Engineering

Technical Standard

TS0440 – Cathodic Protection Part 1 - Pipelines

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Application & Interpretation of this Document

It is the responsibility of the users of this Standard to ensure that the application of information is appropriate and that any designs based on this Standard are fit for SA Water's purposes and comply with all relevant Australian Standards, Acts and regulations.

Users of this Standard accept sole responsibility for interpretation and use of the information contained in this Standard. Users should independently verify the accuracy, fitness for purpose and application of information contained in this Standard.

Only the current revision of this Standard should be used which is available for download from the SA Water website.

Significant/Major Changes Incorporated in This Edition

Update Technical Standards and SA Water drawing numbers

Section 1.4.2 - Table 1-4 - Relevant SA Water standard documents update

Section 1.4.2 - Table 1-5 - SA Water standard drawings update

Section 8 – As Constructed documentation updated

Document Controls

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1 Introduction

SA Water is responsible for operation and maintenance of an extensive network of buried pipelines. Cathodic Protection (CP) is applied to a large proportion of those buried assets which assists with the management of external pipeline corrosion and is therefore and an important asset management tool to greatly increase asset life.

This Standard has been developed to assist in the design, maintenance, construction, and management of SA Water's pipeline CP infrastructure.

1.1 Purpose

The purpose of this Standard is to detail the requirements for each phase of a pipeline CP project from design, construction and commissioning to maintenance and monitoring to ensure a consistent approach is achieved independent of the delivery model of a project, its location, project ownership or other influences.

This Standard is not a design handbook; it provides design guidance, summarises minimum considerations for the design, nominates SA Water standard materials and construction clauses, conventions and requirements to ensure operators will be handed over a familiar product to permit efficient monitoring and maintenance of the CP systems.

The Standard further provides guidance on recommended monitoring and testing regimes and appropriate methodologies.

All works shall address as a minimum the requirements of AS2832.1 and any relevant SA Water standards, however, this Standard will provide more specific requirements, where preferences or conventions exist.

1.2 Glossary

The following glossary items are used in this document. For additional cathodic protection terms and definitions refer to AS2832.1:

Table 1-1 - Glossary of cathodic protection terms

Term	Description
100mV Polarisation	Polarisation achieved against the Natural or Depolarised potential as a result of applying cathodic protection. The polarisation achieved is determined by measuring the Instant OFF potential and subtracting the depolarised potential.
Depolarised potential	Potential of a structure after cathodic protection has been switched off and the structure potential allowed to decay fully. The 100mV Polarisation criterion may be demonstrated without requiring the structure to reach fully depolarised conditions.
Instant OFF potential	IR free polarised potential of a structure measured against a stable reference electrode, usually copper/copper sulphate
IR free potential	The potential of a structure with errors associated with voltage gradients removed. A close estimate to an IR drop free potential measurement can be made by interrupting all current sources simultaneously and taking an "instant off" potential measurement.
Natural state potential	Potential of a structure prior to application of cathodic protection. Also referred to as a 'native state potential'.

1.3 Abbreviations

Table 1-2 - Abbreviations used within this document

Abbreviation	Description
A	Amperes
AC	Alternating Current or Asbestos Cement (refer to context where used)
CI	Cast Iron
CP	Cathodic Protection
CSE	Copper / copper sulphate reference electrode
DDR	Detailed Design Report
DC	Direct Current
DICL	Ductile Iron Cement Lined
EL	Elevation
EPR	Earth Potential Rise
FRP	Fibre reinforced plastic
GRP	Glass fibre reinforced plastic (refer FRP)
ICCP	Impressed Current Cathodic Protection
IR	Voltage drop/Voltage gradient
LFI	Low Frequency Induction
Mb	Megabyte
MEN	Multiple Earthed Neutral
MIJ	Monolithic Insulating Joint
MSCL	Mild Steel Cement Lined
OH	Overhead
PCF	Project Construction File
PVC	Polyvinylchloride
RC	Reinforced concrete
SA Water	South Australian Water Corporation
SACP	Sacrificial Anode Cathodic Protection
SAPN	SA Power Network
TG	SA Water Technical Guideline
TP	Test Point
TR	Transformer Rectifier
TS	SA Water Technical Standard
UG	Underground
V	Volts
WM	Water Main

1.4 References

1.4.1 Australian and International

The following table identifies Australian and International standards and other similar documents referenced in this document:

Table 1-3 - Relevant cathodic protection standards

Number	Title
AS 2239	Galvanic (sacrificial) anodes for cathodic protection
AS 2832.1	Cathodic protection of metals, Part 1: Pipes and Cables
AS 3000	Wiring Rules
AS 4827.1	Coating defect survey for buried pipelines Part 1: Direct current voltage gradient (DCVG)
AS 4832	Cathodic Protection - Installation of galvanic sacrificial anodes in soil
AS/NZS 4853	Electrical hazards on metallic pipelines
AS 3894.1	Site Testing of protective coatings. Method 1: Non-conducting coatings – continuity testing – High voltage (brush) method
AS/NZS 2312	Guide to the protection of structural steel against atmospheric corrosion by the use of protective coatings Hot dip galvanizing
NACE SP0169	Control of External Corrosion on Underground or Submerged Metallic Piping Systems
NACE SP0200	Steel-Cased Pipeline Practices
	The Regulations of the Electricity Act of South Australia 1996

Works shall in general comply with the requirements of the current version of the standards listed above. However, where SA Water specific standards nominate more stringent or specific requirements, the SA Water standards and drawings shall take precedence.

1.4.2 SA Water Documents

The following table identifies the SA Water standards and other similar documents referenced in this document:

Table 1-4 - Relevant SA Water standard documents

Number	Title
TS 18	Protection of Steelwork In Buried Environments
TS 0130	As Constructed Data Requirements for Linear Assets
TS 0131	Asset and Location Hierarchy Data
TS 0132	Operation and Maintenance Manuals
TS 0300	Supply and Installation of Low Voltage Electrical Equipment
TS 0100	Requirements for Technical Drawings

Table 1-5 - SA Water standard drawings

Number	Title
STD-04-00001_01	Cathodic Protection – Drawing Index
STD-04-00001_02	Timber Test Point Assembly
STD-04-00001_03	Aluminium Test Points
STD-04-00001_04	Plastic Test Points
STD-04-00001_05	Standard Streetbox and Cover for Cathodic Protection Test Point
STD-04-00001_06	Standard Cathodic Protection Reference Cell Assembly (Unpaved Areas)
STD-04-00001_07	Standard Cathodic Protection Reference Cell Assembly (Paved Areas)
STD-04-00001_08	Test Point Connections
STD-04-00001_09	Pipe Connections for Test Points
STD-04-00001_10	Bond Cable Connections
STD-04-00001_11	IR Free Coupon Assembly (Unpaved Areas)
STD-04-00001_12	4 Wire Test Span Assembly
STD-04-00001_13	Insulated Flanged Joints 1 of 2
STD-04-00001_14	Insulated Flanged Joints 2 of 2
STD-04-00001_15	Sacrificial Anode CP Systems for Paved Areas
STD-04-00001_16	Sacrificial Anode CP Systems for Unpaved Areas
STD-04-00001_17	Bond Cable Arrangement on Below Ground Valves and MSCL Pipelines
STD-04-00001_18	Bond Cable Arrangement on Below Ground Flow Meter
STD-04-00001_19	Typical Cubicle Construction and Layout
STD-04-00001_20	Transformer Rectifier Earth Stake
STD-04-00001_21	Horizontal ICCP Anode Bed General Arrangement
STD-04-00001_22	Cathodic Protection – Installation of Mixed Metals Oxide Anodes
STD-04-00001_23	Cathodic Protection – Anode Centraliser Details
STD-04-00001_24	Bore Casing
STD-04-00001_25	Dripper System to Anodes
STD-04-00001_26	Anode Junction Box

1.5 Definitions

The following definitions are applicable to this document:

Table 1-6 – List of references and terms used in this document

Term	Description
SA Water's Representative	The SA Water representative with delegated authority under a Contract or engagement, including (as applicable): • Superintendent's Representative (e.g., AS 4300 & AS 2124 etc.) • SA Water Project Manager • SA Water nominated contact person
Responsible Discipline Lead	The engineering discipline expert responsible for TS 0440 defined on Page 3 (via SA Water's Representative)
Designer	Person or company responsible for the design of the CP system and its performance
Cathodic Protection Tester	NACE accredited CP tester (NACE CP1)
Cathodic Protection Technician	As defined in AS 2832.1 (NACE CP2)
Cathodic Protection Technologist	As defined in AS 2832.1 (NACE CP3)

2 Scope

This Technical Standard sets out the minimum requirements for the design, documentation, construction and testing of impressed current and galvanic cathodic protection systems for external corrosion protection of buried SA Water mild steel pipelines. This Standard applies to new systems, retrofitted systems and existing systems that are to be upgraded or replaced.

This document covers the minimum requirements for:

a) Qualifications of skilled staff

b) Design report including design inputs and design assumptions

c) Construction documentation

d) Site-specific drawings

e) Project construction files

f) Specification including materials and installation requirements

g) Pricing schedule

h) Commissioning testing and reports

i) Monitoring testing and reports

j) Interference testing requirements.

Guidance for pipeline designers to ensure compatibility of the pipeline design with the provision of cathodic protection is provided.

2.1 Exclusions

This Standard applies specifically to CP of buried mild steel pipelines only. It does not cover provision of CP for other structures such as:

- Steel reinforced concrete structures
- Internal or external surfaces of tanks
- Mechanical equipment i.e., scrapers in clarifiers
- Locks and weirs
- Steel piled structures such as buried or immersed sheetpile walls, circular steel piles for jetties or pumping stations.

3 Qualifications of Personnel

Personnel undertaking tasks related to cathodic protection systems shall have the appropriate skills, training and competency to undertake the work required. Minimum competencies for common CP related tasks are as per Table 3-1 below.

Table 3-1 – Required personnel competencies

Scope of Work	Requirements	Comments
System installation	The installation team must be supervised by a Cathodic Protection Technician (CP2). The overall project shall also be under indirect supervision of a Cathodic Protection Technologist	A licenced electrician is required for any tasks involving components operating above CP voltages (50V DC) or AC components
System Function Test	A person with training and demonstrated competency in operating and obtaining required measurements from the relevant TR unit.	
Routine testing including potential measurement	A Cathodic Protection Tester (CP1), Cathodic Protection Technician, Cathodic Protection Technologist or other competent tester as approved by the SA Water CP manager.	Reports must be reviewed and signed off by a Cathodic Protection Technician (CP2) or above.
System design analysis and reporting	A Cathodic Protection Technologist (CP3) or alternatively a Cathodic Protection Technician under supervision of a Cathodic Protection Technologist	
System design peer review	A Cathodic Protection Technologist (CP3) who is not involved in design process of the system	
TR repairs or component replacement	A Licenced Electrician shall conduct all electrical works. Cathodic Protection Technician (CP2) or Cathodic Protection Technologist (CP3) will be required to undertake or provide guidance where any modification to system outputs or recommissioning is required.	
LFI and EPR studies	An appropriately qualified electrical engineer experienced in assessing and managing LFI/EPR related risks.	A Cathodic protection Technician (CP2) or Cathodic Protection Technologist (CP3) may be required to assist in these studies and discuss CP implications.

The definitions of a Cathodic Protection Technician and Cathodic Protection Technologist are as per Section 1.4 of AS2832.1-2015.

4 Cathodic Protection System Design

4.1 General

All SA Water CP designs shall address as a minimum:

a) All relevant inputs and considerations to satisfy the requirements of AS 2832.1

b) SA Water Standard Design Drawings

c) SA Water Standard Specification Clauses for Material and Installation

d) The requirements nominated in this Standard.

