SA Water

Engineering

Technical Standard 0460

Liners and Floating Covers for Earth Bank Storages for Potable or Recycled Water

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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 of technical standards numbers and other SA Water documentation

Revision of Sections 4.4.2 and 4.8.2 to include other materials like EIA and specialty materials.

Revision of Section 6.1.3.4 to include the following aspects based on lessons learned:

- Definition of the embankment footprint for backfill purposes
- Introducing three different types of pipe embedment within embankment footprint depending on the risk profile of the EBS
- Introducing the requirements for the pipeline trench in terms of side slopes being battered rather than benched to prevent differential settlement, stress concentration and potential cracking of the embankment which might lead to piping or hydraulic fracturing.

The following appendixes were removed from this technical standard:

- Appendix C – Typical switchboard layout
- Appendix D - Typical rain water removal pump schematic
- Appendix E – Typical underfloor pump schematic.

Document Controls

Revision History

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Contents

1 Introduction 10
1.1 Purpose 10
1.2 Glossary 10
1.3 References 11
1.3.1 Precedence of standards 11
1.3.2 SA Water standards and guidelines 12
1.3.3 Australian standards, guidelines and specifications 12
1.3.4 International standards and guidelines 13
1.3.5 Geosynthetic Research Institute 14
1.4 Definitions 14

2 General 15
2.1 Scope 15
2.2 Contractors responsibility 15
2.3 Quality management system 15
2.4 Design process 16
2.5 Review and approval process 16
2.6 Documentation standards 16
2.6.1 Reporting 16
2.6.2 Drafting 16

3 Safety in design 18
3.1 General 18
3.2 SA Water safety in design technical standard 18
3.3 Key safety in design issues to be considered 18
3.4 Health and safety 19

4 Cover and liner 20
4.1 General 20
4.2 Specific requirements 20
4.3 Performance requirements 21
4.3.1 Design life 21
4.4 Cover and liner materials 21
4.4.1 General 21
4.4.2 Materials 22
4.4.3 Geotextile underlay 24
4.5 Factory fabrication 24
4.5.1 Factory seams 25
4.5.2 Factory seam qualifications 25
4.5.3 Packaging and storage 26
4.6 Field fabrication 26
4.6.1 Seam layout 26
4.6.2 Seaming equipment and materials 26

4.6.3 Seam preparation 27
4.6.4 Weather conditions 27
4.6.5 Trial (pre-weld) seams 27
4.6.6 Seaming procedures 28
4.7 Inlet and outlet requirements 28
4.8 Inspection and testing 29
4.8.1 General 29
4.8.2 Factory inspection and testing of roll goods 29
4.8.3 Inspection of roll goods prior to fabrication 29
4.8.4 Inspection and testing of factory seams 29
4.8.5 Membrane delivery and acceptance 30
4.8.6 Field inspection 30
4.8.7 Floating cover air support testing 32
4.8.8 Floatation testing of cover 32
4.8.9 Defects and repairs 32
4.9 Rainwater removal system 33
4.10 Cover ancillaries 33
4.11 Floats and ballast 33
4.12 Access hatches and sample ports 33
4.13 Floating walkways and platforms 33
4.14 Acceptable leakage rates 34
4.14.1 SA Water acceptable leakage rates 34
4.14.2 Methods for determining leakage rates 35

5 Installation 36
5.1.1 Access for installation 36
5.1.2 Removal of an existing liner and cover 36
5.1.3 Acceptance of reservoir prior to installation 36
5.1.4 Geotextile underlay installation 37
5.1.5 Liner installation 37
5.1.6 Cover installation 37

6 Civil requirements 39
6.1 Earthworks 39
6.1.1 Embankment construction performance requirements 39
6.1.2 Erosion protection 41
6.1.3 Excavation and backfilling requirements 41
6.2 Replacement of conduits (inlet & outlet pipework) 45
6.2.1 Excavation 45
6.2.2 Removal of existing pipework 45
6.2.3 Reinstatement of the embankment 45
6.2.4 Zoning 46
6.2.5 Summary of design considerations 46
6.2.6 Micro-tunnelling and Horizontal Directional Drilling 46

6.3 Access road requirements....47
6.3.1 General....47
6.3.2 Typical road section....47
6.3.3 Design for vehicles....49
6.3.4 Requirements for asphalt pavements....49
6.4 Drainage requirements....49
6.4.1 Rainwater removal system....49
6.4.2 Underdrain system requirements....50
6.4.3 Embankment crest and toe drainage requirements....51
6.4.4 Storm water management....51
6.5 Inlet and outlet work system requirements....51
6.5.1 General....51
6.5.2 Existing inlets or outlets....52
6.5.3 Hydraulic requirements....52
6.6 Overflow system requirements....53
6.7 Perimeter ring beam requirements....53
6.7.1 General....53
6.7.2 Strength and serviceability design....53
6.7.3 Stability....54
6.7.4 Fixing bar and fasteners....54

7 Water Quality....56
7.1 General considerations....56
7.1.1 Material selection....56
7.1.2 Preservation of water quality....57
7.1.3 Contamination prevention....57
7.2 In storage mixing requirements....57
7.2.1 General....57
7.2.2 Computational fluid dynamic modelling....57
7.2.3 Passive mixing (baffles)....58
7.2.4 Active mixing (powered mixers)....58
7.3 Disinfection injection and monitoring requirements....59
7.3.1 Disinfection considerations....59
7.3.2 Disinfectant types....59
7.3.3 Monitoring....60
7.4 Water quality sampling requirements....61
7.4.1 Sample point locations and type....61
7.4.2 Sampling prior to entry into service....61
7.4.3 Water quality....61
7.4.4 Testing....62

8 System Functionality....64
8.1 Rain water removal pumps....64
8.2 Underdrain pumps....64

8.3 Mixers / Recirculation Systems 65
8.4 Health monitoring and alarming 66

9 Typical mechanical and electrical requirements 67
9.1 Approval process 67
9.2 Standards and general requirements 67
9.3 General control and SCADA requirements 67
9.3.1 System Architecture Requirements 67
9.3.2 Logic system programming works 68
9.3.3 Logic controller software programming 68
9.3.4 General programming requirements 68
9.3.5 Documentation 68
9.4 Instrumentation and Electrical Equipment 68
9.4.1 Flow meters 69
9.4.2 Level meters 69
9.4.3 Disinfection injection and monitoring 71
9.4.4 Switchboard 71
9.4.5 Mixers 71
9.4.6 Rainwater removal pumps 72
9.4.7 Underfloor Drainage Pumps 73
9.4.8 Local control station 74

10 Operation and Maintenance 75
10.1 Operation, maintenance, training and manuals 75
10.2 Future repair works 75

11 Security Requirements 76
11.1 General 76
11.2 Equipment Requirements 76
11.2.1 Minimum Requirements 76
11.2.2 Optional Requirements 76
11.3 Security Risk Assessment Process 76
11.4 Access to SA Water security standards 77

Appendix A Performance Specification 78
A1 Preface 78
A2 Scope 78
A3 Reference Documents 78
A4 General requirements 79
A4.1 Operating environment 79
A4.2 Freedom from defects 80
A4.3 Effect on water 80
A5 Performance requirements 80
A5.1 General 80
A5.2 Resistance to disinfectants 80
A5.3 Resistance to chlorine 80

A5.4 Resistance to chloramines 80
A5.5 Effects of disinfectants on welded polymer 80
A5.6 Frequency of tests 81
A5.7 Retesting 81
A6 Warranty 81

Appendix B Schedule of Membrane Properties 82

List of figures

Figure 6-1: Extent of embankment footprint for a typical cut/fill EBS....42
Figure 6-2: An example of (a) benched embankment excavation for pipe penetration, and (b) backfilling around and on top of the pipe embedment zone with progressive battering....44
Figure 6-3 : Example excavation through the embankment to replace inlet / outlet pipework 47
Figure 6-4 : Example embankment crest road section between storages....48
Figure 6-5 : Example embankment crest road section....49
Figure 6-6 : Example perimeter ring beam section and joint detail....54
Figure 6-7 : Example anchorage detail....55

List of tables

Table 1-1 – Table of Glossary Items Used in this Technical Standard 10
Table 1-2 – SA Water Standards and Guidelines Referred to in this Technical Standard 12
Table 1-3 – Australian Standards, Guidelines and Specifications Referred to in this Technical Standard 12
Table 1-4 – International Standards and Guidelines Referred to in this Technical Standard....13
Table 1-5 – Geosynthetic Research Institute Specifications Referred to in this Technical Standard 14
Table 1-6 - Table of Definitions Used in this Technical Standard....14
Table 4-1 – Design Lives 21
Table 4-2 – Minimum Strengths for Shear and Peel Tests 28
Table 6-1 – Performance Requirements for Embankment's Materials....39
Table 6-2 – Load Cases for Embankment Design 40
Table 6-3 - Compaction Requirements for Embankment Materials 40
Table 6-4 – Risk Profile in Accordance with ANCOLD Guidelines....43
Table 6-5 – Risk Assessment Profile 43
Table 6-6 – DPTI PM1/20QG Base-Coarse Road Base Materials Properties 48
Table 7-1 – Disinfectant Types....59
Table 7-2 – Ammonia Types 60
Table 7-3 – Water Quality Parameters....62
Table 7-4 – Water Testing Parameters 63

Table 8-1 - Rule of Operation for the Rainwater Pump.....64
Table 8-2 - Rules of Operations for the Underdrain Pump 65
Table 9-1 - Magnetic induction flow meter requirements.....69
Table 9-2 - Hydrostatic Level Transmitter Specification.....69
Table 9-3 - Capacitive Level Transmitter Specification.....70

1 Introduction

SA Water is responsible for operation and maintenance of an extensive amount of engineering infrastructure.

