	Unit	Quantity	Total				
Labour									
	Four Men	$ 4,000.00	day	4	$ 16,000.00	$ 22,160.00	$ 26,400.00	$ 34,880.00	$ 48,000.00
	Supervisor	$ 1,250.00	day	4	$ 5,000.00	$ 6,925.00	$ 8,250.00	$ 10,900.00	$ 15,000.00
	Accomodation/Meals etc.	$ 1,000.00	day	4	$ 4,000.00	$ 5,540.00	$ 6,600.00	$ 8,720.00	$ 12,000.00
Plant									
	Franna Crane	$ 2,500.00	day	4	$ 10,000.00	$ 13,850.00	$ 16,500.00	$ 21,800.00	$ 30,000.00
Materials									
	Miscellaneous	$ 1,000.00	lump sum	1.00	$ 1,000.00	$ 1,385.00	$ 1,650.00	$ 2,180.00	$ 3,000.00
Thrust Blocks		$ 1,500.00	m^3		$ -	$ -	$ -	$ -	$ -

Figure 6.5 – Construction of Level Two Infrastructure (PN20)

Based on a ten hour working day, as discussed in Section 6.1.5, it was decided that a total of four days would be required to construct this level of infrastructure for 375 mm diameter pipelines. Again, it was adopted that level two infrastructure on a 750 mm diameter pipeline would take three times as long to construct. The interpolation of the multiplication factor for the diameters in between was the same as that described for the level one infrastructure (Section 6.4.1).

The lump sum value adopted for the miscellaneous items in this level of infrastructure is greater than that of the previous level. This is due to the large increase in complexity of the arrangement. The value adopted has again been done so based on previous experience in construction. The same interpolation has been adopted over the diameter range. Finally, no thrust block costs have been included. Costs associated with any thrust issues will have been accounted for in the design of the pit this level of infrastructure is situated in.

The operational costs for the level one infrastructure (PN20 pipe class) were based on the quantities illustrated in Figure 6.6.

					750	375	450	500	600
		Rate	Unit	Quantity	Total				
Labour									
	Four Men	$ 4,000.00	day	2.5	$ 10,000.00	$ 8,000.00	$ 8,500.00	$ 9,000.00	$ 9,500.00
	Accomodation/Meals etc.	$ 800.00	day	2	$ 1,600.00	$ 1,280.00	$ 1,360.00	$ 1,440.00	$ 1,520.00
Plant									
	Franna Crane	$ 2,500.00	day	0.5	$ 1,250.00	$ 1,000.00	$ 1,062.50	$ 1,125.00	$ 1,187.50

Figure 6.6 – Operation of Level Two Infrastructure (PN20)

Also based on a ten hour working day, it was determined that for a 750 mm diameter pipeline using level two infrastructure the pigging process would take two and a half days. Again the operational costs would only slightly vary over the diameter range and hence the same reduction factor of 0.05 has been adopted as that for level one infrastructure.

The two and a half days again allows for everything from the development of work method statements and other related paperwork, the pigging operation itself through to the final reporting at the end of the process.

Level two infrastructure, of the two levels discussed thus far, requires the least amount of time to undertake the pigging process. This is due to the ease of removal of the pipe spool piece. Only two couplings (4-6 bolts) have to be removed and then reinstated. There is also a specialised launch chamber in this arrangement that does enlarge i.e. the pig can be inserted straight into the pipeline with ease.

The crane is required for only half a day. Although for this level of infrastructure it serves two purposes. The first is similar to the level one arrangement, lifting the pipe spool out of and back into place. The second is to act as a rescue device should it be required. Due to the process of removing the pipe spool only requiring two couplings to be un-bolted, the amount of time the crane is on site is reduced. Again the crane is not required while the pig travels through the pipeline. Two nights of accommodation and meals assumes that all personnel will travel to site on the morning of the first day and return home in the early afternoon of the third. Thus there is still the requirement for two nights.

The results of the model created for level two infrastructure using a pipe class on PN20 are contained within Table 6.3. The full model is included as Appendix L.

Table 6.3 – Level Two (PN20) Analysis Results

Costs	Diameter (mm)				
	375	450	500	600	750
Capital	$276,000	$352,000	$421,000	$523,000	$701,000
Operational	$130,000	$138,000	$146,000	$154,000	$162,000
Total	$406,000	$490,000	$567,000	$677,000	$863,000

Calculation of the total capital costs again includes two pieces of infrastructure. The operational costs are again over the entire design life of the pipeline based on their PV. A ten percent contingency has also been added to both the capital costs and the operational costs.

The results show an even larger increase in total costs from the lower end of the diameter range to the upper than that of the level one infrastructure. Of the two levels of infrastructure assessed thus far, level two has by far the highest total costs over the entire diameter range. It is the capital cost of this infrastructure that sees it the most expensive thus far, given the large increase in complexity of the level two arrangement.

As previously discussed, level two infrastructure requires less effort operationally than that of the level one. As a consequence it has lower costs associated with its operation.

6.4.3 Level Three Infrastructure (PN20 Pipe Class)

The construction costs for the level three infrastructure (PN20 pipe class) were based on the quantities illustrated in Figure 6.7.

					375	450	500	600	750
		Rate	Unit	Quantity	Total				
Labour									
	Four Men	$ 4,000.00	day	6	$ 24,000.00	$ 33,240.00	$ 39,600.00	$ 52,320.00	$ 72,000.00
	Supervisor	$ 1,250.00	day	6	$ 7,500.00	$ 10,387.50	$ 12,375.00	$ 16,350.00	$ 22,500.00
	Accomodation/Meals etc.	$ 1,000.00	day	6	$ 6,000.00	$ 8,310.00	$ 9,900.00	$ 13,080.00	$ 18,000.00
Plant									
	Franna Crane	$ 2,500.00	day	6	$ 15,000.00	$ 20,775.00	$ 24,750.00	$ 32,700.00	$ 45,000.00
Materials									
	Miscellaneous	$ 1,000.00	lump sum	1.00	$ 1,000.00	$ 1,385.00	$ 1,650.00	$ 2,180.00	$ 3,000.00
Thrust Blocks		$ 1,500.00	m^3		$ 13,500.00	$ 21,000.00	$ 26,700.00	$ 40,200.00	$ 66,300.00

Figure 6.7 – Construction of Level Three Infrastructure (PN20)

Based on a ten hour working day, it was decided that a total of six days would be required to construct this level of infrastructure for a 375 mm diameter pipeline. As with the previous two levels, it was adopted that the level three infrastructure on a 750 mm diameter pipeline would take three times as long to construct. The interpolation of the multiplication factor for the diameters in between was the same as that described for the level one infrastructure (Section 6.4.1).

The lump sum value adopted for the miscellaneous items in this level of infrastructure is the same as that for level two. Level three infrastructure has a similar level complexity in the arrangement. The value adopted has again been done so based on previous experience in construction. The same interpolation has been adopted over the diameter range. Unlike the previous two levels, thrust blocks are required on level three infrastructure. The rough size of the thrust block required has been determined for each pipe diameter (Section 4.4.4). The thrust calculations were based on the maximum pressure PN20 class pipe could safety operate under.

The operational costs for the level three infrastructure (PN20 pipe class) were based on the quantities illustrated in Figure 6.8.

					750	375	450	500	600
		Rate	Unit	Quantity	Total				
Labour									
	Four Men	$ 4,000.00	day	2.5	$ 10,000.00	$ 8,000.00	$ 8,500.00	$ 9,000.00	$ 9,500.00
	Accomodation/Meals etc.	$ 800.00	day	2	$ 1,600.00	$ 1,280.00	$ 1,360.00	$ 1,440.00	$ 1,520.00
Plant									
	Franna Crane	$ 2,500.00	day	0	$ -	$ -	$ -	$ -	$ -

Figure 6.8 – Operation of Level Three Infrastructure (PN20)

Based on a ten hour working day, it was determined that for a 750 mm diameter pipeline using level three infrastructure the pigging process would take two and a half days. Again the operational costs would only slightly vary over the diameter range and hence the same reduction factor has been adopted as that for level one and two infrastructure.

The two and a half days again allows for all aspects of the pigging operation, from the development of work method statements and other related paperwork, the pigging operation itself through to the final reporting at the end of the process.

Level three infrastructure uses the same amount of time to undertake the pigging process as that for the level two infrastructure. Level three will be quicker than level one as it too has a pipe spool piece allowing for easy pig insertion/removal. However, unlike the level two arrangement it only has one coupling. The opposite end of the pipe spool piece still has a flange set due to the thrust issues associated with this level of infrastructure. Consequently this adds time in having to remove and then reinstate the bolts. Although it would take longer to physically insert and remove the pig than that in level two infrastructure, the entire process takes the same amount of time. This is due to the extra paperwork and process required in the level two infrastructure as a consequence of its inherent WHS issues.

A crane is not required for this level of infrastructure. A roll out arrangement has been included to eliminate the need for a crane. Two nights of accommodation and meals assumes that all personnel will travel to site on the morning of the first day and return home in the early afternoon of the third day. There is therefore still the requirement for two nights.

The results of the model created for level three infrastructure using a pipe class on PN20 are contained within Table 6.4. The full model is included as Appendix M.

Table 6.4 – Level Three (PN20) Analysis Results

Costs	Diameter (mm)				
	375	450	500	600	750
Capital	$242,000	$349,000	$434,000	$579,000	$829,000
Operational	$117,000	$124,000	$132,000	$139,000	$146,000
Total	$359,000	$473,000	$566,000	$718,000	$975,000

As with the previous two levels of infrastructure calculation of the total capital cost includes two pieces of infrastructure. The operational costs are again over the entire design life of the pipeline and they are based on their PV. A ten percent contingency has also been added to both the capital costs and the operational costs.

The results show a similar increase in total costs from the lower end of the diameter range to the upper as that for the level two arrangement. Compared with the level one infrastructure, the level three infrastructure is far more expensive over the entire diameter range. This is again due to the complexity of the arrangement.

Comparing the level three infrastructure to the level two infrastructure tells a different story. In the lower diameter range (less than 500 mm diameter), the level three infrastructure is the cheaper of the two. Conversely, once in the upper diameter range (greater than 500 mm diameter) the level two infrastructure is the cheaper of the options. The driver behind this is the size and cost of the thrust blocks required for the larger diameter arrangements in the level three infrastructure.

As previously discussed, using the level three infrastructure requires the same amount of operational effort as the level two infrastructure. However, its operational costs over the pipe diameter range are lower than that of the level two arrangement due to no crane being required. As per the level two operational costs, the level three operational costs are also lower than that of the level one arrangement.

6.4.4 Level One Infrastructure (PN35 Pipe Class)

The construction and operational costs associated with level one infrastructure (PN35) are based on the same quantities as that for the PN20 class pipe. The methodology was exactly the same.

The results of the model created for level one infrastructure using a pipe class on PN35 are contained within Table 6.5. The full model is included as Appendix N.

Table 6.5 – Level One (PN35) Analysis Results

Costs	Diameter (mm)				
	375	450	500	600	750
Capital	$60,000	$92,000	$119,000	$170,000	$269,000
Operational	$163,000	$173,000	$183,000	$193,000	$203,000
Total	$223,000	$265,000	$302,000	$363,000	$472,000

The PN35 class pipe results contain the same details as those for the PN20 class pipe (Section 6.4.1). The results themselves are also very similar, although slightly higher. The slight increase in the total cost is due to a slight increase in capital investment because of the higher cost of the pipe work.

6.4.5 Level Two Infrastructure (PN35 Pipe Class)

The construction costs for the level two infrastructure (PN20 pipe class) were based on the quantities illustrated in Figure 6.9.

					375	450	500	600	750
		Rate	Unit	Quantity	Total				
Labour									
	Four Men	$ 4,000.00	day	5	$ 20,000.00	$ 27,700.00	$ 33,000.00	$ 43,600.00	$ 60,000.00
	Supervisor	$ 1,250.00	day	5	$ 6,250.00	$ 8,656.25	$ 10,312.50	$ 13,625.00	$ 18,750.00
	Accomodation/Meals etc.	$ 1,000.00	day	5	$ 5,000.00	$ 6,925.00	$ 8,250.00	$ 10,900.00	$ 15,000.00
Plant									
	Franna Crane	$ 2,500.00	day	5	$ 12,500.00	$ 17,312.50	$ 20,625.00	$ 27,250.00	$ 37,500.00
Materials									
	Miscellaneous	$ 1,000.00	lump sum	1.00	$ 1,000.00	$ 1,385.00	$ 1,650.00	$ 2,180.00	$ 3,000.00
Thrust Blocks		$ 1,500.00	m^3		$ -	$ -	$ -	$ -	$ -

Figure 6.9 – Construction of Level Two Infrastructure (PN35)

The construction costs for level two infrastructure on a PN35 class pipeline follow the same methodology as that for a PN20 class pipeline. The only difference is five days have been allowed for construction for a 375 mm diameter pipeline. The extra day is to account for the extra bolting required on PN35 class flanges. The operational costs and the methodology behind them are exactly the same as that for the PN20 class pipeline.

The results of the model created for level two infrastructure using a pipe class on PN35 are contained in Table 6.6. The full model is included as Appendix O.

Table 6.6 – Level Two (PN35) Analysis Results

Costs	Diameter (mm)				
	375	450	500	600	750
Capital	$312,000	$409,000	$491,000	$635,000	$864,000
Operational	$130,000	$138,000	$146,000	$154,000	$162,000
Total	$442,000	$547,000	$637,000	$789,000	$1,026,000

The PN35 class pipe results contain the same details as those for the PN20 class pipe (Section 6.4.2). The results themselves are also very similar, although higher. The increase in the total cost is due to an increase in capital investment. The capital investment has increased because of the higher cost of the pipe work and the extra time required for construction.

6.4.6 Level Three Infrastructure (PN35 Pipe Class)

The construction costs for the level three infrastructure (PN35 pipe class) were based on the quantities illustrated in Figure 6.10.

					375	450	500	600	750
		Rate	Unit	Quantity	Total				
Labour									
	Four Men	$ 4,000.00	day	7	$ 28,000.00	$ 38,780.00	$ 46,200.00	$ 61,040.00	$ 84,000.00
	Supervisor	$ 1,250.00	day	7	$ 8,750.00	$ 12,118.75	$ 14,437.50	$ 19,075.00	$ 26,250.00
	Accomodation/Meals etc.	$ 1,000.00	day	7	$ 7,000.00	$ 9,695.00	$ 11,550.00	$ 15,260.00	$ 21,000.00
Plant									
	Franna Crane	$ 2,500.00	day	7	$ 17,500.00	$ 24,237.50	$ 28,875.00	$ 38,150.00	$ 52,500.00
Materials									
	Miscellaneous	$ 1,000.00	lump sum	1.00	$ 1,000.00	$ 1,385.00	$ 1,650.00	$ 2,180.00	$ 3,000.00
Thrust Blocks		$ 1,500.00	m^3		$ 26,700.00	$ 39,900.00	$ 50,100.00	$ 74,700.00	$121,200.00

Figure 6.10 – Construction of Level Three Infrastructure (PN35)

The construction costs for level three infrastructure on a PN35 class pipeline follow the same methodology as that for a PN20 class pipeline. However, there are two differences. An extra day, seven in total, has been allowed for construction on a 375 mm diameter pipeline. The extra day is to account for the extra bolting required on PN35 class flanges. The second difference is in the size of the thrust blocks required. Obviously the maximum pressure PN35 class pipes can handle is larger than that in PN20 class pipes, hence the thrust blocks need to be bigger. The operational costs and the methodology behind them are exactly the same as that for the PN20 class pipeline.

The results of the model created for level three infrastructure using a pipe class on PN35 are contained in Table 6.7. The full model is included as Appendix P.

Table 6.7 – Level Three (PN35) Analysis Results

Costs	Diameter (mm)				
	375	450	500	600	750
Capital	$306,000	$448,000	$555,000	$768,000	$1,114,000
Operational	$117,000	$124,000	$132,000	$139,000	$146,000
Total	$423,000	$572,000	$687,000	$907,000	$1,260,000

The PN35 class pipe results contain the same details as those for the PN20 class pipe (Section 6.4.3). The results themselves are similar, although the increase itself in total cost is greater than that experienced in the other two levels. This is due to the increase in capital investment because of the increase in the size of the thrust blocks and the extra time required for construction.

6.5 Summary

The quantitative side of the project consisted of developing a number of models. The models were used to analyse the costs associated with the three levels of infrastructure. The analysis included all capital and operational costs of the infrastructure. It also included an options analysis to determine the most cost effective solution to several WHS and operational issues.

In total six models were created to analyse all levels of infrastructure in both PN20 and PN35 class pipes. The diameter range over which the analysis occurred was 375 mm up to 750 mm. The analysis yielded results that were reasonably accurate. A check was undertaken to test the accuracy of the results as far as capital and operational costs are concerned. That check revealed, for the particular pipe class, diameter and level of infrastructure, the results of this analysis were larger than the actual costs of a project undertaken three years ago. Reasons for the higher costs have been looked at in Section 7.3.

Chapter Seven – Research Output

The third part of the research brings the qualitative and quantitative sides of the problem together (Figure 7.1). This third and final stage of the project forms the physical output of the research.

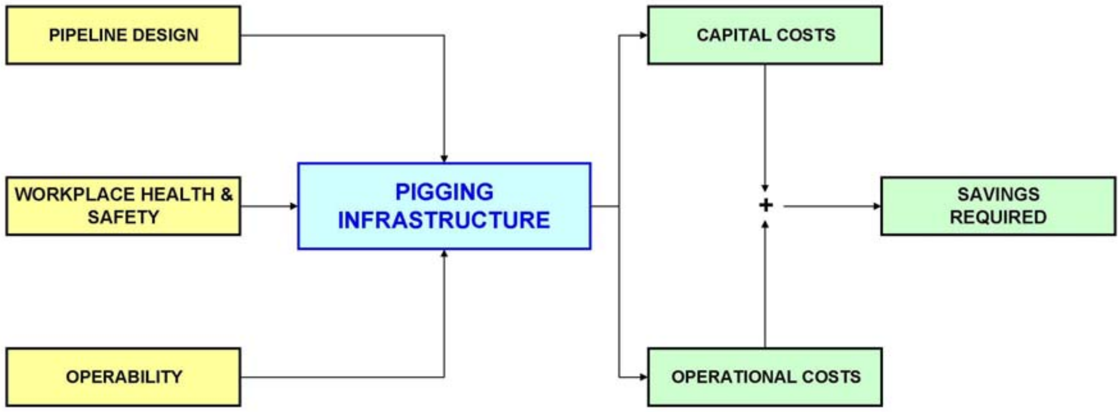


Figure 7.1 – Qualitative and Quantitative Sides of the Problem Combined

There were two physical outputs for the project:

- the pigging infrastructure standard;
- an estimating tool.

7.1 Pigging Infrastructure Standard Development

A pigging infrastructure standard was written utilising the results of the project. This standard is intended to be used as a guide at the conceptual and/or preliminary design stages of a pipeline project. It provides a link between the pigging infrastructure arrangements and the benefits of the pigging process.

The standard initially sets out and describes the different infrastructure levels. It discusses the general arrangements of the infrastructure and their basic operational procedures (Section 4.4). Results from the financial analysis are also included. These results show the benefit or financial saving required from the pigging process to justify the inclusion of that particular infrastructure arrangement in a pipeline design (Section 6.4).

All of the assumptions discussed in Section 6.4 are listed in the standard. This is to allow users of the standard to understand what has been taken into consideration in the analysis as discussed in previous sections. The standard also contains the three infrastructure general arrangement drawings. Finally the standard discusses the estimating tool. It gives a brief procedure on how to use the estimating tool and what assumptions are still relevant.

The standard was developed using a SunWater template. An electronic copy of the final standard will be registered into SunWater's Document Management System. This will allow it to be updated as time dictates. A hard copy of the document will be added to SunWater's Design Library. The standard is included as Appendix Q.

7.2 Pigging Infrastructure Estimating Tool Development

An estimating tool was developed to supplement the pigging infrastructure standard. Like the standard, it has been designed for use in the conceptual and/or preliminary design stages of a pipeline project. It offers the user more flexibility than the analysis within the standard.

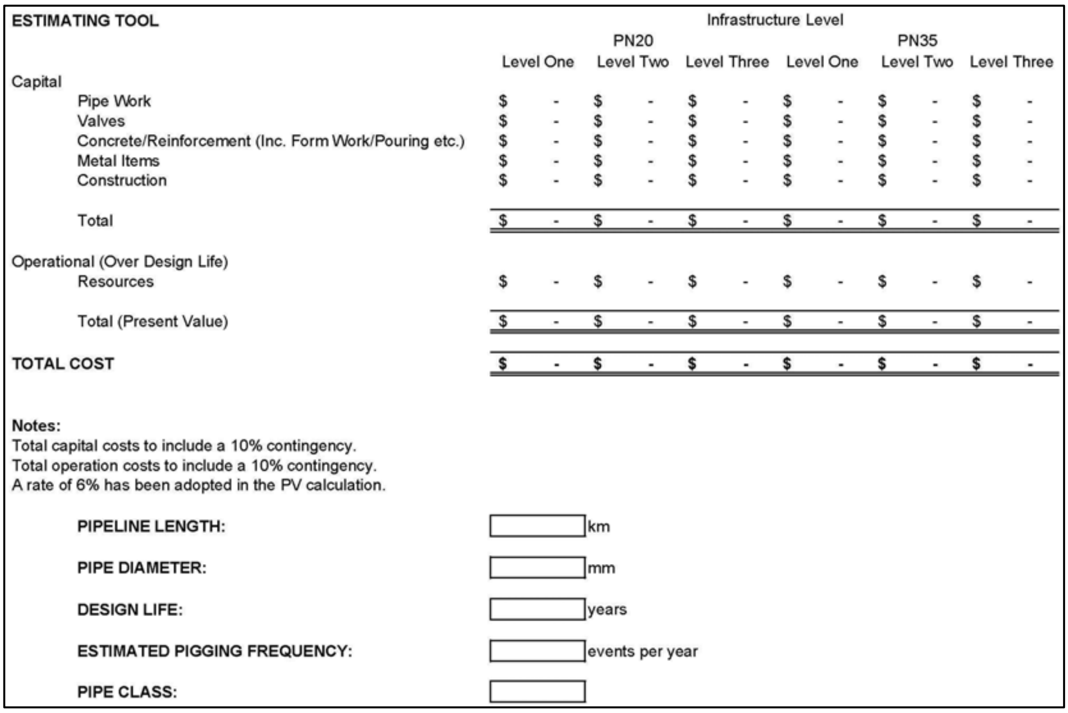
The estimating tool has been based on the model previously created. The extra flexibility it offers the user comes from the elimination of several of the assumptions.

By providing this extra flexibility the above standard can be adopted to a wider range of pipeline design projects.

Three of the assumptions previously stated have been removed. The estimating tool allows the user to select the frequency of the pigging event. This frequency is based on the number of times a pipeline is estimated to require pigging per year. It gives the user the opportunity to input a pipeline length that can be greater than 25km. Essentially this allows for two pieces of infrastructure for the first 25km of a pipeline and then one additional piece of infrastructure for each subsequent 25km. Finally, it allows the user to select the design life of the pipeline.

As previously mentioned, the estimating tool is still an Excel based tool that uses the model previously created as a base. As well as providing more flexibility by eliminating several of the assumptions the model was governed by, it includes a user interface (Figure 7.2). This user interface, while fairly basic, eliminates the requirement for manipulation of the model itself. A copy of the estimating tool is included as Appendix R. The following is a step-by-step guide on how to use the tool:

1. Open the estimating tool named Pigging Infrastructure Estimating Tool.xls and the worksheet shown in figure 7.2 is displayed.
2. Select the pipeline length from the PIPELINE LENGTH drop down menu.
3. Select the pipe diameter from the PIPE DIAMETER drop down menu.
4. Enter a design life in the DESIGN LIFE box.
5. Enter a pigging frequency in the ESTIMATED PIGGING FREQUENCY box.
6. Select a pipe class from the PIPE CLASS drop down menu.
7. The analysis results will now be displayed.



ESTIMATING TOOL

	Infrastructure Level					
	PN20			PN35		
	Level One	Level Two	Level Three	Level One	Level Two	Level Three
Capital						
Pipe Work	$ -	$ -	$ -	$ -	$ -	$ -
Valves	$ -	$ -	$ -	$ -	$ -	$ -
Concrete/Reinforcement (Inc. Form Work/Pouring etc.)	$ -	$ -	$ -	$ -	$ -	$ -
Metal Items	$ -	$ -	$ -	$ -	$ -	$ -
Construction	$ -	$ -	$ -	$ -	$ -	$ -
Total	$ -	$ -	$ -	$ -	$ -	$ -
Operational (Over Design Life)						
Resources	$ -	$ -	$ -	$ -	$ -	$ -
Total (Present Value)	$ -	$ -	$ -	$ -	$ -	$ -
TOTAL COST	$ -	$ -	$ -	$ -	$ -	$ -

Notes:
Total capital costs to include a 10% contingency.
Total operation costs to include a 10% contingency.
A rate of 6% has been adopted in the PV calculation.

PIPELINE LENGTH: ☐ km

PIPE DIAMETER: ☐ mm

DESIGN LIFE: ☐ years

ESTIMATED PIGGING FREQUENCY: ☐ events per year

PIPE CLASS: ☐

Figure 7.2 – Pigging Infrastructure Estimating Tool User Interface

7.3 Pigging Infrastructure Estimating Tool - Case Study

Once the estimating tool had been developed a case study was undertaken. The purpose of the case study was to ensure the tool worked and to compare the results produced by the tool with a past project's actual costs. The pipeline project selected was undertaken by SunWater approximately three years ago. Reference to the project has also been made in the Chapter Six summary (Section 6.5).

The project involved the construction of the Burdekin Moranbah Pipeline (BMP). The pipeline starts at Gorge Weir, located on the Burdekin River and terminates in Moranbah at an existing earth storage. The total length of the pipeline is approximately 220 km and is for the most part constructed using 800mm diameter Mild Steel Concrete Lined (MSCL) pipe. The pigging infrastructure incorporated was constructed using 750 mm diameter DICL pipe work.

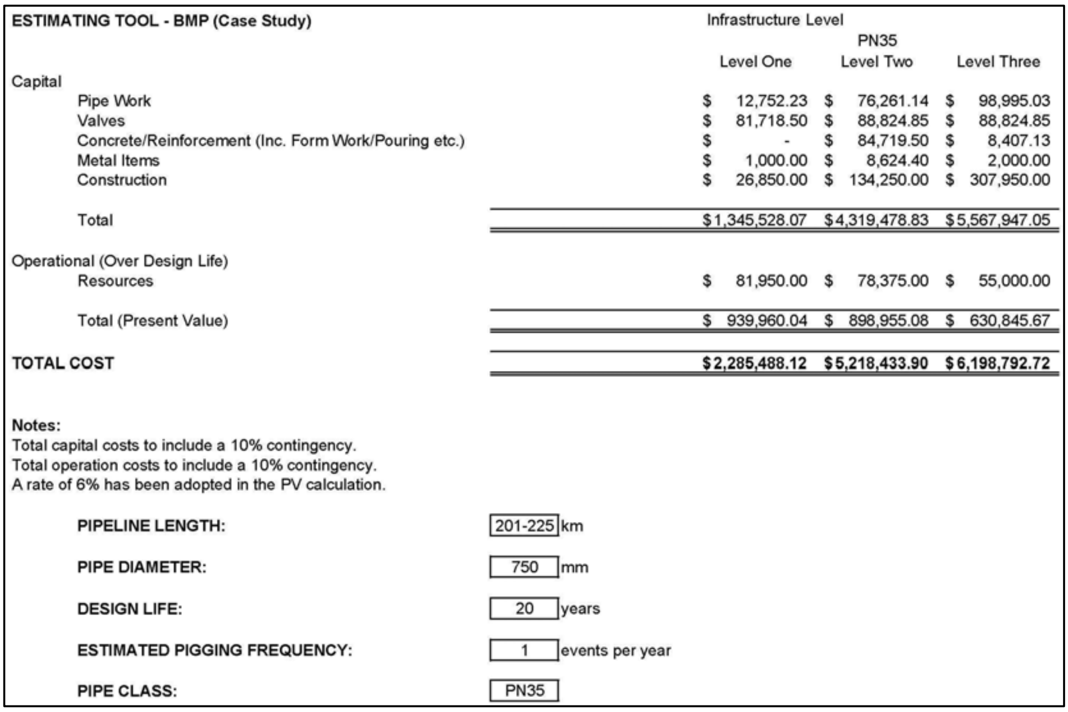
The pigging infrastructure incorporated into the design was similar to that described as level three infrastructure as part of this project. In total there were 13 separate pieces of pigging infrastructure constructed along the pipeline. The average total capital cost of one piece of infrastructure was approximately $340,000 using a pipe class of PN35.

As stated, the BMP incorporates in total 13 pig insertion and/or removal structures. The estimating tool only allows for ten over this particular pipeline length. BMP also incorporates three pump stations along its alignment, not including the initial pump station in the river. A pig cannot be pushed through a pump; therefore additional intermediate infrastructure may have been required to work around the three subsequent pump stations. This accounts for the three additional structures.

To test the estimating tool the following details were entered as per the series of steps described in Section 7.2:

- 201-225km (length);
- 750mm (diameter);
- 20 years (design life);
- 1 event per year (pigging frequency);
- PN35 (pipe class).

The results output by the estimating tool are shown in Figure 7.3.



ESTIMATING TOOL - BMP (Case Study)

	Infrastructure Level PN35 Level One	Level Two	Level Three
Capital			
Pipe Work	$ 12,752.23	$ 76,261.14	$ 98,995.03
Valves	$ 81,718.50	$ 88,824.85	$ 88,824.85
Concrete/Reinforcement (Inc. Form Work/Pouring etc.)	$ -	$ 84,719.50	$ 8,407.13
Metal Items	$ 1,000.00	$ 8,624.40	$ 2,000.00
Construction	$ 26,850.00	$ 134,250.00	$ 307,950.00
Total	$1,345,528.07	$4,319,478.83	$5,567,947.05
Operational (Over Design Life)			
Resources	$ 81,950.00	$ 78,375.00	$ 55,000.00
Total (Present Value)	$ 939,960.04	$ 898,955.08	$ 630,845.67
TOTAL COST	**$2,285,488.12**	**$5,218,433.90**	**$6,198,792.72**

Notes:
Total capital costs to include a 10% contingency.
Total operation costs to include a 10% contingency.
A rate of 6% has been adopted in the PV calculation.

PIPELINE LENGTH: 201-225 km

PIPE DIAMETER: 750 mm

DESIGN LIFE: 20 years

ESTIMATED PIGGING FREQUENCY: 1 events per year

PIPE CLASS: PN35

Figure 7.3 – BMP Case Study Results

It is the level three infrastructure results that are of interest for this case study. The estimating tool shows the total cost of the infrastructure for this pipeline as just under $6,200,000. As shown this is made up of a $5,570,000 capital investment and $630,000 in operational costs. Operational costs of the infrastructure are ignored for the purpose of this case study. BMP has never been pigged and therefore actual costs are not known for comparison.

As previously discussed the estimating tool allows for a particular number of structures along a pipeline based on its length. In the case for the BMP ten structures have been allowed for. With the total capital investment being $5,570,000 the cost of each individual structure is approximately $560,000. This is quite a bit higher than the average actual cost of the BMP structures. There are a number of factors that need to be considered:

- inflation;

- thrust block design;
- contingencies;
- the final arrangement.