All relevant parameters and inputs used in the design shall be summarised in a Detailed Design Report (DDR). Any deviation from the requirements of AS 2832.1, SA Water Standard Specification Clauses, Standard Design Drawings or from this Standard shall be summarised in the DDR and a justification provided for review and approval by the SA Water Representative prior to procurement and installation of any CP components or equipment.

4.2 Protection Criteria

All CP systems shall be designed to satisfy protection criteria in accordance with AS 2832.1. These criteria more specifically are:

a) An IR free polarised potential (instant OFF) equal or more negative than -850mV vs CSE, the preferred range is -900mV to -1050mV vs CSE.

b) 100mV of polarisation. This criteria may only be used when:

i. The -850mV criterion cannot be satisfied,

AND

ii. No galvanic coupling exists on this pipeline such as electrical contact with consumer copper connections, copper earthing,

AND

iii. All valves and CI elements have been fully wrapped.

AND

iv. The pipeline is not affected by stray DC current interference.

c) The instant OFF potential shall not be more negative than -1050mV vs CSE to avoid damage by cathodic disbondment of coal tar enamel coated pipes. If the pipeline is confirmed to be coated with fusion bonded medium density polyethylene (FBMDPE, i.e., Sintakote) or liquid epoxy a more negative potential up to -1200mV vs CSE is permitted

d) The pipeline CP system shall not cause any stray current interference in excess of the limits stipulated in AS 2832.1 or as agreed with the foreign asset owner.

4.3 Cathodic Protection System Type Selection

Pipeline cathodic protection can be provided by either an impressed current cathodic protection system or by sacrificial anodes. If not specifically nominated in the tender documentation or otherwise, the designer shall select the system which provides the most cost effective solution over the design life of the pipeline (typically 100 years). As a minimum, the following criteria shall be considered in the selection process:

a) Cost of installation and replacement of the CP system components over the pipeline design life

b) Compatibility of the selected CP system with the CP systems installed to adjacent sections of this pipeline

c) Current density requirements to satisfy protection criteria as the coating deteriorates over the design life of the selected anode system

d) Even current distribution along the pipeline section (i.e., consider corrosion hot spots, current attenuation)

e) Availability of suitable sites for anode beds and cable runs

f) Future developments in the area which may have an impact upon the chosen sites for equipment

g) Proximity to other buried metallic infrastructure (SA Water and other owners) in order to minimise adverse effects upon this infrastructure

h) Consideration of DC traction electrolysis for pipelines in proximity of DC electrified transport systems

i) Consideration of possible stray current interference effects upon the pipeline from nearby existing foreign structure CP installations.

The following points provide guidance for the provision of CP for SA Water pipelines. However, it shall remain the designer's responsibility to select the appropriate system for approval by SA Water. The designer shall provide justification if a system differing from the selection guidance is chosen.

4.3.1 When should cathodic protection be provided?

As a minimum CP shall be provided for buried mild steel pipelines with:

a) A design life of 100 years

b) A design life of under 100 years and provided with a protective coating system that has a lesser performance than FBMDPE or equivalent type coating, or

c) If neither a) nor b) are applicable but provision of CP is nominated in the project brief.

Cathodic protection is <u>not</u> required for:

- Above ground pipelines
- Non-metallic pipelines
- Cast iron, ductile iron pipelines
- Stainless steel pipelines. Note: stainless steel is not generally recommended for buried service and specific materials advice should be sought in this situation.

4.3.2 Type of CP system

a) An impressed current system is preferred if:

   i. The length of pipeline to be protected exceeds 300m, and/or

   ii. The pipeline is not provided with a coating system with a performance equal or better than FBMDPE or equivalent type coating.

b) Sacrificial anodes should only be considered for:

   i. Pipelines with a length of less than 300m and 'Specials'

   (Specials are short sections of mild steel pipeline incorporated into RC, AC, FRP, Poly etc. pipelines i.e., at road, rail or river crossings, bends etc.)

   and

ii. Pipeline sections provided with a coating quality of equal or better than FB MDPE or equivalent type coating

or

iii. A current drainage test has demonstrated that the section can be economically protected by use of sacrificial anodes

or

iv. Combined with an ICCP system to provide localised supplementary protection to a corrosion hot spot such as creek crossing or local area of low resistivity soil.

4.4 Minimum Design Life

Until this section is superseded by SA Water Technical Standard TS0109:

a) Impressed current systems shall have a minimum design life of 25 years. This requires that the anode beds shall still provide the full design current after 25 years of operation

b) Sacrificial anodes shall have a minimum design life of 15 years at maximum calculated output before replacement.

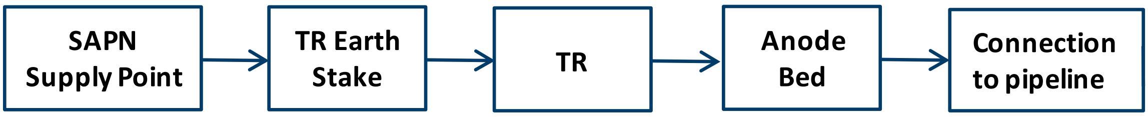
4.5 Impressed Current System Design

The requirements for design of an impressed current cathodic protection design shall be as per the requirements of this section of the Standard.

4.5.1 System Layout

The geographical layout of a CP system must be considered in order to minimise any stray current interference caused by the system. In general, the current path through the soil between the anodes and the pipeline should not be intercepted by any other metallic object (including the TR earth stake and shield) as this can significantly increase the risk of interference to those assets.

The various ICCP components shall be installed in the following relative geographical order wherever possible:



4.5.2 TR Location Selection Criteria

The following aspects shall be taken into due consideration when selecting locations for new or replacement TRs:

a) Confirm suitable 240V AC supply point is available Refer Clause 4.5.7 for requirements.

b) Telstra 3G/4G reception to ensure telemetry will be functional

c) TR accessibility and safety:

i. Select a safe distance to road kerb considering type of road, traffic volume and speed

ii. Maintain min 0.5m spacing all around for maintenance access

iii. Do not locate TR at a location without road access

d) Avoid low points in natural or artificial waterways or drains where TRs can become flooded during rain events. If required include installation of elevated plinth including a suitable concrete working platform into design. Ensure elevated plinth design is in compliance with SAPN meter panel height requirements. Refer to SAPN Installation and Service Rules and SA Water Standards.

4.5.3 Anode Bed Location Selection Criteria

The following aspects shall be taken into due consideration when selecting locations for new or replacement anode beds:

a) Safety considerations, ensure safe access for installation and ongoing testing, i.e.:

   i. A safe distance from roads, railways

   ii. Away from other buried assets

   iii. Away from dangerous environmental features such as cliffs, ledges, embankments etc.

b) Avoidance of stray current interference

   i. Avoid buried metallic services in proximity

   ii. Spacing to foreign buried metallic assets based on output and soil resistivity

   iii. Spacing to pipeline to be protected based on output and soil resistivity

   iv. Consider proximity to any other assets, i.e., concrete structures, OH powerlines interconnected by earth wire and risk of stray current transfer.

e) Optimise length of cable runs, consider directional drilling for cable installations in built up areas and to reduce damage to road surfaces and temporary road closures

f) Identify suitable connection point of water supply for dripping system

g) Allow in the design for possible corrosion 'hot spots' and areas which may cause 'current shielding' such as shallow rocky areas

h) Environmental considerations

   i. Avoid or minimise disturbance of native plants / vegetation

   ii. Avoid waterways and riverbanks to eliminate risk of washout at high water level/floods

   iii. Avoid contaminated land (i.e., disposal of drilled out soil).

i) Review and consider cultural heritage of selected sites

j) Land ownership, for anode beds, TRs and cable runs select:

   i. SA Water owned land, or

   ii. Road easements (Crown land) where possible

   iii. Avoid private land

   iv. Where use of private land is necessary, ensure approval of easement by landowner before finalising the design. The process of easement approval from landowner shall be managed by SA Water.

k) Anode beds and TRs should not be located within extra high voltage transmission line easements unless there are no other alternatives. If there are NO alternate options, the designer must take into account HV induction and risks associated with working under transmission lines. An experienced electrical engineering specialist must be engaged for the design to ensure safety at all times for personnel and the pipeline.

4.5.4 Anode Bed Design

The Designer shall perform the detailed design of the anode beds including all relevant calculations. The minimum details to be considered are summarised under Section 4.12 Detailed Design Report and Calculations.

4.5.4.1 Materials and Layout

Some CP materials, components, equipment and construction methodology are nominated in the Standard Specification Clauses and on the Standard Drawings. These materials and methodologies shall be followed except where changes are justified by the designer and approved by the SA Water Representative.

This selection is based on long term experience and track record, familiarity with the installation and maintenance and serves the purpose to:

- Minimise the various components to be carried and stocked for replacement and repairs
- Achieve consistent designs to simplify operation and maintenance through familiarity with the equipment
- Select reliable equipment and components based on track record and long term experience.

Any CP design shall endeavour to utilise the following CP items which have a preferred material, design or construction type nominated:

a) Anodes

b) Backfill

c) Cable types and sizes

d) Transformer Rectifier Unit

e) SCADA Integration Components (Telemetry)

f) Reference Electrodes

g) Test point posts, pits, studs including terminations and cabling

h) Pit and ground chamber types

i) Anode bed watering system components

j) Cable to pipeline connection details

k) Electrical isolation details for scours and meters

l) Insulating joint protector (surge diverter)

m) Pipeline coating repair and wrapping

n) IR Free Coupons.

Refer to the SA Water Standard Drawings listed in Table 1-5 for all CP items details.

4.5.4.2 Deep Well Anode Beds

If a deep well anode bed is chosen, the designer and installation contractor shall be responsible for the sealing of intersected aquifers to minimise potential contamination avenues. For purposes of this technical standard, a deep well anode is defined as one or more anodes installed vertically at a depth of 15m or more in a drilled hole.

The Department for Environment and Water must be contacted before the design is completed.

The designer shall provide sealing procedure to SA Water for approval and procedures for proper abandonment of the well once it has reached the end of its useful life.

The designer shall provide a drawing with the deep well anode details to the Principal for review and approval.

4.5.4.3 Watering System

All ICCP anode beds shall generally be provided with a watering system (drip system) in accordance with the Standard Specification Clauses and Standard Drawings to mitigate the risk of drying out during prolonged drought periods.

Where the Designer is confident that a drip system is not required, the following shall be provided as a minimum in accordance with the standard drawings:

a) Main cock with poly pipe to Boundary Cock in No 2 Meter Box Pit

b) Blind cap to Boundary Cock.

4.5.5 DC Power Supply

All ICCP systems shall be powered using a SA Water standard DC power supply unit as a Principal supplied Item. The designer shall request the output parameters of the SA Water standard DC power supply unit prior commencing the detailed design to ensure that the unit is compatible with the designed anode bed.

4.5.6 Telemetry

Telemetry systems will be provided as a Principal Supplied Item.

4.5.7 AC Power Connection

The Designer shall identify and confirm availability of AC power at the identified supply point. Where practicable the selected supply point shall:

a) Avoid need for installation of additional SAPN transformer or OH poles.

b) Aim for a short run of consumer main between SAPN Fuse and supply point. Note in some cases SAPN will not allow consumer mains greater than 10m in length.

Designer to submit Form B to SAPN to confirm that the identified supply point is available and has sufficient capacity.

The AC supply shall be designed in compliance with TS 0300 and SAPN Service & Installation Rules.