This standard has been developed to assist in the design, maintenance, construction, and management of this infrastructure.

1.1 Purpose

The purpose of this standard is to detail minimum requirements to ensure that assets covered by the scope of this standard are constructed and maintained to consistent standards and attain the required asset life.

1.2 Glossary

The following glossary items are used in this document:

Table 1-1 – Table of Glossary Items Used in this Technical Standard

Abbreviation / Term	Description
ALR	Acceptable Leakage Rate
AS	Australian Standard
ASTM	American Society of Testing and Materials
AWQC	Australian Water Quality Centre
CFD	Computational Fluid Dynamics
CHAZOP	Control Hazard and Operability
CLSM	Controlled Low Strength Material
CSPE-R	Reinforced Chlorosulfonated Polyethylene
D&C	Design and Construct
DCS	Distributed Control System
DPTI	Department of Planning Transport and Infrastructure
EIA	Ethylene Interpolymer Alloy
EBS	Earth Bank Storage
fPP-R	Reinforced Flexible Polypropylene
GPR	Glass Fibre Reinforced
GRI	Geosynthetic Research Institute
HAZID	Hazard Identification
HAZOP	Hazard and Operability
HDPE	High Density Polyethylene
HMI	Human Machine Interface
HP-OIT	High Pressure – Oxidative Induction Time
LLDPE	Linear Low Density Polyethylene
LCS	Local Control Station

NDT	Non-destructive Testing
MFI	Melt Flow Indexes
MDR	Manufactures Data Requirements
MQA/MQC	Manufactures Quality Assurance / Manufactures Quality Control
MSCL	Mild Steel Cement Lined Pipe
O&M	Operation and Maintenance
PLC	Programme Logic Controller
QA / QC	Quality Assurance / Quality Control
RTO	Registered Training Organisation
RTU	Remote Terminal Unit
SA Water	South Australian Water Corporation
SCADA	Supervisory Control and Data Acquisition
SCR	Stress Cracking Resistance
SiD	Safety in Design
TG	Technical Guideline
TS	Technical Standard
WHS	Work Health and Safety

1.3 References

1.3.1 Precedence of standards

When developing design and specification the Contractor shall, unless noted otherwise, observe the hierarchy of standards should any discrepancy exists among the referred standards and references, as follows:

- Contract
- SA Water Technical Standards and Procedures (this document)
- Technical Specification (if available)
- Tender and Tender Addenda
- Australian Standards and Other Standards
- Codes and Regulations

1.3.2 SA Water standards and guidelines

The following table identifies the SA Water standards and guidelines that are referenced in this document:

Table 1-2 – SA Water Standards and Guidelines Referred to in this Technical Standard

Title	Revision	Date
TS 0101 – Safety in Design Technical Standard	1.1	March 2018
TG 10b – General Technical Information for Geotechnical Design – Part B – Earth Dam Design	-	January 2007
TG 10f – General Technical Information for Geotechnical Design – Part F – Lined Storages	-	January 2007
TS 0620 – Packing Sand (Pipe Embedment and Trench Fill Sand)	1.0	November 2015
TS 0100 – Requirements for Technical Drawings	4.0	September 2018
TS 0120 - Installation Standards for Electronic Security Systems on SA Water Sites.	8.0	September 2016
TS 0121 – Physical Security Systems.	8.0	September 2016
TS 0710 – Reinforced Concrete Construction for Liquid Retaining Structures and/or Aggressive Environments	1.0	November 2016
TS 0300 – Supply and installation of low voltage electrical equipment	2.0	April 2018
TS 1000 – SCADA and DCS Systems	-	May 2012
TS 0522 - Allowable Pipe Size, Class and Materials for Reticulation Water Mains	1.0	March 2017
TS 0132 - Operating & Maintenance Manuals	1.0	May 2016
WQ_G35 – Code of Practice – Disinfection of Water Supplies	1.1	July 2011
WQ_P034 – Mains, Valves & Fittings – Disinfection	-	-

1.3.3 Australian standards, guidelines and specifications

The following table identifies the Australian Standards, documents and/or articles that are referenced in this document:

Table 1-3 – Australian Standards, Guidelines and Specifications Referred to in this Technical Standard

Title	Revision	Date
AS/NZS 4020 - Testing of Products for Use in Contact With Drinking Water	-	2018
AS 3600 – Concrete Structures	-	2018
AS/NZS ISO 9001 – Quality Management System Requirements	-	2016
AS 4586 – Slip Resistance Classification of New Pedestrian Surface Materials	-	2013

AUSTROADS Guide to Pavement Technology: Part 2 – Pavement Structural Design	-	2012
AUSTROADS Pavement Design for Light Traffic: A Supplement to Austroads Pavement Design Guide	-	2006
AUSTROADS Design Vehicles and Turning Path Templates Guide	3	2013
SA Work Health and Safety Act 2012	-	2012
DPTI Specification: Part R09 Supply of CLSM	-	Sept 2011
DPTI Specification: Part R27 Supply of Asphalt	-	July 2015
DPTI Specification: Part R28 Construction of Asphalt Pavements	-	July 2015

1.3.4 International standards and guidelines

The following table identifies the international standards, documents and/or articles that are referenced in this document:

Table 1-4 – International Standards and Guidelines Referred to in this Technical Standard

Title	Revision	Date
AWWA/ ANSI D130-11 - Flexible Membrane Lining and Floating Cover Materials for Potable Water Storage	-	Nov 2011
AWWA M25 - Flexible Membrane Covers and Linings for Potable Water Reservoirs	3	2000
ASTM D751 Method A - Standard Test Methods for Coated Fabrics – Hydrostatic Pressure	-	2011
ASTM D792 - Standard Test Method for Density and Specific Gravity of Plastics	-	2013
ASTM D638 - Standard Test Method for Tensile Properties of Plastics	-	2014
ASTM D1004 - Standard Test Method for Tear Resistance of Plastic Film and Sheeting	-	2013
ASTM D1149 - Standard Test Methods for Rubber Deterioration – Cracking in an Ozone Controlled Environment	-	2012
ASTM D1204 - Standard Test Method for Linear Dimensional Changes of Non Rigid Thermoplastic Sheeting or Film at Elevated Temper	-	2014
ASTM D1790 - Standard Test Method for Brittleness Temperature of Plastic Sheeting by Impact	-	2014
ASTM D4329 - Standard Practice for Fluorescent UV exposure of Plastics	-	2013
ASTM D4545 - Standard Practice for Determining the Integrity of Factory Seams Used in Joining Manufactured Flexible Sheet Geomembranes	-	1999
ASTM D4833 - Standard Test Method for Measuring the Nominal Thickness of Geosynthetics	-	2013
ASTM D5199 - Standard Test Method for Measuring the Nominal Thickness of Geosynthetics	-	2012
ASTM D5641 - Standard Practice for Geomembrane Seam Evaluation by Vacuum Chamber	-	2016
ASTM D5890-11 - Standard Practice for Pressurized Air Channel Evaluation of Dual Seamed Geomembranes	-	2018

ASTM D6392-12 - Standard Test Method for Determining the Integrity of Non Reinforced Geomembrane Seams Produced Using Thermo-Fusion Methods	-	2018
FEMA – Technical Manual : Conduits Through Embankment Dams		Sept 2005
CIRIA C743 - Dams and Reservoir Conduits : Inspection, Monitoring, Investigation, Maintenance and Repair	-	Aug 2015

1.3.5 Geosynthetic Research Institute

Table 1-5 – Geosynthetic Research Institute Specifications Referred to in this Technical Standard

Title / URL	Revision	Date
GM 13 - High Density Polyethylene (HDPE) Smooth and Textured Geomembranes	12	Nov 2014
GM 17 - Linear Low Density Polyethylene (LLDPE) Smooth and Textured Geomembranes	11	April 2015
GM 18 - fPP and fPP-R Geomembranes	8	Sept 2015
GM 25 - LLDPE-R Geomembranes	4	Dec 2012
GM 28 - Reinforced Chlorosulfonated Polyethylene (CSPE-R) Geomembranes	0	Sept 2013

1.4 Definitions

The following definitions are applicable to this document:

Table 1-6 - Table of Definitions Used in this Technical Standard

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 0460 defined on page 3 (via SA Water's Representative)

2 General

2.1 Scope

This Technical Standard presents the minimum performance requirements for the design, construction and specification of Liners and Floating Covers of Earth Bank Storages (EBS) for potable and recycled water. It is intended that this technical standard will aid Designers and Contractors when developing designs for new and existing assets. It is intended to provide a consistent approach across SA Water assets where possible.