Actual costs of the BMP structures were determined approximately three years ago, so inflation needs to be considered. Assuming an inflation of 3.5% per annum (based on CPI) over the last three years the actual cost of the BMP structures would now be closer to $400,000. Adding on the ten percent contingency that is included in the estimate produced by the estimating tool, brings the actual cost of the BMP structures up to approximately $440,000.

The other two factors are hard to put a dollar figure on. The thrust block design, as far as the estimating tool is concerned assumes the pipeline is operating at the capacity of the pipe class, which in reality would generally not be the case. The final arrangement of the BMP structures varies, with some only including one isolation valve. Finally, during the past three years upgrades have been required on all BMP pigging infrastructure. The value of those upgrades is set at approximately $30,000 per structure.

Taking all of this into consideration the relative cost determined by the estimating tool is very close to the actual costs experienced during construction.

7.4 Summary

The final part of the project developed the outputs. Essentially this consisted of two items, a pigging infrastructure standard and an estimating tool. The standard set out the results of the first two parts of the project in a formal document. This document can now be used as a guide in the conceptual and/or preliminary design stages of a pipeline project. The estimating tool was designed to supplement the pigging infrastructure standard. It provides the user of the standard with more flexibility in their options.

A case study was then undertaken to test the accuracy of the estimating tool. A pipeline owned and operated by SunWater was adopted for the case study. The particular pipeline had been constructed approximately three years ago. Detailed construction costs were available for the infrastructure on this pipeline. The case study did not consider operational costs. This case study proved the tool to be quite accurate, at least in its capital investment analysis.

Chapter Eight – Conclusion

SunWater have been and will continue to be involved in the design, construction and operation of major water supply pipelines. A major part of that design and operation is the pigging process and its associated infrastructure. To date, SunWater do not have any guidelines on the design of pigging infrastructure in a pipeline design. This project sought to create a standard, complete with a supporting estimating tool, which would assist in optimising the design of pigging infrastructure in future pipeline projects undertaken by SunWater.

Research was conducted into current pigging practices within the water industry. That research included and focused on the infrastructure that is used as part of the process. To further refine the research, a survey was conducted incorporating a number of people involved in pigging operations. The survey gathered valuable feedback on the performance and safety of the infrastructure in current practice. From this research three ‘standard’ arrangement drawings were drafted, these three drawings representing the three levels of infrastructure to be adopted for this project.

Each of the three levels of infrastructure established were analysed based on their associated capital and operational costs. The analysis determined the total cost of each level of infrastructure, for two pipe classes over a range of pipeline diameters (375 mm – 750 mm). Results of this analysis show the benefits required from the pigging process for each level of infrastructure to be justified in its incorporation in a pipeline design (Table 8.1 and 8.2).

Table 8.1 – PN20 Class Design

		Diameter (mm)				
		375	**450**	**500**	**600**	**700**
Infrastructure Level	**Level One**	$214,000	$249,000	$280,000	$314,000	$391,000
	Level Two	$406,000	$490,000	$567,000	$677,000	$864,000
	Level Three	$359,000	$474,000	$565,000	$718,000	$976,000

Table 8.2 – PN35 Class Design

		Diameter (mm)				
		375	**450**	**500**	**600**	**700**
Infrastructure Level	**Level One**	$223,000	$265,000	$302,000	$363,000	$472,000
	Level Two	$442,000	$547,000	$637,000	$789,000	$1,026,000
	Level Three	$423,000	$572,000	$687,000	$907,000	$1,260,000

Outcomes included a pigging infrastructure standard (Section 7.1) and associated estimating tool (Section 7.2). The standard formally documents the three levels of infrastructure, and based on a number of assumptions (Section 6.4) provides in simple figures the financial benefits required for justification. The estimating tool supports the standard by allowing the analysis to be adapted to wider range of pipeline parameters.

The design of pigging infrastructure based on the financial benefits derived from the pigging process will help ensure all capital investment and subsequent operational costs are suitably justified.

8.1 Recommendation

It is recommended that SunWater implement the pigging infrastructure standard and associated estimating tool developed as part of this thesis. Use of these tools (as a guide) in future conceptual and/or preliminary pipeline design projects will help ensure pigging infrastructure is designed with justification of the capital investment. It will also assist in streamlining the conceptual and/or preliminary design of pigging infrastructure.

It is also recommended that during detailed design of any pigging infrastructure, new technology for pig launching and/or receiving, as discussed in Chapter Three, be investigated. Use of such technology may reduce both capital and operational costs. Again, all detailed designs need to be subject to the risk management process set out in SunWater's WHS Management System.

8.2 Further Work

There are several issues or factors related to this project that require further work:

- necessity of the pigging process;
- frequency of pigging;
- design aids.

8.2.1 Necessity of the Pigging Process

As discussed in Section 1.3, there are pipelines currently owned by SunWater that have never been pigged, regardless of whether or not they have the infrastructure available to do so. This led to the requirement for two investigations within SunWater, the first of which is stated below:

Investigate the benefits derived from the pigging process to determine, on a pipeline by pipeline basis, if and when the process itself and hence the infrastructure should be considered in design.

This investigation needs to be undertaken, the results of which should be used in conjunction with the results of this project. During the conceptual and/or preliminary design stage, it first needs to be determined if the pigging process will be required at all. If the process is determined to be of no use, pigging infrastructure will not be required. Regardless of the level of infrastructure designed it would be an unjustified, wasted capital investment.

Alternatively, if it was determined that the process would be of some benefit, the results of this project will assist in establishing the infrastructure arrangement best suited to a particular design. That is not to say that the only consideration should be the results of this project. All options need to be considered. There exist several alternatives to the pigging process that do not require any form of infrastructure:

- adopt a larger pipe size to account for any reduction due to biofilm build up;
- install pumps possessing a greater range of operating efficiency;
- design the pipeline for a higher flow rate than will be required.

8.2.2 Frequency of Pigging

This project assumes a pigging frequency of one event per year. There is no science or reasoning behind this assumption other than within SunWater that seemed to be the most common approach. It is recommended that a tool needs to be developed that can estimate the frequency a particular pipeline will need to be pigged. This information can then be entered into the estimating tool developed as part of this project. Ultimately this will give results that are much more accurate for the particular pipeline design being undertaken.

8.2.3 Design Aids

Finally, the development of a number of design aids would be useful. The design aids would assist in further streamlining the pigging infrastructure design process, not only at the conceptual and/or preliminary stage of a pipeline project, but in detailed design as well. Design aids to assist with the calculations involved in the following list would be very beneficial:

- thrust block design;
- bypass pipe work sizing.

References

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APPENDIX A

SPECIFICATION

University of Southern Queensland

FACULTY OF ENGINEERING AND SURVEYING

ENG4111/4112 Research Project
PROJECT SPECIFICATION

FOR: **AARON ELPHINSTONE**

TOPIC: OPTIMISATION OF PIGGING INFRASTRUCTURE IN DESIGN

SUPERVISORS: Dr. Malcolm Gillies
Dr. Vasanthadevi Aravinthan (co-supervisor)
Mr Dan Coutts, SunWater Ltd.

SPONSORSHIP: SunWater Ltd.

PROJECT AIM: This project seeks to create a standard, complete with supporting estimating tool that will optimise the design of pigging infrastructure in future pipeline designs undertaken by SunWater. The optimisation is to be based on the frequency with which a pipeline is to be pigged and is to be justified by the benefits derived the pigging process it aids.

PROGRAMME: **Issue B, 14th September 2010**

1. Research background information relating to the pigging of water pipelines.
2. Attend the pigging of a water pipeline to gain practical experience and witness a pigging procedure.
3. Examine the multitude of pigging arrangements for water pipelines in practice at present to establish differing levels of use.
4. Consult with the operators of various water pipelines that are currently pigged to establish the downfalls and benefits associated with each particular arrangement.
5. Consider the inherent Workplace Health and Safety (WHS) issues associated with each pigging arrangement. Discuss those issues with the WHS officer/s associated with each pipeline.
6. Prepare 'standard' arrangement drawings for each differing level of use established.
7. Analyse the current practices, their downfalls, benefits and inherent WH&S issues against pipeline particulars and associated capital, operational and maintenance costs.
8. Develop a standard for pigging frequency using the above analysis, for differing levels of use.
9. Create an estimating tool, to be used in the conceptual/preliminary design phase of a pipeline, to assist in determining the optimal arrangement of pigging infrastructure for a particular pipeline.

As time permits:

10. Prepare design aids to assist with the sizing and detailing of specific installations.

AGREED:

(Student)	(Supervisor)	(Supervisor)
18/10/2010	19 /10 /2010	22 /10/2010

Examiner/Co-examiner: ______________________

APPENDIX B

BLANK QUESTIONNAIRE

DISCUSSION / OUTCOMES

ENG4111/2 Research Project Questionnaire

Date:

Time:

Organisation:

Pipeline Name:

Pipeline Location:

Pipeline Age:

Operator/s:

Discussion / Outcomes	
Item 1	How many years experience do you have in the operation of water pipelines, specifically in pipeline pigging?
Item 2	How often do you pig the pipeline?
Item 3	Can you summarise the process you go through to pig the pipeline?

Discussion / Outcomes	
Item 4	What type/s or model of pig do you use?
Item 5	How long does it take to pig the pipeline (days/hours)?
Item 6	What resources are required to pig the pipeline (human, plant/machinery) and what roles do they play in the process?
Item 7	How much involvement does each of the resources have (the whole process, half the process etc.)?

Discussion / Outcomes	
Item 8	What are the design and safety issues associated with the pigging facilities?
Item 9	What are the design and safety benefits associated with the pigging facilities?
Item 10	How would you describe the water quality before it enters the pipeline – clean, dirty or in-between?

APPENDIX C

COMPLETED QUESTIONNAIRES

DISCUSSION / OUTCOMES

ENG4111/2 Research Project Questionnaire

Date: 10/06/2010

Time: 4pm

Organisation: BMA

Pipeline Name: Bingegang Pipeline

Pipeline Location: Peak Downs Mine

Pipeline Age: 35 Years

Operator/s: Rob Alford

Discussion / Outcomes	
Item 1	How many years experience do you have in the operation of water pipelines, specifically in pipeline pigging?
20 years.	
Item 2	How often do you pig the pipeline?
Every two years.	
Item 3	Can you summarise the process you go through to pig the pipeline?
Shutdown pumps – Drain section of pipeline and insert pig – Close off consumer off-takes before pigging and flush after – Start pump to push pig through – Track pig – Receive pig and flush line until water clears.	
8-10km section of pipeline each day.	
Run pipeline line overnight and pig during the day.	
Item 4	What type/s or model of pig do you use?
High density foam pig (Red Bear).	
Item 5	How long does it take to pig the pipeline (days/hours)?
Pig entire Bingegang pipeline over 15 days (150km in total).	
Item 6	What resources are required to pig the pipeline (human, plant/machinery) and what roles do they play in the process?
Crew of five people, two vehicles with generators.	
Item 7	How much involvement does each of the resources have (the whole process, half the process etc.)?
Whole process.	

<table>
<tr><th colspan="2">Discussion / Outcomes</th></tr>
<tr><td>Item 8</td><td>What are the design and safety issues associated with the pigging facilities?</td></tr>
<tr><td colspan="2"><i>Swab pits installed every 4km, only use every second one.</i></td></tr>
<tr><td colspan="2"><i>Confined space. Need recovery plan for injury. Fall hazard. Had vertical ladder, had to change them to 70° incline.</i></td></tr>
<tr><td colspan="2"><i>Facilities are adequate.</i></td></tr>
<tr><td colspan="2"><i>Some pits too close to ground and fill with local rain.</i></td></tr>
<tr><td>Item 9</td><td>What are the design and safety benefits associated with the pigging facilities?</td></tr>
<tr><td>Item 10</td><td>How would you describe the water quality before it enters the pipeline – clean, dirty or in-between?</td></tr>
<tr><td colspan="2"><i>Dirty water.</i></td></tr>
</table>

DISCUSSION / OUTCOMES

ENG4111/2 Research Project Questionnaire

Date:

Time:

Organisation: SunWater

Pipeline Name: Burdekin Moranbah Pipeline

Pipeline Location: Collinsville/Moranbah

Pipeline Age: 4 Years

Operator/s: Tony Buckingham/Geoff Renton

Discussion / Outcomes	
Item 1	How many years experience do you have in the operation of water pipelines, specifically in pipeline pigging?
More than 30 years combined.	
Item 2	How often do you pig the pipeline?
Never been pigged.	
Item 3	Can you summarise the process you go through to pig the pipeline?
Item 4	What type/s or model of pig do you use?
Item 5	How long does it take to pig the pipeline (days/hours)?
Item 6	What resources are required to pig the pipeline (human, plant/machinery) and what roles do they play in the process?
Item 7	How much involvement does each of the resources have (the whole process, half the process etc.)?
Item 8	What are the design and safety issues associated with the pigging facilities?
Item 9	What are the design and safety benefits associated with the pigging facilities?
Item 10	How would you describe the water quality before it enters the pipeline – clean, dirty or in-between?

DISCUSSION / OUTCOMES

ENG4111/2 Research Project Questionnaire

Date:

Time:

Organisation: SunWater

Pipeline Name: EWP Eastern Extension

Pipeline Location: Moranbah

Pipeline Age: 5 Years

Operator/s: Geoff Renton

Discussion / Outcomes	
Item 1	How many years experience do you have in the operation of water pipelines, specifically in pipeline pigging?
Item 2	How often do you pig the pipeline?
Never been pigged.	
Item 3	Can you summarise the process you go through to pig the pipeline?
Item 4	What type/s or model of pig do you use?
Item 5	How long does it take to pig the pipeline (days/hours)?
Item 6	What resources are required to pig the pipeline (human, plant/machinery) and what roles do they play in the process?
Item 7	How much involvement does each of the resources have (the whole process, half the process etc.)?
Item 8	What are the design and safety issues associated with the pigging facilities?
Item 9	What are the design and safety benefits associated with the pigging facilities?
Item 10	How would you describe the water quality before it enters the pipeline – clean, dirty or in-between?

DISCUSSION / OUTCOMES

ENG4111/2 Research Project Questionnaire

Date:

Time:

Organisation: SunWater

Pipeline Name: Eungella Water Pipeline

Pipeline Location: Collinsville/Moranbah

Pipeline Age: 14 Years

Operator/s: Tony Buckingham/Geoff Renton

Discussion / Outcomes	
Item 1	How many years experience do you have in the operation of water pipelines, specifically in pipeline pigging?
More than 30 years combined.	
Item 2	How often do you pig the pipeline?
Never been pigged.	
Item 3	Can you summarise the process you go through to pig the pipeline?
Item 4	What type/s or model of pig do you use?
Item 5	How long does it take to pig the pipeline (days/hours)?
Item 6	What resources are required to pig the pipeline (human, plant/machinery) and what roles do they play in the process?
Item 7	How much involvement does each of the resources have (the whole process, half the process etc.)?
Item 8	What are the design and safety issues associated with the pigging facilities?
Item 9	What are the design and safety benefits associated with the pigging facilities?
Item 10	How would you describe the water quality before it enters the pipeline – clean, dirty or in-between?

DISCUSSION / OUTCOMES

ENG4111/2 Research Project Questionnaire

Date:	30/07/2010
Time:	12pm
Organisation:	SunWater
Pipeline Name:	Newlands Pipeline
Pipeline Location:	Collinsville
Pipeline Age:	27 Years
Operator/s:	Tony Buckingham

Discussion / Outcomes	
Item 1	How many years experience do you have in the operation of water pipelines, specifically in pipeline pigging?
Item 2	How often do you pig the pipeline?
Done last month. Last time it was done before that was about ten years ago.	
Item 3	Can you summarise the process you go through to pig the pipeline?
Always done by contractor.	
Item 4	What type/s or model of pig do you use?
Item 5	How long does it take to pig the pipeline (days/hours)?
Item 6	What resources are required to pig the pipeline (human, plant/machinery) and what roles do they play in the process?
Item 7	How much involvement does each of the resources have (the whole process, half the process etc.)?
Item 8	What are the design and safety issues associated with the pigging facilities?
Item 9	What are the design and safety benefits associated with the pigging facilities?
Item 10	How would you describe the water quality before it enters the pipeline – clean, dirty or in-between?
Relatively clean water.	

DISCUSSION / OUTCOMES

ENG4111/2 Research Project Questionnaire

Date:

Time:

Organisation: Water Corporation WA

Pipeline Name: Collector Bore Main

Pipeline Location: Perth

Pipeline Age: 40 Years

Operator/s: Merzuk Hodzic

Discussion / Outcomes	
Item 1	How many years experience do you have in the operation of water pipelines, specifically in pipeline pigging?
30 years.	
Item 2	How often do you pig the pipeline?
Every year.	
Item 3	Can you summarise the process you go through to pig the pipeline?
Done in maintenance.	
Item 4	What type/s or model of pig do you use?
Sponge with plastic wrap.	
Some 0.6m long, other 1m long. Varies depending on 90^o bends.	
Item 5	How long does it take to pig the pipeline (days/hours)?
Depends on section. One week to do 10km section.	
Item 6	What resources are required to pig the pipeline (human, plant/machinery) and what roles do they play in the process?
Crane or hiab.	
Four people minimum.	
One vehicle.	
Item 7	How much involvement does each of the resources have (the whole process, half the process etc.)?
Whole process for all.	

Discussion / Outcomes	
Item 8	What are the design and safety issues associated with the pigging facilities?
Confined space. Half a day to launch pig because of WHS paper work.	
Operation setup ok.	
Item 9	What are the design and safety benefits associated with the pigging facilities?
Ramps or stairs to eliminate confined space.	
Item 10	How would you describe the water quality before it enters the pipeline – clean, dirty or in-between?
In between.	

DISCUSSION / OUTCOMES

ENG4111/2 Research Project Questionnaire

Date:

Time:

Organisation: Water Corporation WA

Pipeline Name: Perth – Kalgoorlie Pipeline

Pipeline Location: Perth

Pipeline Age: 107 Years

Operator/s: Scott Miller

Discussion / Outcomes	
Item 1	How many years experience do you have in the operation of water pipelines, specifically in pipeline pigging?
11 years.	
Item 2	How often do you pig the pipeline?
Never been pigged.	
Item 3	Can you summarise the process you go through to pig the pipeline?
Item 4	What type/s or model of pig do you use?
Item 5	How long does it take to pig the pipeline (days/hours)?
Item 6	What resources are required to pig the pipeline (human, plant/machinery) and what roles do they play in the process?
Item 7	How much involvement does each of the resources have (the whole process, half the process etc.)?
Item 8	What are the design and safety issues associated with the pigging facilities?
Item 9	What are the design and safety benefits associated with the pigging facilities?
Item 10	How would you describe the water quality before it enters the pipeline – clean, dirty or in-between?

DISCUSSION / OUTCOMES

ENG4111/2 Research Project Questionnaire

Date:	30/07/2010
Time:	1pm
Organisation:	Flomax
Pipeline Name:	Newlands
Pipeline Location:	Collinsville
Pipeline Age:	27 Years
Operator/s:	Contractor

Discussion / Outcomes	
Item 1	How many years experience do you have in the operation of water pipelines, specifically in pipeline pigging?
Item 2	How often do you pig the pipeline?
Item 3	Can you summarise the process you go through to pig the pipeline?
Pipeline pigged in sections.	
New pig for each section.	
Travels at 0.5m/s.	
Use a less dense pig first to get blue print of pipeline. If necessary then use heavier pig.	
If line done in one go then heavier more durable pig used.	
Item 4	What type/s or model of pig do you use?
Used an RCC (Red Criss Cross) pig. Light density foam.	
Others include RBS (Red Bear Squeegy) or steel pig with poly flanges (modular pig).	
PIG – Polyethylene Intelligence Guidance System	
Type and density of pig depends on pipeline.	
Item 5	How long does it take to pig the pipeline (days/hours)?
3 days working 24 hours a day. Two 12 hours shifts. Depends on economics and water availability.	
Item 6	What resources are required to pig the pipeline (human, plant/machinery) and what roles do they play in the process?
3 people per shift. One controller and two trackers.	
4WD backhoe.	

Discussion / Outcomes	
Item 7	How much involvement does each of the resources have (the whole process, half the process etc.)?
Whole process.	
Item 8	What are the design and safety issues associated with the pigging facilities?
Not very good. No dismantling joint or gibault joint for removal of spool. Straub or gibault are the best.	
Roll out spool better as long as it can be fully rolled out.	
Above ground ok as well. Have used Y launcher.	
Item 9	What are the design and safety benefits associated with the pigging facilities?
Item 10	How would you describe the water quality before it enters the pipeline – clean, dirty or in-between?

DISCUSSION / OUTCOMES

ENG4111/2 Research Project Questionnaire

Date:

Time:

Organisation: SunWater

Pipeline Name: EWP Southern Extension

Pipeline Location: Moranbah

Pipeline Age: 4 Years

Operator/s: Geoff Renton

Discussion / Outcomes	
Item 1	How many years experience do you have in the operation of water pipelines, specifically in pipeline pigging?
Item 2	How often do you pig the pipeline?
Never been pigged.	
Item 3	Can you summarise the process you go through to pig the pipeline?
Item 4	What type/s or model of pig do you use?
Item 5	How long does it take to pig the pipeline (days/hours)?
Item 6	What resources are required to pig the pipeline (human, plant/machinery) and what roles do they play in the process?
Item 7	How much involvement does each of the resources have (the whole process, half the process etc.)?
Item 8	What are the design and safety issues associated with the pigging facilities?
Item 9	What are the design and safety benefits associated with the pigging facilities?
Item 10	How would you describe the water quality before it enters the pipeline – clean, dirty or in-between?

DISCUSSION / OUTCOMES

ENG4111/2 Research Project Questionnaire

Date:

Time:

Organisation: SunWater

Pipeline Name: Stanwell Pipeline

Pipeline Location: Rockhampton

Pipeline Age: 18 Years

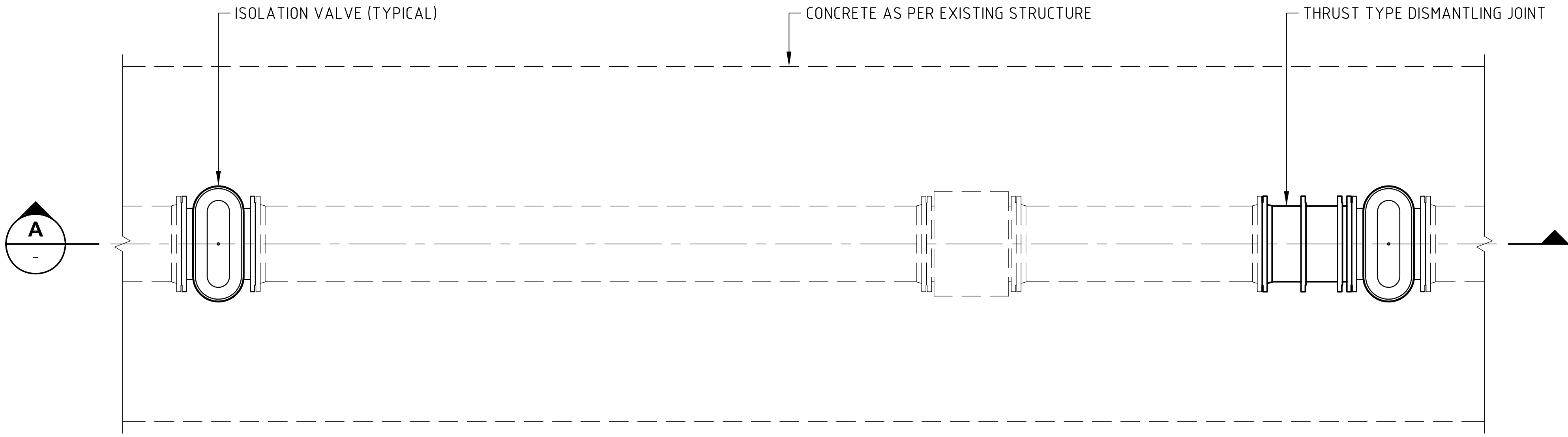
Operator/s: Jim Barry

Discussion / Outcomes	
Item 1	How many years experience do you have in the operation of water pipelines, specifically in pipeline pigging?
20 years.	
Item 2	How often do you pig the pipeline?
Varies, once or twice a year.	
Item 3	Can you summarise the process you go through to pig the pipeline?
Pump overnight – Isolate next morning and drain section of pipe at start – Remove spool, insert pig and reinstate spool – Prime line with bypass valve – Lift isolation and begin pumping – Whole line done in one go – Pump pig until just before receiver – Stop pumping – Remove catcher spool piece and restart pumping – Once pig exits continue pumping until water clears.	
Item 4	What type/s or model of pig do you use?
Metal pig with urethane discs, discs replaced each time. Unfavourable due to potential damage to lining.	
Criss cross pig not as effective.	
Item 5	How long does it take to pig the pipeline (days/hours)?
One day (operation itself only).	
Item 6	What resources are required to pig the pipeline (human, plant/machinery) and what roles do they play in the process?
Four people.	
Three vehicles.	
Franna crane.	

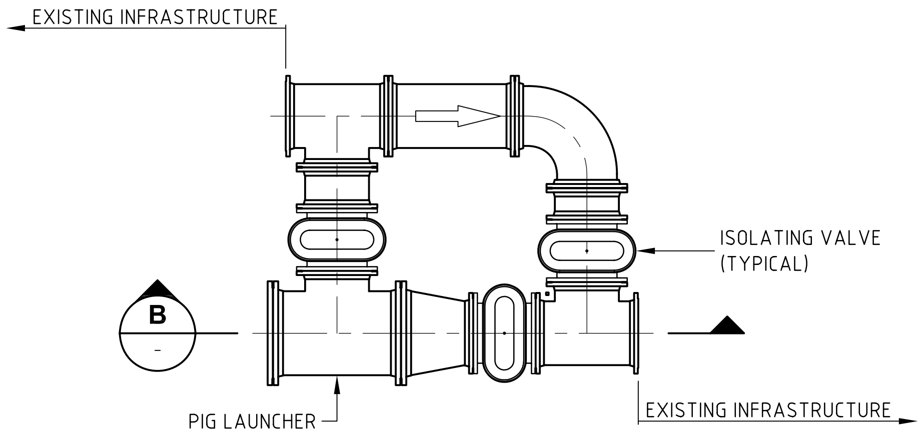
Discussion / Outcomes	
Item 7	How much involvement does each of the resources have (the whole process, half the process etc.)?
Everything for whole process, bar crane. Crane only half of the day.	
Item 8	What are the design and safety issues associated with the pigging facilities?
Vehicle access is good. Power line over one of the pits.	
Risks require assessment to done effectively.	
Confined space.	
Item 9	What are the design and safety benefits associated with the pigging facilities?
Definitely required on this pipeline.	
Item 10	How would you describe the water quality before it enters the pipeline – clean, dirty or in-between?
Generally clean.	

APPENDIX D

LEVEL ONE INFRASTRUCTURE
‘STANDARD’ GENERAL ARRANGEMENT DRAWING



PLAN



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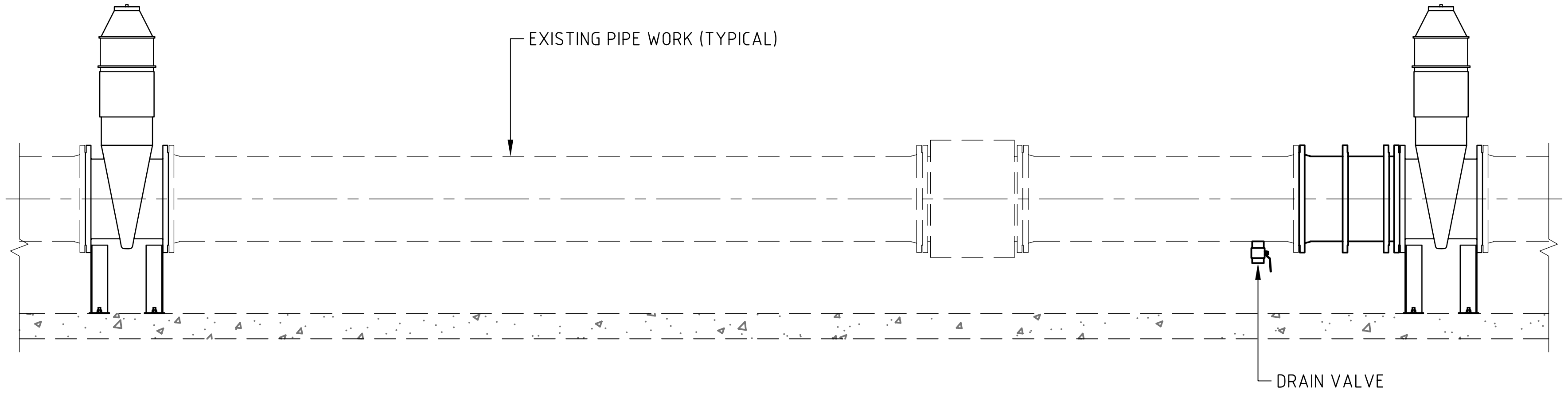
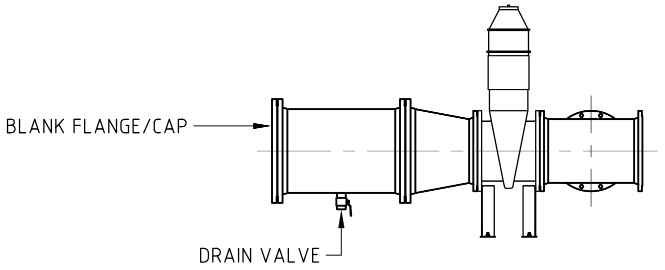


SECTION A
-



SECTION B
-

ALTERNATE ARRANGEMENT

NOTES:

1. GENERAL
   - DRAWING TO BE READ IN CONJUNCTION WITH PIGGING INFRASTRUCTURE STANDARD.
   - FINAL ARRANGEMENT TO BE DETERMINED AS PART OF DETAILED DESIGN.
   - SOME FORM OF ACCESS TO TOP OF VALVES FOR OPENING/CLOSING NEEDS TO BE CONSIDERED.
   - DETAILED DESIGN OF THE INFRASTRUCTURE MUST INCORPORATE A FULL WHS RISK ASSESSMENT.