Some regions apply more stringent rules regarding the permissible length of a buried consumer main and may require additional poles or transformers being installed. The designer shall ensure that a cost effective solution is identified and nominated.

4.5.8 TR Earthing

The earth stake for all new TRs shall be installed with an earth shield as per Standard Specification Clauses and as shown on the Standard Drawings to avoid transfer of stray currents from the CP system into the MEN network.

4.6 Sacrificial Anode System Design

The requirements for design of sacrificial anode cathodic protection design shall be as per the requirements of this section of the Standard.

4.6.1 Anode Location Selection

a) As per the requirements for an impressed current groundbed described in Section 4.5.3 with exception of the requirement for a water connection

b) Anodes should be placed in low resistivity environments where possible

c) Anode location and separation respective to the pipeline to be protected should be in accordance with the SA Water standard drawings except where there are specific CP system design requirements that require a different location. In this situation the DDR should identify these issues and the design drawings clearly identify the design.

Specific soil resistivity testing shall be undertaken at all locations proposed for a SACP system and the measurements used in the design. Estimation of soil resistivity based on nearby measurements or geographical features alone is not permitted.

4.6.2 Anode design

a) The sacrificial anode system shall be designed to provide at least the minimum design current throughout its design life taking into account:

   i. Anode mass, consumption rate and contingency factors such as the efficiency and utilisation factors

   ii. Design current output based on anode dimensions, tested soil resistivity, circuit resistances

b) If magnesium anodes are selected, a mechanism to limit current flow and prevent overprotection of the pipe shall be provided by the design. For example, disconnection of individual smaller anodes or installation of resistive links.

4.6.3 Sacrificial Anode Materials

a) Sacrificial anodes for protection of buried pipelines in soil shall be as defined in AS 2239 including:

   i. Z1 zinc

   ii. M1 high potential magnesium

   iii. M3 low potential magnesium

b) Magnesium anodes shall not be used in soils with soil resistivity lower than 5 ohm-m or below the permanent water table

c) Anodes shall be provided with an appropriate backfill as per AS 2239:

   i. B1 for general use backfill

   ii. B2 use when the anode will be installed below the permanent water table

d) The anode shall typically be provided pre-packaged with backfill in a calico bag. The bag shall be designed to ensure that the backfill provides complete coverage to the anode with minimum 50mm cover to sides and 25mm cover to corners of the anode. Alternatively backfill can be provided separately and tamped around the anode or pumped as slurry using a tremie pipe ensuring uniform void free coverage

e) Anodes shall be provided with a factory encapsulated cable tail connection and sufficient length of cable to run to the relevant test point or box.

4.6.4 System Layout

a) The SACP system shall be designed as per the SA Water Standard drawings where detailed in the DDR and as approved by SA Water

b) A timber test post, plastic test point or inground street box shall be used for terminating the anodes to the pipeline.

4.7 Cathode Connection

Cathode connections shall be as per Standard Specification Clauses and Standard Drawings.

Where the cathode connection pit is located in the road surface, a secondary pit shall be installed next to the road kerb in the nature strip as shown in the Standard Drawing 4004-00001-15 and Standard Specification Clauses.

4.8 Test Points

4.8.1 Test point selection

Guidance for selection of test points is provided in the following:

a) Maximum test point spacing in metropolitan area: 300m

b) Maximum test point spacing in remote area: 500m

c) Consider test points at both sides of major road crossings, rail crossings, and change of pipeline direction

d) Install at cased crossings with test points on the pipeline and on the casing.

e) Install at low points and waterway crossings

f) Install at insulating joints. NOTE: These test points shall have connections to both sides of the joint. If both pipelines are mild steel, crossbonding cables shall be provided in addition to the test cables, which shall be left disconnected in an in-ground pit

g) Install interference test points as appropriate. NOTE: These test points shall be installed with a reference electrode placed midway between the two pipelines (or as close as possible) where the protected water main crosses major foreign pipelines i.e., an oil or gas transmission pipelines or high pressure distribution pipelines. Consideration for interference test points shall be given at crossings between SA Water Mains, which are not connected to the same CP system, at strategic points along sections where the protected main runs parallel to a non-SA Water buried metallic pipeline

h) DC traction interference test points at strategically selected locations where the water main is located near a DC electrified tram or train line.

4.8.2 Test point construction type selection

The following test point types shall be used and are described in detail in the Standard Specification Clauses and on the Standard Drawings:

a) Aluminium Posts shall be installed when:

   i. A TP is a single cable test point only

   ii. The TP is located in a nature strip along a road

   iii. A post does not impede traffic or create a hazard for pedestrians (i.e., do not install near bus stops or pedestrian crossings)

   iv. The TP is located in a bush fire area

b) Timber posts shall be installed when:

   i. Multiple test point connections are required, i.e., for insulating joint test points or for sacrificial anode connections
   ii. In areas such as paddocks with livestock

c) An alternative to timber posts are plastic posts that may be installed when:
   i. Multiple test point connections are required, i.e., for insulating joint test points or for sacrificial anode connections

d) Where the post impedes traffic or create a hazard for pedestrians, an aluminium, plastic or timber post may be unsuitable, so a groundbox shall be provided. For example, a groundbox would be required in the following situations:
   i. The test point is located in a trafficable area
   ii. Where a post would be a hazard for pedestrians, i.e., near bus stops or pedestrian crossings
   iii. Where more than 2 cables are required i.e., test cables and crossbonding cables at an insulating joint test point between mild steel pipelines.

Note: Cast iron in-ground pits shall be used for cathode connection/reference cell installation. When this connection is under a road, the cables shall be extended to a groundbox beside the kerb for safe access during inspection, in accordance with the SA Water standard drawings.

4.8.3 Test point numbering system

SA Water has developed a test point numbering system which is outlined in this section and summarised in Table 4-1. This numbering system shall be used for all new designs and its principles applied to all CP system modifications i.e., addition of insulating joints, addition of test points etc.:

a) The labels shall be painted onto the test point posts in accordance with the Standard Specification clauses showing the pipeline number in the first row and the test point number in the second row, or for test point in pits shall have the pipeline number and TP number embossed in a stainless steel label. The use of engraved aluminium or stainless steel labels, fixed with stainless steel screws onto timber posts or rivets onto aluminium posts is permissible

b) Test points for each pipeline system (running plan) shall be numbered in numerical order in direction of water flow beginning with TP1

c) At metallic casings, the test point shall be labelled with “C” to allow identification of the Casing. e.g., TPC4. Numbering of the casing test point shall be in sequence with the pipeline test points

d) Test point labels shall show the pipeline number followed by the test point number, for example Pipeline File No. 01-05 Test point TP1, the test points shall be labelled: “01-05 TP1”

e) At insulating joints, the test points shall be numbered to allow identification of the protected and non-protected side, referred to as “District” as follows:
   i. Protected pipeline: “01-05 TP1”
   ii. District side: “01-05 TP1D”

f) Test points at insulating joints installed between two mild steel pipelines shall be provided with crossbonding cables as per Standard Specification Clauses. They shall be terminated in an in-ground pit and labelled with the pipeline numbers (running plans) and pipeline diameters

g) Test points added between existing test points shall have the same number as the previous test point followed by a letter. For example, if an off-take with an insulating joint is installed downstream within a short distance of an existing test point TP7, this IJ test point shall be labelled TP7A and the District Side TP7AD. If another test point is required between this test point and TP 8 it shall be numbered TP7B etc.

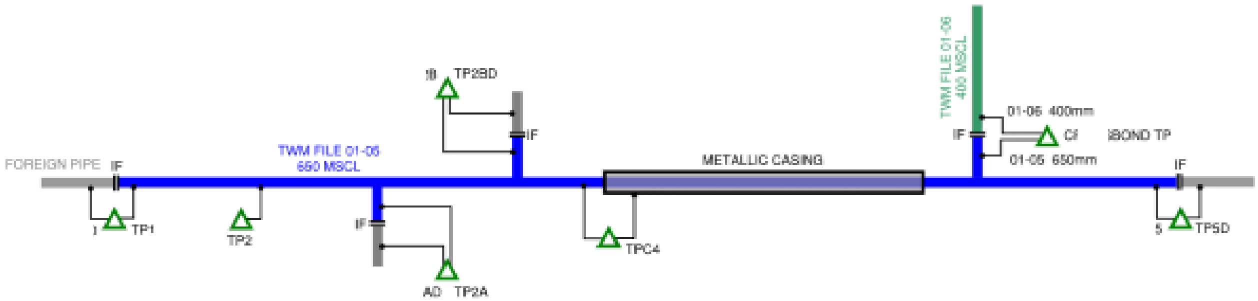


Figure 1 – Example Test Point Designation for TWM File 01-05 650 MSCL

Table 4-1 – Test point numbering system summary

Type of test point	Example test point number for Test Point 1 on pipeline system File 01-05	Comments
Standard CP Test Point	01-05 TP1	Marked either in paint on the test post, or embossed/engraved on a stainless or aluminium label plate
Test Point added after the CP System is installed	01-05 TP1A	Number followed by a letter in alphabetical order(D is not used) These provide additional data points
Test Point at insulating flange on non-protected side	01-05 TP1D	
Test point at metallic casing	01-05 TPC1	
Crossbonding cable in pits at insulating joint	01-05, 650mm	In this case the cable is labelled as per the pipeline number and diameter, in the example 650mm. The cable will be located in a ground box associated with a test point. The other cable from the 'District' pipeline shall show the corresponding running plan No and pipeline diameter.

4.9 Electrical Continuity

For effective CP, all sections of a pipeline needing to be protected by a dedicated CP system must be electrically continuous. The following scenarios may require crossbonding to be installed in accordance with the Standard Specification Clauses and Standard Drawings:

a) At rubber ring joints. Note: All rubber ring joints shall be provided with two (2) independent crossbonds at the time of pipeline installation to allow for CP installation or retrofit later and to mitigate the risk of bond failure by providing redundancy. Retrofitting RRJ pipes with crossbonds at a later time is not cost effective.

b) At in-line valves and bypasses in accordance with the Standard Specification Clauses and Standard Drawings

c) Across motorised valves which have been insulated from the main pipeline

d) Across electrically isolated flowmeters, i.e., Magflow meters

e) Across assembly and Gibault joints

f) Across non-metallic joints or spool pieces

No test points are needed at these crossbond locations, except for electrically isolated flowmeters and motorised valves, where the testing of the insulating joints is required. For all cases, the existence of these crossbonds must be shown on the project Running Plan Part B drawings.

4.10 Electrical Isolation

A cathodically protected section of pipeline must be isolated at its extents and at all metallic connections along the protected pipeline section to ensure protective current is not lost to other pipe systems, earthing systems or assets. Where a pipeline is electrically shorted to an external metallic asset current loss may occur which affects the performance of the CP system.

Cathodic protection designs must consider all current paths which could result in current loss.

For existing pipe systems, a site inspection shall be undertaken to identify possible losses and to test the function of existing isolations such as insulating flanges. The design should include provision of all required isolations, however where it is not possible or economically viable to provide an isolation the design must provide an appropriate contingency current to allow for predicted losses. Ideally a current drainage test should be performed during the design phase to assess the quantity of current loss.

New pipe systems should incorporate continuity bonding and electrical isolation as required to permit economic and efficient application of cathodic protection.