This Technical Standard is not intended to be prescriptive and allows for advances in technology, materials and construction techniques. Where innovative solutions or construction approaches become available and that could provide benefit to the design, construction process or safety of these types of structures, then they should be considered during the design and construction process in consultation with SA Water Discipline Lead Engineer.

2.2 Contractors responsibility

Designers and construction Contractors shall meet the requirements of this Technical Standard when designing and/or constructing Liners and Floating Covers of Earth Bank Storages (EBS) for potable and recycled water.

2.3 Quality management system

The whole of the works shall be subject to a Quality Assurance / Quality Control system that includes the following elements:

- The civil and structural design elements, reporting and drafting requirements
- The geomembrane manufacturers' Quality Assurance programs that includes raw materials control, process control and finished product control in accordance with the requirements of AS/NZS ISO 9001
- A Fabrication Quality Assurance program that includes membrane inspection, welding process control and non-destructive and destructive testing in accordance with the requirements of AS/NZS ISO 9001
- A Field Installation Quality Assurance program that includes deployed membrane panel inspection, welding process control and non-destructive and destructive testing in accordance with the requirements of AS/NZS ISO 9001.

The Contractor is to provide full details of these programs to SA Water prior to the commencement of manufacture, transportation and installation.

At each stage of the work the Contractor is to nominate a person who is to act as QA / QC officer and who shall coordinate all testing and shall retain all results, reports and certificates as they are generated for that section of the work.

The Contractor's Quality Assurance Plan, Quality Control system and procedures shall include all requirements of this Standard and all requirements of the Geomembrane Manufacturer's requirements and recommendations.

If the requirements / recommendations in the Geomembrane Manufacturer's documents conflict with the requirements of this Technical Standard, then this shall be brought to the attention of SA

Water. SA Water shall provide instruction on which requirements to adopt, but generally the instruction will be to follow the more rigorous set of requirements.

2.4 Design process

The following design process is generally adopted for SA Water projects:

- Project Inception – SA Water will initiate a project as part of an on-going maintenance program or a requirement to improve aspects of the supply system
- Project Brief – SA Water develop a project brief which specifies the extent of the proposed works
- Design Basis Report – The design basis report is generally prepared by a Consultant and provides high level performance requirements for the main aspect of the project
- Concept Design – The concept design may be undertaken by SA Water or a Consultant and provides concept level designs, drawings and specifications, schedules for the works
- Detailed Design – The detailed design may be undertaken by SA Water or a Consultant and provides designs and drawing which are ready for construction.

The detailed design phase may also include a Design and Construct (D&C) option, if a D&C Contractor is appointed to undertake the works.

2.5 Review and approval process

The following review process shall be adopted for design elements:

- Internal reviews - Prior to the issue of any documents to SA Water reviews and checks shall be undertaken by senior engineers with appropriate experience within the Consultant company, and In accordance with the their Quality Management Systems
- SA Water reviews - SA Water to undertake reviews of all submitted design documents and provide consolidated comments to the consultant, which shall be addressed in any following submissions. SA Waters decision shall be final.

2.6 Documentation standards

2.6.1 Reporting

All reporting shall be as per SA Waters requirements and be presented in a clear and concise manner.

2.6.2 Drafting

The drafting standards shall meet the requirements of TS 0100 – Requirements for Technical Drawings and shall as minimum included the following information.

2.6.2.1 Concept design drawings

Concept design drawings shall as a minimum include the following:

- General arrangement drawings - Two general arrangement drawings shall be prepared one including the cover and a second without the cover and liner. They shall include general drainage lines, cable routes and access tracks as well as safety signage

- Underdrain drawing - The underdrain drawing shall include the general layout of the system including pumps, pipe type, backfill, sampling and collection point details

- Civil and structural details drawing(s) - The civil and structural detail drawing(s) shall include the access and sampling hatch details, rainwater sumps and proposed pump types, access road pavement details and any site specific drainage requirements

- Electrical and Instrumentations drawing(s) - The electrical and instrumentation drawing(s) shall include a single line diagram of the electrical components, panel layout and starter schematics for pump systems.

2.6.2.2 Detailed design drawings

Detailed design drawings shall as a minimum include the following and shall be of sufficient detail to enable the works to be constructed and maintained by a competent tradesperson / maintenance operator.

- General arrangement drawings - Two general arrangement drawings shall be prepared one including the cover and a second without the cover and liner. They shall include general drainage lines, cable routes, access tracks and safety signage

- Underdrain drawing(s) - The underdrain drawing shall include the general layout of the system including pumps, pipe type, cabling and backfill as well as sampling and collection point details

- Civil and structural details drawing(s) - The civil and structural detail drawing(s) shall include the access and sampling hatch details, rainwater sumps and proposed pump types, as well access road pavement details, ring beam and anchorage details and inlet and out let details

- Cover drawing(s) - The cover drawing shall include the panel layout, location of hatches, walkway, vents and inflation points. A separate drawing shall show the panel layout for the cover

- Liner drawing(s) - The liner drawing shall include the panel layout for the liner and inlet, outlets and underdrain system

- Cover components drawing(s) - The cover components drawing shall include details of the floats, walkways, vents, inflation port and sand ballast details

- Electrical and Instrumentations drawing(s) - The electrical and instrumentation drawing(s) shall include a single line diagram of the electrical components, panel layout and starter schematics for pump systems.

2.6.2.3 As constructed drawings

As constructed drawings shall be prepared by the Contractor as the works are undertaken, to ensure all changes are captured as the work progresses. Prior to the issue of the Certificate of Practical Completion, the Contractor shall submit to SA Water, a complete set of fully marked up "As-Constructed" drawings in accordance with TS 0100. "As-Constructed" drawings in marked-up hard copy format will not be acceptable.

3 Safety in design

3.1 General

It is essential that the Safety in Design (SiD) aspects of each project is identified and document at the inception of the project. This will assist each stage of the design process to fully consider the SiD issues and develop acceptable safe design solutions where required.

3.2 SA Water safety in design technical standard

SiD shall be undertaken in accordance with the following SA Water Technical Standard:

- TS 0101 – Safety in Design.

TS 0101 provides a comprehensive summary of the processes to be undertaken by the Designer. The main aspects of the process are summarised Section 5 of the document and the key deliverables as part of the SiD process are summarised below:

- HAZID – at the project initiation and options stage
- SiD Risk Assessment 1 – at concept design stage
- SiD Risk Assessment 2 – at detailed design stage
- HAZOPS & CHAZOPS – at detailed design stage (for process related projects)
- Post Construction Design Review.

3.3 Key safety in design issues to be considered

SA Water is responsible for a significant number of covered and lined earth bank storages throughout South Australia which required regular inspections, maintenance and renewal works.

The list below identifies key SiD issues that have previously been encountered by SA Water during the operation, maintenance and design of the floating covered and lined earth bank storages. The designer shall demonstrate how these key SiD issues have been addressed as part of the design process.

- Unsafe access to rain water sumps
- Unsafe removal of rain water pumps
- Unsafe removal of mixers
- Unsafe cleaning practices (internal and external)
- Embankment stability
- Handling and installation of liners and covers.

This list is not an exhaustive and project specific SiD shall be undertaken to identify additional project specific safety considerations for the full lifecycle of the asset; construction, operations and decommissioning.

3.4 Health and safety

Work associated with the installation of a new liner and cover will include a combination of Health and Safety hazards that are not normally present in the construction industry. Some of the more significant hazards and their associated risks include:

- Working with large quantities of unrestrained / partly restrained membrane in conjunction with wind presents physical risk to personnel.
- Working with welding equipment that operates at high temperatures.
- Working with large sheets of membrane and heavy cover components increases risk of physical injury.
- These types of structures are often constructed as pairs of EBS's, while one is renewed the other will often remain online. Therefore, working, driving vehicles and operating machinery adjacent to a water body presenting a risk of drowning, with the risk increased due to the presence of the cover, the opacity of the water and possible instability of the embankments.
- Works associated with installing pipework and pits presents further significant Health and Safety hazards (See Section 6), especially when retro fitted in existing structures.