PRELIMINARY DRAWING ONLY

F:\ENG4112\Level 1.dwg
25 Oct 2010 8:30 PM

Drawing Produced By:
SunWater Limited
126 Giddy Rd,
Ayr Qld 4807
Tel: (07) 4783 0555

REVISION	DATE	REMARKS	CKD	PSD

REFERENCE DRAWINGS

SCALES (A3 SIZE)

NOT TO SCALE

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ADE	
CHECKED	CHECKED
APPROVED	

SunWater

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PIPELINE DESIGN
STANDARD PIGGING INFRASTRUCTURE
LEVEL ONE
GENERAL ARRANGEMENT

CONTRACT NUMBER

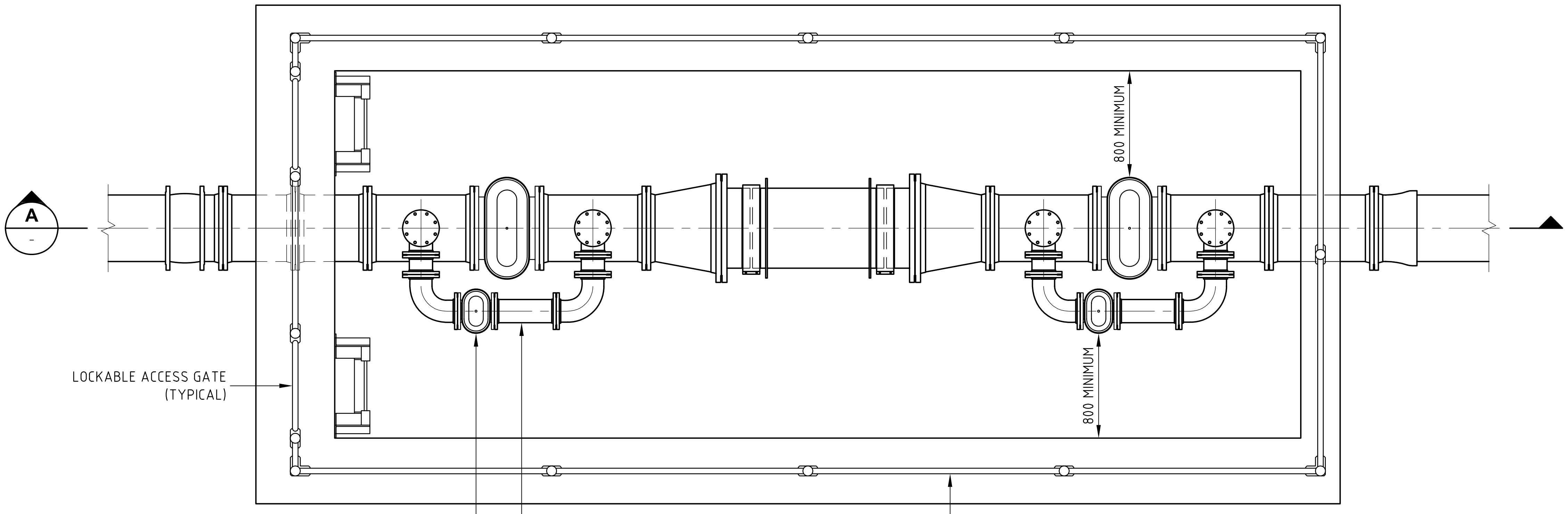
DRAWING NUMBER

DATE AUGUST 2010

APPENDIX E

LEVEL TWO INFRASTRUCTURE

‘STANDARD’ GENERAL ARRANGEMENT DRAWING



PLAN

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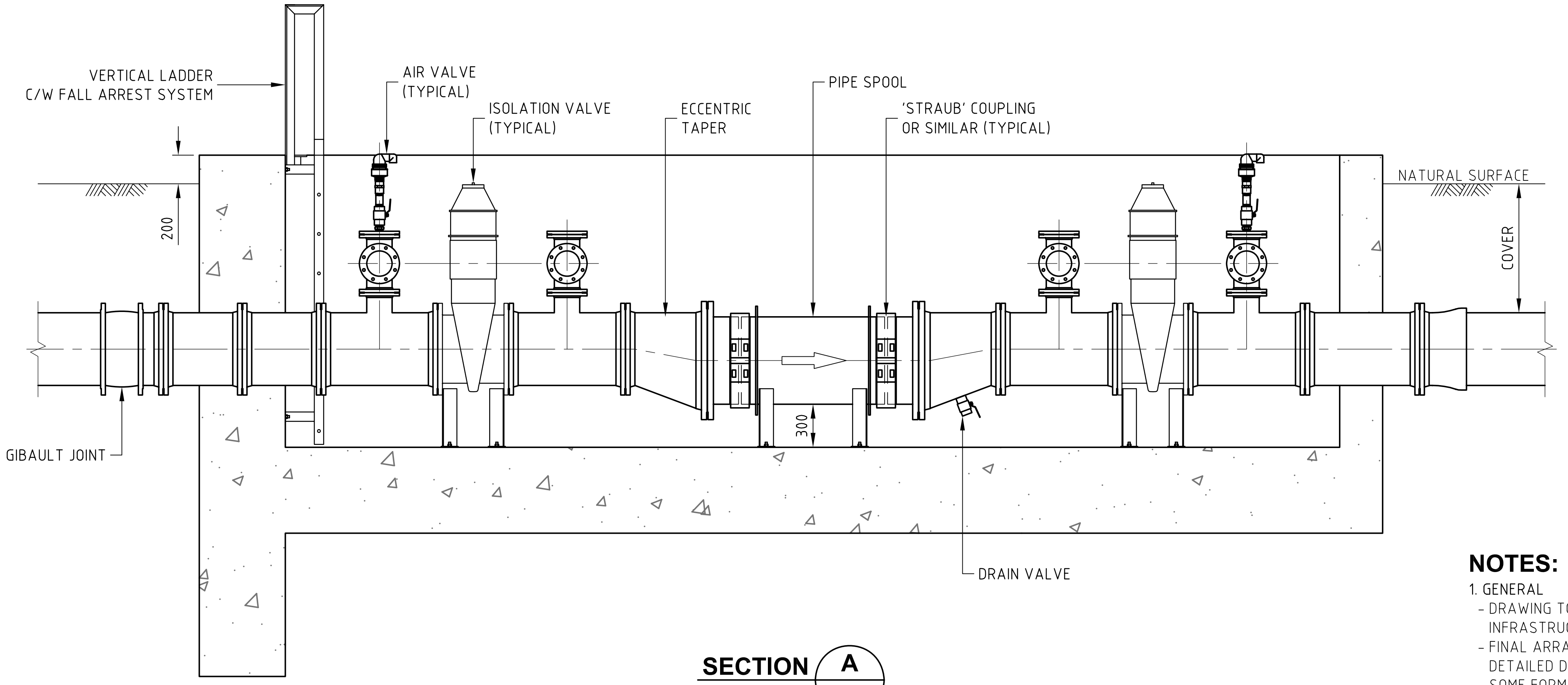

SECTION A -

(BYPASS PIPE WORK AND HANDRAILS OMITTED FOR CLARITY)

NOTES:

1. GENERAL
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   - FINAL ARRANGEMENT TO BE DETERMINED AS PART OF DETAILED DESIGN.
   - SOME FORM OF ACCESS TO TOP OF VALVES FOR OPENING/CLOSING NEEDS TO BE CONSIDERED.
   - DETAILED DESIGN OF THE INFRASTRUCTURE MUST INCORPORATE A FULL WHS RISK ASSESSMENT.

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25 Oct 2010 8:31 PM

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CHECKED
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APPROVED

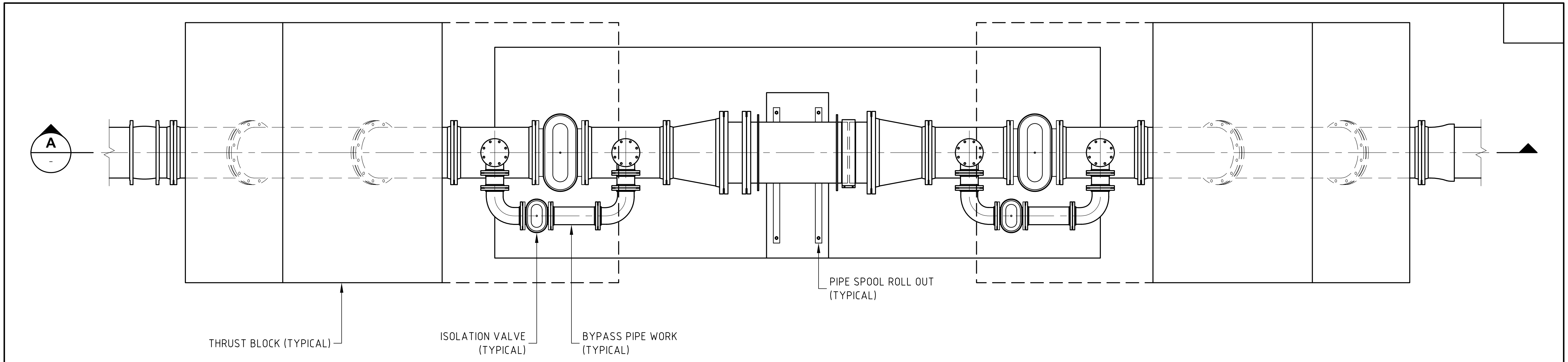
SunWater

PIPELINE DESIGN
STANDARD PIGGING INFRASTRUCTURE
LEVEL TWO
GENERAL ARRANGEMENT

CONTRACT NUMBER
DRAWING NUMBER
DATE AUGUST 2010

APPENDIX F

LEVEL THREE INFRASTRUCTURE
‘STANDARD’ GENERAL ARRANGEMENT DRAWING

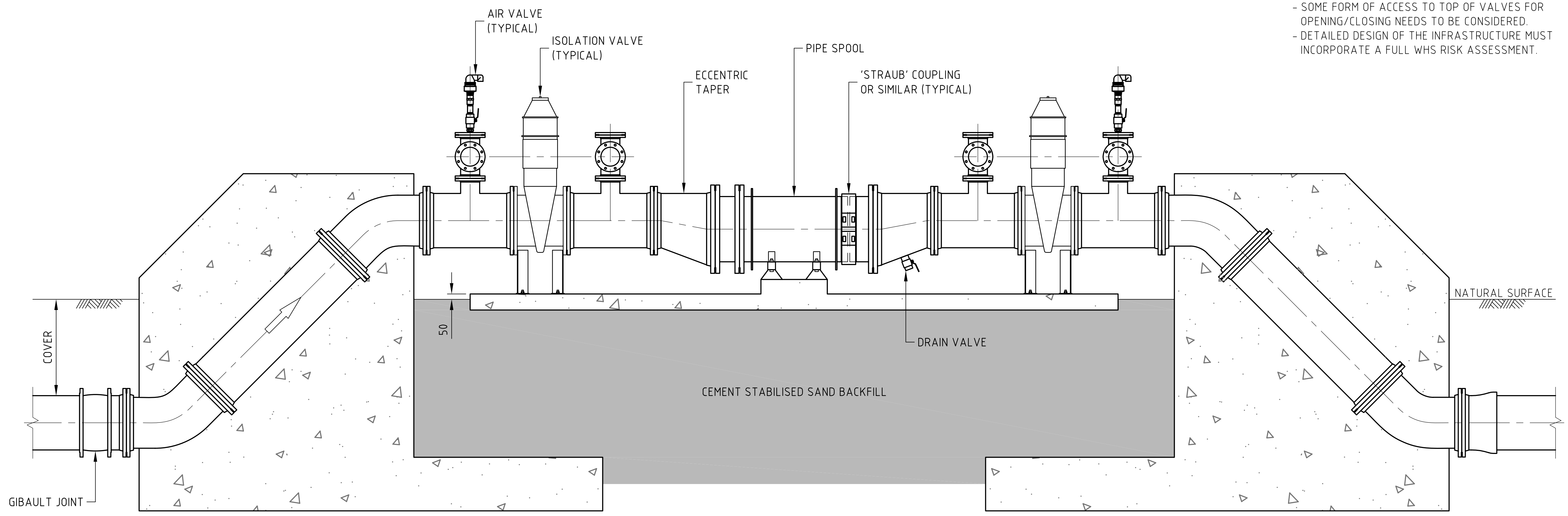


PLAN

(AIR VALVES OMITTED FOR CLARITY)

NOTES:

1. GENERAL
   - DRAWING TO BE READ IN CONJUNCTION WITH PIGGING INFRASTRUCTURE STANDARD.
   - FINAL ARRANGEMENT TO BE DETERMINED AS PART OF DETAILED DESIGN.
   - SOME FORM OF ACCESS TO TOP OF VALVES FOR OPENING/CLOSING NEEDS TO BE CONSIDERED.
   - DETAILED DESIGN OF THE INFRASTRUCTURE MUST INCORPORATE A FULL WHS RISK ASSESSMENT.



SECTION A -

(BYPASS PIPE WORK OMITTED FOR CLARITY)

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SCALES (A3 SIZE)

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PIPELINE DESIGN
STANDARD PIGGING INFRASTRUCTURE
LEVEL THREE
GENERAL ARRANGEMENT

CONTRACT NUMBER

DRAWING NUMBER

DATE AUGUST 2010

APPENDIX G

THRUST CALCULATION SPREADSHEET

Data Input: Vertical Thrust Block

On this page input the following thrust block details below in the cells highlighted green.

Example:

1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
							Block Section Dimensions	
Location	**TYPE**	**Soil Bearing q (kPa)**	**Test Head (m)**	**Invert Elevation (m)**	**DN**	**Angle (Deg)**	**Height**	**Width**
33944.604	VAB	100	120		375	11.25	1500	1500

For each bend enter the following data:

1. The bend location or chainage

2. The thrust block type (Vertical Anchor Block VAB, or Vertical Thrust Block VTB)

3. Soil bearing capacity in kPa at the bend location

4. The maximum design or test head of the pipe location at the location of the bent

5. The elevation of the bend invert. (Note: this is used to calculate the differential head at the bend. If designing for a constant head just set the design head to the desired constant and leave the invert head blank.

6. Bend nominal diameter.

7. Bend angle. (Note: if bend is not a standard angle, combine multiple standard bends to make up the required angle and list the standard bends separately in the table.)

8. & 9. Enter the cross sectional height and width of the thrust block. These dimensions may correspond to the trench dimensions.

Project Data:

							Block Section Dimensions	
Location	**TYPE**	**Soil Bearing q (kPa)**	**Test Head (m)**	**Invert Elevation (m)**	**DN**	**Angle (Deg)**	**Height**	**Width**
0	VTB	100	200	0.00	375	45	1575	1375
1	VTB	100	200	0.00	450	45	1650	1450
2	VTB	100	200	0.00	500	45	1700	1500
3	VTB	100	200	0.00	600	45	1800	1600
4	VTB	100	200	0.00	750	45	1950	1750
0	VTB	100	350	0.00	375	45	1575	1375
1	VTB	100	350	0.00	450	45	1650	1450
2	VTB	100	350	0.00	500	45	1700	1500
3	VTB	100	350	0.00	600	45	1800	1600
4	VTB	100	350	0.00	750	45	1950	1750

Vertical Thrust Block Calculations

															VerticalAB							
Chainage	TYPE	Test Head	Invert Elevation	Total Head	q	DESIGN BASIS	DN	ACTUAL Ø	ANGLE DIAMETER	THRUST	DEPTH	WIDTH	SECTION AREA	REQD BEARING AREA	Reqd Conc Volume	Reqd Length	Perp Force	BEARING LENGTH (ONE ARM)	TOTAL LENGTH	VOLUME CONCRETE	Moment arm	Max Moment
			(m)		(kPa)		(mm)	m		kN	(mm)	(mm)	m^3/m	m^2	m^3	m	kN	m	(m)	(m^3)	m	kNm
0.0	VTB	200	0	200	100	B	375	426	45	214	1575	1375	2.02	2.1	0.0	0.0	197.617	1.4	2.9	4.5	0.1	29
1.0	VTB	200	0	200	100	B	450	507	45	303	1650	1450	2.19	3.0	0.0	0.0	279.912	1.9	3.9	7.0	0.4	102
2.0	VTB	200	0	200	100	B	500	560	45	370	1700	1500	2.30	3.7	0.0	0.0	341.493	2.3	4.6	8.9	0.5	177
3.0	VTB	200	0	200	100	B	600	667	45	524	1800	1600	2.53	5.2	0.0	0.0	484.459	3.0	6.1	13.4	0.9	412
4.0	VTB	200	0	200	100	B	750	826	45	804	1950	1750	2.88	8.0	0.0	0.0	742.961	4.2	8.5	22.1	1.4	1039
0.0	VTB	350	0	350	100	B	375	426	45	374	1575	1375	2.02	3.7	0.0	0.0	345.830	2.5	5.0	8.9	0.7	238
1.0	VTB	350	0	350	100	B	450	507	45	530	1650	1450	2.19	5.3	0.0	0.0	489.846	3.4	6.8	13.3	1.1	533
2.0	VTB	350	0	350	100	B	500	560	45	647	1700	1500	2.30	6.5	0.0	0.0	597.613	4.0	8.0	16.7	1.4	819
3.0	VTB	350	0	350	100	B	600	667	45	918	1800	1600	2.53	9.2	0.0	0.0	847.804	5.3	10.6	24.9	2.0	1684
4.0	VTB	350	0	350	100	B	750	826	45	1407	1950	1750	2.88	14.1	0.0	0.0	1300.181	7.4	14.9	40.4	3.0	3887

APPENDIX H

PROJECT RISK ASSESSMENT, WMS & SAFE DESIGN REVIEW

HSE PROJECT RISK ASSESSMENT FORM

WHS15_F1
Revision: 14
Revision Date: Jul 2009
Approved by: M BPS
Owner: M BPS

This Form is to be **completed as per Standard WHS15** HSE Project Risk Management. The Project Manager is responsible for ensuring that the WHS15 and associated processes[1] and forms are completed. WHS49_F2 Safe Design Review and WHS49-F1 Safe Design Checklist should be used at the design review stage.

Version Number[2]	
PROJECT DETAILS	
Project Name	ENG4111/2 Research Project
Project Description	Desktop Research
Project Ref. No. / File No.	
Scheme or Location	
PROJECT MANAGER DETAILS	
Name	Aaron Elphinstone
Contact Number	(07) 4783 0563

CONTRACTOR DETAILS

Contractor Representative	Name	Contact Details

HSE RISK MANAGEMENT TEAM MEMBERS

Job Title	Name	Date	Signature
Project Manager	Aaron Elphinstone	21/05/2010	AE

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[1] Includes WHS10, WHS15 & WHS49 as applicable to the project.
[2] Used where the form is reviewed at various stages during the process.

	HSE PROJECT RISK ASSESSMENT FORM	**WHS15_F1** Revision: 14 Revision Date: Jul 2009 Approved by: M BPS Owner: M BPS

This Form is to be **completed as per Standard WHS15** HSE Project Risk Management. The Project Manager is responsible for ensuring that the WHS15 and associated processes[1] and forms are completed. WHS49_F2 Safe Design Review and WHS49-F1 Safe Design Checklist should be used at the design review stage.

Version Number[2]	
PROJECT DETAILS	
Project Name	ENG4111/2 Research Project
Project Description	Field Research
Project Ref. No. / File No.	
Scheme or Location	
PROJECT MANAGER DETAILS	
Name	Aaron Elphinstone
Contact Number	(07) 4783 0563

CONTRACTOR DETAILS

Contractor Representative	Name	Contact Details

HSE RISK MANAGEMENT TEAM MEMBERS

Job Title	Name	Date	Signature
Project Manager	Aaron Elphinstone	21/05/2010	AE

---

[1] Includes WHS10, WHS15 & WHS49 as applicable to the project.

[2] Used where the form is reviewed at various stages during the process.

POST PROJECT REVIEW TEAM MEMBERS

Job Title	Name	Date	Signature
Project Manager	Aaron Elphinstone	21/05/2010	AE

POTENTIAL WORKPLACE HEALTH & SAFETY HAZARDS

WH&S Hazard Category	**Potential WH&S Hazards**	**SunWater Procedure**	**Applicable**		*** If Applicable (YES) complete the relevant columns below**				
			***YES**	**NO**	**SW & Other Forms**	**High Risk Activity - WMS, ERP**	**Licences/ Permits? (see relevant Std)**	**Communication, i.e. prestart meeting**	**Further Details**
Human Energy √	Lifting, carrying, pushing, pulling, twisting	WHS32							
	Awkward or sustained posture								
	Repetitive or prolonged task eg: shovelling, hammering, drilling, cutting (masonry saw)								
	Impact of part of body with external structure fixed, moveable or mobile.		**YES**					WMS	Refer WMS
	Extended work hours - fatigue	WHS42 WHS07							
	Solitary/remote work	WHS34							
	Ergonomic hazards	WHS32							
Gravitational Energy √	Fall through a penetration such as removed decking.	WHS31							
	Fall from height > 2 metres	WHS31				WMS09			
	Fall from height < 2 metres to hard surface								
	Slip, trip, fall to same level		**YES**					WMS	Refer WMS

POTENTIAL WORKPLACE HEALTH & SAFETY HAZARDS

WH&S Hazard Category	Potential WH&S Hazards	SunWater Procedure	Applicable		* If Applicable (YES) complete the relevant columns below				
			*YES	NO	SW & Other Forms	High Risk Activity - WMS, ERP	Licences/ Permits? (see relevant Std)	Communication, i.e. prestart meeting	Further Details
	Destabilised while walking, carrying or working on equipment or platforms including ladders								
	Fall while descending/ascending								
	Hit by falling, sliding, rolling object/s								
Vehicular Energy (Includes Mobile Plant) √	Driving long distances – fatigue hazard	WHS07							
	Driving in remote areas	WHS34			WHS34_F1 WHS34_F2 WHS34_F3				
	Driving on gravel or single lane roads		**YES**					WMS	Refer WMS
	Vehicles striking workers or pedestrians	WMS71 WHS54				WMS14			
	Vehicle strikes other vehicles		**YES**					WMS	Refer WMS
	Vehicle not fit for purpose								
Object ☐ N/A	Hit by moving objects in unconstrained path e.g. windblown objects, piece of steel after being struck by hammer								
	Hit by moving objects in constrained path, e.g. load on sling	WHS54							

POTENTIAL WORKPLACE HEALTH & SAFETY HAZARDS

WH&S Hazard Category	**Potential WH&S Hazards**	**SunWater Procedure**	**Applicable**		*** If Applicable (YES) complete the relevant columns below**				
			***YES**	**NO**	**SW & Other Forms**	**High Risk Activity - WMS, ERP**	**Licences/ Permits? (see relevant Std)**	**Communication, i.e. prestart meeting**	**Further Details**
Machine Energy (Fixed, Semi-Portable or Portable Machine) ☐ N/A	Person my be pulled into, struck, cut by, crushed								
	Damage from vibration and jarring, kickback								
	Injury from fragmentation, explosion or fracture e.g. tools, power tools, pressure vessels etc								
Electrical Energy ☐ N/A	Overhead wires	WHS23 WHS24 WHS28			WHS28_F1	WMS01 WMS02 WMS08			
	Underground services								
	Working near possible live parts (HV, LV) including batteries and UPS's	WHS21 WHS22 WHS23			WHS22_F1 WHS22_F2 WHS23_F1 WHS23_F2 WHS23_F4	WMS01			
	Working near cathodic protection systems consider lightning also					WMS03			
	Appliances, portable generators, power tools, leads etc					WMS04 WMS05 WMS06 WMS07 WMS16 WMS18			
	Other electrical hazard	WHS22							

POTENTIAL WORKPLACE HEALTH & SAFETY HAZARDS

WH&S Hazard Category	Potential WH&S Hazards	SunWater Procedure	Applicable		* If Applicable (YES) complete the relevant columns below				
			*YES	NO	SW & Other Forms	High Risk Activity - WMS, ERP	Licences/ Permits? (see relevant Std)	Communication, i.e. prestart meeting	Further Details
Thermal Energy ☐ N/A	Extreme temperatures (hot/cold) – environment, contact with hot objects, flammable atmosphere, sun.	WHS33							
	Fire/bush fire e.g. burning off activity								
	Hot work (welding, grinding etc) – explosion, fire, molten metal	WHS27			WHS27_F1				
	Use of explosives								
Chemical Energy ☐ N/A	Spill, leak of chemicals								
	Explosion								
	Toxic gases/fumes/liquids/chemicals refer to MSDS								
	Oxygen deprivation or engulfment eg: confined spaces	WHS26			WHS26_F1	WMS26			
	Exposure or contamination from asbestos, lead, mercury or PCBs	WHS38 ACM Plan				WMS27 WMS28	✓		
	Handling and transport of chemicals	WHS29 EM11							
Radiation √	Damage from ultraviolet rays from the sun		**YES**					WMS	Refer WMS
	Damage from manufactured rays, e.g. microwaves, radio, electro-magnetic								

POTENTIAL WORKPLACE HEALTH & SAFETY HAZARDS

WH&S Hazard Category	Potential WH&S Hazards	SunWater Procedure	Applicable		* If Applicable (YES) complete the relevant columns below				
			*YES	NO	SW & Other Forms	High Risk Activity - WMS, ERP	Licences/ Permits? (see relevant Std)	Communication, i.e. prestart meeting	Further Details
Noise (eg: from machinery, tools, construction activities) ☐ N/A	Short extreme exposure								
	Intermittent exposure								
	Continuous exposure								
Pressure / Potential Energy √	Being struck by fluid under pressure (chemical, fuel, refrigerant line)								
	Gas pipes under pressure								
	Handling industrial gases	WHS44							
	Structural collapse, collapse of construction materials eg tilt up, precast materials, temporary support structures; demolition work								
	Drowning hazard - work in, on, near or over water, flooding, cyclone; construction diving	WHS20	**YES**			WMS29 WMS30 WMS70 ERP06	✓	WMS	Refer WMS
	Engulfment, e.g. trench, carbon monoxide water etc	WHS28			WHS28_F1	WMS08			
	Component under pressure or strain, e.g. wire, rope, chain								

POTENTIAL WORKPLACE HEALTH & SAFETY HAZARDS

WH&S Hazard Category	Potential WH&S Hazards	SunWater Procedure	Applicable		* If Applicable (YES) complete the relevant columns below				
			*YES	NO	SW & Other Forms	High Risk Activity - WMS, ERP	Licences/ Permits? (see relevant Std)	Communication, i.e. prestart meeting	Further Details
Susceptible Part ☐ N/A	Low velocity, e.g. dust in eye, lungs; respiratory irritation								
	High velocity, e.g. grinding fragment in eye, nail gun etc								
	Thermal, e.g. hot slag in ear								
	Liquids/gas, e.g. brake fluid in eyes								
	UV radiation – e.g. welding flash to eyes								
	Fluids, grinding fragment, slag etc in eyes, ears or skin penetration	WHS43							
Specialised Shape ☐ N/A	Cuts								
	Punctures								
Animal hazards √	Snakes, spiders, wasps & bees		**YES**					WMS	Refer WMS
	Crocodiles	WHS39							
	Aggressive animals								

POTENTIAL WORKPLACE HEALTH & SAFETY HAZARDS

WH&S Hazard Category	Potential WH&S Hazards	SunWater Procedure	Applicable		* If Applicable (YES) complete the relevant columns below				
			*YES	NO	SW & Other Forms	High Risk Activity - WMS, ERP	Licences/ Permits? (see relevant Std)	Communication, i.e. prestart meeting	Further Details
Biological Hazards ☐ N/A	Needle-stick injury								
	Contact with sewage/ wastewater								
	Contact with dead/injured wildlife								
	Infection, virus, e.g. Dengue Fever, Ross River Fever, Barmah Forest Fever, hepatitis, tetanus etc								
Simultaneous activities ☐ N/A	Confined Spaces + Hot Work for example	WHS25 + other relevant Standards, e.g: WHS26 Confined Space; WHS27 Hot Work			WMS25_F1, WMS25_F2 + other relevant forms, eg: WHS26 F1, WHS27 F1	WHS10_F1			
	Different work parties on same site and workers unfamiliar with work site								
	Work performed at distances from isolation points, involving various points of isolation								
Housekeeping ☐ N/A	Poor housekeeping hazards pre , during and post project.	WHS19			WHS19_F1, WHS19_F3				

POTENTIAL WORKPLACE HEALTH & SAFETY HAZARDS

WH&S Hazard Category	Potential WH&S Hazards	SunWater Procedure	Applicable		* If Applicable (YES) complete the relevant columns below				
			*YES	NO	SW & Other Forms	High Risk Activity - WMS, ERP	Licences/ Permits? (see relevant Std)	Communication, i.e. prestart meeting	Further Details
Workplace Amenities ☐ N/A	Provision of amenities - toilets, drinking water, lunchrooms and shade								
	Emergency equipment - emergency showers, fire extinguishers first aid kits, spill kits ERP's								
Public Safety/Public Relations ☐ N/A	Public protection considerations – access, hazards, security, signage etc	WHS17, WHS18			WHS17_F1				
	Dealing with the public – potential conflict, aggression	EM11.13							

PART A SIGN –OFF

PROJECT MANAGER

The HSE project risk has been assessed and appropriate actions will be taken to control the identifed risks.

Completed by:	Name: Aaron Elphinstone	Position: Project Manager	Date: 21/05/2010
	Signature: AE		

RELEVANT JOB SUPERVISOR/S (Only for R&E Projects)

HSE Controls will be implemented to address the risks identified above eg. forms, inductions, licences, compliance with relevant Standards, WMSs, ERPs

Completed (reviewed) by:	Name:	Position:	Date:
	Signature:		

PART B SIGN –OFF: AT PROJECT BUSINESS CASE STAGE			
The risks identified in the above processes will be considered during project planning and implementation.			
PROJECT MANAGER / LEADER			
Completed by:	Name: Aaron Elphinstone	Position: Project Manager	Date: 21/05/2010
	Signature: AE		
OTHER PERSONS CONSULTED			
Reviewed by:	Name:	Position:	Date:
	Signature:		
Reviewed by:	Name:	Position:	Date:
	Signature:		
Reviewed by:	Name:	Position:	Date:
	Signature:		
Reviewed by:	Name:	Position:	Date:
	Signature:		
Reviewed by:	Name:	Position:	Date:
	Signature:		

PART B SIGN –OFF: AT PROJECT COMMENCEMENT STAGE			
PROJECT MANAGER / LEADER			
Controls have been developed to address the risks identified in the above eg. EMPs, WMS's, ERPs, forms, licences, etc.			
Completed by:	Name: Aaron Elphinstone	Position: Project Manager	Date: 21/05/2010
	Signature: AE		
OTHER PERSONS CONSULTED			
Reviewed by:	Name:	Position:	Date:
	Signature:		
Reviewed by:	Name:	Position:	Date:
	Signature:		
Reviewed by:	Name:	Position:	Date:
	Signature:		
Reviewed by:	Name:	Position:	Date:
	Signature:		
Reviewed by:	Name:	Position:	Date:
	Signature:		

SunWater	**Work Method Statement – Field Research**	**WHS10_F1** Revision: 9 Revision Date: Jul 2009 Approved by: M BPS Owner: M BPS

Job Name: (Format: Job Location and Description): ENG4111/2 Research Project	***Work Order Number:***
Site Supervisor (person in control on site): Aaron Elphinstone	***Work Commencement Date: June 2010***

1. Check Job Supervisor Responsibilities – completed by Job Supervisor

	Signature & Date
A. This Work Method Statement and the separate Permit, where applicable have been reviewed and communicated to all employees and contractors involved in the job.	
B. SunWater staff have been trained and are competent to carry out this job safely. An untrained person must NOT [insert any restrictions].	
C. Contractors engaged to perform this work have provided evidence of training and current competency, and copies of their Risk Assessment or Work Method Statement and Permit as applicable. If Contractors are undertaking this work in conjunction with SunWater employees, this Work Method Statement [and Permit if applicable] will apply.	