The following is a summary of typical considerations where electrical isolation may be required and typical isolation methodologies:

a) At the extent of the protected section of pipeline. Install insulating flanges, monolithic insulating joints or non-metallic spool pieces.

b) At all off-takes to pipelines which are not intended to be protected by the pipeline CP system, i.e., distribution networks systems, consumer mains. Install insulating flanges, monolithic insulating joints or non-metallic spool pieces.

c) At scours with metallic spools as per Standard Specification Clauses.

d) At metered off-takes where the offtake is metallic. Install insulating unions.

e) Motorised valves where the motor is bonded to electrical earth.

   i. Install insulating fittings on both sides of the valve and bond across the valve through a bond pit to ensure electrical continuity of the pipeline OR

   ii. Electrically isolate the valve motor from the valve gear box with a proprietary isolation kit.

f) At pumps. Install insulating fittings on both sides of the pump and if required by the CP strategy, bond around the pump to provide continuity along the pipeline.

g) At connection to tanks. Install insulating fittings at the connection.

h) Mag Flow meters are normally bonded to electrically earth. Provide insulating flanges on both sides of the meter and bond around the meter to provide continuity along the pipeline. Bond cables to be run to a bonding pit and provision of test cables shall be required

i) Ultrasonic flowmeters can be electrically earthed.

   i. If the meter is operating on a 24V instrumentation supply the earth connection to the meter may be disconnected from the flowmeter in some situations. Confirm with the site electrician or electrical engineer to confirm. OR

   ii. If the earth connection cannot be removed, electrical isolation of the spool piece or flanges either side of the meter and bond around the meter to provide continuity along the pipeline. Bond cables to be run to a bonding pit and provision of test cables shall be required.

j) Reinforcing steel in concrete pits, wall penetrations etc. Provide plastic spacers to prevent reinforcement to pipeline contact. All cast in steel sections of the pipeline must be coated. Test points to the steel reinforcement and pipeline can be provided to confirm isolation has been achieved

k) Any buried stainless steel elements such as manifolds. Provide insulating joints at the manifold/pipeline interface. Alternatively, the manifolds can be bonded to the CP protected mild steel pipeline and wrapped with a Denso wrapping system to provide electrical isolation from soil. As noted above: The use of stainless steel in buried installation is not recommended

l) Any contacts with metallic items in contact with the earth or other metallic structure, for example copper earthing or pipe rack. Remove the contact or electrically isolate. Seek guidance from an electrical engineer prior to disconnecting any electrical earthing

m) At below ground / above ground transitions. Typically, an electrical isolation such as insulating flange is required at the transition

n) Any dissimilar pipeline metals, i.e., cast iron or ductile iron pipeline networks shall be isolated from the mild steel pipeline by the use of insulating fittings.
   Note: Cast iron valves connected to the protected MS pipeline shall be bonded and wrapped as per Standard Specification Clauses and Standard Drawings. This shall be conducted for all new pipeline installations, valve repairs etc. even if CP is not currently planned as this will permit more cost-efficient provision in the future.

All isolations and crossbonds shall be shown on the project Running Plan Part B drawings, independently of IJ test points shown on Running Plan Part A.

Testing of isolations shall be performed using the interrupted flange method outlined in Section 6.1.

4.10.1 Electrical Hazards at Insulating Joints

Where insulating joints are installed, the designer shall consider the need for a surge diverter(s) for protection of personnel against electrical hazards.

A surge diverter may protect the IF from damage or an operator working on the flange from electrical touch potential risks across the flange during electrical fault or lightning scenarios. However, the device can also transfer EPR/LFI hazards from one pipeline system to another, potentially expanding the risk.

The risks and benefits associated with the installation of a surge diverter shall be assessed and addressed as part of the Detailed Design Report (DDR).

If a surge diverter is required, it shall conform to the following typical requirements:

a) The surge diverter shall be installed within the cathodic protection groundbox adjacent to the flange. Where bond cables terminate at a test post or valve chamber, the surge diverter shall be installed in a separate groundbox next to the main test box.

b) Where the immersion of the surge diverter is unlikely a Dehn EXFS 100 or an approved equivalent for situations is suitable

c) Where temporary flooding (immersion) is possible, i.e., in an inground pit, an EXFS 100 KU or approved equivalent should be provided

d) Where an electrical isolation has been installed to segregate the pipeline into shorter section i.e., for the purpose of reducing the LFI exposure, the firing and quenching voltages of the devices must be higher than that caused by a powerline fault so that they do not conduct and defeat the purpose of the insulated joint.

In each situation, installation shall be in accordance with the Manufacturer's Installation Instructions.

Certain circumstances or situations may require changes to the above typical requirements, for example in a hazardous area or lightning prone area with above ground appurtenances. In this case the surge diverter design must be reviewed and approved by an appropriately qualified engineer.

4.11 Low Frequency Induction and Earth Potential Rise

For any new metallic pipeline design or upgrade, irrespective of whether CP is provided or not, a Low Frequency Induction (LFI) and Earth Potential Rise (EPR) study satisfying the requirements of AS4853 is required. A study will also be required as part of any pipeline CP upgrades or retrofits.

Where previous assessments exist, the associated reports shall be reviewed to confirm that the inputs used and that the assessment made remains valid. If changes have occurred such as a pipeline route change or transmission line upgrade or the reports are insufficiently detailed, the study shall be repeated.

LFI/EPR assessment shall be in accordance with the requirements of AS 4853 and typically comprise of the following three levels:

- Level 1: Assessment against conservative compliance criteria
- Level 2: Predetermined voltage limit criteria
- Level 3: Risk based (personnel safety) compliance.

The CP design shall incorporate any requirements of the LFI/EPR study to satisfactorily address any faults. This may include, but is not limited to:

a) Gravel bed or asphalt covering around test points, valves etc. to provide electrical insulation

b) Gradient rings at test points, valves etc., including solid state decouplers to dissipate voltage gradients to safe levels

c) Safety earth beds

d) Relocation of pipeline, test points, appurtenances if the mitigation measures above cannot provide safe conditions.

4.12 Casings

It is preferred not to install casings on CP protected mild steel pipelines. However, if cased crossing is a mandatory requirement of a stakeholder i.e., at railway crossings or under major highways, casing design shall comply with all requirements of AS 2832.1 (Section 4.7 *Road, Rail and Other Crossings*).

In addition, where casings must be used, the carrier pipe must be electrically isolated from the casing. An SA Water test point shall be provided to the SA Water pipeline at every casing, a test point is required at each end of the casing where the casing length is greater than 50m. Where the casing is metallic, a connection to the casing shall be provided in addition to the SA Water test point to allow isolation testing.

Where casings must be used, the order of preference for the various design options is as follows:

1. Reinforced concrete casing with the annular space grout filled
2. Mild steel uncoated or galvanised steel casing with the annular space grout filled. The pipe is to be separated from the casing with non-metallic spacers
3. Reinforced concrete casing with the annular space of air and sealed
4. Mild steel uncoated or galvanised casing with a watertight seal around the pipe and vent pipes installed at both ends of the casing. The pipe is to be isolated from the carrier pipe using non-metallic spacers.

Metallic casings shall not be coated or lined with an insulating coating and shall not be provided with cathodic protection. For more information refer to AS 2832.1 Section 4.7 or NACE SP0200. The designer shall demonstrate that the design life of the casing can be achieved in the expected environmental conditions.

4.13 Detailed Design Report and Calculations

A Detailed Design Report (DDR) shall be prepared for each new CP system, replacement CP system or CP upgrade. The DDR shall be issued as a minimum twice:

- Draft Issue: Prior to procurement and finalisation of detailed design for SA Water review. SA Water may require changes to be made to the design concept and may provide comments for implementation by the designer. Performance of the final CP system will remain the responsibility of the designer

- Final Issue: As part of the Issued for Construction package.

The content expected in a typical DDR for a new CP system (CP for a new pipeline or retrofit to an existing pipeline) is specified below. Not all sections will be required for refurbishment or small system upgrades.

4.13.1 Detailed Design Report Typical Contents

a) Introduction

This section shall describe the project, the asset to be protected including the limit of works and the objective of the project.

b) Scope

An overview of the extent of the DDR and details covered, i.e., number of ICCP systems, test points, crossbonds and isolations required shall be provided.

c) Codes and Standards

All standards and codes including SA Water Standards and Standard Drawings which are relevant to the design and the designed system shall be listed including the year of issue used. The author shall ensure that the revisions used are valid at the time of design.

d) Site Investigations

Where site investigations have been undertaken all findings which influenced the design shall be summarised, including observations and test results. Typical investigations would include, but are not limited to:

- Soil resistivity testing
- AC power supply points
- Presence of AC power lines

- Status of isolation i.e., at the ends of the pipeline to be protected, at off-takes and connections, scours, in-line and by-pass valves, motorised valves and flowmeters, supply meters, tanks etc.
- Requirements for bonding or crossbonding
- Foreign buried metallic structures
- Existing nearby CP systems
- Nearby electric tram or train lines

e) Discussion of CP Strategy

The designer shall outline the strategy for providing cathodic protection to the pipeline or pipeline system including options considered and the rationale why the selected option was chosen.

The strategy shall take into consideration all test results, site observations, isolation and bonding options, LFI/EPR considerations, stray current interference and voltage gradients caused by CP systems connected to adjacent pipelines.

f) Requirements for Electrical Isolation

All fixings, fittings, pipelines etc. which may require electrical isolation such as pipeline ends, off-takes, pumps, tanks, metered connections, appurtenances shall be listed including a brief description of the type of isolation proposed, i.e., insulating flange, monolithic insulating joint, insulating union, plastic spool piece etc. Isolation may further include motorised valves, flowmeters, reinforced concrete pits etc. This summary provides guidance on what to consider and is not fully comprehensive.

g) Requirements for Electrical Continuity and Bonding

All locations where bonding is required to ensure functioning of the CP system shall be summarised. This may include flanged connections, assembling joints, valves, bypasses, Gibault joints, non-metallic spool pieces or pipeline sections, isolated magnetic flowmeters etc.

h) Performance Criteria

The performance criteria which the system shall achieve and will be tested against during commissioning shall be nominated.

i. CP protection criteria
ii. Stray current interference criteria
iii. Design life
iv. Anode bed(s) minimum design output capacity (to be achievable at the end of the design life).

i) Design parameters

Specific design parameters adopted for the basis of design including calculations shall be nominated. Minimum design parameters are listed below. The designer shall nominate the selected value for each parameter in the detailed design report and shall demonstrate in the design calculations how the selected parameter will be met throughout the design life. The list below is not comprehensive and using these parameters will not guarantee performance of the system, which will remain the responsibility of the Designer:

i. Maximum design anode current output density
ii. Anode consumption rate
iii. Maximum permissible coke to soil current density
iv. Coke consumption rate
v. Maximum permissible anode driving voltage

vi. System design current requirements and associated assumptions which may include:

- Steel surface area of the asset to be protected
- Design current density required for protection (i.e., based on assumed coating loss)
- Calculations or testing undertaken to determine system current demand
- Attenuation calculations

vii. Maximum permissible voltage rises requirements (to the protected pipeline / to other metallic assets).

j) Test point selection requirements

This section shall summarise the criteria selected by the designer for test point selection, i.e., typical spacing, interference test points, isolation test points, crossbonding test points etc.

k) Locality plan of anode bed/TR locations

The DDR shall include a sketch (or sketches) of the proposed anode bed/TR locations on an aerial image as background showing as a minimum anode bed extension, TR location, water and AC supply, and proposed cable and pipeline routes

l) LFI and EPR assessment

For any new metallic pipeline design or upgrade, independent of whether CP is provided or not, a Low Frequency Induction (LFI) and Earth Potential Rise (EPR) study is required. The same is required as part of any pipeline CP upgrades or retrofits. The study including inputs, assumptions, modelling, outcome and required mitigation measures shall be included into the DDR

m) Safety in design considerations

A Safety in Design (SID) workshop shall be conducted by the designer during the design phase. All risks identified must be documented and measures to mitigate the risks nominated. The assessment shall cover all stages throughout the life of the CP system from the design to construction, commissioning, operation and decommissioning/disposal of the system.