4 Cover and liner

4.1 General

The design of the cover and liner shall comply with this and all other applicable SA Water Engineering, Australian / International Standards, Commonwealth and South Australian Acts and Regulations including standard approvals and certification.

Designers shall be fully competent in the work they are undertaking.

Equipment and materials covered by this standard shall comply with the requirements and recommendations listed, and good engineering practice.

Quality controls for the review, verification and management of the design, manufacture and installation shall be planned, implemented and documented by appropriately skilled and qualified people. ISO 9001 Quality Assurance Standard certification shall be in place.

All components and materials shall be new and of the best quality to suit the site condition ensuring reliable and safe operation and facilitating inspection, cleaning and maintenance.

The liner and cover shall:

- Store potable or recycled water for future use, preventing leakage from the reservoir
- Operate at a variety of levels between the specified minimum and the maximum level
- Prevent contamination of the water from vermin, debris, leaves and other external contaminants
- Allow, should or include removal of rainwater from the floating cover
- Allow safe access by operation staff to hatches and sampling points
- Allow safe access onto the cover and into the storage volume for cleaning and inspection purposes when the storage is full or partially full (e.g. by the use of divers or remote operated vehicles).

4.2 Specific requirements

The liner and floating cover will be exposed to drinking water and therefore shall meet the requirements of Australian Drinking Water Guidelines. The water will contain disinfectants such as chlorine or chloramines.

The floating cover shall:

- Be non-combustible under normal operating conditions
- Prevent sunlight penetration to the stored water
- Have sufficient strength to perform under imposed wind loads over the design life and during the construction period
- Fully enclose the basin so as to prevent entry of rainwater, runoff, insects, rodents, birds etc.
- Be designed to minimise air pockets at the water/ cover interface
- Be capable of being repaired/ patched without the need to withdraw water from the storage tank. The Contractor shall document the method of repair available for the proposed material in the operation and maintenance manual, and supply any floatation devices or other aids required to implement the method

- Be designed to accommodate stresses imposed as a result of the rise and fall in the water storage level from full supply level to the storage invert
- Be designed to avoid suction uplift and accommodate imposed wind loading to AS1170.
- Incorporate adequate access hatches and sample ports
- Incorporate reinforced buoyant non-slip walkways to the access hatches and sampling ports
- Incorporate rainwater removal systems to remove rainwater from the floating cover/s
- Be capable of being inflated for test and maintenance purposes
- Be capable of supporting, without damage, foot traffic and light duty rubber tyred equipment used for maintenance purposes and/or during construction.

4.3 Performance requirements

4.3.1 Design life

The liner, cover and associated works shall meet the following design lives:

Table 4-1 – Design Lives

Asset	Design Life (Years)
Inlet and outlet pipes	80
Concrete structures	80
Flexible cover and liner	25
Mechanical assets	25
Electrical assets	25
Instrumentation / control assets	15
SCADA assets	15

4.4 Cover and liner materials

4.4.1 General

The cover and liner shall be suitable for use in chlorinated or chloraminated drinking water and be compliant with AS/NZS 4020: Testing of Products for Use in Contact with Drinking Water.

The liner and floating cover can be either reinforced or unreinforced. Reinforced membrane as a minimum shall be of 3 ply construction consisting of a layer polyester scrim fabric encapsulated between two layers of membrane polymer. The scrim shall be 10 x 10, 1000 denier polyester fabric with an open weave. Alternative weaves may be accepted, subject to SA Water Approval. The liner and cover shall be designed using fabricated panels which are transported on site where the final installation is completed using field welding techniques.

The cover and liner shall be puncture resistant, and free from holes, blisters, folds, undispersed raw material, contaminants and defects, resistant to attacks from disinfectants, micro-organisms, root and plant growth and stable at temperatures and UV radiation levels that will be experienced after installation. The liner and cover shall not support the growth of bio-films, harbour bacteria or promote the growth of fungi or similar biological species.

The cover and liner shall be impermeable to water under normal operating conditions. The liner shall form a watertight seal around all penetrations, including but not limited to the inlet and outlet pipework, and shall be compatible in contact with the in situ basin material and geotextile underlay.

The membrane liner shall be a single colour. The top surface of the cover shall be beige or similar light colour subject to approval by SA Water. The colour shall be achieved by appropriate pigmentation of the polymer during the membrane manufacture. A separate coloured coating or paint will not be accepted.

The chlorine or chloramine levels of the water would not normally be expected to be above 2 mg/l but may experience brief excursions up to 5 mg/l. The liner and cover material supplier must provide evidence of extended performance in disinfected water applications as detailed in Appendix A.

The bulk water temperatures may range from 5°C to 30°C and the ambient air temperature may range from -3°C to 46°C.

The cover and liner shall be fusion welded throughout the fabrication and installation process by hot wedge and extrusion welding and shall be able to be repaired throughout its life.

Ground water leakage into the water storage or any compartments formed during the liner installation is not permitted and rain water leakage into the water storage or any compartments formed during the cover installation is not permitted.

The membrane cover shall also be capable of supporting, without damage, foot traffic and light duty rubber tyred equipment for maintenance and shall also be capable of being inflated to allow access for maintenance and repair.

Workmanship to the cover and liner shall be such that patching and repairs shall be kept to a minimum (12 defects/hectare as per industry practice, exclusive of patching resulting from QA weld samples). **Excessive patching will not be accepted**.

4.4.2 Materials

Membrane materials shall meet the performance requirements detailed in GRI specifications GM-13, GM-17, GM-18, GM-25 or GM-28. If none of the GRI specifications apply to the membrane material, the Manufacturer shall provide the required tests and properties for that type of material. In addition to the general requirements of the GRI specifications, proposed membrane materials shall also be tested for resistance to disinfectants as detailed in Appendix A.

The performance requirements in Appendix A are considered to be a type test for the particular resin to be used in the manufacture of the membrane. This performance specification was developed for Flexible Polypropylene (fPP), Thermoplastic Olefins (TPO) and Chlorosulphonated Polyethylene (CSPE or Hypalon®). For other materials, like Ethylene Interpolymer Alloy (EIA) and other specialty materials, the Manufacturer shall submit proposed testing and expected properties to SA Water for review, including disinfectant immersion tests (chlorine and chloramine).

When tests of the Appendix A are carried out for polyolefins, the membrane Manufacturer shall provide details of the test method and results and shall declare the minimum initial HP-OIT or OIT time required by the polymer to achieve compliance to modified ASTM D1693 as detailed in Appendix A. The declared initial HP-OIT or OIT test method and time shall be adopted as a quality control test measure by the Manufacturer to ensure batch to batch performance for resistance to disinfectants.

The Manufacturer shall supply a schedule of all material properties as detailed in Appendix B.

4.4.2.1 Approved materials

Products which are known to have long term resistance to disinfectants used in the SA Water reticulation systems or have been tested to Appendix A are exempt from re-testing to Appendix A. Approved products include:

- Reinforced Chlorosulphonated Polyethylene (CSPE-R) or Hypalon®
- High Performance Polyolefin – Enviro Liner® 6040^{HD} (Extra UV/AO for cover applications)

Approval for resistance to disinfectants does not absolve the Manufacturer to conform to all other requirements of this standard.

4.4.2.2 Membrane welding

All membrane welding is to be undertaken by qualified welders who have been trained in each of the welding techniques to be used on the project. The International Association of Geosynthetic Installers (IAGI) provides examiners (proctors) to provide training of Certified Welding Technician (C.W.T.) or master seamer. It's required that welders hold this or an equivalent qualification.

The lead welder / master seamer shall have installed a minimum of 10 projects and seamed a minimum of 500,000 squere metres of material. Where personnel do not meet these criteria they shall be supervised by a competent person at all times.

The Welding Supervisor shall have the same minimum qualifications as the welders and in addition shall have a minimum of 2 years' experience in welding, installation and undertaking plastic weld testing to required standards.

Welding and joining personnel who have not produced any fusion joint in the previous 12 months shall be re-qualified. Evidence of continuity of skills can be made available via QA documentation and records of previous projects where the welder was actively engaged in producing fusion joints in thermoplastic materials.

Re-qualification may be carried out by attending the entire course through a registered training organisation (RTO) or by the producing a welded test piece and submitting the same for testing as per the destructive testing criteria stated in Section 4.8.