D. PPE&C has been checked prior to entry and is in good condition.	**PPE&C/Safety Equipment Required**	**PPE&C checked and in good condition (Signature Required)**	**PPE&C/Safety Equipment Required**	**PPE&C checked and in good condition (Signature Required)**
WHAT PPE&C and SAFETY EQUIPMENT IS REQUIRED FOR THIS SITE/JOB?	☐ Barricades and warning signs		☐ Mechanical lifting aids	
	☐ Broad brim hat		☐ Overalls	
	☐ Carry bag, rope		☐ Overalls for chemical use	
	☒ Communications equipment	**AE**	☐ Personal flotation device (life jacket)	
	☐ Dusk mask /vapour mask		☐ Personal isolation lock and key	
	☐ Ear muffs/plugs		☐ Rescue equipment	
	☐ Eye protection (clear or tinted)		☐ Respiratory protection/Breathing Apparatus	
	☒ First aid kit	**AE**	☒ Safety footwear	**AE**
	☒ Fire extinguisher	**AE**	☐ Safety harness and lines	
	☐ Fire blanket		☐ Shade protection	
	☐ Full coverage clothing		☒ Sunscreen, lip balm	**AE**
	☐ Gas detector		☐ Rubber boots	
	☐ Gloves - chemical		☐ Torch and batteries, neon sticks	
	☐ Gloves - cotton/leather		☒ Water	**AE**
	☐ Hard hat		☒ Wasp/ant Spray	**AE**
	☒ Hi vis clothing	**AE**	☐ Other (List)	
	☐ Lights			

E. Is a Permit required?	☐ **Yes /** ☒ **No**	**If Yes, insert type of Permit**	

**Notes: Air-supplied breathing apparatus is only to be used by trained, competent personnel. No compressed air or liquid gas cylinders are to be taken into the confined space.*

2. IDENTIFY THE HAZARDS – PRELIMINARY ASSESSMENT. Consider and mark ALL hazards associated with the specific job tasks, the equipment that will be used in the job, the infrastructure, and the surrounding work environment.

WHAT ARE ALL OF THE POTENTIAL HAZARDS?

- ☐ Air Pollutants
- ☐ Air Pressure
- ☐ Asbestos
- ☐ Chemicals
- ☐ Confined Space
- ☐ Contaminated Air
- ☐ Electrical
- ☐ Others (List)
- ☐ Excavation/Engulfment
- ☐ Eye Irritation/Injury
- ☐ Fall hazard
- ☐ Fall from Heights
- ☒ Fauna bites/stings
- ☐ Fatigue
- ☐ Fire/explosion/ignition
- ☐ Fish Stranding
- ☐ Gas (LPG)
- ☐ Heat/Cold
- ☐ Hydraulic Pressure
- ☐ Lift/Pull/Push
- ☐ Mobile Plant
- ☐ Moving Parts
- ☐ Noise
- ☐ Overhead Wires
- ☐ Oxygen Low/High
- ☒ Remote Area
- ☐ Restricted Access
- ☒ Slips, Trips, Falls
- ☐ Skin Irritation
- ☒ Sun Exposure
- ☐ Tools
- ☐ Traffic Management Plan
- ☐ Underground
- ☐ Vapours
- ☒ Vehicles / Pedestrians
- ☒ Water/Drowning
- ☐ Weather Conditions
- ☒ Wildlife

3. DOCUMENT EACH JOB STEP, POTENTIAL HAZARDS ASSOCIATED WITH EACH JOB STEP, AND RISK CONTROL ACTIONS. You must assess the risk and document the Risk Rating prior to and after implementing risk controls. Do not proceed with the work if the risk rating, after the controls are in place, remains at HIGH or EXTREME. Risk must be reduced to at least MEDIUM before proceeding. COMPLETE AND ATTACH A RELEVANT WORK PERMIT IF APPLICABLE.

Job Step No.	Activities Required to Complete the Job	Potential Hazards (WH&S, Environment, Other)	Initial Risk Rating	Risk Control Actions	Responsibility for the Risk Control Action	Residual Risk Rating (to be inserted by Site Supervisor)
1	Field Research	Body impact with infrastructure	M	Take care when moving around, watch where going	ADE	L
		Slip, trip or fall	M	Take care when moving around, watch where going	ADE	L
		Driving on gravel road	H	Drive to conditions, obey road rules	ADE	M
		Other vehicles	H	Obey road rules, watch for other vehicles	ADE	M
		Sunburn	H	Wear sunscreen, hat, long clothes and stay in shade	ADE	L
		Drowning	E	Ensure you can swim	ADE	M
		Wildlife	H	Avoid and leave along	ADE	L
List additional any additional activities and hazards and risk controls identified and applied during the job and improvements after the work is completed.						

Prepared and reviewed and endorsed by Site Supervisor:
Name: Aaron Elphinstone **Signature: AE** **Date: 21/05/2010**

SIGN OFF FOR ALL PERSON INVOLVED IN ANY OF THE ABOVE TASKS (prior to starting the job)

I have completed an induction to the contents of this Work Method Statement and agree to apply the risk controls identified and any additional controls identified during the job.

All persons on site undertaking work (including contractors)

Name	Organisation	Signature	Date
Aaron Elphinstone	SunWater	AE	21/05/2010

HSE DESIGN CHECKLIST

Project Name: Development of Pigging Infrastructure G.A.	Project No.
Design Phase: [✓ Preliminary] Detailed/Final	Hummingbird File No (Design):
Design Manager (name & contact nos): Aaron Elphinstone	Designer (name & contact nos):

Brief description & purpose of the plant/equipment/structure to be designed:
Standard general arrangement infrastructure for pig insertion and/or removal.

What are the major components of the plant/equipment/structure:
Pipework, valving, concrete structure (where applicable) and assocaited metal items.

Does the proposed plant/equipment/structure currently exist elsewhere in SunWater? If Yes, contact the site and speak to site personnel about potential WH&S hazards. List issues identified here.

Yes. Done.

Has similar plant/equipment/structure been designed or constructed by SunWater? If Yes, consult the design and construction reports and the staff involved about lessons learned. List issues identified here.
Yes. Done.

Scope of HSE Review:

List of Drawing Numbers (incl Revision):

Level One Infrastructure	
Level Two Infrastructure	
Level Three Infrastructure	

Design Review Team (names & roles on team):

Aaron Elphinstone	

CHECKLIST

Item	Applicable	Not Applicable	Reference AS/NZS Standard as Relevant	Comments on Design Amendments or Proposed Design Amendments.
MATERIALS Does the design consider:-				
- Appropriate materials employed Durability/corrosion resistant/corrosion protection, safe installation & use	☑	☐		All metal items are galvanised steel.
- Non-slip materials	☐	☑		
POSITIONING Does the design consider integration or positioning in a workplace or site to avoid creating hazards - consider:				
- Access/egress	☑	☐		Ladder c/w fallarrest system where applicable.
- Stability & security	☐	☑		
- Slips, trips, falls	☑	☐		Handrails where applicable.
- Public safety	☐	☑		
ENERGY SOURCES Does the design consider:-				
- Electrical Power Supply including Solar Systems & Diesel Alternators: *Isolation/Surge protection*	☐	☑		
- Oil Hydraulic and Pneumatic Energy Sources: *Isolation/Surge Protection Accurate Hydraulic Circuits*	☐	☑		
- High Pressure Water: *Isolation/energy dissipation/pressure reduction devices/component failure*	☐	☑		
- Water Hammer: *Surge control/non return valve selection/valve closure rates*	☑	☐		Thrust blocks.
- Electrical Hazards: *Earthing/static electricity/lightning strike/induced voltages*	☐	☑		
- Counterweights: *Supports/guards/speed of operation/buffers*	☐	☑		
- Wire Ropes *Guidance/appropriate construction/rotating or non rotating/elastic energy/guards/adequate termination*	☐	☑		
- Emergency and normal stopping	☐	☑		

Item	Applicable	Not Applicable	Reference AS/NZS Standard as Relevant	Comments on Design Amendments or Proposed Design Amendments.
- Labelling of Isolation Points	☐	☑		
MACHINERY/MOVING PARTS Does the design consider:				
- Guarding of moving parts & parts at hot temperatures (eg: exhausts)	☐	☑		
- Anchoring to floor	☑	☐		Valves are supported by and bolted to floor.
- Locking and isolation	☑	☐		Valve keys removed from site.
- Failsafe/emergency shutdown/stop buttons	☐	☑		
- Labelling of controls	☐	☑		
VENTILATION/AIR CONDITIONING SYSTEMS & LIGHTING Does the design consider:-				
- Heating/cooling systems and loads	☐	☑		
- Air filtration	☐	☑		
- Air changes	☐	☑		
- Air distribution	☐	☑		
- Pressure on access/exit doors	☐	☑		
- General and emergency lighting	☐	☑		
VIBRATION & NOISE Does the design consider:-				
- Pressure/Flow Pulsation	☐	☑		
- Natural Frequencies	☐	☑		

Item	Applicable	Not Applicable	Reference AS/NZS Standard as Relevant	Comments on Design Amendments or Proposed Design Amendments.
- Uncontrolled Motion	☐	☑		
- Fatigue Failure	☐	☑		
- Noise Levels	☐	☑		
ACCESS/EGRESS/HEIGHTS Does the design consider:-				
- Operation/operator - clearance dimensions	☑	☐		In pits 800mm minimum width clearance allowed.
- Maintenance/maintainer - clearance dimensions	☐	☑		
- Safe and stable access to pits, valves, surge tanks, screens, inlet structures, outlet structures, fish trap	☑	☐		Vertical ladder c/w fall arrest system.
- Guard rails/hand rails/ladders/stairways - *ref AS 1657 & attached guideline*	☑	☐		Handrails where applicable.
- Harness anchor points for height work	☐	☑		
- Ladders with fall arrest	☑	☐		Included.
- Protection against falling objects	☐	☑		
- Confined spaces - *eliminate where possible*	☑	☐		Rescue device considered and provided.
- Walkways/stairs/floors - treatment to avoid slipping/tripping	☐	☐		
- Emergency exits	☐	☑		
- Lifts/emergency lowering	☐	☑		
- Weight of moveable panels or grates/safe handling provisions	☐	☑		
- Access roads, loading/parking areas, road markings to designate areas	☐	☑		
- Communications/Phones/CCTV	☐	☑		
- Safety signage	☐	☑		

Item	Applicable	Not Applicable	Reference AS/NZS Standard as Relevant	Comments on Design Amendments or Proposed Design Amendments.
ELECTRICAL CONTROL/SWITCHGEAR SYSTEMS Does the design consider:-				
- Control voltage	☐	☑		
- Access for resetting flags and trip relays	☐	☑		
- Clearance around switchboards & prevention of contact with live electrical parts	☐	☑		
- Reset buttons on outside of cabinets	☐	☑		
- Residual energy devices	☐	☑		
- Cubicle segregtation	☐	☑		
- Isolation system	☐	☑		
- Labelling of isolation points	☐	☑		
- Access provisions	☐	☑		
- As built circuit drawings	☐	☑		
- Physical location of cables & embedded electrical conduits marked on drawings	☐	☑		
- Heat load	☐	☑		
- Electro magnetic interference	☐	☑		
- Warning devices	☐	☑		
- Safety signage	☐	☑		
- Cubicle sunshade	☐	☑		
- Earthing, earthing mats	☐	☑		
- Induced voltage	☐	☑		
- Underground cables marked	☐	☑		
- Fail safe/emergency shutdown	☐	☑		

Item	Applicable	Not Applicable	Reference AS/NZS Standard as Relevant	Comments on Design Amendments or Proposed Design Amendments.
- Fire/explosion	☐	☑		
TRANSFORMERS Does the design consider:-				
- Isolation	☐	☑		
- Surge protection	☐	☑		
- Earthing	☐	☑		
- Oil cooled or resin core	☐	☑		
- Bunding	☐	☑		
- Safety signage	☐	☑		
- Security provisions	☐	☑		
- Explosion/fire	☐	☑		
REMOVING TRASH/SAND & GRAVEL DEPOSITS Does the design consider:-				
- Access/provision to safely remove covers/install safety barriers	☐	☑		
- Removal process - pump/earth moving equipment/manual	☐	☑		
- Disposal	☐	☑		
LIFTING/MANUAL HANDLING - TRASH RACKS, BAULKS, BH GATES, PIT LIDS, GRATING, Does the design consider:-				
- Safe and adequate access - human, vehicle/crane truck	☐	☑		Provided 800mm clearance for personel.
- Position of maintainer to clean screens, racks	☐	☑		

Item	Applicable	Not Applicable	Reference AS/NZS Standard as Relevant	Comments on Design Amendments or Proposed Design Amendments.
- Weight of the item, actuation, force & duration of lift	☐	☑		
- Design, connection/disconnection of lifting equipment & attachments for use of lifting equipment	☐	☑		
- Control of automatic disengagement form lifting frame	☐	☑		
- Provision of storage racks/stability	☐	☑		
FIRE Does the design consider:-				
- Exit signs	☐	☑		
- Extinguishers/signage	☐	☑		
- Fire rating of building/enclosures	☐	☑		
- Fire alarms - back to base or local	☐	☑		
- Gas flooding/automatic door closure	☐	☑		
- Ventilation/air conditioning controls	☐	☑		
- Toxic by-products	☐	☑		
PUBLIC SAFETY & SECURITY - *Base decisions on risk assessment* Does the design consider:-				
- Fencing	☐	☑		
- Gates or other physical barriers	☐	☑		
- Screening, locking - inlets, outlets, trash screens, amyl gates, pits, standpipes	☐	☑		
- Signage including warning signs, restricted access etc	☐	☑		
- Solid core doors on buildings	☐	☑		

Item	Applicable	Not Applicable	Reference AS/NZS Standard as Relevant	Comments on Design Amendments or Proposed Design Amendments.
- Security access systems	☐	☑		
- Autodialler systems	☐	☑		
- Communication systems for personnel inside the building/structure	☐	☑		
- Locking systems	☐	☑		
- Security lighting	☐	☑		
- Intruder alarms	☐	☑		
STORAGE AREAS Does the design consider:-				
- Storage to ensure area is not cluttered	☐	☑		
- Chemical, fuel storage & bunding	☐	☑		
- Security of storage areas relative to items stored	☐	☑		
AMENITIES - If used as a workplace Does the design consider:-				
- Office space	☐	☑		
- Toilets	☐	☑		
- Eating area and facilities	☐	☑		
- Drinking water	☐	☑		
- Emergency shower facilities	☐	☑		
INSTALLATION Will the installation of the equipment create any hazards in the form of :				

Item	Applicable	Not Applicable	Reference AS/NZS Standard as Relevant	Comments on Design Amendments or Proposed Design Amendments.
Manual handling whilst installing	☑	☐		Crane would be required.
Manual handling to get equipment on site / in position	☑	☐		As above.
Hazardous substances	☐	☑		
Initial calibration / certification of equipment (incl SWL)	☐	☑		
Acquiring MSDS, PPE and spill kits for all chemicals	☑	☐		Required for chemical anchoring.
Will an Emergency Response Plan need to be developed for the plant or any of the chemicals it uses	☐	☑		
MAINTENANCE Will the plant or equipment have an ongoing maintenance concerns in the form of :				
Calibration costs	☐	☑		
Recertification of equipment (lifting equip etc)	☐	☑		
Use and disposal of hazardous substances	☐	☑		
TRAINING Will the installation of the equipment require specialist skills or training :				
Familiarisation training	☐	☑		
Manual handling to get equipment on site / in position	☐	☑		
Hazardous substances	☐	☑		
Training in Emergency Response Plans	☐	☑		
Training in the use of calibration equipment	☐	☑		
Licencing to operate the equipment	☐	☑		
Are standby operators required when operating the equipment (eg. Conf Space rescue equip)	☑	☐		Confined space training would be required.

Item	Applicable	Not Applicable	Reference AS/NZS Standard as Relevant	Comments on Design Amendments or Proposed Design Amendments.
ENVIRONMENTAL Is there a Potential Environmental Impact from the Design?				
ATMOSPHERE				
Air quality - emissions - dust, smoke, gas, fumes, odour, particulate matter	☐	☑		
Climate - microclimate	☐	☑		
Audible quality - noise	☐	☑		
COMMUNITY				
Displacement	☐	☑		
Community expectations/requirements	☐	☑		
Natural economic resources	☐	☑		
Regional development/employment/ economic base	☐	☑		
Cultural patterns – community services	☐	☑		
Cultural patterns – cultural features/heritage	☐	☑		
SunWater reputation/image	☐	☑		
FLORA & FAUNA				
Fish passage	☐	☑		
Flooding regime changes	☐	☑		
Impacts on marine/tidal areas	☐	☑		
Impacts on protected species, protected area/habitat – individual and population responses – community responses	☐	☑		
MATERIALS				

Item	Applicable	Not Applicable	Reference AS/NZS Standard as Relevant	Comments on Design Amendments or Proposed Design Amendments.
Energy source/usage	☐	☑		
Life cycle requirements (operations, maintenance, decommissioning etc)	☐	☑		
Sourcing and selection of materials – environmental responsibility	☐	☑		
PROPERTY				
Access to infrastructure	☐	☑		
Devaluation	☐	☑		
Land use change	☐	☑		
Layout including emergency access	☐	☑		
LAND & SOIL				
Existing land use	☐	☑		
Land use - circulation	☐	☑		
Land configuration, slope stability, subsidence	☐	☑		
Land use/soil quality/productivity	☐	☑		
WATER RESOURCES				
Cross catchment transfers	☐	☑		
Evaporation/losses	☐	☑		
Surface runoff	☐	☑		
Streamflow and flood regime changes	☐	☑		
Impact on groundwater	☐	☑		
Release/flow requirements	☐	☑		

Item	Applicable	Not Applicable	Reference AS/NZS Standard as Relevant	Comments on Design Amendments or Proposed Design Amendments.
Water quality – chemical changes, turbidity/sedimentation	☐	☑		
Waterway barriers	☐	☑		
VEGETATION – TERRESTRIAL & AQUATIC				
Form and structure	☐	☑		
Density	☐	☑		
Productivity	☐	☑		
Rare and endangered	☐	☑		
WASTE GENERATION & DISPOSAL				
Solid waste generation	☐	☑		
Waste water	☐	☑		
Waste disposal facilities	☐	☑		
PUBLIC HEALTH				
Risk to public health	☐	☑		
Vector borne disease	☐	☑		
Fire hazard	☐	☑		
OTHER - Provide process/piping and instrumentation diagrams - overview of total plant operation	☐	☑		
Other:				

Item	Applicable	Not Applicable	Reference AS/NZS Standard as Relevant	Comments on Design Amendments or Proposed Design Amendments.
HSE Design Review Date(s): September 2010				HSE Design Review Finalisation Date:
All agreed design amendments resulting from this HSE review and as approved by the Project Manager will be incorporated into the design documentation prior to construction. **Design Managers Signature:**				**Date:**

APPENDIX I

OPTIONS ANALYSIS

Infrastructure Type	Issues	Potential Negation of Safety Issues	Cost of Negation
Level Two	Access	Stairs	$48,000.00
		Vertical Ladder With Fall Arrest System	$12,800.00
	Confined Space - No Rescue	Davit Arm or Similar	$20,000.00
		Crane (PV)	$9,749.43
		Stairs	$48,000.00
	Spool Removal	Crane (PV)	$9,749.43
		Roll Out Arrangement	$1,000.00
Level Three	Spool Removal	Crane (PV)	$9,749.43
		Roll Out Arrangement	$1,000.00
Options			
Level Two			
	Stairs/Crane		$57,749.43
	Stairs/Roll Out		$49,000.00
	Ladder/Davit/Roll Out		$33,800.00
	Ladder/Crane		$22,549.43

Rescue Gear	
Davit Arm	2 x 4800 (1 per structure, 2 structures per pipeline)
Flush Floor Mount Sleeve	4 x 900 (2 per structure, 2 structures per pipeline)
Winch	2 x 3400 (1 per structure, 2 structures per pipeline)
Lad-Saf	4 x 1200 (1 per ladder install, 2 ladders per structure, 2 structures per pipeline)
Stairs	
Additional Concrete In Pit	2 x 14000 (2 structures per pipeline)
Cost of Stairs	4 x 5000 (2 stairs per structure, 2 structures per pipeline)
Vertical Ladder	
Cost of Ladders	4 x 2000 (2 ladders per structure, 2 structures per pipeline)
Crane	
0.5 Days @ $170/hr	5 x 170 x 20 (1 event per year, 20 years)

APPENDIX J

RAW ANALYSIS MODEL

RAW MODEL

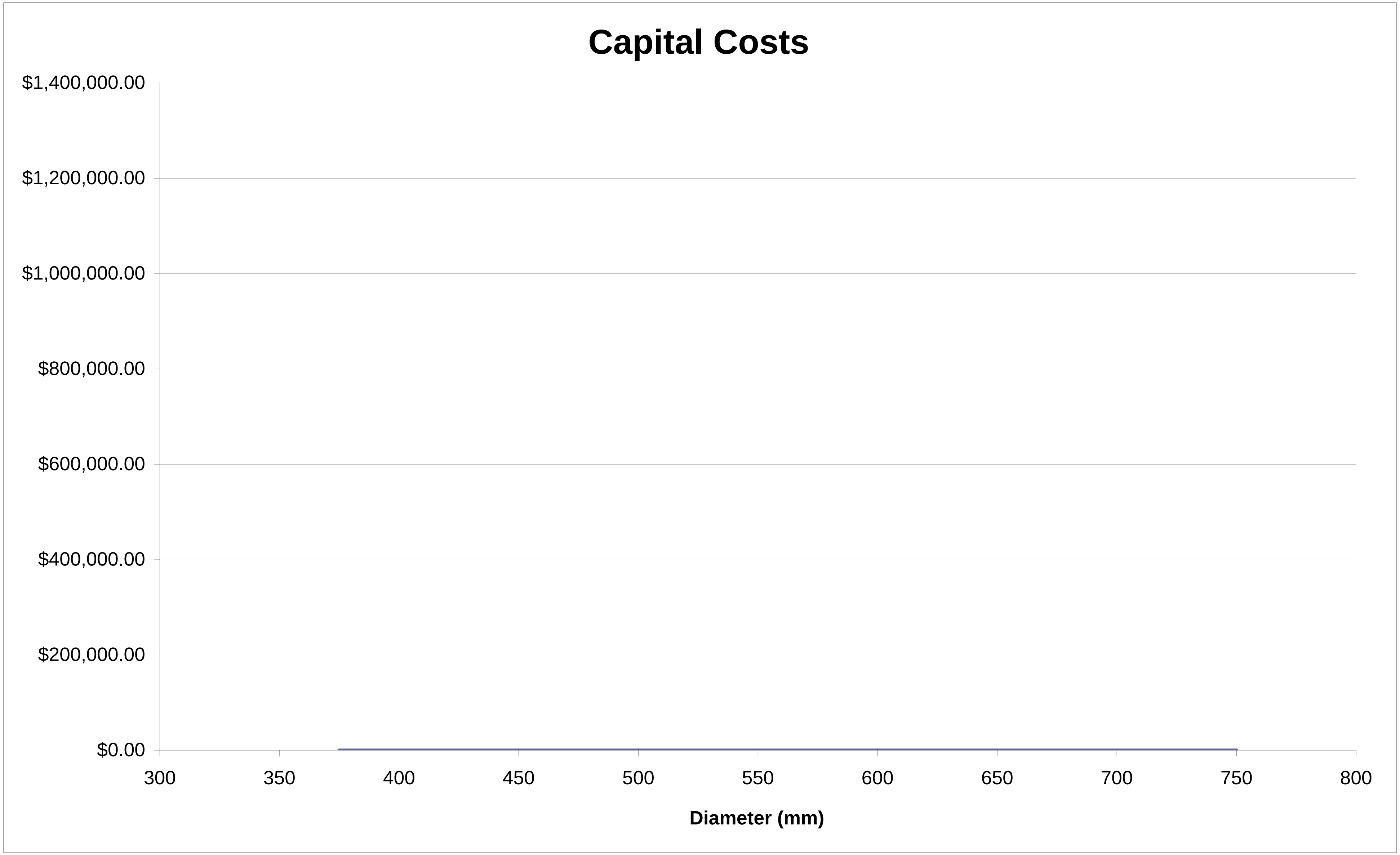
	Diameter (mm)				
	375	450	500	600	750
Capital					
Pipe Work	$ -	$ -	$ -	$ -	$ -
Valves	$ -	$ -	$ -	$ -	$ -
Concrete/Reinforcement (Inc. Form Work/Pouring etc.)	$ -	$ -	$ -	$ -	$ -
Metal Items	$ -	$ -	$ -	$ -	$ -
Construction	$ -	$ -	$ -	$ -	$ -
Total	$ -	$ -	$ -	$ -	$ -
Operational (Over Design Life)					
Resources	$ -	$ -	$ -	$ -	$ -
Total (Present Value)	$ -	$ -	$ -	$ -	$ -
TOTAL COST	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**

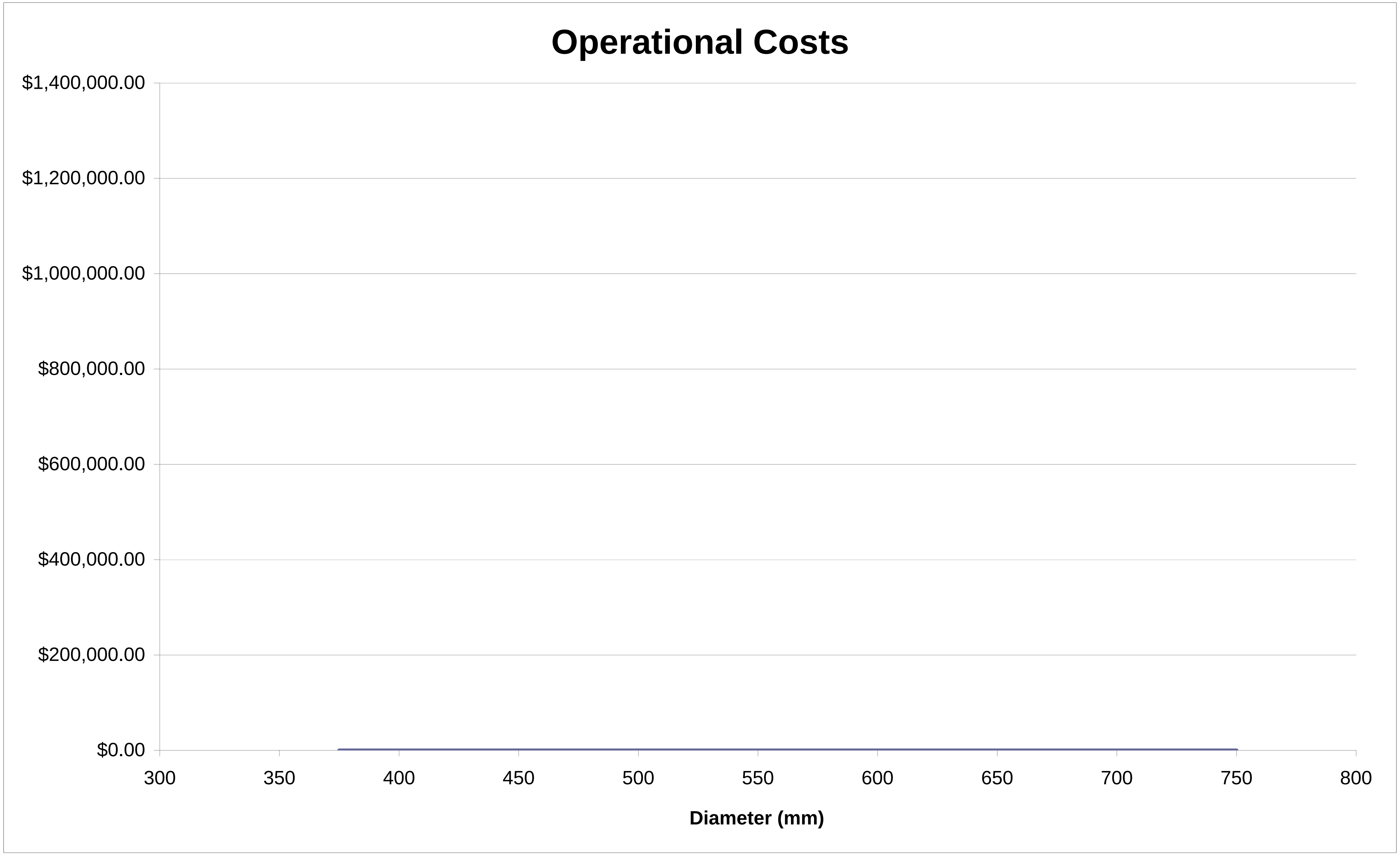
Notes:

Construction costs to include a 10% contingency.

Operation costs to include a 10% contingency.

A rate of 6% has been adopted in the PV calculation.