The SA Water risk assessment template shall be used to document the discussions, identified risks and required mitigation; nomination of the parties responsible for action of mitigation

n) Materials selection

SA Water has selected preferred materials to be used for CP projects as nominated in the Standard Specification Clauses and on the Standard Drawings listed in Section 1.4.2 and the DDR shall confirm conformance with these requirements.

If non-standard materials are proposed a justification must be included into the DDR as to why an alternative material has been selected and confirm that an approval from the SA Water Representative has been obtained to use such material. The designer shall note that SA Water approval to use an alternative material does not release the designer/constructor from their responsibility to design a functional CP system which will satisfy the selected performance criteria

o) Specific installation considerations

The Standard Specification Clauses provided in Appendix A and on the Standard CP drawings listed in Section 1.4.2 provide installation instructions for CP designs compliant with the SA Water Standard CP design. If the Designer selects and justifies a design which departs from the Standard Design, specific installation considerations shall be provided in this section of the report

p) Specific testing and commissioning requirements

CP system testing, inspection and commissioning shall satisfy the requirements of AS 2832.1 and Section 7of this Standard.

Any inspection, testing and commissioning requirements which are outside the standard procedures nominated in this Standard shall be detailed.

q) Operation and maintenance requirements

Any operations and maintenance requirements, which are in addition or differ to standard operations and monitoring requirements outlined in Section 10 of this Standard, shall be discussed.

r) Design calculations

The DDR shall include design calculations which are detailed enough to allow an experienced CP Technologist to review and conduct a complete verification of the proposed system. Where an element is calculated, the equations and input parameters used shall be included and the explanation of how to use and interpret the data/calculations should be clear. Design calculations shall be included into the DDR and provided separately in original native format, i.e., Excel spreadsheet.

The calculations shall typically cover the following elements or include a justification if not provided:

- Basis for the selected total design current and allowed contingency
- Soil resistivity at anode bed locations including test data and strata calculations
- Loop resistances for each system including cable resistances, back EMF etc.
- Anode bed maximum output and calculations showing that the design output can be delivered at the end of the design life
- TR maximum output current and voltage (available continuous output current and driving voltage at positive/negative terminals)
- Actual parameters achieved by the design:
  - i. Maximum design anode current output density and comparison to limit
  - ii. Maximum design coke to soil current density and comparison to limit
  - iii. Maximum required anode driving voltage and the end of the design life and comparison to available limit
  - iv. Minimum spacing requirements to the protected pipeline from each anode bed
  - v. Minimum spacing requirements to other buried metallic assets from each anode bed.

s) Summary of issues raised and issues requiring resolution

The DDR shall summarise any issues raised with SA Water during the design process and the agreed resolutions as well as issues which have not been resolved in this section of the report.

4.14 Design Verification

Prior to issuing "For Construction" documentation all CP designs shall be verified and approved by a peer reviewer. The Peer Reviewer shall be an independent reviewer who has not been involved in the CP system design and has a level of training and experience that is appropriate to the design and as per Table 3-1.

Final approval of the "Issued For Construction" documentation shall be done by SA Water Engineering.

5 For Construction Documentation

The following minimum documentation is required to document construction of a cathodic protection project. An "Issued For Construction" package shall typically comprise of a specification for materials, installation and testing based on:

a) The Standard Specification Clauses provided in Appendix A, modified to suit the specific project,

b) The Standard Drawings

c) Project specific drawings for each ICCP system

d) A project construction file (PCF) detailing all works associated with test points, electrical isolation and continuity bonding

e) A pricing schedule.

The requirements for each of these sections are discussed in the following.

5.1 Standard Specification Clauses

The materials used and methods of installation shall be in accordance with the Standard Specification Clauses provided in Appendix A and the Standard Design Drawings provided in Section 1.4.2.

The key purpose of this Standard Specification Clauses and Drawings is consistency in the design which permits more efficient monitoring and maintenance of the CP systems by limiting number of differing spare parts being required and ensuring familiarity of the operations and maintenance personnel with the equipment to be expected even at new or unfamiliar sites.

These clauses and drawings inform the Designer and Installation contractor of the preferred equipment and materials and typical design details which shall only be modified with valid justification provided in the DDR for SA Water review and approval. The Standard Specification Clauses are not a complete specification and the Designer must specify the works and materials for the system designed by making changes, selecting the appropriate details and including any aspects not captured in the Standard Specification Clauses.

The Standard Specification Clauses outline further minimum installation, testing, pre-commissioning tests and requirements for "as built" documentation.

5.2 Standard Drawings

The Designer shall utilise SA Water Standard Drawings as much as possible to document the designed system. The applicable drawings have been listed in Section 1.4.2. Some drawings such as the anode bed design will require additional detail such as anode number, depth of anode wells and length of coke column to be determined by the Designer and provided on the Site Specific Drawings described in Section 5.3.

5.3 Site Specific Drawings

All new or modified CP systems require a set of site specific drawings to document the works. The drawings shall be prepared in accordance with TS 0100. Format shall be A3. Typically, three A3 drawings will be required:

a) Locality plan

b) Anode bed details, watering system details, TR location and AC supply point

c) Cathode connection and reference electrode location

The drawings shall use the Aquamap GIS reference files as background images, which can be obtained from the SA Water Representative upon request.

The drawings shall make reference to details shown on the Standard Drawings, clearly document cable and pipeline runs with off-sets to fence lines or kerbs or other fixed features, length and dimensions of the anode bed and cover all details not specifically shown on the Standard Drawings but essential for the construction of the system.

5.4 Project Construction File

Project construction files are used to outline the scope of works outside new CP systems using both text and maps. The following items are typically documented in a PCF:

a) Test points including numbering

b) Electrical isolation works including IJs and nomination of IJ protectors where required, motor isolators at valves, provisions of electrical isolation for flowmeters

c) Electrical bonding works i.e., an assembly joints, at valves, across isolated sections

d) Wrapping and coating works

e) Earthing systems for electrical safety (to be supplemented with a site-specific drawing if required)

f) Coating dig-ups to inspect pipeline coating condition where connections are made or at specified locations.

The PCF shall be used by the construction contractor to document the works performed and note any changes to permit preparation of as-built documentation including running plans.

All test results for insulating joints, insulated flanges and cable connections to the pipeline shall be documented in the tables at the end of the PCF.

6 Inspection and Testing Requirements during Construction

All installations shall be inspected and tested in accordance with the requirements outlined in AS 2832.1 and the Standard Specification Clauses. An inspection and test plan (ITP) shall be prepared by the Construction Contractor to ensure the construction will be in accordance with the design. Where applicable the ITP can utilise the PCF to record findings and results.

6.1 Insulating Joint Testing

Insulated joints of pipelines must be tested for isolation whenever a new insulated joint is installed.

6.1.1 Insulating Joints installed in pipeline with both sides buried

Insulating joint testing shall be completed at all insulations required for all new or upgraded CP systems and shall include:

a) IJs already installed in a pipeline and

b) Flanges being retrofitted with IJs

These joints shall be tested with the following interrupted flange method. Other methods outlined in AS 2832.1 are also considered appropriate and may be used for an additional confirmation check.

Interrupted flange potential method:

This test should be completed using a high input impedance (min 10 megaohm) digital voltmeter or multimeter and ensuring that the probes contact clean bare metal surfaces of the flanges.

1. *Prior to testing remove any equipotential bonding conductors installed across the insulated joint. With the bonding conductors removed care shall be taken to avoid simultaneous contact to both sides of the joint by personnel as electrical hazards may exist*
2. *Set the meter to its highest DC voltage range and measure across the flange, then repeat at the highest AC voltage range to check that there are no dangerous AC or DC voltages present across the joint before proceeding*
3. *Impress an interrupting DC voltage on one side of the flange i.e., by setting a nearby CP TR to interrupt or installing a temporary anodebed consisting of a 12V car battery and earth stakes*
4. *With the voltmeter set to DC millivolts measure the potential difference across the flange*
   i. *If the voltage difference measured is greater than 50mV, then the joint can be considered isolated and functional*
   ii. *If the voltage measured is between 3mV and 50mV, further testing is required to confirm adequacy of the insulation. Refer to additional methods in AS 2832.1 (Appendix P)*
   iii. *If the voltage measured is less than 3mV, then the flange is considered to be failed by a short circuit. Remedial action will be required.*

Note: The tester shall consider all CP systems connected to either side of an IJ and any installed IJ surge protection devices when selecting the test method and interpreting the data. Where surge protection devices are installed and need to be adjusted for testing, an appropriate plan should be in place to mitigate any risks associated with electrical hazards that may be present with the device removed.

6.1.2 Factory pre-assembled insulating joints

Any new factory preassembled joints or MIJs, shall be tested prior to installation (in the factory or warehouse) using an insulation tester with a minimum test voltage of 250V. All bolts shall be tested against each flange and the flanges tested against each other and test results recorded (Refer to Table P1 of AS 2832.1).

6.2 Coating Condition Inspection

The Contractor shall excavate the pipeline at locations advised in the PCF or on the drawings, undertake direct visual inspection of the external surfaces of the pipeline and prepare a report detailing the as-found condition. SA Water shall be given a minimum of 5 working days' notice prior to each excavation, their representative may elect to independently inspect the pipeline condition.

At each location the pipeline shall be exposed for a 1m length of pipe over the full diameter or as advised by the SA Water Representative. Care shall be taken not to damage the pipeline and associated coating.

The inspection shall include:

a) Record inspection details including, date, time, location of pipeline, extent of inspection
b) Measure depth of main, assess backfill type and soil type
c) Assessment of coating condition
    i. Percentage of coating loss, refer Figure extracted from AS/NZS2312.1:2014 below
    ii. Variation across pipeline area, i.e., 12o'clock, 3o'clock 6o'clock etc.
    iii. Adhesion, visually flaking or loosely adherent on surface
    iv. Any physical damage
    v. Type of coating (if able to be determined)
d) In an area of loosely adherent or damaged coating:
    i. Scrape off damaged coating to determine area of damage
    ii. Clean the surface below coating assess as surface or pitting corrosion as below
e) Inspect visible surface corrosion
    i. Estimate area of corrosion and extent of metal loss. I.e., single small area of corrosion or widespread large areas of corrosion
f) Inspect any pitting corrosion
    i. Estimate size (diameter) of pits
    ii. Estimate depth of pits (mm)
    iii. Estimate extent of pitting i.e., number of pits per m^2
g) Take photographs of all areas of exposed pipeline showing:
    i. Wide angle overview photos
    ii. Closeup photos of any typical defects
    iii. Closeup photos of specific local defects.

At completion of the inspection the Contractor shall suitably backfill and reinstate any damaged surfaces to their original or better condition in accordance with TS 0402.