4.4.2.3 Manufacturers data requirements

The Contractor shall provide a Manufacturer's Data Report (MDR), containing the following as a minimum:

- Batch identification numbers for all geomembrane used in the cover and liner fabrication.
- Manufacturer Quality Assurance / Manufacturer Quality Control (MQA / MQC) certificates and other documentation from the material Manufacturers and Fabricators
- Test certificates for all batches of geomembrane used
- Test certificates for consumables used in the fabrication
- AS4020 compliance testing documentation
- Drawings showing the location of all panels used in the fabrication, individually identifying the batch number of the material used to fabricate each panel
- Qualified seaming procedures used for all joints (field and factory) used in the construction, including test results for all seam qualification tests
- Qualification records for all fabricators (field and factory) involved in seaming for all seam types undertaken by the fabricator

- Seaming and testing equipment calibration reports
- Drawings showing seam maps which:
    - Uniquely identify all seams (field and factory) made during the construction
    - Identifies the seaming procedure used for each seam
    - Uniquely identifies the fabricator who performed the seam fabrication
    - Documentation of factory and field seam tests and location from which the sample is taken.

4.4.3 Geotextile underlay

The Contractor shall ensure that the liner is sufficiently protected from rips, snags or other damage, by installation of a geotextile underlay. The geotextile fabric shall be specifically manufactured for use as a membrane liner underlay and be of sufficient thickness to fully protect the liner.

The Contractor shall provide the following items for review and approval by SA Water:

- Geotextile Manufacturer's information sheets
- Geotextile installation and seaming procedures
- Design and shop drawings showing the geotextile layout indicating the location and overlap of all field joints

The Contractor shall supply SA Water with the name of the Manufacturer, and certified test reports from the manufacturer of the product that confirm that the nominated geotextile material meets the requirements of this standard.

4.5 Factory fabrication

Cover and liner components shall be pre-fabricated into larger panels in a controlled factory environment as far as practicable, before transport to site.

Some materials such as High Density Polyethylene (HDPE) preclude the fabrication into large panels, and it is therefore expected that these materials will be installed sheet by sheet at site. It is also expected that it will not be practicable to unroll membrane, pre-install sleeves, access ports and the like.

However, it is expected that sections of primary flotation and secondary flotation can be fully factory preassembled and transported to site as completed sections / units.

The assembly of prefabricated components shall meet the requirements of Section 4.6.5 of this Standard, with the following clarifications and exceptions:

- Preassembled components shall be numbered in a similar fashion as field assembled sheets.
- Factory welding shall meet the requirements of Section 4.6.5 of this Standard, with the exception that pre-weld trials are not required.
- Destructive testing of factory welds shall meet the requirements of Section 4.8 of this Standard, with the exception that welds shall be made on off-cuts of liner/cover in order to verify that adequate seams can be produced by the chosen equipment and settings in the prevailing conditions, rather than being extracted from the actual fabrication.
- Failed weld tests shall place the whole of the prefabrication undertaken before and after the failed weld test in doubt. Samples shall then be taken from the actual fabrication for testing in accordance with the requirements of Section 4.6.5.

Fabrication and placement of the fabricated panels shall not commence until the panel layouts have been reviewed by the Superintendent. The Contractor shall provide the following items for review and approval:

- Geomembrane factory seaming procedures, including seaming qualification procedures for seam design and seam fabrication
- Detailed shop drawings showing the location of all factory seams, and the seaming method specified for all seams
- Design and shop drawings showing the geomembrane liner and cover panel layout with proposed size, number, position, weight, and sequence of placing all factory fabricated panels, and indicating the location and overlap of all field joints and the direction of all factory joints on each panel
- Seams used in the fabrication and installation of the baffles shall comply with the requirements for fabrication and installation of the cover and liner.

4.5.1 Factory seams

Individual roll widths of geomembrane shall be factory fabricated into large sheets ("panels"), so as to minimise field seaming.

All factory seams shall be staggered as required to ensure that no more than 3 layers of geomembrane meet at any joint.

The Fabricator shall provide procedures for where three layers of geomembrane liner material occur at a "T" joint to SA Water for review.

Factory seams shall be by heat welding unless approved otherwise by SA Water and shall meet the design life requirements. All factory seaming must be completed in a timely manner to ensure the liner and cover material does not deteriorate so as to increase the risk of poor weld integrity.

Factory seaming equipment shall be calibrated at the beginning of each shift. Calibration records shall be included as part of the MDR. Calibration shall consist of a test seam, which shall be subjected to peel strength, tensile strength, and break away peel strength testing. Testing may be carried out in-house, or by an independent laboratory.

4.5.2 Factory seam qualifications

The Contractor shall develop weld procedures for all seam types that will be employed during factory pre-fabrication.

All procedures shall be qualified, by carrying out a trial seam over at least a 1000mm length, and subjecting the trial seaming specimen to the required tests for seams to ensure the strength and durability meet the required specification.

Factory seams shall develop at least 90% of the specified tensile strength of the parent material when tested in accordance with ASTM D751.

All factory seams shall ensure that they are fully bonded on all sides so that no loose edges occur. Any cut edges of reinforced membranes which will be exposed to water shall be sealed by extrusion welding.

Copies of the procedure, including the results of qualification testing, shall be submitted to the Superintendent's Representative for approval 10 days prior to fabrication commencing, and included in the MDR.

All Fabricators required to make factory seams shall qualify to each procedure they are required to use. Qualification shall consist of the fabricator performing a trial seam at least 1000mm long. The trial seam shall be subjected to testing to ensure the strength and durability meets the required specification.

Copies of the Fabricator Weld Qualification Records for each fabricator shall be included in the MDR.

4.5.3 Packaging and storage

Each roll or factory fabricated panel shall be prominently and indelibly marked with the roll or panel number and dimensions in accordance with the panel layout.

Materials shall be stored at the factory, at the Fabricator's premises, or on-site in an area approved by SA Water.

Rolls shall be packed and stored in such a manner that no surface irregularities or other influences will apply point loads, abrasions, cuts or distortions or other forms of damage to the rolls. No more than two rolls of membrane shall be stacked one on top of the other.

All pre-fabricated components and panels shall be suitably packed on a pallet, or similar, to enable safe handling. Packaging and storage shall ensure the membranes avoid abrasion, scuffing, scouring or other damage. Particular care is to be taken to prevent rubbing of membrane edges, folds and corners. Palletised panels shall not be stacked on top of each other.

4.6 Field fabrication

4.6.1 Seam layout

Field seams shall be indicated on the panel layout drawing. Any variation to this seaming layout shall be indicated on the daily welding report and adjustments made to the as-built drawings. Seams shall be identified by a numbering system compatible with the panel identification numbering system.

4.6.2 Seaming equipment and materials

Seaming shall be by heat fusion or extrusion methods. Solvent welding or adhesives shall not be permitted.

Weld shall be as shown on the Drawings, and shall only consist of:

- Automatic travel hot wedge welding by machines which enable the operator to regulate the temperature of the wedge and to regulate the speed of welding to ensure adequate fusion without excessive melting or burn-through. Dual track wedge welds to enable leak testing shall be used for unreinforced HDPE liner materials except at areas where it is impractical due to geometry constraints. Other reinforced or unreinforced materials shall use conventional automatic hot wedge welding except where it is impractical due to geometry constraints
- Extrusion Fillet Welding by hand held extrusion welding machines. The extrudate shall be supplied by the geomembrane Manufacturer and shall use the same polymer / additive formulation as the supplied membrane, (and shall have the same Melt Flow Indexes (MFI), density, High Pressure-Oxidative Induction Time (HP-OIT) and Stress Cracking Resistance (SCR) as the parent membrane). Extrusion fillet welds shall only be used in locations shown on design drawings, with the exception that it may be used for patching, curves and other welds not accessible to the automatic wedge weld machines.

Hot wedge weld machines shall:

- Have full control of temperature and speed, with correct operation of these functions confirmed by calibration certificate at the commencement of the project and at not more than 180 days intervals
- Have visual output for measuring and calibrating the temperature
- Have a daily calibration check, with the temperature of the wedges checked with an external thermocouple
- Be checked and cleaned daily
- Have a completely clean and smooth base and not leave any score marks on the geomembrane liner surface.

Any proposal to use other welding methods shall be subjected to a review of effectiveness and performance by SA Water, whose decision shall be final.

4.6.3 Seam preparation

Prior to any welding, the panels are to be aligned with appropriate overlaps for the equipment used and shall have no wrinkles or kinks. The surfaces to be welded shall be clean and dry. Surface waxes or blocking agents shall be removed using a dry rag, followed by a cloth wipe impregnated with a solvent approved by SA Water. The on-site use and storage of free liquid solvents is not permitted due to the risk of fire when used in the vicinity of welding and other electrical equipment.

For the extrusion fillet weld it is necessary to surface buff the sheet in the weld zone with a suitable abrasive disc on a flexible rubber pad in order to remove surface waxes.