Capital Costs
$1,400,000.00
$1,200,000.00
$1,000,000.00
$800,000.00
$600,000.00
$400,000.00
$200,000.00
$0.00
300
350
400
450
500
550
600
650
700
750
800
Diameter (mm)


Operational Costs
$1,400,000.00
$1,200,000.00
$1,000,000.00
$800,000.00
$600,000.00
$400,000.00
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350
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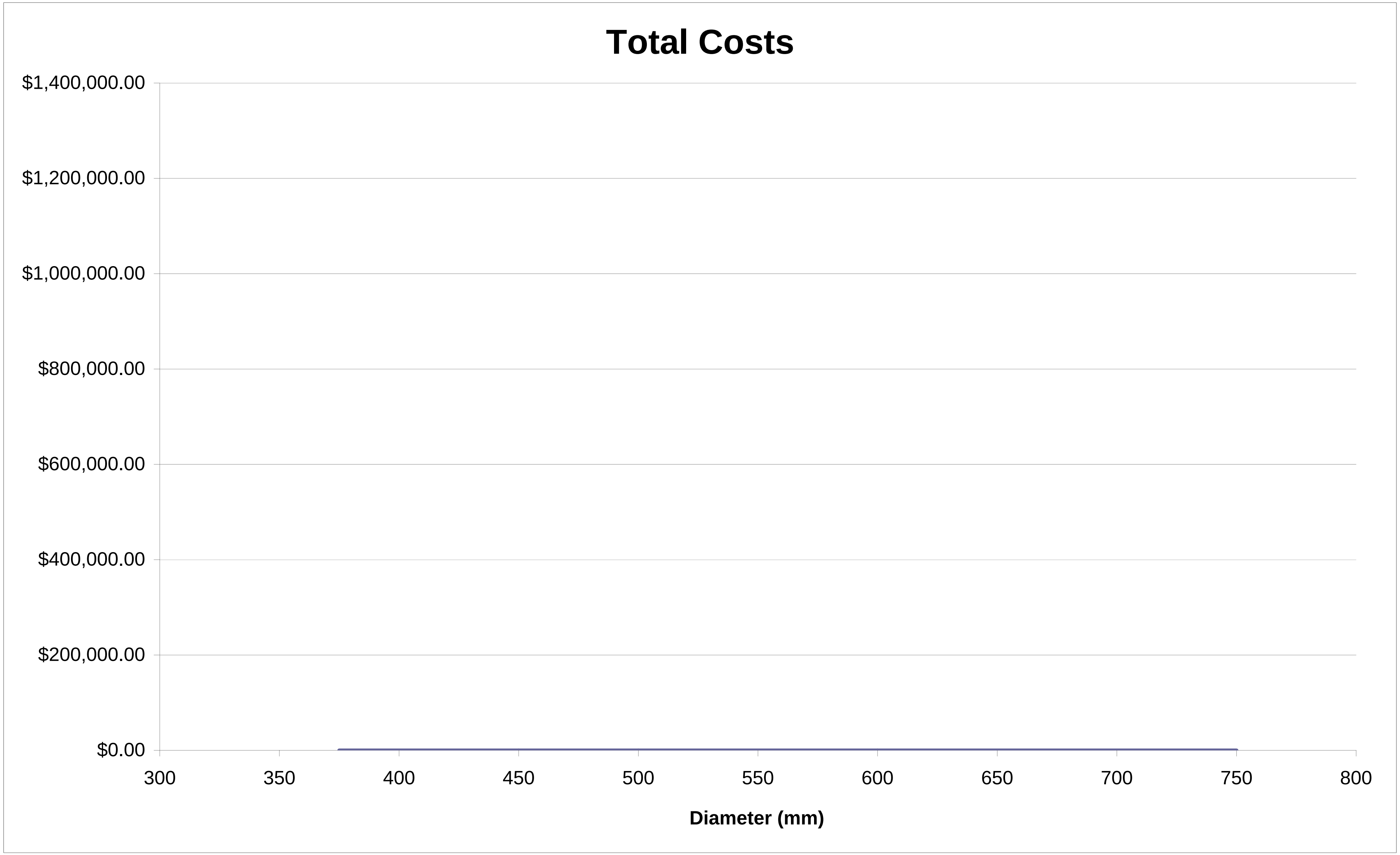
600
650
700
750
800
Diameter (mm)


Total Costs
$1,400,000.00
$1,200,000.00
$1,000,000.00
$800,000.00
$600,000.00
$400,000.00
$200,000.00
$0.00
300
350
400
450
500
550
600
650
700
750
800
Diameter (mm)

		Diameter (mm)				
		375	450	500	600	750
Length of Concrete Structure (m)						
	Level 1 PN20	0.000	0.000	0.000	0.000	0.000
	Level 2 PN20	7.674	8.056	8.818	9.894	11.040
	Level 3 PN20	5.674	6.056	6.818	7.894	9.040
	Level 1 PN35	0.000	0.000	0.000	0.000	0.000
	Level 2 PN35	7.984	8.386	9.218	10.324	11.540
	Level 3 PN35	5.984	6.386	7.218	8.324	9.540
Volume of Concrete (m^3) (Ex. Thrust Blocks)						
	Level 1 PN20	0.000	0.000	0.000	0.000	0.000
	Level 2 PN20	20.704	22.322	24.484	28.059	32.740
	Level 3 PN20	1.681	1.862	2.148	2.605	3.187
	Level 1 PN35	0.000	0.000	0.000	0.000	0.000
	Level 2 PN35	21.311	22.990	25.312	28.988	33.888
	Level 3 PN35	1.773	1.964	2.274	2.747	3.363

Notes:

		Diameter (mm)										
		100	150	200	225	250	300	375	450	500	600	750
Straight (Standard 5.35m Long)		$ 818.15	$ 1,235.94	$ 1,571.63	$ 1,865.71	$ 2,150.24	$ 2,600.08	$ 3,999.64	$ 4,684.52	$ 6,083.52	$ 7,904.81	$ 11,592.94
Flanged Tee												
	100 Branch	$ 127.86	$ 182.45	$ 390.07	$ 489.20	$ 628.09	$ 778.33	$ 1,149.34	$ 1,875.83	$ 2,335.79	$ 3,011.12	
	150 Branch		$ 215.24	$ 363.03	$ 507.76	$ 651.14	$ 756.91	$ 1,221.88	$ 1,940.50	$ 2,420.70	$ 3,120.77	
	200 Branch			$ 421.56	$ 658.45	$ 794.53	$ 923.30	$ 1,224.62	$ 1,788.68	$ 2,438.13	$ 3,234.91	
	225 Branch				$ 659.02	$ 799.03	$ 1,010.45	$ 1,256.74	$ 1,974.24	$ 2,433.07	$ 3,252.34	
	250 Branch					$ 675.80	$ 1,057.69	$ 1,300.04	$ 2,029.34	$ 2,440.38	$ 3,509.88	
	300 Branch						$ 885.85	$ 1,411.94	$ 1,992.23	$ 2,665.30	$ 3,439.59	$ 4,739.95
	375 Branch							$ 1,377.07	$ 2,269.44	$ 2,555.09	$ 3,353.56	$ 4,996.70
	450 Branch								$ 2,247.83	$ 2,619.76	$ 3,717.93	$ 6,650.88
	500 Branch									$ 2,152.03	$ 3,756.73	$ 7,591.05
	600 Branch										$ 4,235.81	$ 6,156.62
	750 Branch											$ 7,440.75
Flanged Eccentric Taper												
	450 Enlargement							$ 1,519.33				
	500 Enlargement							$ 2,183.97	$ 2,083.88			
	600 Enlargement							$ 2,642.25	$ 2,640.56	$ 2,792.38		
	750 Enlargement							$ 3,765.15	$ 4,487.15	$ 3,999.08	$ 4,477.02	
								$ 4,118.72	$ 4,871.90	$ 4,401.36	$ 4,919.24	$ 5,350.55
Flanged Connector												
	Socket							$ 475.80	$ 930.45	$ 1,272.05	$ 1,576.07	$ 1,965.15
	Spigot							$ 551.73	$ 822.63	$ 1,119.47	$ 1,457.85	$ 1,965.15
Gibault Joint		$ 106.42	$ 132.25	$ 228.34	$ 313.56	$ 332.61	$ 445.71	$ 566.02	$ 1,291.14	$ 2,482.75	$ 2,778.89	$ 4,459.61
Flanged Bend												
	90º	$ 104.55	$ 177.63	$ 356.53	$ 518.93	$ 478.89	$ 662.11	$ 1,352.90	$ 2,013.03	$ 2,559.59	$ 4,004.34	$ 6,182.19
	45º							$ 1,312.75	$ 2,211.53	$ 2,522.48	$ 3,618.40	$ 4,083.34
Blank Flange		$ 30.98	$ 50.82	$ 78.52	$ 104.03	$ 113.64	$ 190.25	$ 491.45	$ 519.16	$ 940.73	$ 1,205.01	$ 1,853.34
Resilient Seated Sluice Valve		$ 315.70	$ 510.86	$ 924.14	$ 1,142.26	$ 1,549.80	$ 2,077.88	$ 4,712.54	$ 8,349.29	$ 11,159.41	$ 13,213.25	$ 22,940.00
Spool Arrangement		$ 1,235.94	$ 1,571.63	$ 1,865.71	$ 2,150.24	$ 2,600.08	$ 3,999.64	$ 4,684.52	$ 6,083.52	$ 7,904.81	$ 11,592.94	$ 17,686.68
Air Valve		$ 1,000.00	$ 1,000.00	$ 1,000.00	$ 1,000.00	$ 1,000.00	$ 1,000.00	$ 1,000.00	$ 1,000.00	$ 1,000.00	$ 1,000.00	$ 1,000.00

		Diameter (mm)										
		100	150	200	225	250	300	375	450	500	600	750
Straight (Standard 5.35m Long)		$ 899.97	$ 1,359.53	$ 1,728.79	$ 2,052.28	$ 2,365.26	$ 2,860.09	$ 4,399.60	$ 5,152.97	$ 6,691.87	$ 8,695.29	$ 12,752.23
Flanged Tee												
	100 Branch	$ 140.65	$ 200.70	$ 429.08	$ 538.12	$ 690.90	$ 856.16	$ 1,264.27	$ 2,063.41	$ 2,569.37	$ 3,312.23	
	150 Branch		$ 236.76	$ 399.33	$ 558.54	$ 716.25	$ 832.60	$ 1,344.07	$ 2,134.55	$ 2,662.77	$ 3,432.85	
	200 Branch			$ 463.72	$ 724.30	$ 873.98	$ 1,015.63	$ 1,347.08	$ 1,967.55	$ 2,681.94	$ 3,558.40	
	225 Branch				$ 724.92	$ 878.93	$ 1,111.50	$ 1,382.41	$ 2,171.66	$ 2,676.38	$ 3,577.57	
	250 Branch					$ 743.38	$ 1,163.46	$ 1,430.04	$ 2,232.27	$ 2,684.42	$ 3,860.87	
	300 Branch						$ 974.44	$ 1,553.13	$ 2,191.45	$ 2,931.83	$ 3,783.55	$ 5,213.95
	375 Branch							$ 1,514.78	$ 2,496.38	$ 2,810.60	$ 3,688.92	$ 5,496.37
	450 Branch								$ 2,472.61	$ 2,881.74	$ 4,089.72	$ 7,315.97
	500 Branch									$ 2,367.23	$ 4,132.40	$ 8,350.16
	600 Branch										$ 4,659.39	$ 6,772.28
	750 Branch											$ 8,184.83
Flanged Eccentric Taper												
	450 Enlargement							$ 1,671.26				
	500 Enlargement							$ 2,402.37	$ 2,292.27			
	600 Enlargement							$ 2,906.48	$ 2,904.62	$ 3,071.62		
	750 Enlargement							$ 4,141.67	$ 4,935.87	$ 4,398.99	$ 4,924.72	
								$ 4,530.59	$ 5,359.09	$ 4,841.50	$ 5,411.16	$ 5,885.61
Flanged Connector												
	Socket							$ 523.38	$ 1,023.50	$ 1,399.26	$ 1,733.68	$ 2,161.67
	Spigot							$ 606.90	$ 904.89	$ 1,231.42	$ 1,603.64	$ 2,161.67
Gibault Joint		$ 117.06	$ 145.48	$ 251.17	$ 344.92	$ 365.87	$ 490.28	$ 622.62	$ 1,420.25	$ 2,731.03	$ 3,056.78	$ 4,905.57
Flanged Bend												
	90º	$ 115.01	$ 195.39	$ 392.18	$ 570.82	$ 526.78	$ 728.32	$ 1,488.19	$ 2,214.33	$ 2,815.55	$ 4,404.77	$ 6,800.41
	45º							$ 1,444.03	$ 2,432.68	$ 2,774.73	$ 3,980.24	$ 4,491.67
Blank Flange		$ 34.08	$ 55.90	$ 86.37	$ 114.43	$ 125.00	$ 209.28	$ 540.60	$ 571.08	$ 1,034.80	$ 1,325.51	$ 2,038.67
Resilient Seated Sluice Valve		$ 527.22	$ 894.01	$ 2,467.45	$ 2,398.75	$ 3,285.58	$ 3,553.17	$ 6,550.43	$ 11,689.01	$ 15,957.96	$ 24,074.10	$ 40,859.25
Spool Arrangement		$ 1,359.53	$ 1,728.79	$ 2,052.28	$ 2,365.26	$ 2,860.09	$ 4,399.60	$ 5,152.97	$ 6,691.87	$ 8,695.29	$ 12,752.23	$ 19,455.34
Air Valve		$ 1,000.00	$ 1,000.00	$ 1,000.00	$ 1,000.00	$ 1,000.00	$ 1,000.00	$ 1,000.00	$ 1,000.00	$ 1,000.00	$ 1,000.00	$ 1,000.00

		Diameter (mm)																					
		100		150		200		225		250		300		375		450		500		600		750	
		L (mm)	W (mm)	L (mm)	W (mm)	L (mm)	W (mm)	L (mm)	W (mm)	L (mm)	W (mm)	L (mm)	W (mm)	L (mm)	W (mm)	L (mm)	W (mm)	L (mm)	W (mm)	L (mm)	W (mm)	L (mm)	W (mm)
Flanged Tee																							
	100 Branch	356	178	406	203	484	241	508	254	534	267	610	305										
	150 Branch			406	203	484	241	508	254	534	267	610	305										
	200 Branch					484	241	508	254	534	267	610	305	738	356								
	225 Branch							508	254	534	267	610	305	738	356								
	250 Branch									534	267	610	305	738	356	814	394	890	432				
	300 Branch											610	305	738	356	814	394	890	432	1016	483	890	615
	375 Branch													738	368	814	406	890	444	1016	495	1000	645
	450 Branch															814	406	890	444	1016	495	1080	655
	500 Branch																	890	444	1016	495	1160	680
	600 Branch																			1016	508	1260	695
	750 Branch																					1450	725
Flanged Eccentric Taper																							
	450 Enlargement													356									
	500 Enlargement													483		305							
	600 Enlargement													749		572		444					
	750 Enlargement													1180		1000		885		645			
																						780	
Flanged Connector																							
	Socket	110		135		135		155		155		170		195		200		215		230		250	
	Spigot	205		205		230		230		230		255		280		280		305		330		370	
Gibault Joint		180		180		180		180		180		230		230		230		230		230		300	
Flanged Bend																							
	90º																						
	45º																						
Resilient Seated Sluice Valve																							
	PN20	255		280		320		330		355		380		455		495		510		570		1210	
	PN35	305		330		380		405		420		430		610		660		710		785		1460	
Spool Arrangement														1100		1200		1350		1400		1500	

Reinfroced Concrete (Formed/Poured) $ 2,500.00 m^3

Metal Items

	375	450	500	600	750
Ladders	$ 4,175.00	$ 4,250.00	$ 4,300.00	$ 4,400.00	$ 4,550.00
Handrails	$ 2,268.84	$ 2,366.91	$ 2,544.78	$ 2,794.89	$ 3,074.40
Supports	$ 1,000.00	$ 1,000.00	$ 1,000.00	$ 1,000.00	$ 1,000.00
Roll Out Rail Arrangement	$ 1,000.00	$ 1,000.00	$ 1,000.00	$ 1,000.00	$ 1,000.00

Notes:

Handrails based on $105.00/m.

Ladders based on $500.00/m

Ladders include $1200 for fall arrest system.

					375	450	500	600	750
		Rate	Unit	Quantity	Total				
Labour									
	Four Men	$ 4,000.00	day		$ -	$ -	$ -	$ -	$ -
	Supervisor	$ 1,250.00	day		$ -	$ -	$ -	$ -	$ -
	Accomodation/Meals etc.	$ 1,000.00	day		$ -	$ -	$ -	$ -	$ -
Plant									
	Franna Crane	$ 2,500.00	day		$ -	$ -	$ -	$ -	$ -
Materials									
	Miscellaneous	$ -	lump sum	1.00	$ -	$ -	$ -	$ -	$ -
Thrust Blocks		$ 1,500.00	m^3		$ -	$ -	$ -	$ -	$ -

Notes:

4 Men Rate - based on a 10 hour day at $100/hr/man.

Supervisor Rate - based on a 10 hour day at $125/hr.

Accomodation/Meals etc. Rate - based on $200/night/man.

Franna Crane Rate - based on a 10 hour day at $250/hr including a dogman.

					750	375	450	500	600
		Rate	Unit	Quantity	Total				
Labour									
	Four Men	$ 4,000.00	day		$ -	$ -	$ -	$ -	$ -
	Accomodation/Meals etc.	$ 800.00	day		$ -	$ -	$ -	$ -	$ -
Plant									
	Franna Crane	$ 2,500.00	day		$ -	$ -	$ -	$ -	$ -

Notes:

4 Men Rate - based on a 10 hour day at $100/hr/man.
Accomodation/Meals etc. Rate - based on $200/night/man.
Franna Crane Rate - based on a 10 hour day at $250/hr including a dogman.

APPENDIX K

LEVEL ONE PN20 MODEL

LEVEL ONE PN20

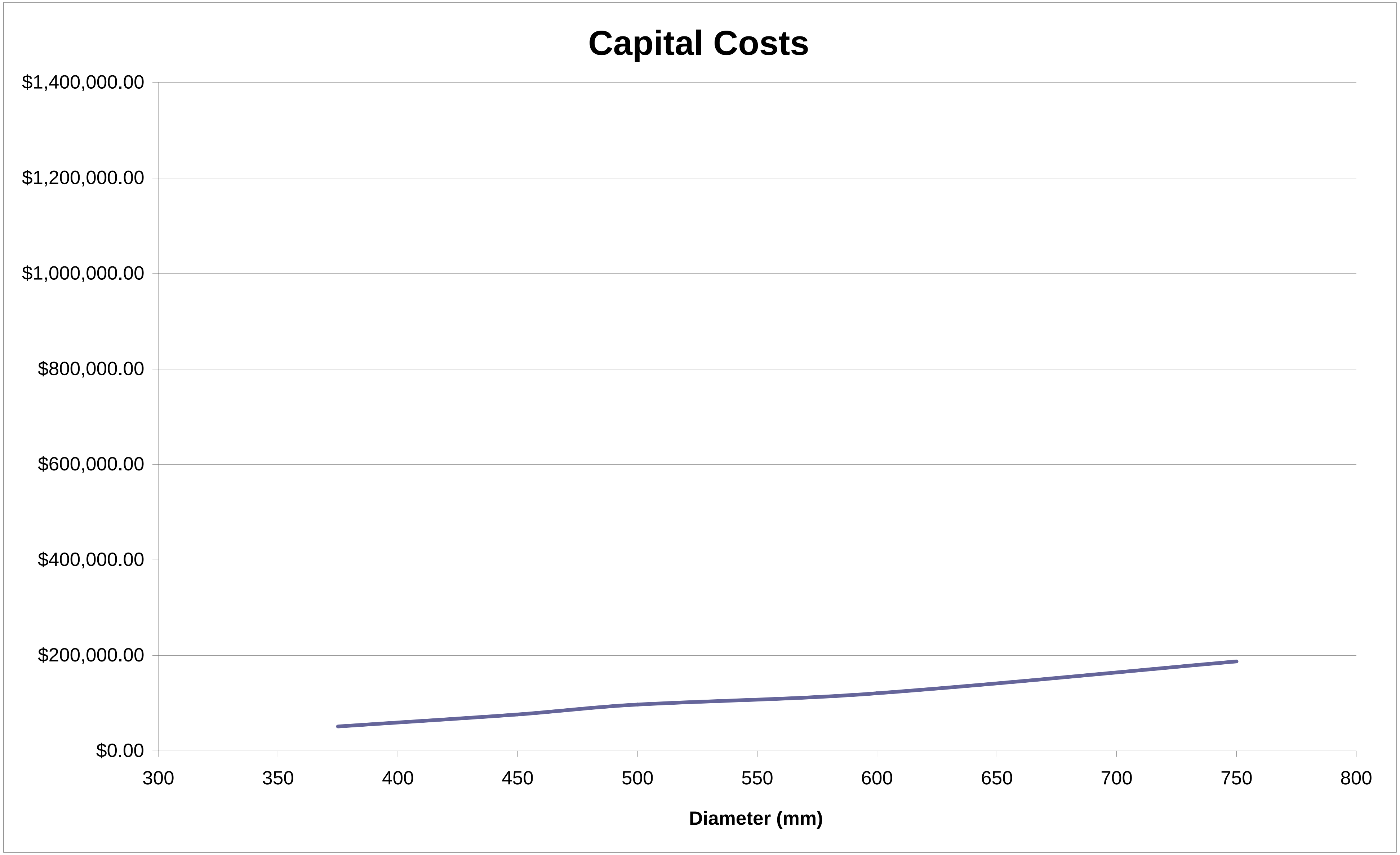
	Diameter (mm)				
	375	450	500	600	750
Capital					
Pipe Work	$ 3,999.64	$ 4,684.52	$ 6,083.52	$ 7,904.81	$ 11,592.94
Valves	$ 9,425.08	$ 16,698.58	$ 22,318.82	$ 26,426.50	$ 45,879.99
Concrete/Reinforcement (Inc. Form Work/Pouring etc.)	$ -	$ -	$ -	$ -	$ -
Metal Items	$ 1,000.00	$ 1,000.00	$ 1,000.00	$ 1,000.00	$ 1,000.00
Construction	$ 8,950.00	$ 12,395.75	$ 14,767.50	$ 19,511.00	$ 26,850.00
Total	$ 51,424.38	$ 76,513.47	$ 97,173.65	$ 120,653.08	$ 187,710.45
Operational (Over Design Life)					
Resources	$ 14,168.00	$ 15,053.50	$ 15,939.00	$ 16,824.50	$ 17,710.00
Total (Present Value)	$162,505.84	$172,662.46	$182,819.07	$192,975.69	$203,132.30
TOTAL COST	**$ 213,930.23**	**$ 249,175.93**	**$ 279,992.72**	**$ 313,628.77**	**$ 390,842.75**

Notes:

Construction costs to include a 10% contingency.

Operation costs to include a 10% contingency.

A rate of 6% has been adopted in the PV calculation.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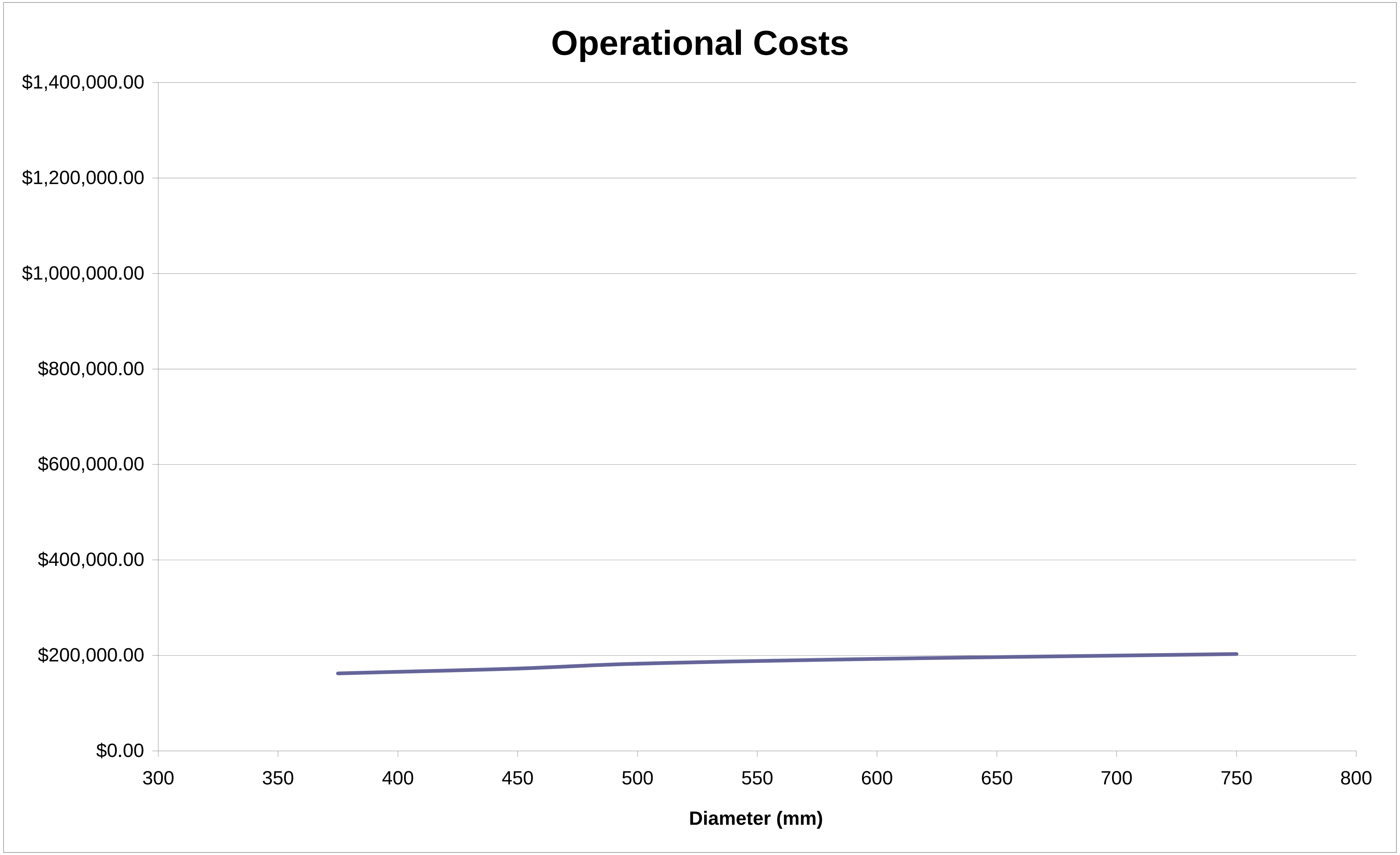
Diameter (mm)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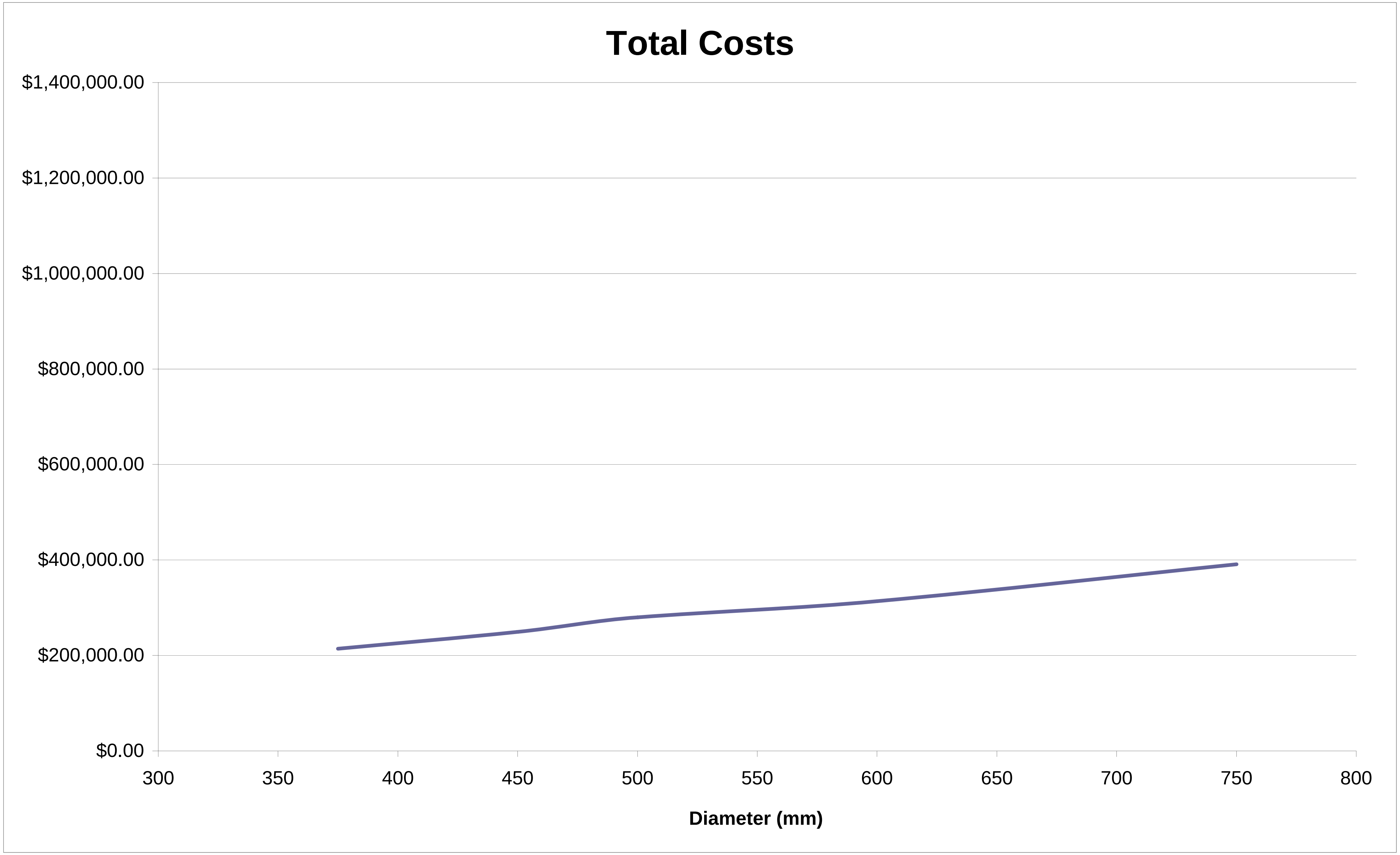
Diameter (mm)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Diameter (mm)

APPENDIX L

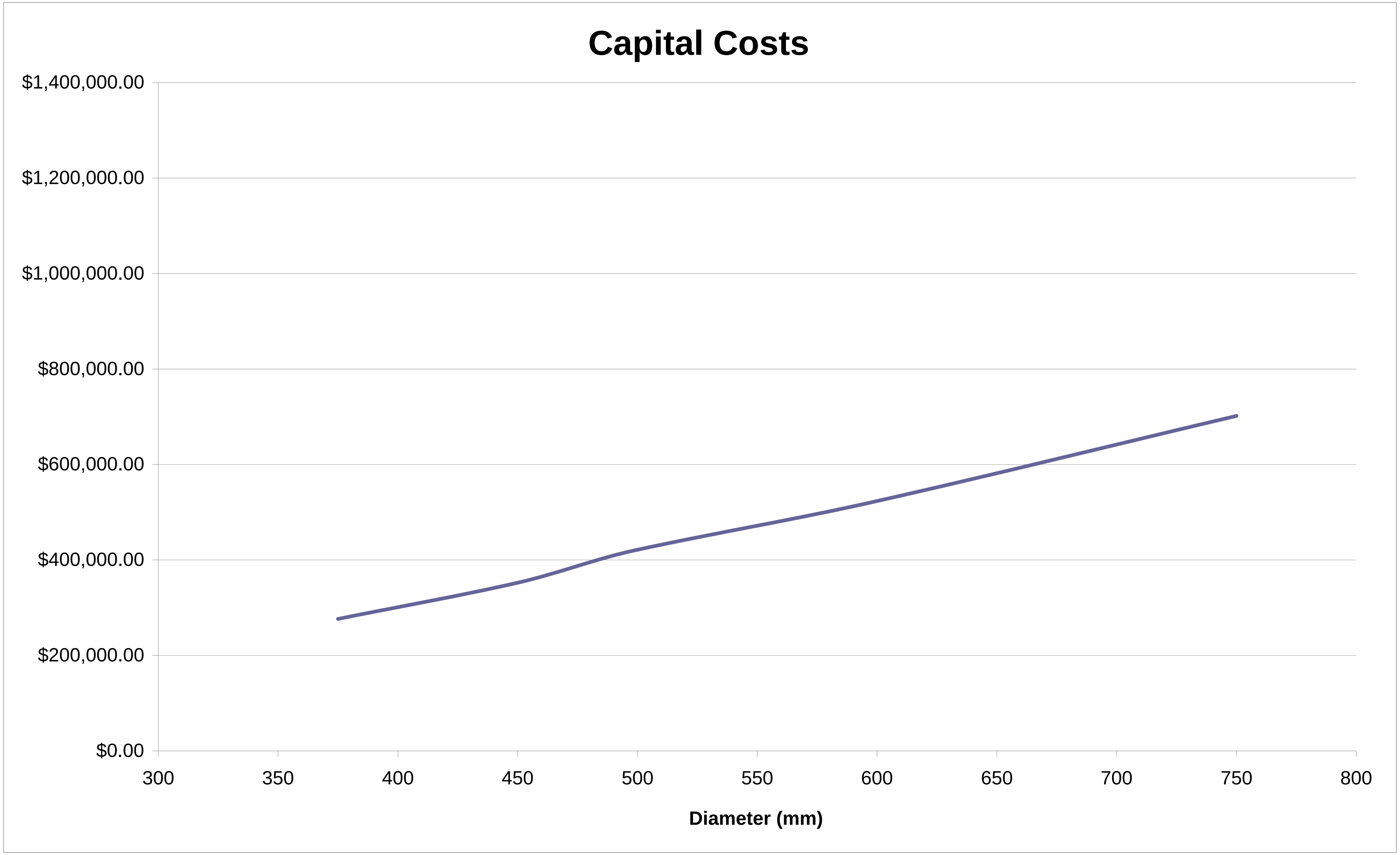
LEVEL TWO PN20 MODEL

LEVEL TWO PN20

	Diameter (mm)				
	375	450	500	600	750
Capital					
Pipe Work	$ 19,969.72	$ 28,378.33	$ 38,474.10	$ 51,494.83	$ 70,401.55
Valves	$ 10,446.80	$ 18,546.86	$ 24,603.34	$ 29,526.10	$ 50,035.75
Concrete/Reinforcement (Inc. Form Work/Pouring etc.)	$ 51,760.26	$ 55,804.75	$ 61,210.65	$ 70,147.60	$ 81,850.75
Metal Items	$ 7,443.84	$ 7,616.91	$ 7,844.78	$ 8,194.89	$ 8,624.40
Construction	$ 36,000.00	$ 49,860.00	$ 59,400.00	$ 78,480.00	$ 108,000.00
Total	$ 276,365.37	$ 352,455.06	$ 421,372.32	$ 523,255.53	$ 701,607.39
Operational (Over Design Life)					
Resources	$ 11,308.00	$ 12,014.75	$ 12,721.50	$ 13,428.25	$ 14,135.00
Total (Present Value)	$129,701.87	$137,808.24	$145,914.60	$154,020.97	$162,127.34
TOTAL COST	**$ 406,067.24**	**$ 490,263.30**	**$ 567,286.93**	**$ 677,276.50**	**$ 863,734.73**