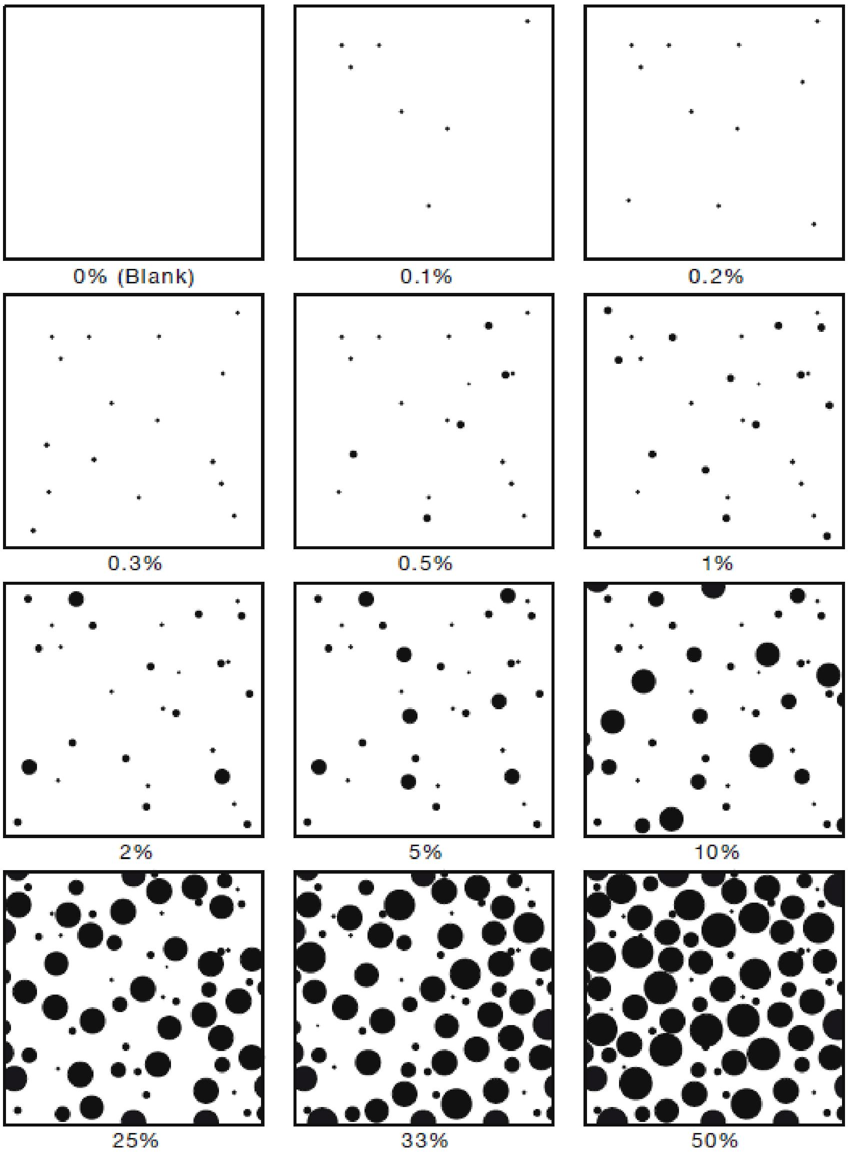


FIGURE 8.1 EXAMPLE DIAGRAMS FOR ESTIMATING RUST PERCENTAGES

Figure extracted from AS/NZS2312.1:2014 showing typical coating loss percentages.

6.3 Coating Defect Survey

A coating defect survey shall be conducted on all new fully welded MSCL pipelines and replacement sections greater than 100 metres in length. The Coating defect testing shall consist of a spark test before backfilling in accordance with AS 3894.1 and repair of all defects observed in accordance with coating manufacturer's specification.

6.4 Electrical Continuity and Cable Connections

All new cable connections shall be tested using a continuity tester where multiple connections are available. Where only single connections are available, the testing procedure for "cables attached to pipework" in the Standard Specification Clauses shall be followed.

6.5 Casings

All metallic casings around SA Water pipelines within the project limits must be tested to confirm the electrical connection or isolation. Casings shall be tested using the methods outlined in AS 2832.1. The casing isolation or otherwise must be approved as appropriate by the Cathodic Protection Designer. Guidelines on casing design have been provided in section 4.12.

6.6 Civil Works

Testing associated with civil works like compaction testing is specified in the Standard Specification Clauses.

6.7 AC Supply Works

Where existing consumer mains are to be reused, they shall be disconnected and inspected and tested to confirm compliance with the requirements of AS 3000. Unless stated otherwise, cables shall be insulation tested at 500V. Any cable with an insulation resistance of less than 1 Mohm shall not be re-used.

7 Commissioning

Commissioning of any CP system shall satisfy as a minimum the requirements of AS 2832.1. In particular the test equipment, qualification of personnel, type of tests and records should comply with AS 2832.1.

Some CP systems, particularly larger systems with multiple TR units and anode beds will require a commissioning plan to be prepared which should incorporate all the requirements of this section and be approved by SA Water prior to commencement of the commissioning works. The requirement for a plan to be prepared will be identified in the design documentation.

Commissioning shall be conducted in three stages with the requirements below considered to be in addition to AS 2832.1. Prior to commissioning, the SA Electrolysis Committee is to be advised of the system details and permission to operate and test the system must be obtained.

7.1 Stage 1 - Pre-energisation testing

a) Undertake a visual inspection of the CP system components including the TR, groundbeds, in ground pits, test points and all other elements installed as part of the works. Any defects are to be recorded and rectified prior to energisation

b) Inspect the TR output terminals and confirm correct polarity of all anodes and cathode connections

c) Test and record open circuit potentials of each galvanic anode against a CSE electrode

d) All pre-energisation measurements shall be taken and recorded, the records on the PCF reviewed and confirmed

e) Inspect and test any facilities provided for LFI/EPR risk mitigation

f) Test and record the natural potentials of all test points, including district (D) and casing (C) test points. Where a potential versus the pipeline is unstable and telluric or interference currents are suspected, this information is to be relayed to SA Water and to the CP system designer. More detailed testing is to be conducted to identify the issue in consultation with the SA Electrolysis Committee

g) Measure open circuit potentials of all sacrificial anodes

h) Calibrate all permanent reference electrodes as per AS 2832.1 methods.

7.2 Stage 2 - System operation and adjustment

a) At initial energisation of an impressed current system, turn the TR unit on at zero output, and then increase output to an initial current of approximately 10% of the designed current output. Measure potentials of the nearby permanent reference electrode and at least one nearby test point and assess whether the pipeline potential is moving in the positive or negative direction. If the potential is moving more positive, the system shall be turned off immediately, polarity of circuits checked and SA Water and the CP designer alerted of the test results. Commissioning is to be stopped until the reason for the positive potential shift is identified and rectified

b) Test all isolation joints as per the method prescribed in Section 6. This includes all isolations on the pipeline including to insulated motors, valves, flowmeters etc.

c) Test continuity and measure current flow across all cross bonds, record the current and direction of current flow

d) Adjust system current output to design current output or as advised by the CP system designer and allow the system to polarise

7.3 Stage 3 - Post energisation tests

Allow an appropriate time period following adjustments to permit the pipeline to polarise to protected levels. The required time will vary depending on the type of pipeline system, quality of the pipeline coating and the local buried environment. Pipelines which polarise quickly such as well-coated fusion bonded medium density polyethylene (FBMDPE) coated pipes will need care to ensure they are not overprotected, since this can lead to cathodic disbondment of the coating.

After the polarisation period:

a) Undertake a detailed instant OFF potential survey after to confirm protection levels satisfy the criteria set in AS 2832.1. The survey shall include every test point on the pipeline and all associated district test points

b) Review the survey results and assess the level of protection achieved on the pipeline as a whole. Make adjustments to TR outputs as required

c) With final outputs set conduct interference testing in accordance with AS 2832.1 and as per any requirements specified by the SA Electrolysis Committee. Owners of any foreign assets that may be impacted by the CP system under commissioning should be notified by sending Form A to the SA Electrolysis Committee members and may wish to be involved in the commissioning process. Once the results have been analysed and reviewed by the foreign structure owner, the report shall be presented to the Committee using Form B. All forms can be downloaded from the SA Electrolysis Committee web site (https://www.saec.com.au/installation-forms/).

7.4 Commissioning Report

Following commissioning works a report shall be prepared which comprises of the completed PCF and associated test sheets, the ITP and recorded data including all inspection and test results required to satisfy the requirements of AS 2832.1. Typically, the report should include the following:

a) Project, pipeline CP system details

b) Name of tester

c) Equipment used and calibration details

d) Weather conditions

e) Visual inspection findings

f) Confirmation of polarity of all anodes and circuits

g) Confirmation of safe electrical conditions for the TR installation and AC supply

h) TR output voltage/current

i) Calibration of TR meters

j) Loop resistance / Back EMF

k) Calibration of permanent and temporary reference electrodes

l) Individual anode output current

m) Anode open circuit potential (Galvanic anodes only)

n) Cross bond currents

o) Isolation test results (IJs, flowmeters, motorised valves etc.)

p) Natural state, ON and instant OFF-potentials on all test points vs CSE

q) Final commission current output(s) ON and instant OFF potentials vs CSE

r) Interference testing results

s) Details of any identified interference that was encountered and the applied mitigation

t) Performance of any LFI/EPR mitigation facilities

u) Confirmation of full protection according to the criteria, alternatively, an action plan should be proposed if any anomalies or non-compliances are noted

v) Identification of any outstanding issues or recommendations.

Submission and approval by SA Water of these documents is a prerequisite to obtaining Practical Completion of the works.

8 As Constructed Documentation

The following documentation shall be submitted by the Construction Contractor to the SA Water Representative no later than 3 weeks after commissioning of a CP system has been completed:

a) Revised site-specific drawings in pdf and AutoCAD format with all changes incorporated. Updated drawings shall include as a minimum exact dimensions and off-sets for test point and pit locations to a recognisable feature i.e., property fence or road kerb

b) Running plans for each pipeline system (or updated if a retrofit/upgrade). Running plans consist of:

   i. Part A, showing all test points and IJs with test points

   ii. Part B, showing all other electrical isolations, bonds, crossbonds etc.

   An example running plan Part A is provided in Appendix A. Updates to the drawings shall include exact dimensions and off-sets for test point and pit locations to a recognisable feature i.e., property fence or road kerb.

c) Completed PCF

d) Operations and Maintenance Manual for any new CP system as per TS 0132

e) GPS coordinates with an accuracy of better than ±5m of:

   i. Test points

   ii. Cathode connections

   iii. TRs

   iv. Crossbonds

   v. Electrical Insulations

   vi. Cable runs.

Data shall comply with the requirements of TS 0130 As Constructed Data Requirements for Linear Assets.

Submission of these documents and approval by SA Water is a prerequisite to obtain Practical Completion of the works.

For new cathodic protection systems, a file number shall be created and entered in Maximo. The Project Manager shall provide the required information as per TS 0131.

9 Ongoing Monitoring Requirements

Maintenance and regular monitoring of CP systems will ensure that CP systems are operating correctly and providing corrosion protection to the protected assets.

This section provides guidance respective ongoing monitoring requirements to be conducted on SA Water's CP protected pipelines.

9.1 Routine Monitoring Regime and Test Summary

Table 9-1 lists routine monitoring tasks to be undertaken on SA Water's CP systems protecting mild steel pipelines. A series of different tests are used to minimise the effort required to undertake monitoring while providing a reasonable level of certainty that the systems are indeed providing protection.

The intervals for each of these tasks are dependent on the type of system and criticality of the associated pipeline to the SA Water network and is summarised in

Table 9-2.