Grinding marks should be perpendicular to the seam, not parallel to the seam. The buffed areas shall extend 6mm past the proposed limit of the weld extrudate. Rigid cutting or abrasive discs are not to be used. "Excessive grinding" that has reduced membrane thickness (by more than 10% of the total membrane thickness) or has left scratches in the membrane surface shall be noted as a defect and must be repaired. Materials in excess of 1.5mm thick require the upper edge to be chamfered prior to extrusion welding.

4.6.4 Weather conditions

Welding shall not be undertaken in conditions that can cause the membrane to be wet or moist. This includes rain, fog, dew or spray. Seaming shall not proceed unless the temperature of the material is at least 3°C above dew point.

Field welding quality is impacted by high or low ambient temperature and by excessive wind.

Specific field conditions, geomembrane sheet thickness and other factors shall influence the limits of acceptable atmospheric conditions but welding outside of the range 0°C to 40°C is likely to be difficult and unreliable. High wind is likely to create difficulties in maintaining panel alignment as ballast is removed for welding such that continuing work is impracticable. Care needs to be taken that wind chill factor is not reducing welding temperature such that fusion is inadequate or that excess heat is being used to overcome wind chill.

The Contractor shall consider means on minimising downtime from weather conditions. However, any measures (like barriers and tent structures) must consider all risks.

4.6.5 Trial (pre-weld) seams

Trial seams shall be made on off-cuts of liner in order to verify that adequate seams can be produced by the chosen equipment and settings in the prevailing conditions. It is important that the conditions under which these seams are made reflect the actual temperature and ambient conditions influencing the seam welding. Frequency of trial seams shall be based on any resumption of work after a break or any change in conditions but shall not be less than twice per day per machine and/or operator.

The seams shall be at least 1000mm long with adequate 'tails' each side of the weld for testing. For unreinforced membrane material, 25mm wide test samples shall be cut from weld and these shall be tested in shear and peel using a field tensiometer in accordance with GRI GM-19. The specimens shall pass or fail according to seam strength criteria set out in GRI Test Methods GM19. For reinforced materials wider sample widths are required – see ASTM D7747. For CSPE-R the minimum seam strengths in below shall be achieved.

Table 4-2 – Minimum Strengths for Shear and Peel Tests

Test	Minimum Strength (N)
Hot wedge or extrusion fillet seams. Shear Strength N/25mm	1000
Hot wedge or extrusion fillet seams. Peel Strength N/25mm	100

If the specimens fail the above criteria, changes shall be made to welding conditions. A new trial seam shall be prepared, and samples taken and tested. Weld samples shall pass the criteria set out in GRI Test Method GM19 before the weld can be accepted and welding of the cover sheet can commence.

Trial (pre-weld) seam production and testing is to be recorded on an appropriate form and include the MDR.

4.6.6 Seaming procedures

The seam weld procedures shall satisfy the following requirements:

- Automatic Wedge Welds. The sheet edges shall be aligned with an overlap of approximately 150mm. The seam faces are to be cleaned and free of moisture, dust, dirt or other debris. No grinding of the faces is required. The welder shall be positioned and drive engaged to set the welder in motion. It may be desirable to have a drag sheet of membrane material placed under the welder and dragged along to provide a smooth surface for the welder to roll on. The Welder shall be steered and controlled continuously by the Operator. Should any 'fishmouths' occur they are to be slit and patched. T-joints are also to be patched. The welder shall not cause any scoring or scratching parallel to the seam as these could act as damaging stress concentrations
- Manual Extrusion Welds. The sheet edges shall be aligned with an overlap of approximately 150 mm and a hot air tack weld laid in the overlap to stop the overlapped sheet from shifting. The surfaces shall be thoroughly cleaned and dried. The weld surfaces are to be ground as described in Section 4.6.3. The extruder shall be purged of any preheated extrudate and the weld bead shall be laid carefully along the line of the edge of the top sheet such that the fillet is evenly distributed across the two sheets.

Any proposal to use other welding methods shall be subjected to a review of effectiveness and performance by SA Water whose decision shall be final.

4.7 Inlet and outlet requirements

EBS liners must be designed to allow for inlet and outlet infrastructure, without compromising its continuity or integrity.

The membrane liner must form a watertight seal around all pipe penetrations, including the inlet and outlet pipework. This may be done using a custom made boot sleeve attached integrally to the liner by extrusion welding or other approved method, and attached to the pipework using pipe clamps or other method designed to prevent creation of a possible leakage path. Flanged make-offs may also be considered, where SS316 is preferred.

The outlet and scour works must include consideration of prevention of damage to the cover as the storage empties and comes in contact with the outlet / scour or other structures.

Direct access to the inlet, outlet, scour connection and overflow location is to be provided in the cover via access hatch or equivalent.

Inlets and outlets should be positioned with consideration of prevention of short-circuiting in the storage and associated water quality effects. Refer to Section 7.2 – In storage mixing requirements.

4.8 Inspection and testing

4.8.1 General

SA Water shall be provided with the opportunity to undertake an inspection of the manufacturing facility leading up to and during formulation of the resin and the production, sampling and testing of the ordered membrane.

4.8.2 Factory inspection and testing of roll goods

Factory sampling and testing of materials shall be in conformance with ASTM D 4354 (Standard Practice for Sampling of Geosynthetics for Testing). The Membrane Manufacturer shall prepare factory testing reports, which includes results of all sampling and testing defined in this Standard, and shall include all additional tests as may be required by the Membrane Manufacturer's Quality Assurance/Quality Control Plan.

Testing and reporting will be required for both the base resin and for the manufactured product membrane. Testing requirements are in accordance with Section 4.4.2. OIT or HP-OIT testing will also be required for all non-approved polyolefin resins (as defined in Section 4.4.2) to demonstrate resistance to disinfectants. The OIT or HP-OIT acceptance criteria will be determined in accordance with Appendix A Section A4.2, A4.3 and A4.4 (This only applies to polyolefins).

The testing identified in the GRI specifications or Manufacturer's Quality Assurance / Quality Control Plan is required for each batch of base resin and for each batch of manufactured product and will be used for the purposes of compliance testing. If the supply contains membrane with a coloured upper ply / film, it is possible that the upper ply and lower ply(s) will be manufactured from different resin batches. If this is the case, testing and reporting shall be provided for both base resins.

However, it should be noted that the manufactured membrane shall comply with all of the requirements of this Standard and shall equal or exceed all of the "Minimum Values" ** nominated by the Membrane Manufacturer in the Tender Schedules (Appendix B).

** *Melt Flow Index, Low Temperature Brittleness and Flexibility shall be lower than the values nominated. Dimensional Stability shall be within the range nominated.*

Frequency of testing shall be in accordance with the GRI specifications. OIT or HP-OIT testing for resistance to disinfectants shall be in accordance with Appendix A Section A5.6.

4.8.3 Inspection of roll goods prior to fabrication

The Contractor shall inspect the roll goods prior to factory seaming. The methodology and quality control regime of this inspection shall be submitted in Membrane Manufacturer's Quality Assurance/Quality Control Plan.

4.8.4 Inspection and testing of factory seams

The Manufacturer shall inspect and test the factory seams in accordance with the Membrane Manufacturer's Quality Assurance/Quality Control Plan. As a minimum 100% of all factory seams shall be non-destructively tested in accordance with Section 4.8.6.1.

4.8.5 Membrane delivery and acceptance

The membrane materials shall be supplied and manufactured according to the requirements of this standard.

The Installation Contractor shall not commence any fabrication or installation works until the following has been submitted to and has been approved by SA Water:

- All of the required Manufacturer's Quality Assurance/Quality Control requirements and materials properties tests report.
- Documentation demonstrating that the supplied materials conform to the requirements of current GRI specifications and variations required in this standard if applicable
- The Membrane Manufacturer's installation quality assurance manual, (or similar document)
- Submission of all relevant documentation and drawings "for Construction"

On taking delivery of materials and after unrolling and spreading out the membrane sheet, the entire surface area of each side of each and every roll shall be inspected to ensure that the membrane is free from tears, abrasions, indentations, holes, cracks, blisters, thin spots, undispersed raw materials, embedded foreign matter, exposed scrim or other faults in the material.

The formulation and manufacture shall be uniform such that all properties detailed within the GRI and this standard will be met at all times. Manufacturing process irregularities which present irregular thickness and imperfections that will not provide even stress distribution throughout the sheet will be rejected and replaced. Other faults may be repaired subject to the acceptance by SA Water.

4.8.6 Field inspection

The membrane shall be inspected to ensure that there are no tears, score-lines, abrasions, indentations, inclusions, cracks, thin-spots, gels, blobs, cold slugs, unmelts, die drool, orange peel finish, evidence of poor pigment dispersion, evidence of poor mixing, creasing, folds, holes, blisters, contamination by foreign matter or other faults in the material. The formulation and manufacture shall be uniform such that all properties detailed within the membrane manufacture and specification will be met at all times.