Notes:

Capital costs to include a 10% contingency.
Operation costs to include a 10% contingency.
A rate of 6% has been adopted in the PV calculation.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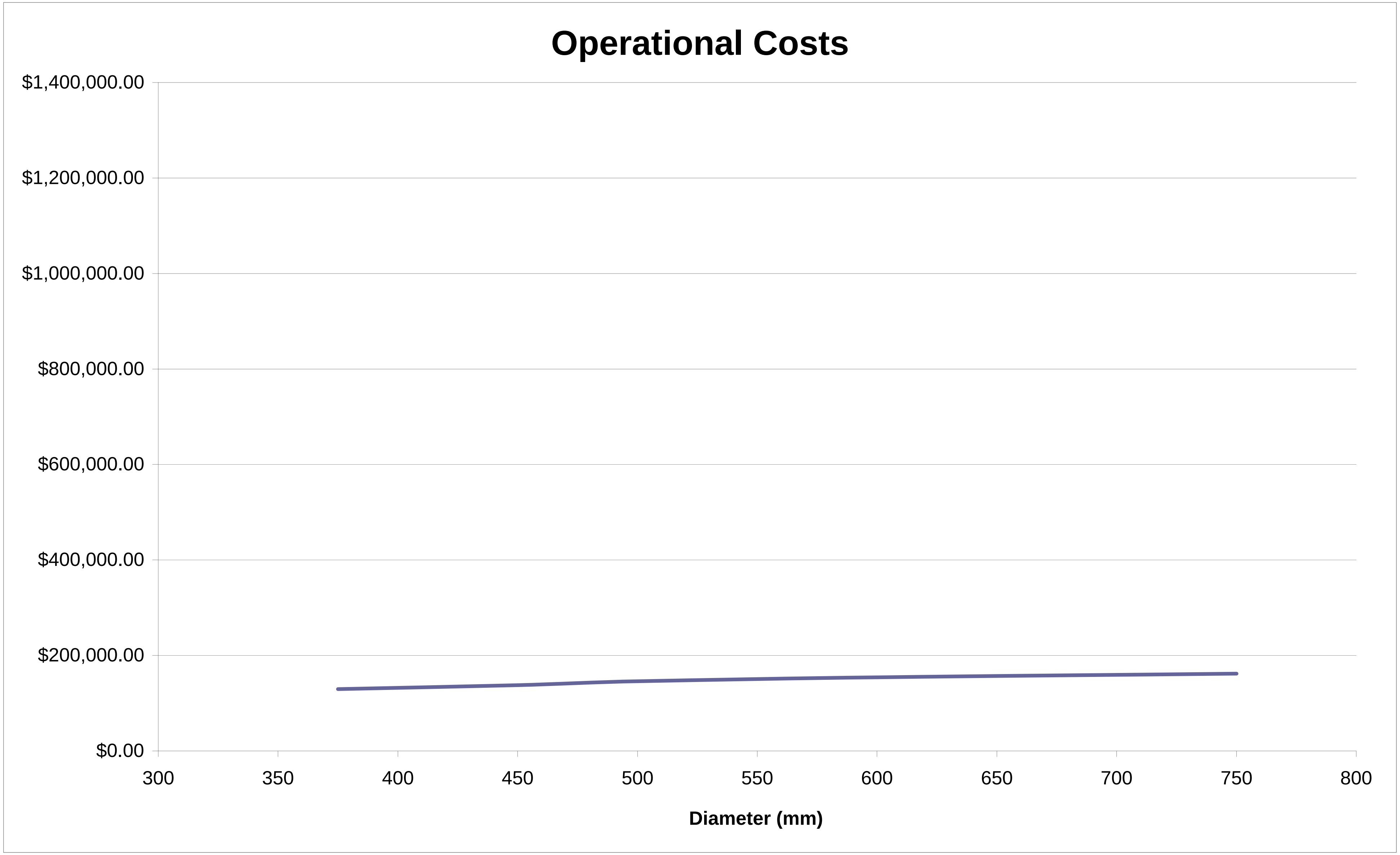
Diameter (mm)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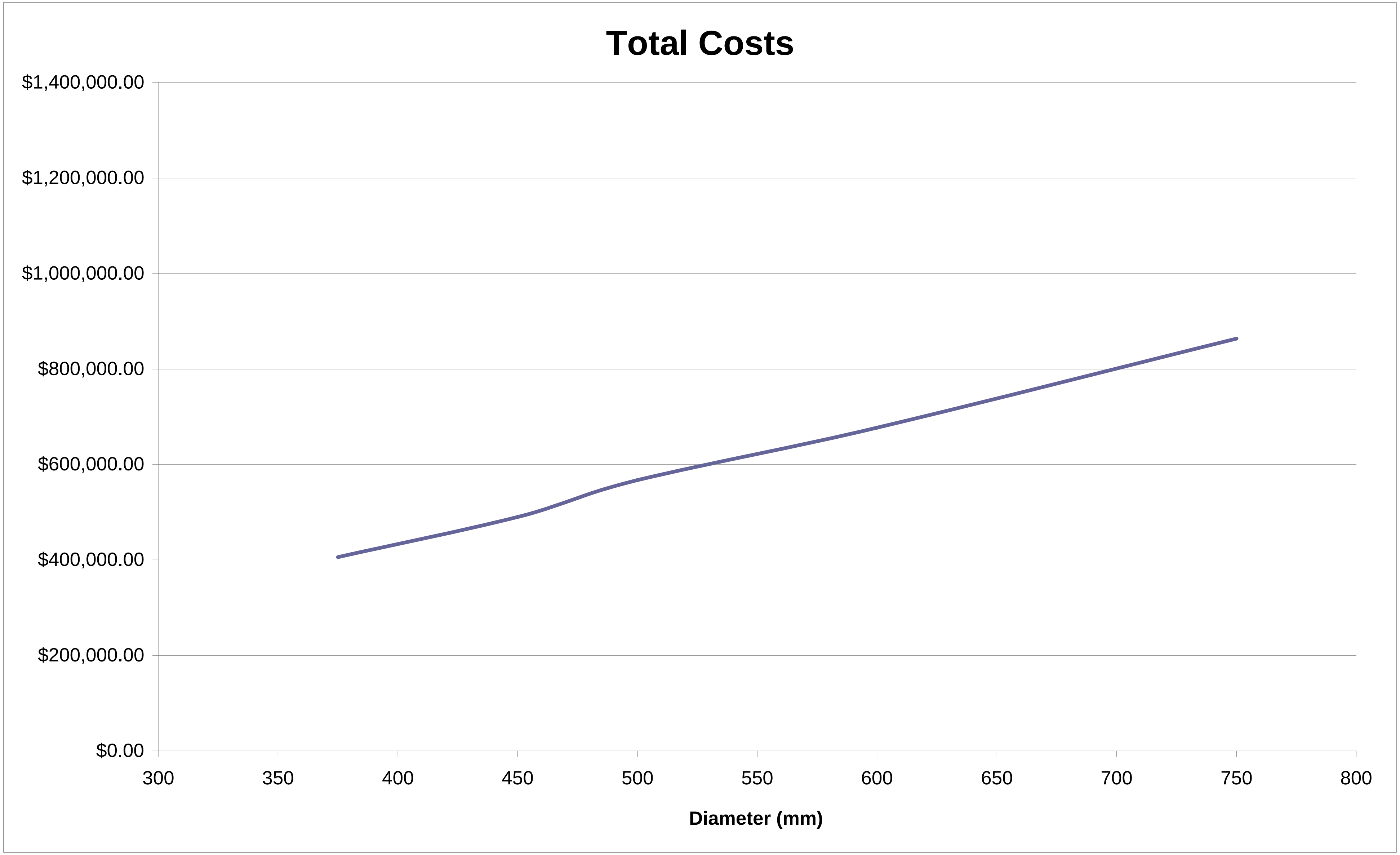
Diameter (mm)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$600,000.00
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Diameter (mm)

APPENDIX M

LEVEL THREE PN20 MODEL

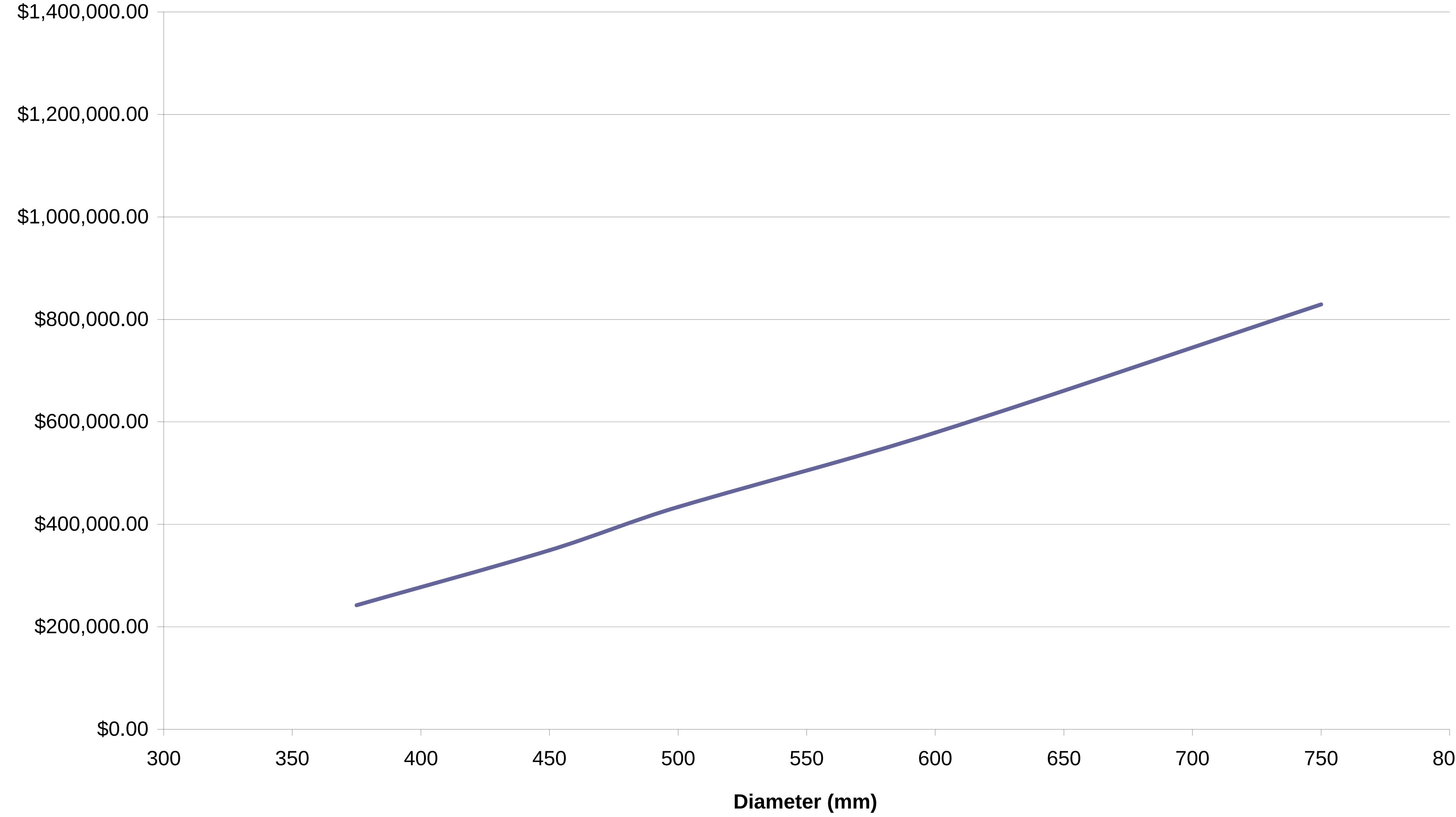
LEVEL THREE PN20

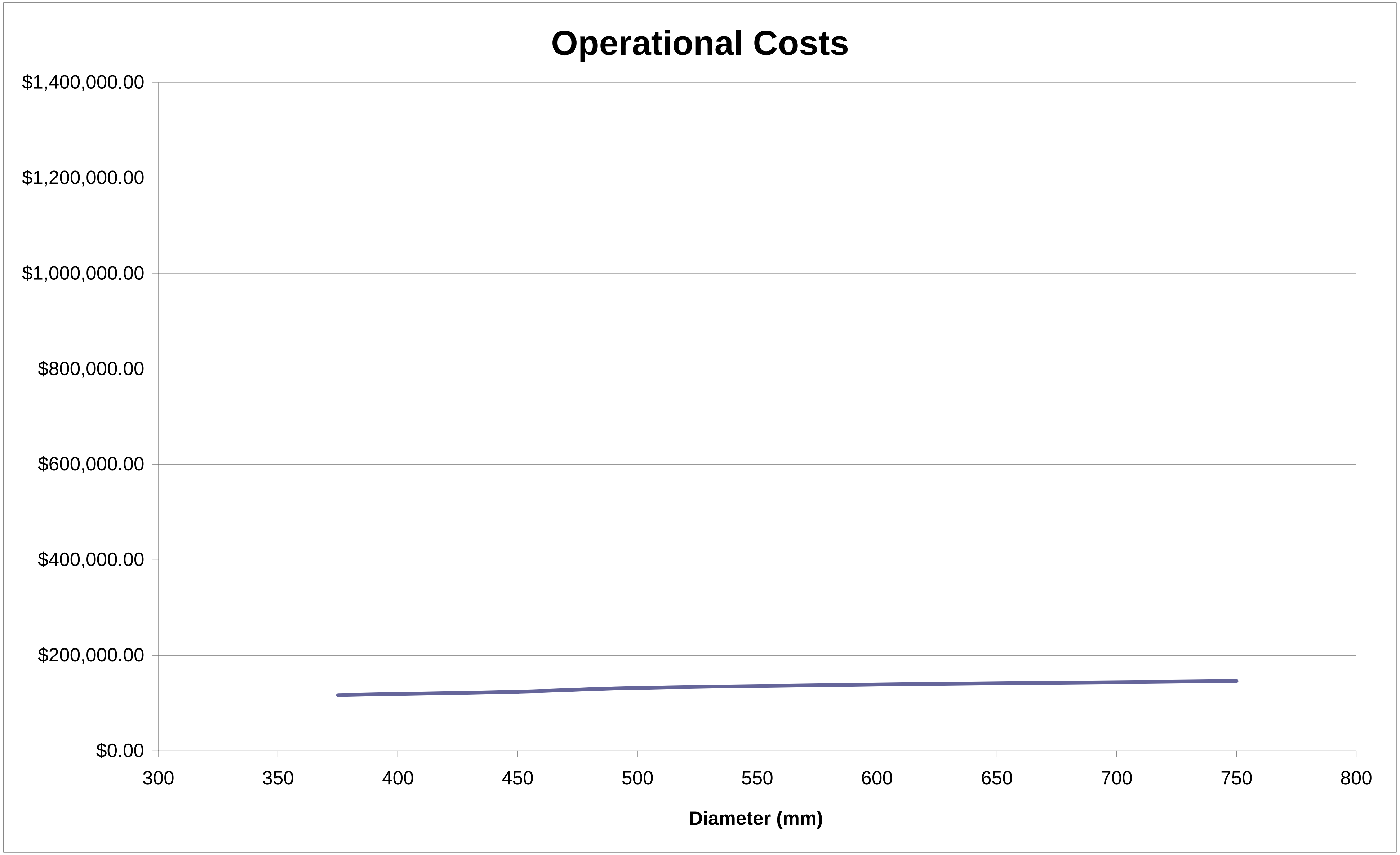
			Diameter (mm)		
	375	450	500	600	750
Capital					
Pipe Work	$ 26,451.41	$ 38,518.99	$ 50,211.12	$ 68,258.28	$ 90,177.30
Valves	$ 10,446.80	$ 18,546.86	$ 24,603.34	$ 29,526.10	$ 50,035.75
Concrete/Reinforcement (Inc. Form Work/Pouring etc.)	$ 4,202.31	$ 4,655.55	$ 5,369.18	$ 6,512.55	$ 7,966.50
Metal Items	$ 2,000.00	$ 2,000.00	$ 2,000.00	$ 2,000.00	$ 2,000.00
Construction	$ 67,000.00	$ 95,097.50	$ 114,975.00	$ 156,830.00	$ 226,800.00
Total	$ 242,221.14	$ 349,401.57	$ 433,748.99	$ 578,879.25	$ 829,355.01
Operational (Over Design Life)					
Resources	$ 10,208.00	$ 10,846.00	$ 11,484.00	$ 12,122.00	$ 12,760.00
Total (Present Value)	$117,084.96	$124,402.77	$131,720.58	$139,038.39	$146,356.19
TOTAL COST	**$ 359,306.10**	**$ 473,804.34**	**$ 565,469.57**	**$ 717,917.64**	**$ 975,711.20**

Notes:

Construction costs to include a 10% contingency.
Operation costs to include a 10% contingency.
A rate of 6% has been adopted in the PV calculation.

Capital Costs

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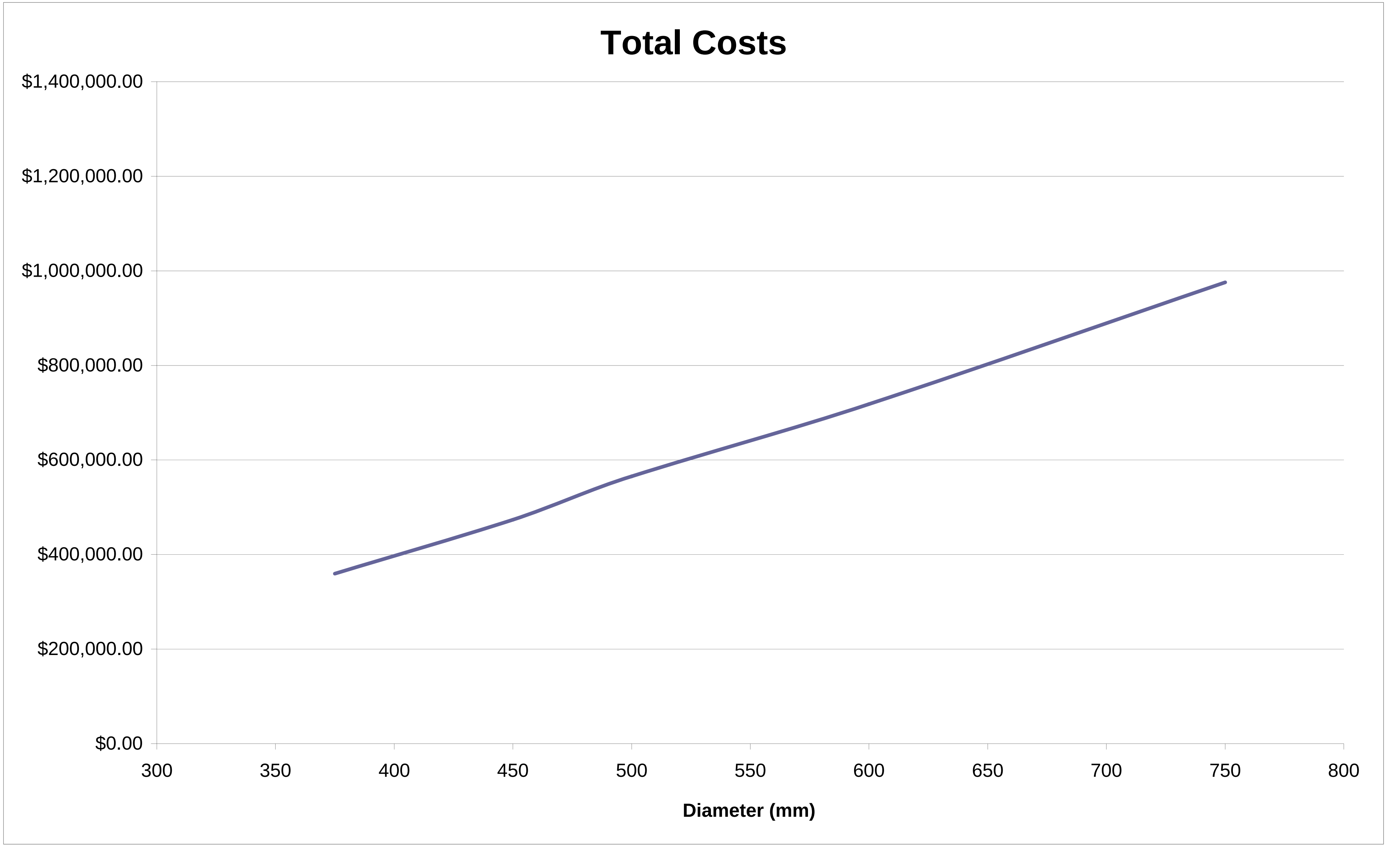
Diameter (mm)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Diameter (mm)

APPENDIX N

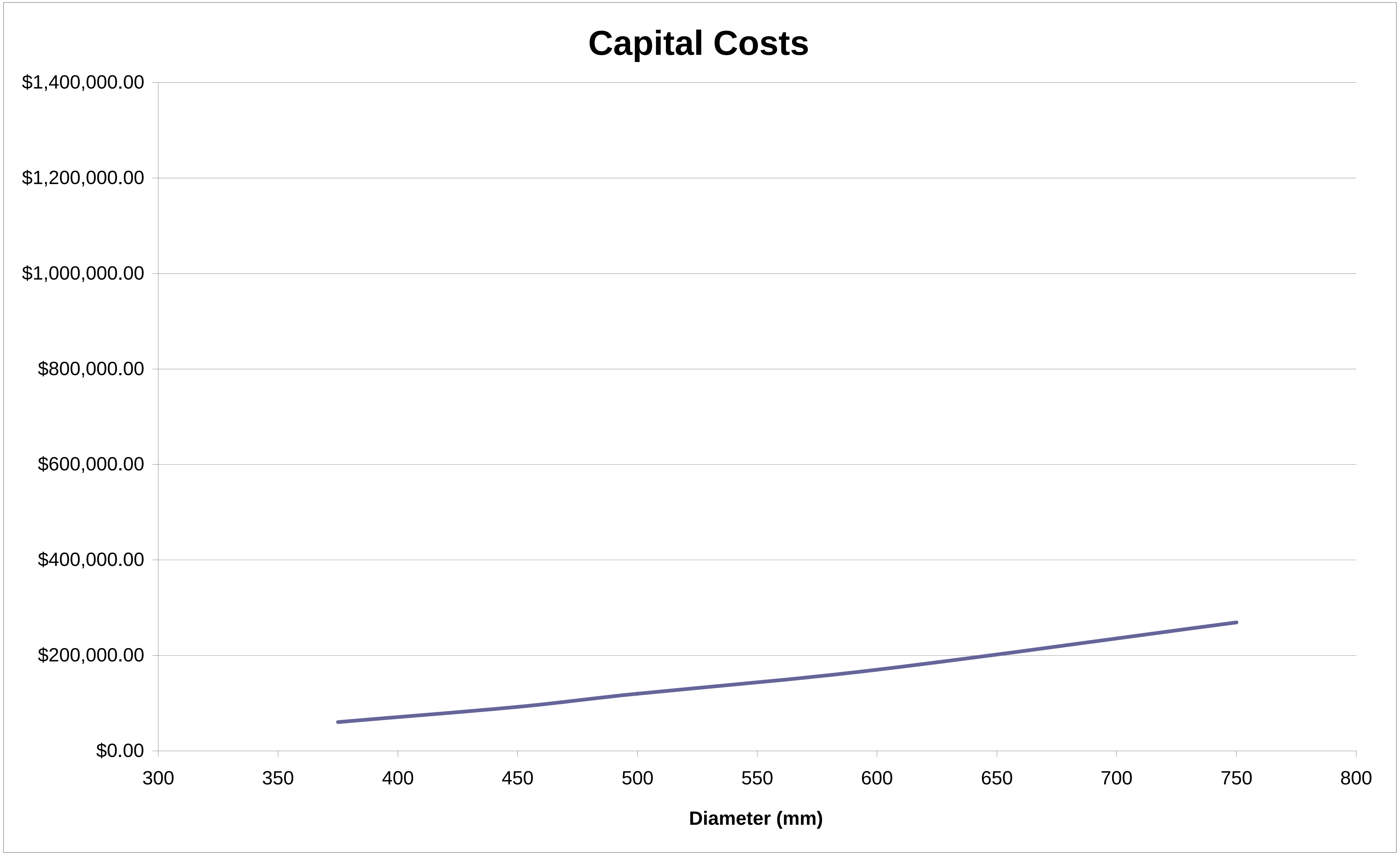
LEVEL ONE PN35 MODEL

LEVEL ONE PN35

	Diameter (mm)				
	375	450	500	600	750
Capital					
Pipe Work	$ 4,399.60	$ 5,152.97	$ 6,691.87	$ 8,695.29	$ 12,752.23
Valves	$ 13,100.86	$ 23,378.01	$ 31,915.91	$ 48,148.20	$ 81,718.50
Concrete/Reinforcement (Inc. Form Work/Pouring etc.)	$ -	$ -	$ -	$ -	$ -
Metal Items	$ 1,000.00	$ 1,000.00	$ 1,000.00	$ 1,000.00	$ 1,000.00
Construction	$ 8,950.00	$ 12,395.75	$ 14,767.50	$ 19,511.00	$ 26,850.00
Total	$ 60,391.02	$ 92,238.81	$ 119,625.63	$ 170,179.88	$ 269,105.61
Operational (Over Design Life)					
Resources	$ 14,168.00	$ 15,053.50	$ 15,939.00	$ 16,824.50	$ 17,710.00
Total (Present Value)	$162,505.84	$172,662.46	$182,819.07	$192,975.69	$203,132.30
TOTAL COST	**$ 222,896.87**	**$ 264,901.27**	**$ 302,444.70**	**$ 363,155.57**	**$ 472,237.92**

Notes:

Construction costs to include a 10% contingency.
Operation costs to include a 10% contingency.
A rate of 6% has been adopted in the PV calculation.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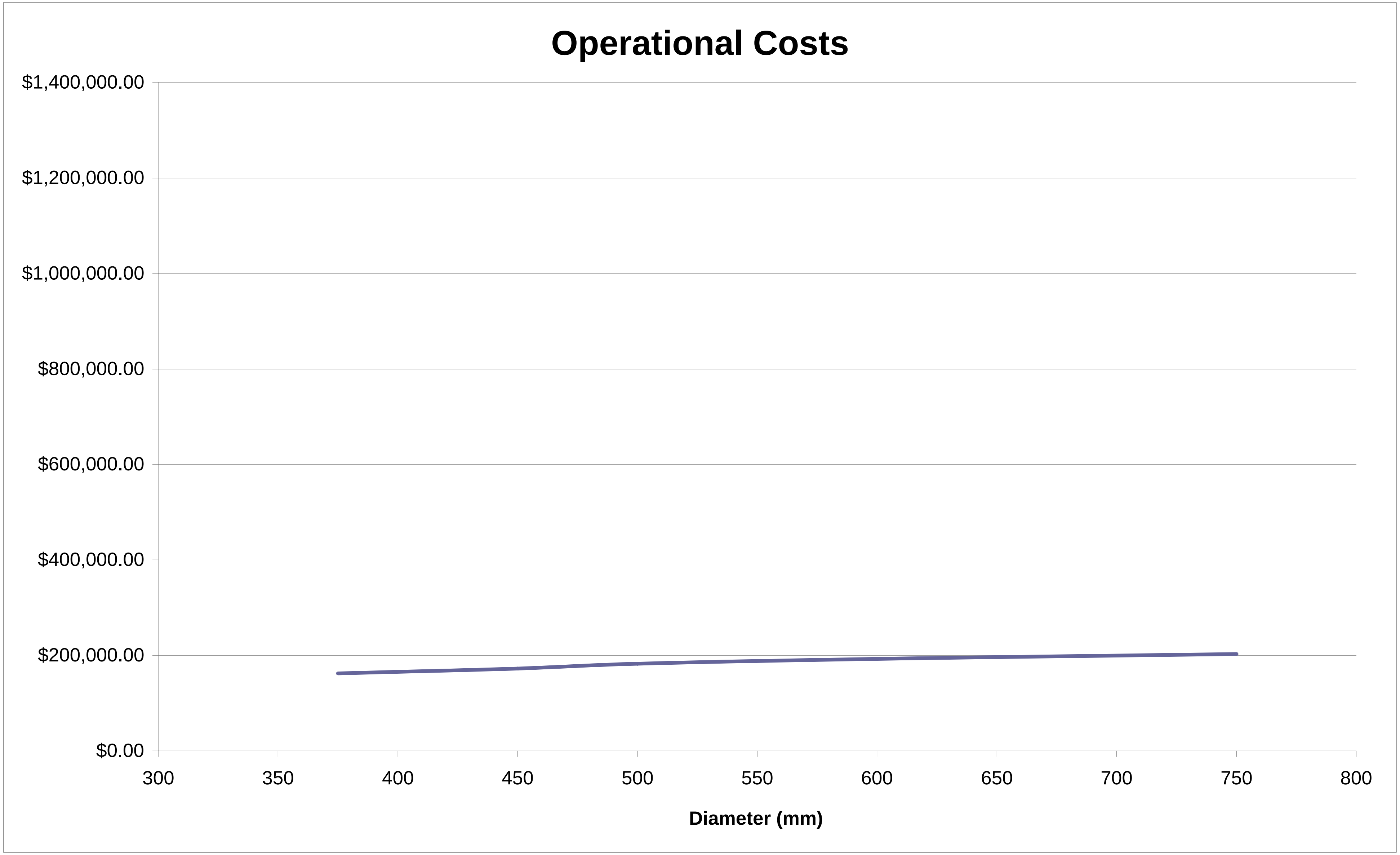
Diameter (mm)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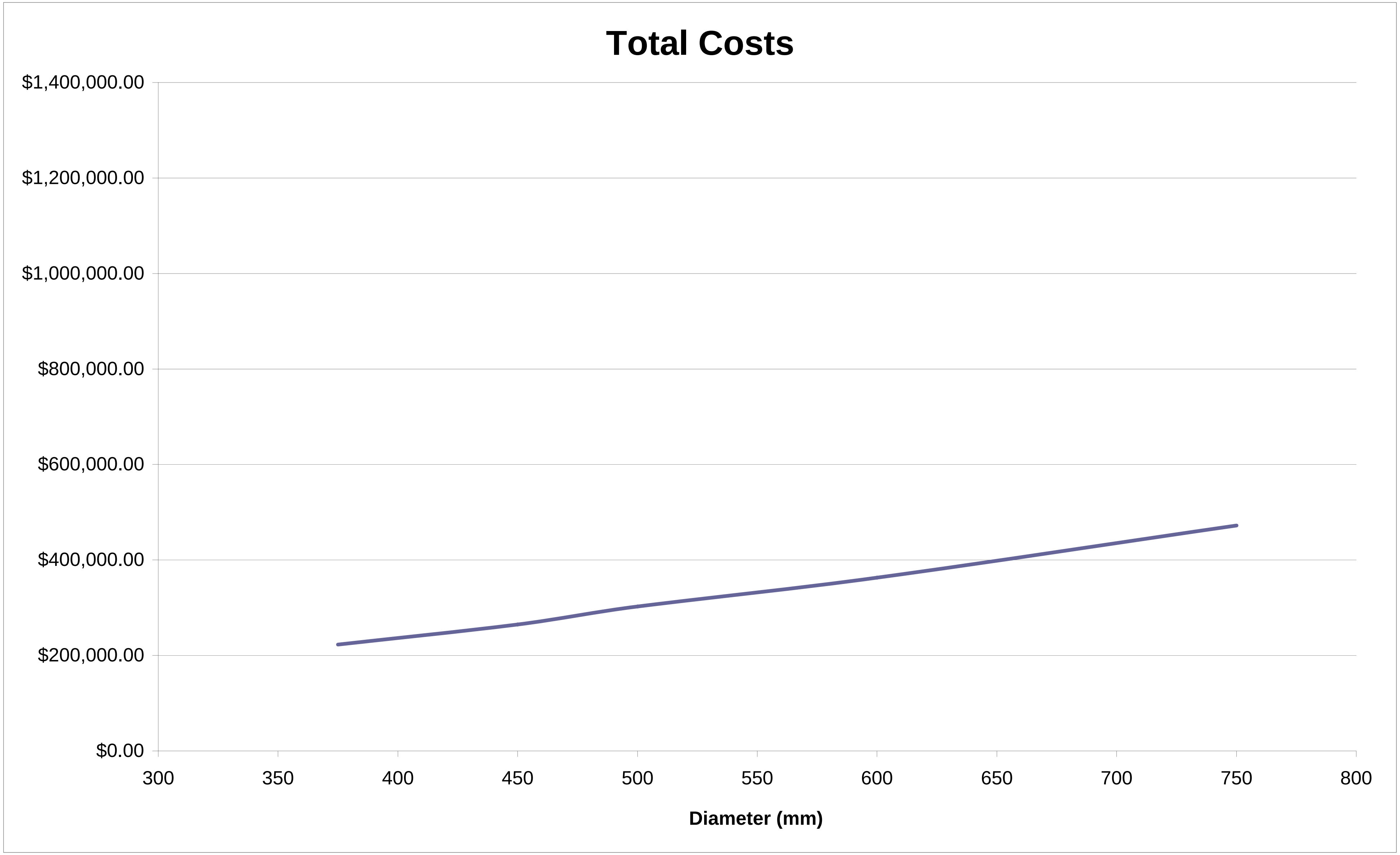
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Diameter (mm)