Table 9-1 - Routine Monitoring Tasks

Test ID	Test	Requirements	Comments
1	System Functional Check	a) Confirm unit is supplied with AC power and is operating normally b) Test and record output current and voltage c) Test and record inbuilt (cathode) reference ON potential	This test can be completed via telemetry where fitted. Local inspection would not be required in that case. SACP systems are excluded from this test
2	Major Potential Survey	a) Visual inspection of TR unit and cabinet b) Confirm TR is supplied with AC power and is operating normally c) Test and record output current and voltage d) Test and record inbuilt (cathode) reference ON potential e) Individual anode current measurements f) All TR units that may influence the system under test shall be set to synchronously interrupt g) ON and Instant OFF Potential Survey of all standard test points h) Depolarisation test if required i) Measure current across any crossbonds installed on the system j) Measure loop resistance of TR/anode bed k) Check operation of watering system l) Check internal metering (voltage and current etc.) for calibration against calibrated portable meters m) Review protection levels and adjust output as required	Additional potential surveys or datalogging may be required where subject to DC traction currents from trams. Testing at all test points and district points.

		n) Identify any maintenance or replacement requirements.	
3	Surge diverter check	Testing of all surge diverters installed as part of the pipeline system to confirm satisfactory operation. Test in accordance with the Manufacturer's recommendations for the specific unit installed.	Precautions against high voltage hazards need to be incorporated into this test procedure. i.e., shorting across flange before diverter is disconnected for testing.
4	Safety Earth Bed Testing		At all locations where fitted/installed Precautions against high voltage hazards need to be incorporated into this test procedure. I.e., limiting access to the area and use of insulating gloves when disconnecting earth bed/gradient rings.
5	Sacrificial Anode CP System Testing	a) Visual Inspection of the test point b) Measure anode open potential c) Measure current output d) Measure ON Potential or ON/OFF potential of the structures if the anode (s) is (are) connected to a single test point.	

Table 9-2 - Routine Monitoring Programme Intervals

Asset type	Period	Test Requirements	Notes
All assets (ICCP Systems)	3 monthly	Functional check	Excluding SACP systems
	9 monthly	Major survey	Excluding SACP systems
	5 yearly	Surge diverter check Safety earth bed test	
Sacrificial anode system	2 yearly	Minor Survey	If potentials more positive than -950mV vs CSE are measured, an ON/Instant OFF potential survey if possible and measurement of individual anode currents along the route is also required

9.2 Supplementary Testing

In some situations, additional testing may be required such as where specific issues are identified or problems such as underprotection or a significant drop in protection levels are detected. The tests regime needs to be designed specifically for the pipeline system being assessed, a list of typical tests has been provided for information.

Some of these tests would also be conducted as part of other works on the system and can provide supplementary information regarding the operation of the CP system or the condition of the pipeline. For example, where a pipeline section is being excavated for other works or due to a local fault a coating condition inspection should be completed which provides useful information on the pipeline condition and can be used for adjustment or design of the CP system upgrades or replacements.

Table 9-3 – Supplementary Test Requirements

Test	Test Trigger	Requirements	Comments
Insulation testing	Overall or localised reduction in protection level not associated with TR output changes	Test isolation of insulating flanges and isolations required along pipeline route	May include new assets recently installed such as flow meters, motorised valves, new offtakes, pumps etc. Refer Section 4.10
Coating condition inspection	a) During installation or replacement of ICCP cathode connection b) Where protection levels achieved with similar output levels continue to decline	As per Section 6.2	Can also be completed during other works which require excavation and exposure of the pipeline or as identified as a result of protection level review.
DCVG Survey	a) Localised drop in protection in otherwise well protected pipeline	As per Section 6.3	Generally, for well coated and electrically isolated pipelines only. May not provide useful information with a poorly coated pipeline or pipeline with largely degraded coating or with copper/DI/CI consumer connections.
CIPS Survey	a) Localised drop in protection in otherwise well protected pipeline b) Through area of high corrosion risk (corrosion hotspot) such as swamps, waterway crossing, change in ground condition etc.	CIPS survey across region affected by underprotection	To assess protection levels in more detail and identify local corrosion hotspots or electrical shorts
TR Electrical Safety Audit	a) Physical damage to unit b) Unit has been subject to water inundation c) Repeated tripping of circuit breakers or blowing of fuses	As per TS 0300 site tests	Electrician required
Additional Test Point Potential Survey (TP..A, TP..B etc.)	a) Drop in protection along otherwise well protected pipeline b) Marginal protection levels achieved	Complete ON/Instant OFF potential of test points along a specific pipeline	Prior to testing review nearby assets and assess whether additional TR's required interruption or an area. This may include foreign assets such as petrochemical pipelines or other buried services.

Interference with foreign structures testing	a) When a new SA Water CP system is being commissioned and another asset owner requires interference testing b) When SA Water is contacted through the SA Electrolysis Committee to conduct interference testing between a third party buried asset and SA Water CP Systems or between foreign CP Systems and SA Water MSCL mains	Complete testing as per Section 8 of AS 2832.1:2015 and / or agreed procedure between the parties involved	Present results of the testing to the SA Electrolysis Committee on Form B.

9.3 Unsafe or Unsecured Equipment

If any mains powered equipment such as a TR, distribution board or other asset is found to be in an unsafe or unsecured condition, immediate steps shall be taken to rectify the situation. This may include undertaking or arranging of immediate repair, advising the relevant department or authority of the condition and arranging their site attendance or contacting SA Power Networks to arrange for an emergency disconnection of electricity supply to the site.

If repairs are to be attempted, they shall be undertaken in a safe manner in accordance with a safe work method statement and be limited to tasks the repairer is qualified for and competent to perform.

The site shall not be left unattended until it has been made safe and/or secure.

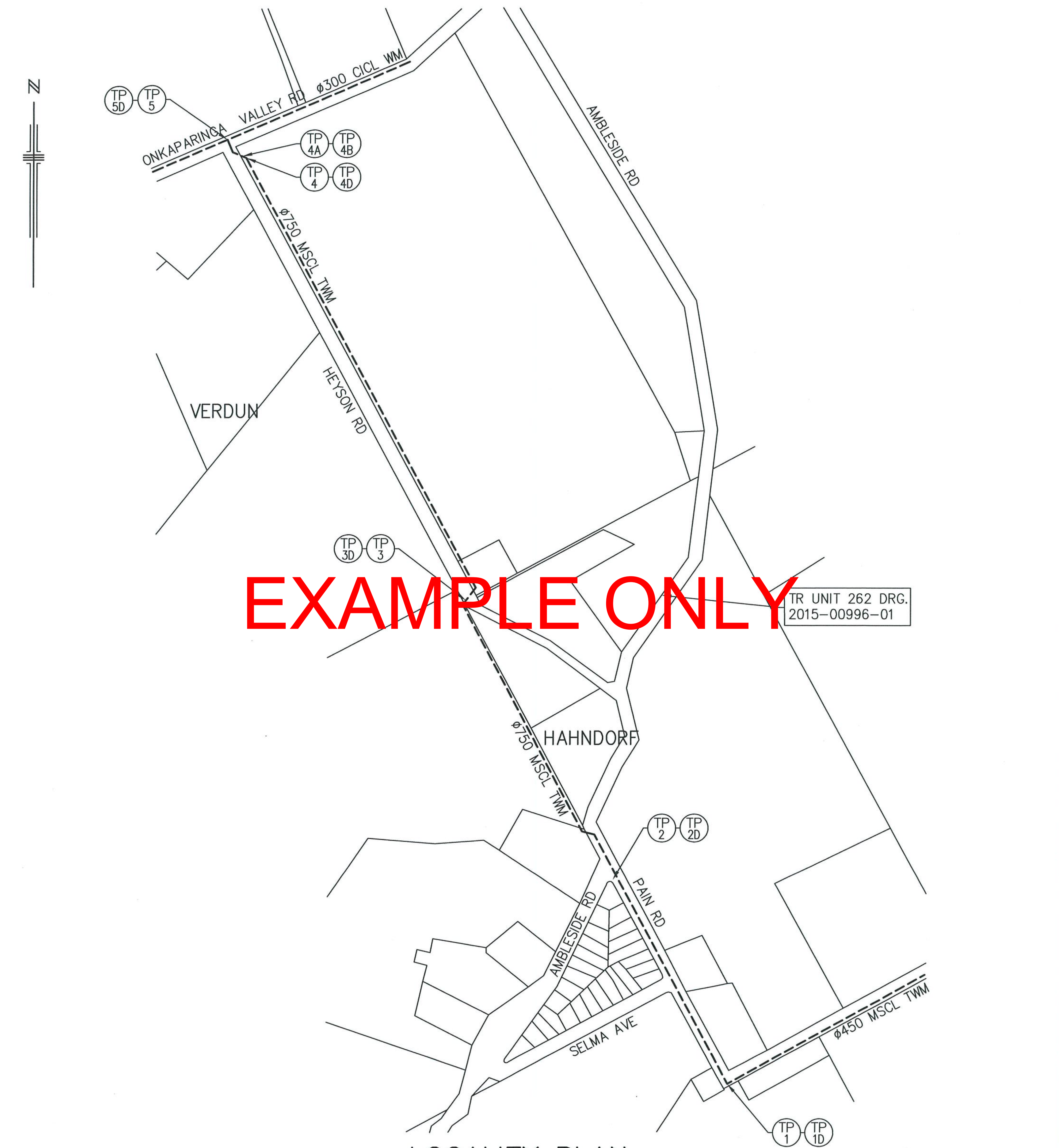
Appendix A Running Plan Example

DO NOT SCALE PAPER PRINT

CATHODIC PROTECTION RUNNING PLAN TITLE **ONKAPARINGA VALLEY SPUR WM** FILE No. : **C7-08**

LEGEND

- TP 1 TEST POINT & NUMBER
- C CATHODE CONNECTION
- RC TEST POINT IN ROAD CHAMBER
- GB TEST POINT IN GROUND BOX
- TP–A ANODE LOCATION AT TEST POINT
- MP–A MARKER POST AT ANODE POSITION
- (Wd) WOOD TEST POST
- (Al) ALUMINIUM TEST POST



LOCALITY PLAN
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	INITIALS	DATE	
DESIGNED			AUTHORIZED
DRAWN	AND	22/11/2016	SIGNATURE [signature] DATE 3/3/17
REVIEWED	AT	23/11/16	PRINT NAME ALLAN THONG

CONTRACTOR/COMPANY NAME: TEAM CIVIL PTY. LTD
CONTRACTORS REFERENCE: PHIL MENZIES (08) 8376 8852

Government of South Australia — SA Water

ONKAPARINGA VALLEY SPUR WM
PAIN/ONKAPARINGA VALLEY ROAD, HAHNDORF
CATHODIC PROTECTION SYSTEM FILE C7-08
RUNNING PLANS

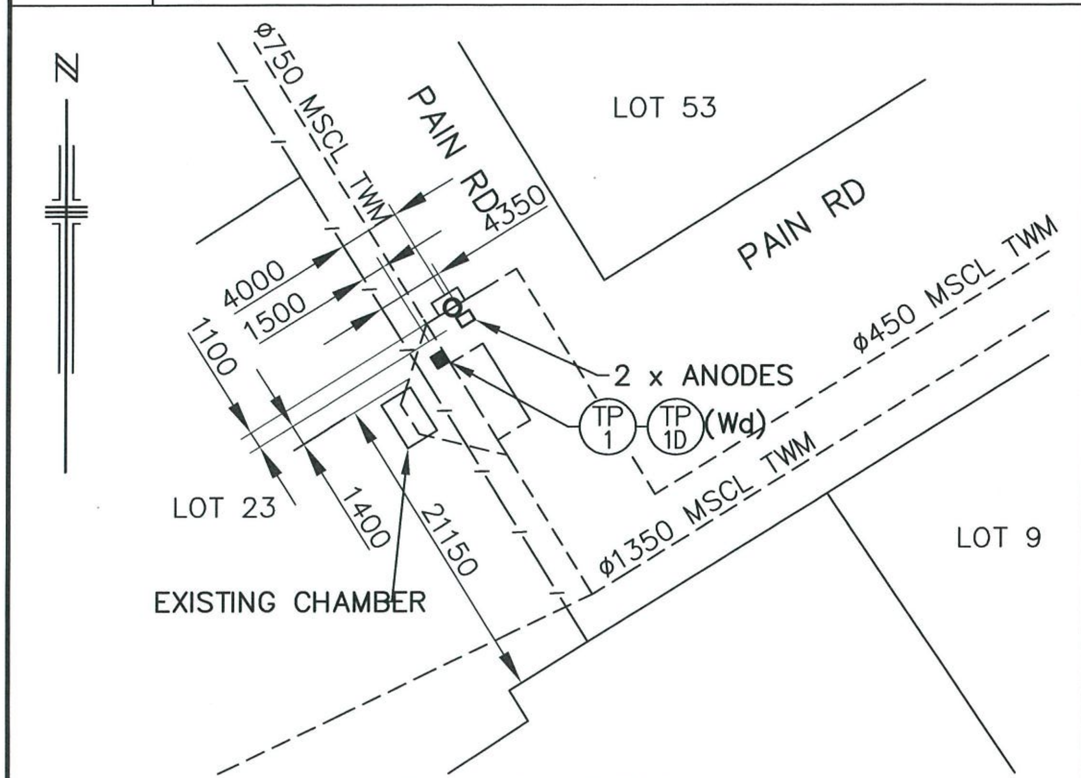
SHEET SIZE	SAW PROJECT No.	C2304	REVISION
A3	SAW DOCKET No.	–	
	CONTRACT No.	CW8512-05	
SHEET COUNT	01 OF 02		