The underside of the membrane may be inspected on the roll as the roll as is it unwound. This inspection will be critical in cases where the underside of the membrane will no longer be visible / accessible after unrolling. This inspection must be undertaken with full attention and diligence. If it is found that a defect has not been detected then SA Water may instruct the Installation Contractor to lay all future membrane flat on both sides for full inspection.

Manufacturing process irregularities which present irregular thickness and imperfections that will not provide even stress distribution throughout the sheet will be rejected and replaced. Other faults may be repaired subject to the acceptance by SA Water.

4.8.6.1 Inspection and testing of field seams

The Contractor shall ensure that the field seams are suitable to meet the design life and the Manufacturer's installation specification.

Non-destructive seam testing shall proceed continuously as the installation is carried out. Delay of testing until the work is nearly complete is not acceptable.

Non-destructive testing

Non-destructive testing (NDT) of welded seams is carried out to ensure continuity of the seams and is to be applied to 100% of the field seams. The procedures are not intended to provide information about seam strength. The air pressure test method shall be used for all seams produced by dual-track hot wedge welders and the other non-destructive methods shall be used for all other

seams. The Contractor shall submit a testing methodology incorporating the test methods detailed below.

a) Air Pressure Testing. Air Pressure Testing shall be performed in accordance with ASTM D5820. An internal pressure is applied to the weld air gap and the weld is accepted if pressure loss is within an acceptable range. The applied pressure is normally 200 kPa and the testing period 5 minutes. Pressure gauges are required at each end of the weld to ensure continuity - alternatively the seal can be released at the end without a gauge and the pressure drop observed to ensure continuity. The air pump should be mounted on cushioning pads and the air pump should not be dragged across the geomembrane. Pressure testing of seams is reported on the appropriate daily report form.

b) Electrical Methods. A number of electrical based test methods can be used including

- ASTM D6747 provides guidance for the selection of techniques for electrical detection of potential leak paths in geomembranes
- ASTM D7703 provides guidance for a performance based test using a water lance to detect leaks in exposed geomembranes
- ASTM D7007 provides guidance for detecting leaks within a liner when full. Separate tests will need to be carried out for the secondary outer liner and primary inner liner.

c) Air Lance Testing. Air-lance tests shall be performed in the field by the Contractor in the presence of SA Water during daylight hours. The air-lance shall have a 1/8-inch diameter orifice. Pressure at the orifice shall be between 60 and 80 psi. The jet of air shall be directed at the edge of seams and patches to effect the lifting of un-bonded edges. The air-lance testing shall be done in a manner so as to allow the Contractor sufficient time to observe and document any leaks or suspect areas. Leak paths or suspect areas revealed by these inspections shall be marked and repaired. All defects found during probing shall not be repaired until the defect is tested by air lancing. ASTM D4437 Method 7.2 provides guidance on the operation of the Air Lance test.

d) Vacuum Testing. Vacuum Testing shall be performed in accordance with ASTM D5820. For vacuum testing a box with a transparent top, neoprene rubber base seal and a connection to a suitable vacuum device is required. A soapy solution is applied to the geomembrane surface, the vacuum box positioned and a vacuum of 35 kPa drawn on the box. After observation for bubbles for 10 seconds the vacuum is released and the process repeated on the next piece of seam with a suitable overlap to ensure continuity. Vacuum testing of seams is reported on the appropriate report form.

e) Manual Probe Testing. This requires a blunt tipped probe such as a screwdriver or circlip remover. The probe is gently and systematically used to feel the weld bead and ensure continuity along its length. Manual probe testing of seams is reported on the appropriate report form.

f) Failed Weld Procedure. Should a weld fail an air pressure test it is necessary to progressively halve the length of weld tested in order to eventually isolate the defective portion. Should a weld fail any of the other tests the area shall be marked for subsequent repair or patching.

Destructive testing

The purpose of destructive seam tests is to:

a) Evaluate the consistency of welds produced by an operator dependent procedure

b) Provide a check on the strength and integrity of the welds as produced in practice.

Destructive seam sampling and testing shall proceed continuously as the installation is carried out. Delay of testing until the work is nearly complete is not acceptable. The Fabrication and Installation Contractor shall ensure that there are no unnecessary delays in taking field samples and undertaking the field based strength tests. The Fabrication and Installation Contractor shall provide

onsite calibrated testing equipment to enable peel and shear tests to be carried out in a timely manner.

Testing frequency shall be based on one sample for every second sheet placed. The frequency may be increased or decreased based on the outcomes of prior destructive weld tests, but as a minimum samples shall be taken every 150m of seam weld.

The weld samples shall be at least 1000m along the weld and 600mm wide with the seam in the centre. The sample shall be assigned a consecutive number and its location shall be noted on the report form for destructive testing and shall also be noted on the as-built drawing.

The sample shall be divided into three equal sections for use as follows:

a) The first shall be used for field testing in shear and peel, (five specimens in shear and five specimens in peel).

b) The second is to be retained by SA Water for third-party laboratory testing.

c) The third is to be archived for reference in case of dispute or other future incident.

Destructive seam samples are to be taken at locations selected by SA Water and may include areas where SA Water considers that the seam integrity may be in question, such as near T seams or wrinkled areas.

4.8.7 Floating cover air support testing

Prior to final inspection and initial filling, the floating cover on the reservoir shall be air supported by inflating to allow internal inspection.

The cover shall be fully inspected from the inside during daylight hours while inflated and all points where light from the outside is observed shall be carefully marked and repaired.

The shape of the inflated cover shall be examined and any region which puts an excessive concentrated force on the anchorage or any other part of the cover which could induce tearing of any part of the cover shall be assessed and modified to the acceptance of SA Water.

4.8.8 Floatation testing of cover

The floating cover will be deemed to be acceptable by SA Water if its flotation performs as specified over the full range of storage depth and if it is watertight. Watertight shall mean that:

- There is no apparent leakage of stored water onto the cover surface
- The cover sits flat
- Surface water drains to sumps
- No excessive wrinkling

4.8.9 Defects and repairs

Weld or membrane defects may be repaired by use of the following methods:

- Patching – For repair of large holes, multiple score lines, tears and filling of destructive sample extraction locations. All patches shall extend 150mm beyond the edges of the defect and all corners of patches shall be rounded
- Grinding and Welding – For repair of sections of extruded fillet seam.
- Spot Welding or Seaming – For repair of single score lines, small tears, pinholes or other minor flaws
- Capping* – For repair of faulty extrusion or wedge welded seams
- Extrudate Overlap – For repair of failed wedge welds
- Seam Replacement – For removal of bad seams and replacement with strip of new material

- Wrinkling of sheet due to temperature differentials – Cut out full weld length, relap and reweld
- Workmanship to the cover and liner shall be such that patching and repairs shall be kept to a minimum and not including QA weld test sample patches (12 defects/hectare as per industry practice). Excessive patching will not be accepted.

*Capping refers to applying a new strip of membrane over the faulty seam. The cap strip shall generally extend at least 150mm beyond the limit of the seam and the edges shall be extrusion seamed to the underlying membrane.

All proposed repairs and repair methodology shall be subject to acceptance by SA Water.

4.9 Rainwater removal system

The Contractor shall supply and install rainwater removal systems on the floating covers to prevent build-up of water on the covers. Further details are provided in Section 6.4.1.

4.10 Cover ancillaries

All cover ancillaries such as membrane encapsulation for floats and walkways including non-slip sections, weights and straps, sample ports, hatch and pump floats shall be factory fabricated.

4.11 Floats and ballast

The floating cover Contractor shall incorporate such floats as are required for the successful operation of the cover. The Contractor shall provide details of the fixing of the floats to the cover. All floats shall be fully encapsulated in a geomembrane material identical to the floating cover material.

Similarly, the Contractor shall incorporate a ballast system to maintain satisfactory tension on the cover. The Contractor shall specify the choice of material for the ballast, the manufacture and the method of fixing to the cover. All ballast material shall be fully encapsulated in geomembrane material identical to the floating cover material.

Floats shall be constructed of rigid, solid extruded, closed cell polyethylene foam with a density of nominally 35 kg/m^3, and capable of supporting a load of 17.5 kPa (e.g. Ethafoam 220 or approved equivalent).

4.12 Access hatches and sample ports

The Contractor shall design and install access hatches and sample ports in location and number as indicated by SA Water and the requirements of Section 7.4.

All access hatch and sample port covers, including support frames, hinges and locking mechanisms, shall be fabricated of 316SS. All sharp edges shall be removed

All access hatch and sample port covers shall be lockable.

4.13 Floating walkways and platforms

The Contractor shall design and install floating walkways and platforms. The minimum requirements for location and number of walkways/ platforms shall be agreed with SA Water.

Walkway floats shall be fully encapsulated in geomembrane material equivalent to the cover material.