APPENDIX O

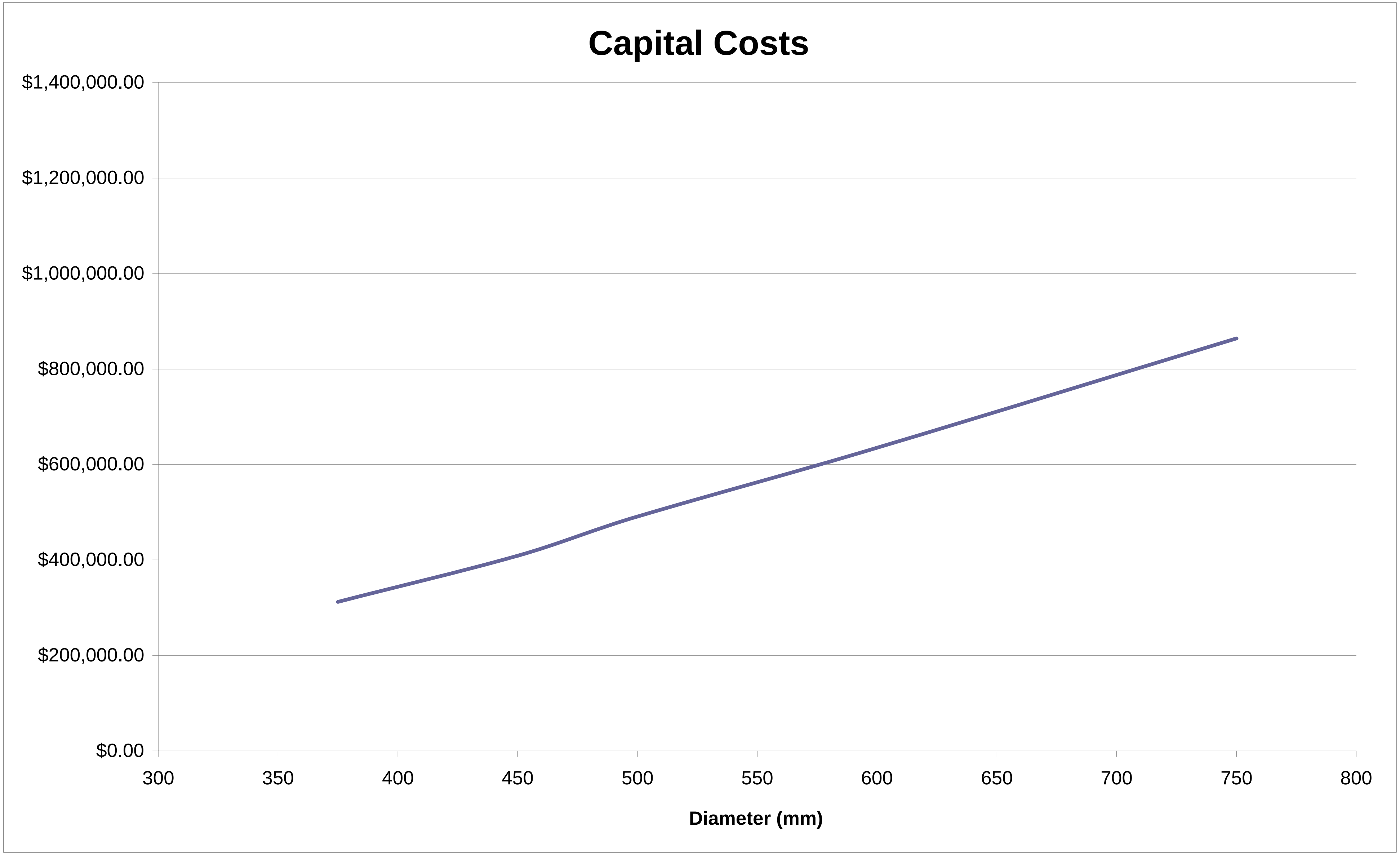
LEVEL TWO PN35 MODEL

LEVEL TWO PN35

	Diameter (mm)				
	375	450	500	600	750
Capital					
Pipe Work	$ 21,475.74	$ 30,513.81	$ 41,431.68	$ 55,712.57	$ 76,261.14
Valves	$ 14,888.87	$ 28,312.92	$ 36,713.40	$ 54,719.35	$ 88,824.85
Concrete/Reinforcement (Inc. Form Work/Pouring etc.)	$ 53,277.33	$ 57,475.38	$ 63,280.65	$ 72,469.60	$ 84,719.50
Metal Items	$ 7,443.84	$ 7,616.91	$ 7,844.78	$ 8,194.89	$ 8,624.40
Construction	$ 44,750.00	$ 61,978.75	$ 73,837.50	$ 97,555.00	$ 134,250.00
Total	$ 312,038.71	$ 408,975.08	$ 490,837.64	$ 635,033.12	$ 863,895.77
Operational (Over Design Life)					
Resources	$ 11,308.00	$ 12,014.75	$ 12,721.50	$ 13,428.25	$ 14,135.00
Total (Present Value)	$129,701.87	$137,808.24	$145,914.60	$154,020.97	$162,127.34
TOTAL COST	**$ 441,740.58**	**$ 546,783.32**	**$ 636,752.24**	**$ 789,054.09**	**$1,026,023.10**

Notes:

Construction costs to include a 10% contingency.
Operation costs to include a 10% contingency.
A rate of 6% has been adopted in the PV calculation.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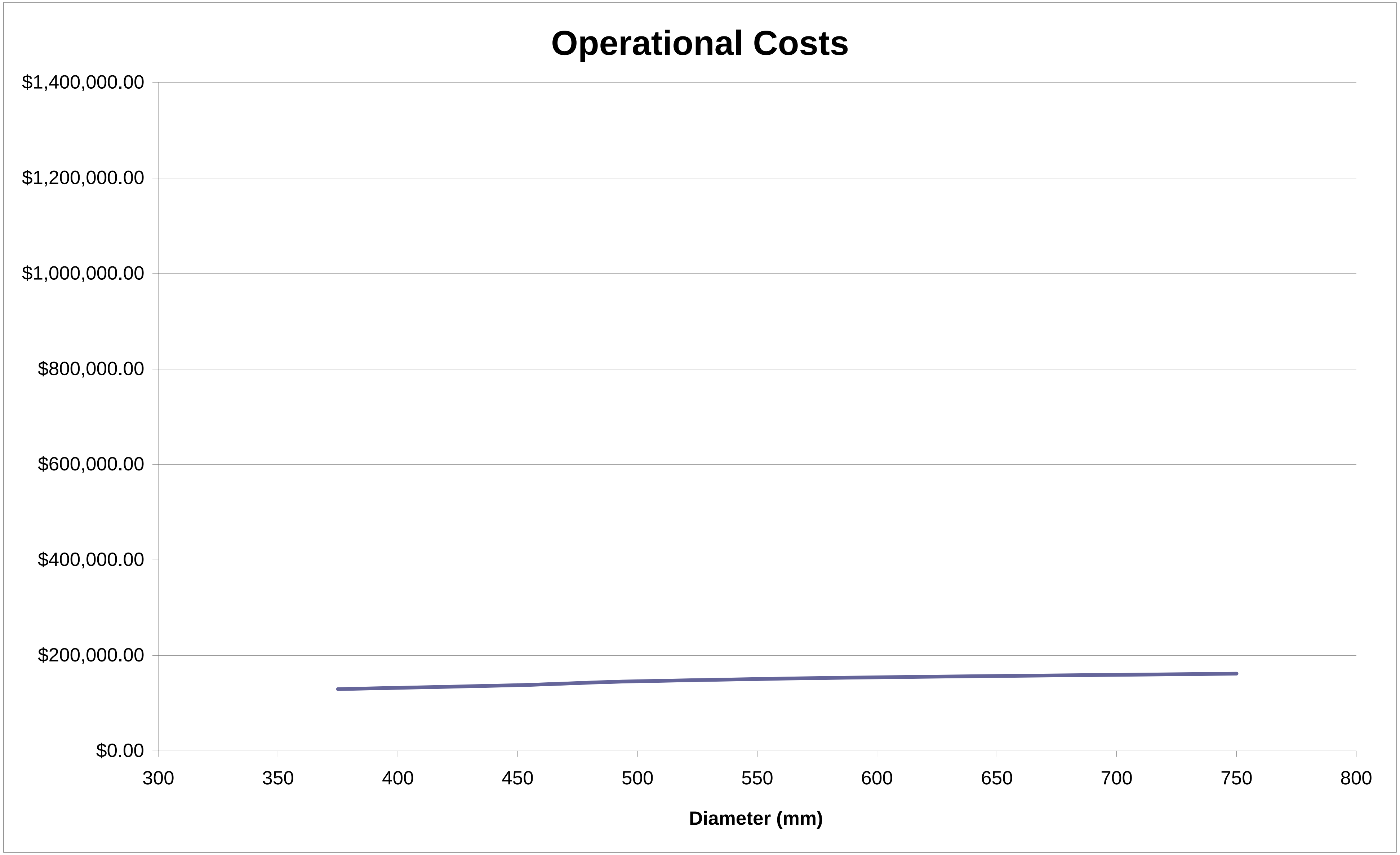
Diameter (mm)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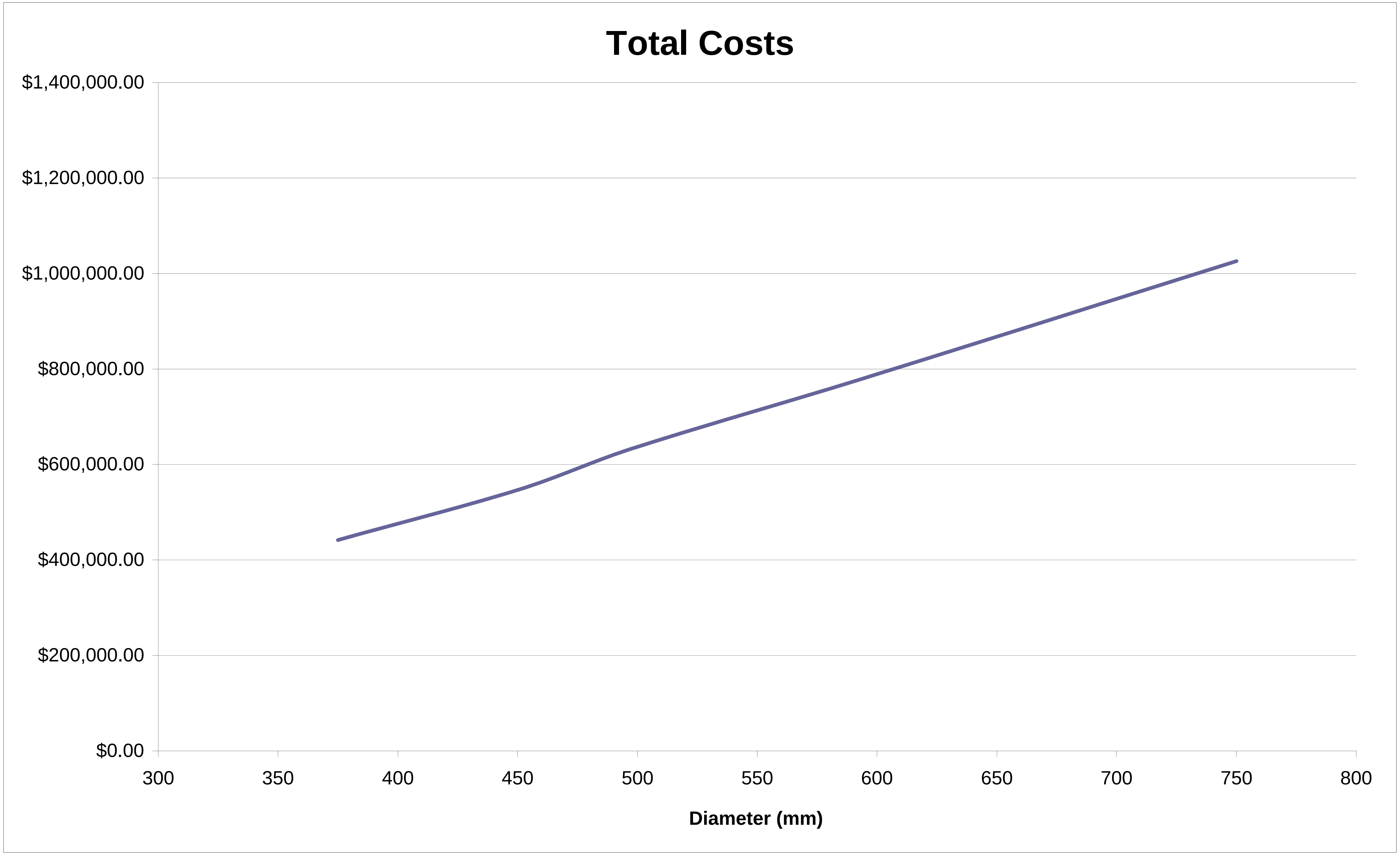
Diameter (mm)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Diameter (mm)

APPENDIX P

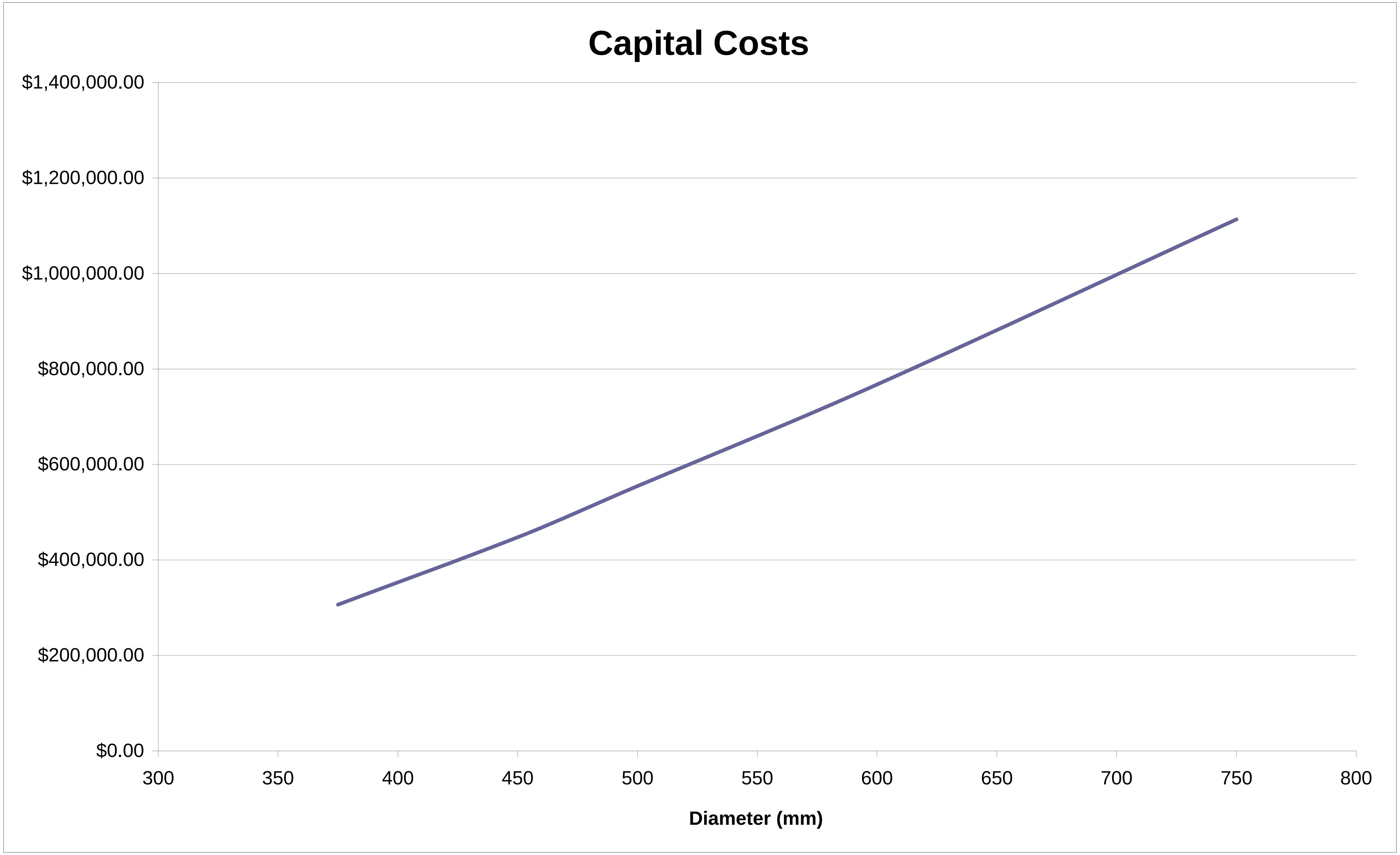
LEVEL THREE PN35 MODEL

LEVEL 3 PN35

	Diameter (mm)				
	375	450	500	600	750
Capital					
Pipe Work	$ 28,896.55	$ 42,170.89	$ 55,032.23	$ 74,884.11	$ 98,995.03
Valves	$ 14,888.87	$ 28,312.92	$ 36,713.40	$ 54,719.35	$ 88,824.85
Concrete/Reinforcement (Inc. Form Work/Pouring etc.)	$ 4,431.90	$ 4,909.24	$ 5,684.18	$ 6,867.30	$ 8,407.13
Metal Items	$ 2,000.00	$ 2,000.00	$ 2,000.00	$ 2,000.00	$ 2,000.00
Construction	$ 88,950.00	$ 126,116.25	$ 152,812.50	$ 210,405.00	$ 307,950.00
Total	$ 306,168.11	$ 447,720.45	$ 554,933.08	$ 767,526.68	$1,113,589.41
Operational (Over Design Life)					
Resources	$ 10,208.00	$ 10,846.00	$ 11,484.00	$ 12,122.00	$ 12,760.00
Total (Present Value)	$117,084.96	$124,402.77	$131,720.58	$139,038.39	$146,356.19
TOTAL COST	**$ 423,253.07**	**$ 572,123.21**	**$ 686,653.65**	**$ 906,565.06**	**$1,259,945.60**

Notes:

Construction costs to include a 10% contingency.
Operation costs to include a 10% contingency.
A rate of 6% has been adopted in the PV calculation.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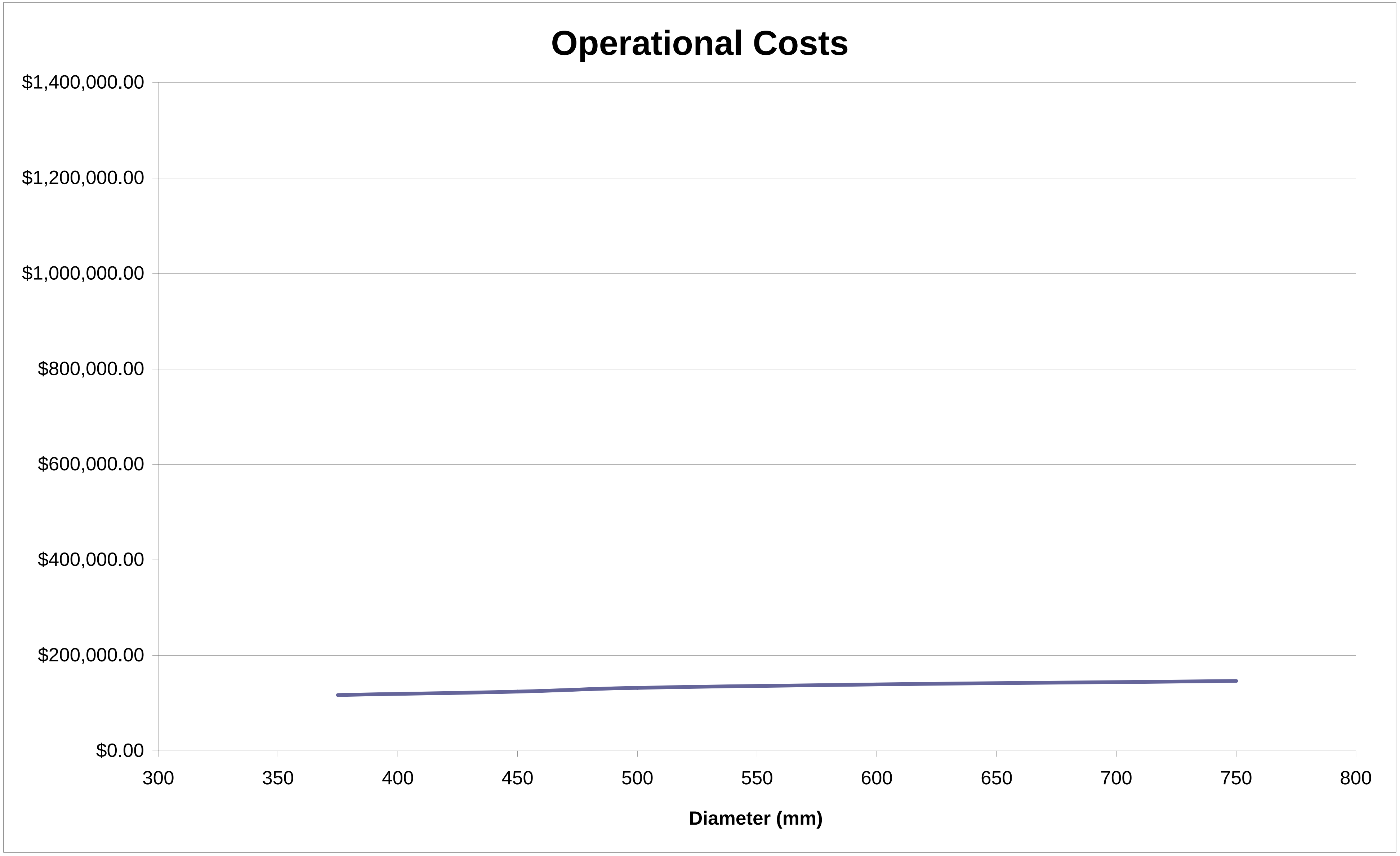
Diameter (mm)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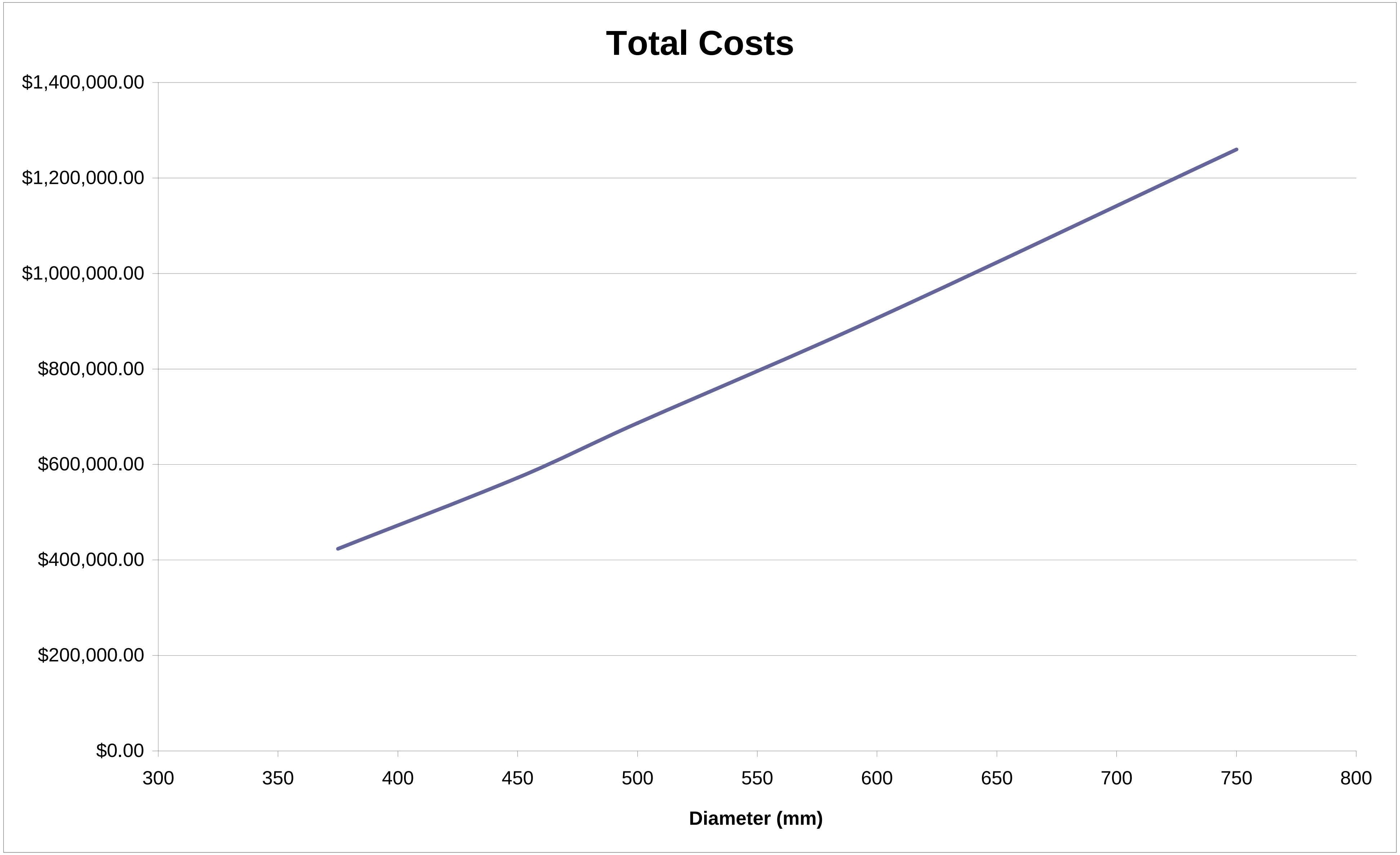
Diameter (mm)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APPENDIX Q

PIGGING INFRASTRUCTURE STANDARD

EXECUTIVE SUMMARY

The following standard contains three alternate pigging infrastructure general arrangements. For each arrangement the total cost of the infrastructure (capital and operational) over its design life has been established. These costs relate the pigging infrastructure to the financial benefit of the pigging process. A link between the infrastructure costs and the financial benefit of the pigging process is required for justification that a particular level of infrastructure's inclusion in a pipeline design is warranted. This standard is to be used as a guide during the conceptual and/or preliminary design stage of a pipeline project.

As stated, the standard incorporates three infrastructure general arrangements (as Appendices) including a description of their basic operation. Total costs of the infrastructure over a 20 year design life (capital and operational) have been tabulated. The standard lists all of the assumptions the cost analysis is based on. Finally, there is a description of and instruction on how to use the estimating tool associated with this standard.

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LIST OF FIGURES

LIST OF APPENDICES

1.0 INTRODUCTION

1.1 SCOPE OF STANDARD

This standard provides a guide in the selection and design of pigging infrastructure at the conceptual and/or preliminary design stage of a pipeline project.

1.2 PURPOSE OF STANDARD

The purpose of this standard is to set out differing levels of pigging infrastructure for consideration during conceptual and/or preliminary pipeline designs. Costs associated with the differing levels of infrastructure have been calculated and summarised in this standard.

The differing levels of infrastructure and associated costs are to be used to relate each level of infrastructure to the financial benefit of the pigging process. This will assist in making informed decisions on what pigging infrastructure to incorporate in a particular pipeline design.

1.3 BACKGROUND

The current practice of pipeline design within SunWater has no written guideline relating to the incorporation of pigging infrastructure. As such, capital investments in pigging infrastructure have never been justified and therefore have potentially been excessive. This standard brings together set infrastructure arrangements, complete with their associated costs, which can be linked to the financial benefit obtained from the pigging process. Use of this standard in conceptual and/or preliminary pipeline designs should be done so as a guide only.

2.0 ASSUMPTIONS

Development of this standard has been based on a number of assumptions. Use of the standard should take into consideration the following:

- all infrastructure pipe work is Ductile Iron Cement Lined (DICL) with the only exception being the spool arrangement where applicable,
- operational costs have been determined based on a pigging frequency of one event per year,
- capital costs are based on a pipeline length of not greater than 25 kilometres. Essentially this only allows for one pig insertion structure and one pig removal structure,
- operational costs are based on a pipeline design life of 20 years,
- detailed design costs of the infrastructure have not been taken into consideration, and
- drainage of the infrastructure during the pigging process has not been taken into consideration.