DRAWING NUMBER
2016–00667–01
YEAR NUMBER SHEET

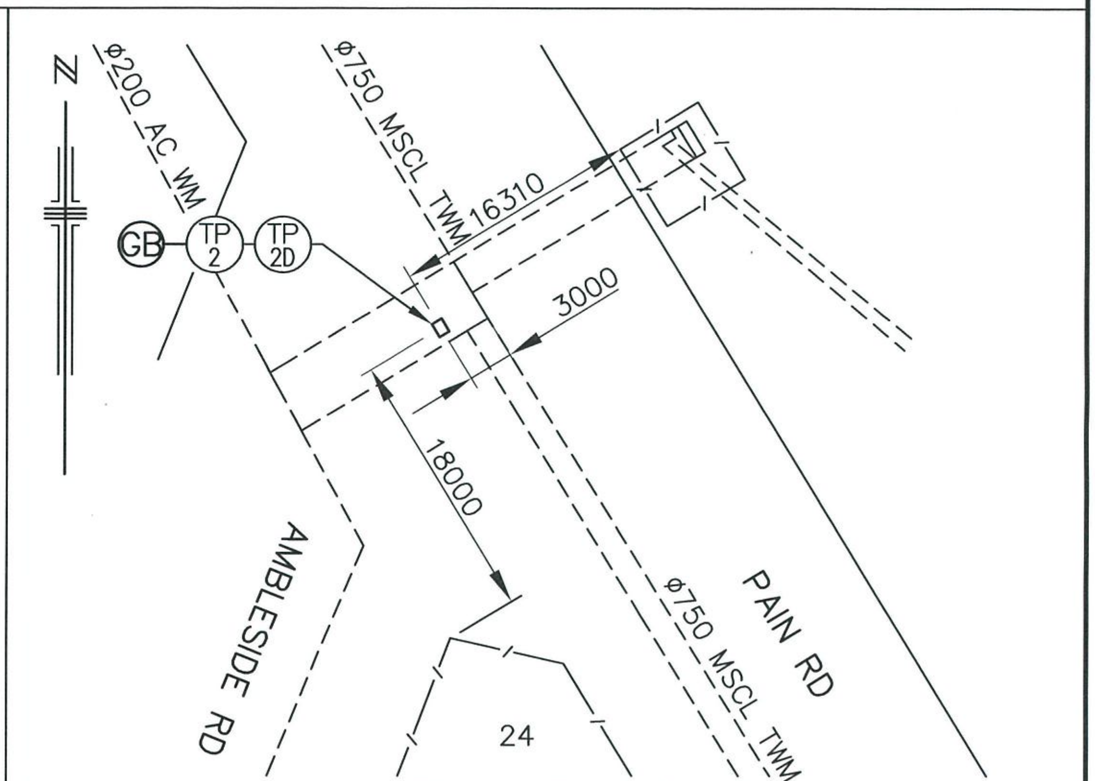
CATHODIC PROTECTION RUNNING PLAN TITLE **ONKAPARINGA VALLEY SPUR WM** — FILE No. : **C7–08**

LEGEND

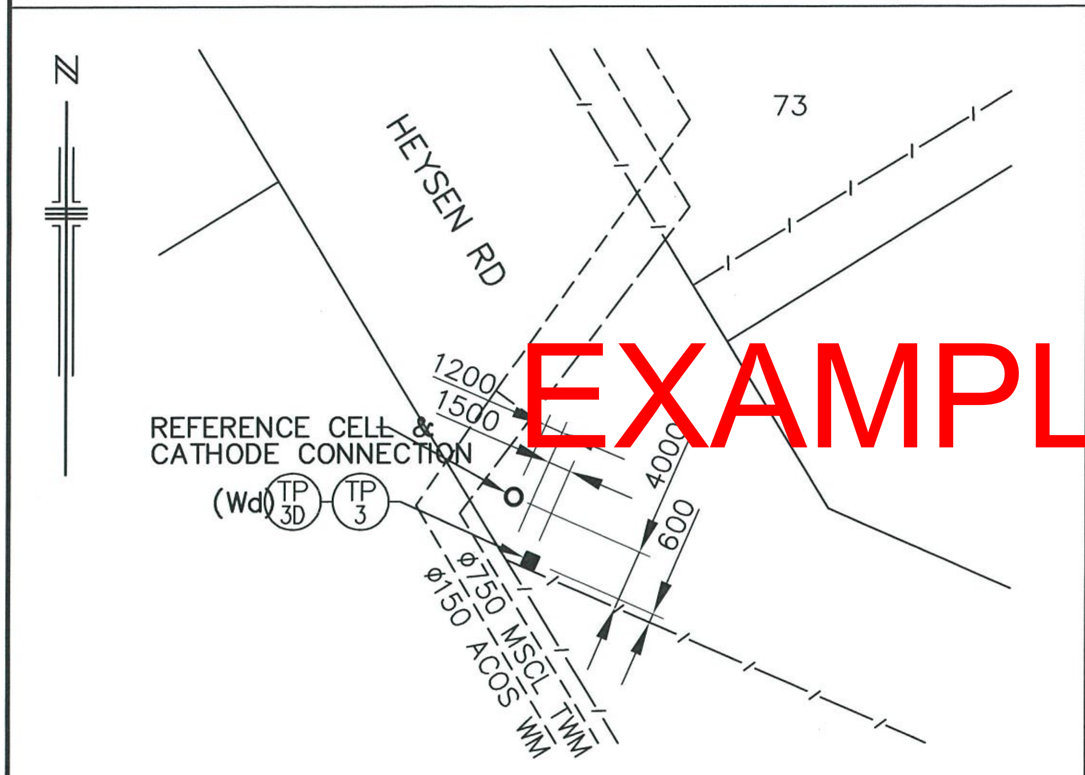
- (TP 1) TEST POINT & NUMBER
- (C) CATHODE CONNECTION
- (RC) TEST POINT IN ROAD CHAMBER
- (GB) TEST POINT IN GROUND BOX
- (TP)-(A) ANODE LOCATION AT TEST POINT
- (MP)-(A) MARKER POST AT ANODE POSITION
- ■ (Wd) WOOD TEST POST
- ● (Al) ALUMINIUM TEST POST



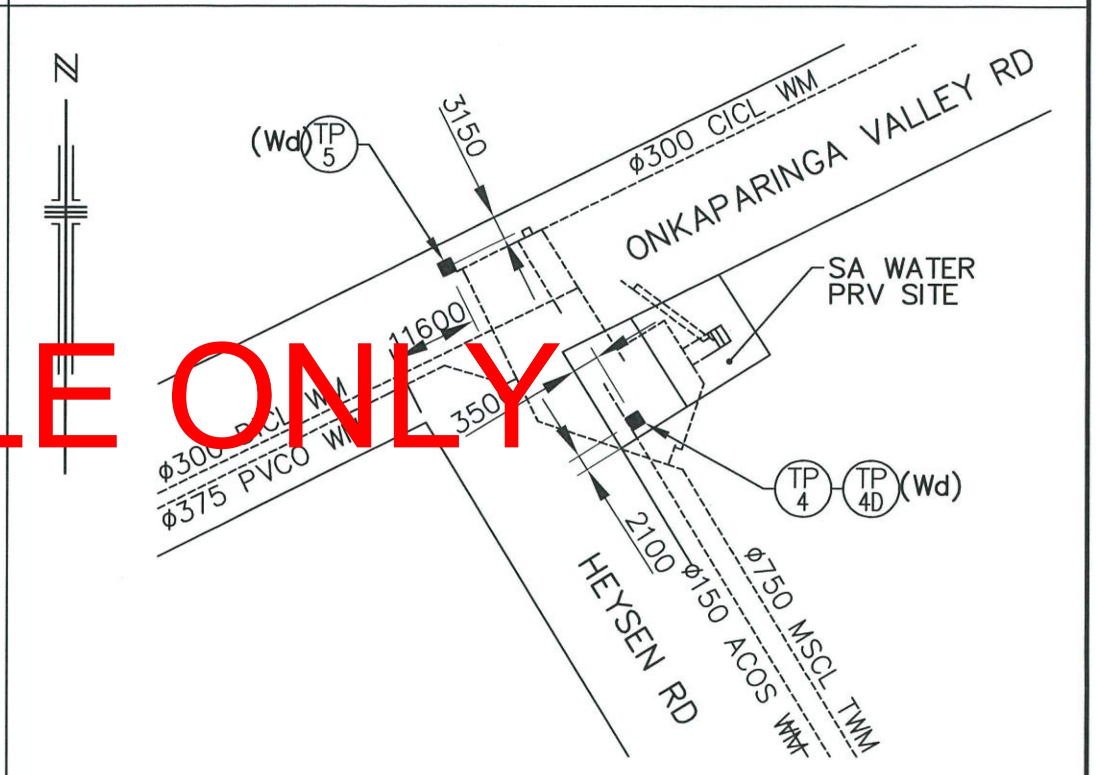
TP1 & TP1D



TP2 & TP2D



TP3 & TP3D



TP4, TP4D & TP5

EXAMPLE ONLY

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DESIGNED			AUTHORIZED	
DRAWN	AND	22/11/2016	SIGNATURE: *[signature]*	DATE: 3/3/17
REVIEWED	*AT*	*23/11/16*	PRINT NAME: *ALLAN THONG*	
	INITIALS	DATE		
CONTRACTOR/COMPANY NAME:	TEAM CIVIL PTY. LTD			
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Government of South Australia — SA Water

ONKAPARINGA VALLEY SPUR WM
PAIN/ONKAPARINGA VALLEY ROAD, HAHNDORF
CATHODIC PROTECTION SYSTEM FILE C7–08
RUNNING PLANS

SHEET SIZE: A3	SAW PROJECT No: C2304	REVISION
	SAW DOCKET No.: –	
	CONTRACT No: CW8512–05	
SHEET COUNT: 02 OF 02		
DRAWING NUMBER: 2016–00667–02 (YEAR – NUMBER – SHEET)		