3.0 INFRASTRUCTURE LEVELS

Three infrastructure levels are set out as part of this standard. Each level of infrastructure increases the level of operability, although the associated costs also increase. All arrangements are conceptual and should only be used as a guide in conceptual and/or preliminary designs. The final arrangement will require detailed design, Workplace Health and Safety (WHS) and operational reviews.

3.1 LEVEL ONE INFRASTRUCTURE

Level one infrastructure is not specifically designed for the pigging process. It is designed as an 'add-on' for another piece of infrastructure in the pipeline design. It consists of two isolation valves and a dismantling joint. The arrangement itself will depend upon the infrastructure it is being 'added' to. The 'standard' general arrangement drawing is included as Appendix A.

The basic operational procedure requires the two isolation valves to be closed. The dismantling joint is then removed, after the isolated section of pipe work has been drained. A pig is inserted into the pipeline and the dismantling joint is reinstated. The two isolation valves are then opened ready to launch the pig into the pipeline. No enlargement in the pipe work is included to insert the pig. There exists a requirement for the pig to be vacuum packed before it is inserted into the pipeline. The packaging is then broken before the pig is launched, eventually being eroded as the pig moves through the pipeline.

The general arrangement drawing also consists of an alternate arrangement. This is a slightly more dedicated arrangement for the pigging process; however it is still designed to be an 'add-on' for another piece of infrastructure. For the costing purposes of this standard the alternate arrangement is not considered.

3.2 LEVEL TWO INFRASTRUCTURE

Level two infrastructure is specifically designed for the pigging process. It consists of a series of pipe fittings and valves. This particular arrangement is located in a pit below the natural surface level. The 'standard' general arrangement drawing is included as Appendix B.

The basic operational procedure requires the two isolation valves to be closed, followed by draining of the isolated section of pipe work. The two couplings on either end of the pipe spool piece are loosened and pushed to the side, after which the pipe spool piece is removed. This arrangement does not include the facilities to roll the pipe spool piece to one side. It requires a crane to be on site to lift the pipe spool piece out of the pit. A pig is then inserted into the pipe spool piece, which is then reinstated. The two couplings are also then reinstated. Bypass pipe work around the two isolation valves is used to fill the small section of line containing the pipe spool piece. Once the line is full the two isolation valves are opened ready to launch the pig into the pipeline.

This arrangement, being a pit, has a number of inherent WHS issues. The first issue relates to access. Should a vertical ladder be included, as in the 'standard' general arrangement drawing, some form of fall arrest system will be required. The second issue relates to confined spaces; namely rescue of an injured person from the pit. Given the only access is a vertical ladder, rescue would be difficult. The issue of limited access for rescue is solved by having a crane (already on site to remove the pipe spool piece) and rescue gear (harness, stretcher etc.) on site during operation. An alternative to having a crane on site would be to install some form of davit arm. All WHS issues need to be considered during detailed design.

3.3 LEVEL THREE INFRASTRUCTURE

Level three infrastructure is also specifically designed for the pigging process. It also consists of a series of pipe fittings and valves. This particular arrangement, however, is located above ground. The ‘standard’ general arrangement drawing is included as Appendix C.

The basic operational procedure is almost identical to that of the level two infrastructure. It requires the two isolation valves to be closed, followed by draining of the isolated section of pipe work. The coupling on one end of the pipe spool piece is loosened and pushed to the side and the flange on the other end is unbolted. The pipe spool piece is then removed. Unlike the level two infrastructure, this arrangement does include the facilities to roll the pipe spool piece to one side. A pig is inserted into the pipe spool piece, which is then reinstated. The coupling is also then reinstated. Bypass pipe work around the two isolation valves is used to fill the small section of line containing the pipe spool piece. Once the line is full the two isolation valves are opened ready to launch the pig into the pipeline.

The main objective of this arrangement is the elimination of the inherent WHS issues associated with the level two infrastructure. This is achieved by bringing the pipe work above ground. In bringing the pipe work above ground, however, the issue of thrust is increased. Thrust issues are solved using large concrete thrust blocks. For the purpose of this standard the thrust blocks have been designed and costed based on the pipe pressure class. Thrust blocks were sized based on the pipeline operating at full capacity for a particular pipe class. Further thrust block design will be required at the detailed design stage of a project.

3.4 WORKPLACE HEALTH AND SAFETY

Each of the above three infrastructure arrangements have been designed and drafted for use in conceptual and/or preliminary designs as a guide only. Detailed design needs to be undertaken to determine the final arrangement. There are a number of factors detailed design needs to consider, one of the main factors being WHS.

The final design of any pigging infrastructure arrangement will require a full WHS risk assessment. Any risk assessment undertaken should consider the hierarchy of controls as set out in SunWater's Safety Management System. There are key staff that should be involved in all risk assessment activities, including but not limited to:

- project management,
- senior design engineers,
- workplace health and safety officers, and
- operations and maintenance staff.

The final arrangement drawings also need to be subjected to all checks associated with SunWater's Quality Management Systems.

4.0 DESIGN OF INFRASTRUCTURE FOR PN20 CLASS PIPE

Table 4.1 illustrates the financial benefit (savings) required from the pigging process for each level of infrastructure to be justified (refer SunWater's Pipeline Pigging Decision Support System). The savings depicted in the table are based on a pipeline design using PN20 class pipe.

Table 4.1 – PN20 Class Design

		Diameter (mm)				
		375	**450**	**500**	**600**	**700**
Infrastructure Level	**Level One**	$214,000	$249,000	$280,000	$314,000	$391,000
	Level Two	$406,000	$490,000	$567,000	$677,000	$864,000
	Level Three	$359,000	$474,000	$565,000	$718,000	$976,000

The savings required for each level of infrastructure over the given diameter range have been determined considering both capital and operational costs.

Capital Costs

The capital costs, depending on the level of infrastructure, are made up of one or more of the following:

- pipe fittings and valves,
- concrete (including reinforcement and laying),
- metal item fabrication and installation, and
- associated construction.

Operational Costs

The only material required for the pigging process is the pig itself. This cost is common across the infrastructure range, therefore has not been included. Resource costs include:

- labour, and
- plant/machinery (where applicable).

Operational costs been calculated over the design life of the pipeline. They are based on their Present Value assuming an interest rate of 6% per annum.

5.0 DESIGN OF INFRASTRUCTURE FOR PN35 CLASS PIPE

Table 5.1 illustrates the financial benefit (savings) required from the pigging process for each level of infrastructure to be justified (refer SunWater's Pipeline Pigging Decision Support System). The savings depicted in the table are based on a pipeline design using PN35 class pipe.

Table 5.1 – PN35 Class Design

		Diameter (mm)				
		375	**450**	**500**	**600**	**700**
Infrastructure Level	**Level One**	$223,000	$265,000	$302,000	$363,000	$472,000
	Level Two	$442,000	$547,000	$637,000	$789,000	$1,026,000
	Level Three	$423,000	$572,000	$687,000	$907,000	$1,260,000

The savings required for each level of infrastructure over the given diameter range have been determined considering both capital and operational costs.

Capital Costs

The capital costs, depending on the level of infrastructure, are made up of one or more of the following:

- pipe fittings and valves,
- concrete (including reinforcement and laying),
- metal item fabrication and installation, and
- associated construction.

Operational Costs

The only material required for the pigging process is the pig itself. This cost is common across the infrastructure range, therefore has not been included. Resource costs include:

- labour, and
- plant/machinery (where applicable).

Operational costs been calculated over the design life of the pipeline. They are based on their Present Value assuming an interest rate of 6% per annum.

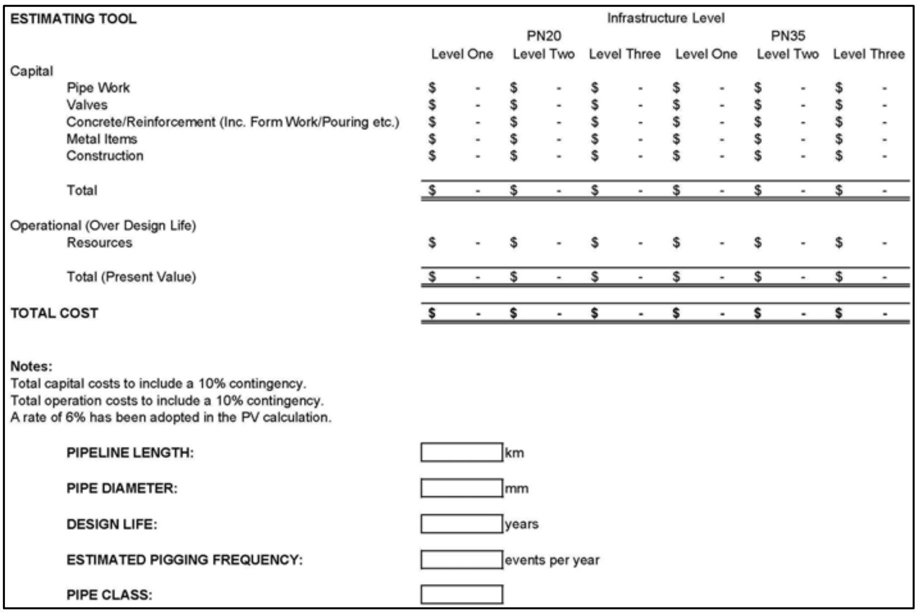
6.0 ESTIMATING TOOL

An estimating tool has been developed to supplement this standard. The estimating tool is used to undertake the financial analysis of the different infrastructure levels. It allows for more flexibility in the analysis than what was used to obtain the results in this standard. Three of the assumptions (Section 2) have been eliminated from the analysis:

- pipeline lengths of greater than 25km can be adopted,
- design life can be specified, and
- the estimated pigging frequency can be specified.

The estimating tool is a Microsoft Excel based tool that is simple to use. The following provides a step-by-step guide on how to use the tool.

1. Open the estimating tool named Pigging Infrastructure Estimating Tool.xls and the worksheet in Figure 6.1 will be displayed.



ESTIMATING TOOL	Infrastructure Level					
	PN20			PN35		
	Level One	Level Two	Level Three	Level One	Level Two	Level Three
Capital						
Pipe Work	$ -	$ -	$ -	$ -	$ -	$ -
Valves	$ -	$ -	$ -	$ -	$ -	$ -
Concrete/Reinforcement (Inc. Form Work/Pouring etc.)	$ -	$ -	$ -	$ -	$ -	$ -
Metal Items	$ -	$ -	$ -	$ -	$ -	$ -
Construction	$ -	$ -	$ -	$ -	$ -	$ -
Total	$ -	$ -	$ -	$ -	$ -	$ -
Operational (Over Design Life)						
Resources	$ -	$ -	$ -	$ -	$ -	$ -
Total (Present Value)	$ -	$ -	$ -	$ -	$ -	$ -
TOTAL COST	$ -	$ -	$ -	$ -	$ -	$ -

Notes:
Total capital costs to include a 10% contingency.
Total operation costs to include a 10% contingency.
A rate of 6% has been adopted in the PV calculation.

PIPELINE LENGTH: ☐ km

PIPE DIAMETER: ☐ mm

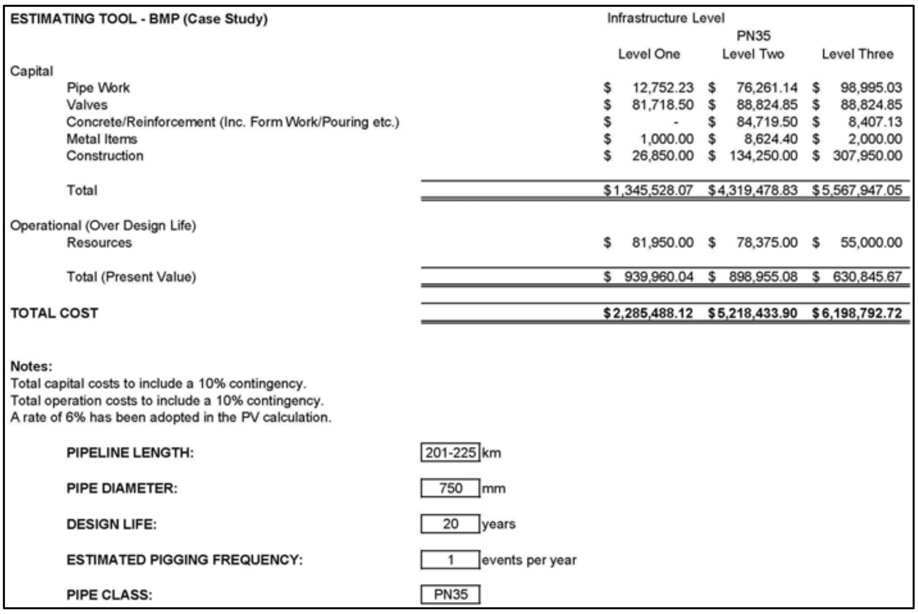
DESIGN LIFE: ☐ years

ESTIMATED PIGGING FREQUENCY: ☐ events per year

PIPE CLASS: ☐

Figure 6.1 – Pigging Infrastructure Estimating Tool Interface

2. Select the pipeline length from the PIPELINE LENGTH drop down menu.
3. Select the pipe diameter from the PIPE DIAMETER drop down menu.
4. Enter a design life in the DESIGN LIFE box.
5. Enter a pigging frequency in the ESTIMATED PIGGING FREQUENCY box.
6. Select a pipe class from the PIPE CLASS drop down menu.
7. The analysis results will now be displayed as in Figure 6.2.



ESTIMATING TOOL - BMP (Case Study)

	Infrastructure Level		
		PN35	
	Level One	Level Two	Level Three
Capital			
Pipe Work	$ 12,752.23	$ 76,261.14	$ 98,995.03
Valves	$ 81,718.50	$ 88,824.85	$ 88,824.85
Concrete/Reinforcement (Inc. Form Work/Pouring etc.)	$ -	$ 84,719.50	$ 8,407.13
Metal Items	$ 1,000.00	$ 8,624.40	$ 2,000.00
Construction	$ 26,850.00	$ 134,250.00	$ 307,950.00
Total	$1,345,528.07	$4,319,478.83	$5,567,947.05
Operational (Over Design Life)			
Resources	$ 81,950.00	$ 78,375.00	$ 55,000.00
Total (Present Value)	$ 939,960.04	$ 898,955.08	$ 630,845.67
TOTAL COST	**$2,285,488.12**	**$5,218,433.90**	**$6,198,792.72**

Notes:
Total capital costs to include a 10% contingency.
Total operation costs to include a 10% contingency.
A rate of 6% has been adopted in the PV calculation.

PIPELINE LENGTH: 201-225 km

PIPE DIAMETER: 750 mm

DESIGN LIFE: 20 years

ESTIMATED PIGGING FREQUENCY: 1 events per year

PIPE CLASS: PN35

Figure 6.2 – Example of Analysis Results

APPENDIX R

PIGGING INFRASTRUCTURE ESTIMATING TOOL

ESTIMATING TOOL

	Infrastructure Level					
	PN20			PN35		
	Level One	Level Two	Level Three	Level One	Level Two	Level Three
Capital						
Pipe Work	$ -	$ -	$ -	$ -	$ -	$ -
Valves	$ -	$ -	$ -	$ -	$ -	$ -
Concrete/Reinforcement (Inc. Form Work/Pouring etc.)	$ -	$ -	$ -	$ -	$ -	$ -
Metal Items	$ -	$ -	$ -	$ -	$ -	$ -
Construction	$ -	$ -	$ -	$ -	$ -	$ -
Total	$ -	$ -	$ -	$ -	$ -	$ -
Operational (Over Design Life)						
Resources	$ -	$ -	$ -	$ -	$ -	$ -
Total (Present Value)	$ -	$ -	$ -	$ -	$ -	$ -
TOTAL COST	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**

Notes:

Total capital costs to include a 10% contingency.
Total operation costs to include a 10% contingency.
A rate of 6% has been adopted in the PV calculation.

PIPELINE LENGTH:		km
PIPE DIAMETER:		mm
DESIGN LIFE:		years
ESTIMATED PIGGING FREQUENCY:		events per year
PIPE CLASS:		

Pipe Work	375	450	500	600	750
	$ 3,999.64	$ 4,684.52	$ 6,083.52	$ 7,904.81	$ 11,592.94

Valves	375	450	500	600	750
	$ 9,425.08	$ 16,698.58	$ 22,318.82	$ 26,426.50	$ 45,879.99

Concrete/Reinforcement (Inc. Form Work/Pouring etc.)	375	450	500	600	750
	$ -	$ -	$ -	$ -	$ -

Metal Items	375	450	500	600	750
	$ 1,000.00	$ 1,000.00	$ 1,000.00	$ 1,000.00	$ 1,000.00

Construction					375	450	500	600	750
		Rate	Unit	Quantity	Total				
Labour									
	Four Men	$ 4,000.00	day	1	$ 4,000.00	$ 5,540.00	$ 6,600.00	$ 8,720.00	$ 12,000.00
	Supervisor	$ 1,250.00	day	1	$ 1,250.00	$ 1,731.25	$ 2,062.50	$ 2,725.00	$ 3,750.00
	Accomodation/Meals etc.	$ 1,000.00	day	1	$ 1,000.00	$ 1,385.00	$ 1,650.00	$ 2,180.00	$ 3,000.00
Plant									
	Franna Crane	$ 2,500.00	day	1	$ 2,500.00	$ 3,462.50	$ 4,125.00	$ 5,450.00	$ 7,500.00
Materials									
	Miscellaneous	$ 200.00	lump sum	1.00	$ 200.00	$ 277.00	$ 330.00	$ 436.00	$ 600.00
Thrust Blocks		$ 1,500.00	m^3		$ -	$ -	$ -	$ -	$ -

Notes:

4 Men Rate - based on a 10 hour day at $100/hr/man.
Supervisor Rate - based on a 10 hour day at $125/hr.
Accomodation/Meals etc. Rate - based on $200/night/man.
Franna Crane Rate - based on a 10 hour day at $250/hr including a dogman.

Operation	750	375	450	500	600

		Rate	Unit	Quantity	Total				
Labour									
	Four Men	$ 4,000.00	day	0	$ -	$ -	$ -	$ -	$ -
	Accomodation/Meals etc.	$ 800.00	day	0	$ -	$ -	$ -	$ -	$ -
Plant									
	Franna Crane	$ 2,500.00	day	0	$ -	$ -	$ -	$ -	$ -

Notes:

4 Men Rate - based on a 10 hour day at $100/hr/man.

Accomodation/Meals etc. Rate - based on $200/night/man.

Franna Crane Rate - based on a 10 hour day at $250/hr including a dogman.

Pipe Work	375	450	500	600	750
	$ 4,399.60	$ 5,152.97	$ 6,691.87	$ 8,695.29	$ 12,752.23

Valves	375	450	500	600	750
	$ 13,100.86	$ 23,378.01	$ 31,915.91	$ 48,148.20	$ 81,718.50

Concrete/Reinforcement (Inc. Form Work/Pouring etc.)	375	450	500	600	750
	$ -	$ -	$ -	$ -	$ -

Metal Items	375	450	500	600	750
	$ 1,000.00	$ 1,000.00	$ 1,000.00	$ 1,000.00	$ 1,000.00

Construction					375	450	500	600	750
		Rate	Unit	Quantity	Total				
Labour									
	Four Men	$ 4,000.00	day	1	$ 4,000.00	$ 5,540.00	$ 6,600.00	$ 8,720.00	$ 12,000.00
	Supervisor	$ 1,250.00	day	1	$ 1,250.00	$ 1,731.25	$ 2,062.50	$ 2,725.00	$ 3,750.00
	Accomodation/Meals etc.	$ 1,000.00	day	1	$ 1,000.00	$ 1,385.00	$ 1,650.00	$ 2,180.00	$ 3,000.00
Plant									
	Franna Crane	$ 2,500.00	day	1	$ 2,500.00	$ 3,462.50	$ 4,125.00	$ 5,450.00	$ 7,500.00
Materials									
	Miscellaneous	$ 200.00	lump sum	1.00	$ 200.00	$ 277.00	$ 330.00	$ 436.00	$ 600.00
Thrust Blocks		$ 1,500.00	m^3		$ -	$ -	$ -	$ -	$ -

Notes:
4 Men Rate - based on a 10 hour day at $100/hr/man.
Supervisor Rate - based on a 10 hour day at $125/hr.
Accomodation/Meals etc. Rate - based on $200/night/man.
Franna Crane Rate - based on a 10 hour day at $250/hr including a dogman.

Operation	750	375	450	500	600

		Rate	Unit	Quantity	Total				
Labour									
	Four Men	$ 4,000.00	day	0	$ -	$ -	$ -	$ -	$ -
	Accomodation/Meals etc.	$ 800.00	day	0	$ -	$ -	$ -	$ -	$ -
Plant									
	Franna Crane	$ 2,500.00	day	0	$ -	$ -	$ -	$ -	$ -

Notes:

4 Men Rate - based on a 10 hour day at $100/hr/man.
Accomodation/Meals etc. Rate - based on $200/night/man.
Franna Crane Rate - based on a 10 hour day at $250/hr including a dogman.

Pipe Work	375	450	500	600	750
	$ 19,969.72	$ 28,378.33	$ 38,474.10	$ 51,494.83	$ 70,401.55

Valves	375	450	500	600	750
	$ 10,446.80	$ 18,546.86	$ 24,603.34	$ 29,526.10	$ 50,035.75

Concrete/Reinforcement (Inc. Form Work/Pouring etc.)	375	450	500	600	750
	$ 51,760.26	$ 55,804.75	$ 61,210.65	$ 70,147.60	$ 81,850.75

Metal Items	375	450	500	600	750
	$ 7,443.84	$ 7,616.91	$ 7,844.78	$ 8,194.89	$ 8,624.40

Construction					375	450	500	600	750
		Rate	Unit	Quantity	Total				
Labour									
	Four Men	$ 4,000.00	day	4	$ 16,000.00	$ 22,160.00	$ 26,400.00	$ 34,880.00	$ 48,000.00
	Supervisor	$ 1,250.00	day	4	$ 5,000.00	$ 6,925.00	$ 8,250.00	$ 10,900.00	$ 15,000.00
	Accomodation/Meals etc.	$ 1,000.00	day	4	$ 4,000.00	$ 5,540.00	$ 6,600.00	$ 8,720.00	$ 12,000.00
Plant									
	Franna Crane	$ 2,500.00	day	4	$ 10,000.00	$ 13,850.00	$ 16,500.00	$ 21,800.00	$ 30,000.00
Materials									
	Miscellaneous	$ 1,000.00	lump sum	1.00	$ 1,000.00	$ 1,385.00	$ 1,650.00	$ 2,180.00	$ 3,000.00
Thrust Blocks		$ 1,500.00	m^3		$ -	$ -	$ -	$ -	$ -

Notes:

4 Men Rate - based on a 10 hour day at $100/hr/man.
Supervisor Rate - based on a 10 hour day at $125/hr.
Accomodation/Meals etc. Rate - based on $200/night/man.
Franna Crane Rate - based on a 10 hour day at $250/hr including a dogman.

Operation	750	375	450	500	600

		Rate	Unit	Quantity	Total				
Labour									
	Four Men	$ 4,000.00	day	0	$ -	$ -	$ -	$ -	$ -
	Accomodation/Meals etc.	$ 800.00	day	0	$ -	$ -	$ -	$ -	$ -
Plant									
	Franna Crane	$ 2,500.00	day	0	$ -	$ -	$ -	$ -	$ -

Notes:
4 Men Rate - based on a 10 hour day at $100/hr/man.
Accomodation/Meals etc. Rate - based on $200/night/man.
Franna Crane Rate - based on a 10 hour day at $250/hr including a dogman.

Pipe Work	375	450	500	600	750
	$ 21,475.74	$ 30,513.81	$ 41,431.68	$ 55,712.57	$ 76,261.14

Valves	375	450	500	600	750
	$ 14,888.87	$ 28,312.92	$ 36,713.40	$ 54,719.35	$ 88,824.85

Concrete/Reinforcement (Inc. Form Work/Pouring etc.)	375	450	500	600	750
	$ 53,277.33	$ 57,475.38	$ 63,280.65	$ 72,469.60	$ 84,719.50

Metal Items	375	450	500	600	750
	$ 7,443.84	$ 7,616.91	$ 7,844.78	$ 8,194.89	$ 8,624.40

Construction					375	450	500	600	750
		Rate	Unit	Quantity	Total				
Labour									
	Four Men	$ 4,000.00	day	5	$ 20,000.00	$ 27,700.00	$ 33,000.00	$ 43,600.00	$ 60,000.00
	Supervisor	$ 1,250.00	day	5	$ 6,250.00	$ 8,656.25	$ 10,312.50	$ 13,625.00	$ 18,750.00
	Accomodation/Meals etc.	$ 1,000.00	day	5	$ 5,000.00	$ 6,925.00	$ 8,250.00	$ 10,900.00	$ 15,000.00
Plant									
	Franna Crane	$ 2,500.00	day	5	$ 12,500.00	$ 17,312.50	$ 20,625.00	$ 27,250.00	$ 37,500.00
Materials									
	Miscellaneous	$ 1,000.00	lump sum	1.00	$ 1,000.00	$ 1,385.00	$ 1,650.00	$ 2,180.00	$ 3,000.00
Thrust Blocks		$ 1,500.00	m^3		$ -	$ -	$ -	$ -	$ -

Notes:
4 Men Rate - based on a 10 hour day at $100/hr/man.
Supervisor Rate - based on a 10 hour day at $125/hr.
Accomodation/Meals etc. Rate - based on $200/night/man.
Franna Crane Rate - based on a 10 hour day at $250/hr including a dogman.

Operation	750	375	450	500	600

		Rate	Unit	Quantity	Total				
Labour									
	Four Men	$ 4,000.00	day	0	$ -	$ -	$ -	$ -	$ -
	Accomodation/Meals etc.	$ 800.00	day	0	$ -	$ -	$ -	$ -	$ -
Plant									
	Franna Crane	$ 2,500.00	day	0	$ -	$ -	$ -	$ -	$ -

Notes:

4 Men Rate - based on a 10 hour day at $100/hr/man.
Accomodation/Meals etc. Rate - based on $200/night/man.
Franna Crane Rate - based on a 10 hour day at $250/hr including a dogman.

Pipe Work	375	450	500	600	750
	$ 26,451.41	$ 38,518.99	$ 50,211.12	$ 68,258.28	$ 90,177.30

Valves	375	450	500	600	750
	$ 10,446.80	$ 18,546.86	$ 24,603.34	$ 29,526.10	$ 50,035.75

Concrete/Reinforcement (Inc. Form Work/Pouring etc.)	375	450	500	600	750
	$ 4,202.31	$ 4,655.55	$ 5,369.18	$ 6,512.55	$ 7,966.50

Metal Items	375	450	500	600	750
	$ 2,000.00	$ 2,000.00	$ 2,000.00	$ 2,000.00	$ 2,000.00

Construction					375	450	500	600	750
		Rate	Unit	Quantity	Total				
Labour									
	Four Men	$ 4,000.00	day	6	$ 24,000.00	$ 33,240.00	$ 39,600.00	$ 52,320.00	$ 72,000.00
	Supervisor	$ 1,250.00	day	6	$ 7,500.00	$ 10,387.50	$ 12,375.00	$ 16,350.00	$ 22,500.00
	Accomodation/Meals etc.	$ 1,000.00	day	6	$ 6,000.00	$ 8,310.00	$ 9,900.00	$ 13,080.00	$ 18,000.00
Plant									
	Franna Crane	$ 2,500.00	day	6	$ 15,000.00	$ 20,775.00	$ 24,750.00	$ 32,700.00	$ 45,000.00
Materials									
	Miscellaneous	$ 1,000.00	lump sum	1.00	$ 1,000.00	$ 1,385.00	$ 1,650.00	$ 2,180.00	$ 3,000.00
Thrust Blocks		$ 1,500.00	m^3		$ 13,500.00	$ 21,000.00	$ 26,700.00	$ 40,200.00	$ 66,300.00

Notes:

4 Men Rate - based on a 10 hour day at $100/hr/man.
Supervisor Rate - based on a 10 hour day at $125/hr.
Accomodation/Meals etc. Rate - based on $200/night/man.
Franna Crane Rate - based on a 10 hour day at $250/hr including a dogman.

Operation	750	375	450	500	600

		Rate	Unit	Quantity	Total				
Labour									
	Four Men	$ 4,000.00	day	0	$ -	$ -	$ -	$ -	$ -
	Accomodation/Meals etc.	$ 800.00	day	0	$ -	$ -	$ -	$ -	$ -
Plant									
	Franna Crane	$ 2,500.00	day		$ -	$ -	$ -	$ -	$ -

Notes:

4 Men Rate - based on a 10 hour day at $100/hr/man.

Accomodation/Meals etc. Rate - based on $200/night/man.

Franna Crane Rate - based on a 10 hour day at $250/hr including a dogman.

Pipe Work	375	450	500	600	750
	$ 28,896.55	$ 42,170.89	$ 55,032.23	$ 74,884.11	$ 98,995.03

Valves	375	450	500	600	750
	$ 14,888.87	$ 28,312.92	$ 36,713.40	$ 54,719.35	$ 88,824.85

Concrete/Reinforcement (Inc. Form Work/Pouring etc.)	375	450	500	600	750
	$ 4,431.90	$ 4,909.24	$ 5,684.18	$ 6,867.30	$ 8,407.13

Metal Items	375	450	500	600	750
	$ 2,000.00	$ 2,000.00	$ 2,000.00	$ 2,000.00	$ 2,000.00

Construction					375	450	500	600	750
		Rate	Unit	Quantity	Total				
Labour									
	Four Men	$ 4,000.00	day	7	$ 28,000.00	$ 38,780.00	$ 46,200.00	$ 61,040.00	$ 84,000.00
	Supervisor	$ 1,250.00	day	7	$ 8,750.00	$ 12,118.75	$ 14,437.50	$ 19,075.00	$ 26,250.00
	Accomodation/Meals etc.	$ 1,000.00	day	7	$ 7,000.00	$ 9,695.00	$ 11,550.00	$ 15,260.00	$ 21,000.00
Plant									
	Franna Crane	$ 2,500.00	day	7	$ 17,500.00	$ 24,237.50	$ 28,875.00	$ 38,150.00	$ 52,500.00
Materials									
	Miscellaneous	$ 1,000.00	lump sum	1.00	$ 1,000.00	$ 1,385.00	$ 1,650.00	$ 2,180.00	$ 3,000.00
Thrust Blocks		$ 1,500.00	m^3		$ 26,700.00	$ 39,900.00	$ 50,100.00	$ 74,700.00	$121,200.00

Notes:

4 Men Rate - based on a 10 hour day at $100/hr/man.

Supervisor Rate - based on a 10 hour day at $125/hr.

Accomodation/Meals etc. Rate - based on $200/night/man.

Franna Crane Rate - based on a 10 hour day at $250/hr including a dogman.

Operation	750	375	450	500	600

		Rate	Unit	Quantity	Total				
Labour									
	Four Men	$ 4,000.00	day	0	$ -	$ -	$ -	$ -	$ -
	Accomodation/Meals etc.	$ 800.00	day	0	$ -	$ -	$ -	$ -	$ -
Plant									
	Franna Crane	$ 2,500.00	day		$ -	$ -	$ -	$ -	$ -

Notes:
4 Men Rate - based on a 10 hour day at $100/hr/man.
Accomodation/Meals etc. Rate - based on $200/night/man.
Franna Crane Rate - based on a 10 hour day at $250/hr including a dogman.