The top of walkways shall be a texture pattern to provide a non-slip walking surface with positive and patterned indentations. The non-slip surface can be provided by a specific coarse textured material bonded to the membrane or an aggregate material bonded to the membrane surface. The non-slip surface shall prevent slippage of foot traffic under normal operating conditions when the surface is wet. Non slip surfaces shall meet the requirements of Classification R12 of AS 4586 -

Slip resistance classification of new pedestrian surface materials. Roughened or abraded surface of standard geomembrane material shall not be acceptable. The exposed top surface shall be the same colour as the floating cover.

Walkways shall be fully seamed to the top of the geomembrane floating cover and shall be laid flat and parallel to the embankment slope.

4.14 Acceptable leakage rates

4.14.1 SA Water acceptable leakage rates

The Contractor shall determine and specify the Acceptable Leakage Rate (ALR) of the proposed material for the liner. The ALR shall be estimated using industry practice formulations for lined storages like the Giroud & Bonaparte (1989) method, Fluet (2002) equation or equivalent empirical equations developed in accordance with the liner performance.

The Giroud & Bonaparte method of leakage assessment is expressed in the equation below:

$$Q = C_b a (2gh_w)^{1/2}$$

Where:

Q	**leakage rate (m^3/s)**
a	hole area (m^2)
C_b	dimensionless coefficient taken as 0.6
h_w	liquid depth under consideration (m)
g	gravitational acceleration (m/s^2)

The Fluet formula for calculating leakage rate is:

$$Q = 0.6\left[1 + 0.1\left(h/t_s\right)^{0.95}\right] a^{0.1} h^{0.9} k_s^{0.74}$$

Where:

Q	**flow rate through the composite liner (m^3/s)**
a	area of circular hole in the geomembrane (m^2)
t_s	thickness of the lower component of composite liner (m)
h	hydraulic head above geomembrane (m)
k	hydraulic conductivity of the lower component of the composite liner (m/s)

The calculated leakage rate may vary depending on the method used and as such, the Contractor shall propose ALR and agreed by SA Water prior to liner fabrication.

The liner will be deemed to be acceptable by SA Water if there is no measurable decrease in water level over the 14 day test period and flow in the underdrain system is less than the accepted allowable leakage rates.

4.14.2 Methods for determining leakage rates

The liner shall be tested by filling the completed reservoir (with floating cover installed) to overflow level and observing the water level for a minimum of 14 days unless directed otherwise by SA Water. The leakage collected via the underdrain system of the storage shall be monitored over the 14 day period. Refer Section 6.4.2 for underdrain system requirements. Additionally there shall be no detectable loss in static level of the tank or increase in flow in the underdrain during the maintenance period. Rainwater removal and rainwater evaporation will change the apparent level of the water and therefore needs to be considered.

5 Installation

The liner and floating cover shall be installed in strict accordance with the approved design details and the membrane Manufacturer's recommended instructions.

The Contractor shall at all times work in a clean manner to avoid unnecessary contamination or damage to the surfaces of the liner, cover, structures and pipe work.

The Contractor shall ensure foreign material is not dragged down the embankment during installation of the geotextile layer and liner. If this does occur, the Contractor shall remove all lumps or fragments of material prior to final placement and/or seaming occurring.

The Contractor shall ensure that the geomembrane is protected from damage during installation, including ensuring that:

- Workers walking over the geomembrane wear smooth rubber soled shoes. Shoes with soles with an aggressive pattern (e.g. trainers) that can pick up potentially damaging debris shall not be permitted
- Equipment and materials are not dragged across the geomembrane
- Any vehicles (e.g. trolleys) have soft rubber tyres, with narrow tread to limit the risk of picking up damaging debris
- Marker pens used do not contain wax, oil or grease
- High traffic areas are protected by temporarily installing a cover material to protect the geomembrane (e.g. a geotextile).

5.1.1 Access for installation

The Contractor shall visit the site prior to commencement to confirm sufficient access to undertake the works.

5.1.2 Removal of an existing liner and cover

If the project requires the removal of an existing liner and cover, the Contractor shall remove and dispose of the existing geotextile underlay, liner and cover. Re-use of mechanical fixings that are deemed to be in good condition and are appropriate for the new installation shall be subject to approval by SA Water.

The Contractor shall submit a liner and cover removal plan to SA Water for approval prior to commencing the work. In the removal plan, the Contractor shall include the strategy on how to prevent the damage of the storage sub base and embankment due to uncontrolled surface run-off during rainfall events once the geotextile underlay, liner and cover are removed.

5.1.3 Acceptance of reservoir prior to installation

After final embankment compaction and installation of underdrain system or after removal of the existing membrane liner and cover, the Contractor shall conduct a first inspection of the reservoir surface to ensure its suitability for lining. The Contractor shall advise SA Water of the time and date of this inspection to allow SA Water personnel to attend. The Contractor shall ensure that all foreign material (e.g. stones, plant material, wind-blown detritus) is removed from the sub-base prior to installation of the geotextile underlay.

If the surface is suitable for lining, the Contractor shall confirm acceptance in writing and proceed with the installation of the liner.

If the Contractor or SA Water identifies that the surface is not suitable, then additional works shall be undertaken to rectify the surface for acceptance of the liner.

Upon completion of this work, the Contractor is required to conduct a second inspection and accept the condition of the prepared surface as suitable for installation of the new system. Confirmation is to be in writing. It is the Contractors responsibility to maintain the storage sub-base in a condition suitable to allow for installation of the liner.

5.1.4 Geotextile underlay installation

Geotextile shall be installed as an underlay and be shall be neatly installed over the accepted subgrade surface without slack, folds, wrinkles or excessive tension prior to installing each section of liner. Installation of geotextile shall immediately precede liner installation, to avoid excessive exposure of the geotextile to the elements.

5.1.5 Liner installation

The Contractor shall clean the sub-base to remove all foreign material prior to installation of the liner.

Factory fabricated panels or rolls shall be placed and seams made in accordance with the location and sequence described in the construction plan.

The liner shall be secured with sandbags or an approved equivalent at all times during installation to prevent damage or displacement due to wind. SA Water reserves the right to direct the Contractor to cease installation and make the site safe in the event of inclement weather that may threaten the integrity of the liner installation and safety of the site personnel. Sandbags installed at the top of or on the side slopes, shall be secured to stop them moving down the slope in an uncontrolled manner.

Installation practices shall comply with the requirements of this standard and the Manufacturer's recommendations, and ensure that there is minimal damage to the liner.

The liner shall closely fit and seal around inlets, outlets and other penetrations.

Lining to concrete seals shall be water tight. The arrangement and procedure for these seals shall be provided as part of the design documentation.

The liner shall be installed in a relaxed condition without excessive wrinkles, creases or folds and shall be free of tension upon completion of the installation.

The liner shall be fully supported by the sub-base or concrete structures over its entire area, and shall not bridge gaps.

5.1.6 Cover installation

The Contractor shall clean the top surface of the liner and remove all scraps and dirt prior to installation of the cover.

The cover shall be secured with sandbags or an approved equivalent at all times during installation to prevent damage or displacement due to wind. SA Water reserves the right to direct the Contractor to cease installation and make the site safe in the event of inclement weather that may threaten the integrity of the cover installation and safety of the site personnel.

Installation practices shall comply with the requirements of this standard and the Manufacturer's recommendations, and ensure that there is minimal damage to the cover.

The cover shall be installed to allow for instrumentation, sampling points, hatches and walkways, as agreed with SA Water.

Installation shall ensure the cover is suitable for air inflation and operation under a varying water level, from the design top water level to storage invert levels.

6 Civil requirements

6.1 Earthworks

6.1.1 Embankment construction performance requirements

Where new embankments are to be designed and constructed as part of a project, the performance requirements in Sections 6.1.1.1 to 6.1.1.4 shall be adopted. With further guidance provided in the flowing SA Water Technical Guidelines:

- TG 10b – General Technical Information for Geotechnical Design – Part B – Earth Dam Design
- TG 10f – General Technical Information for Geotechnical Design – Part F – Lined Storages

6.1.1.1 Embankment materials

Where embankments are constructed for new EBS's the materials shall meet the following performance requirements:

Table 6-1 – Performance Requirements for Embankment's Materials

Parameter	Test	Acceptance Limit
Permeability	AS 1289.6.7.3	≤ 1 x 10^{-9} m/sec
Grading	AS 1289.3.6.3 AS 1289.3.6.1	≥ 30% passing the 75 µ sieve ≤ 20 % passing the 19 mm sieve
Emerson Class	AS 1289.3.8.1	≥ Class 4 – (non-dispersive)
Atterberg Limits	AS 1289.3.1.2, 3.2.1, 3.3.1, 3.4.1	Low to medium plasticity CLAY
Remoulded Undrained Shear Strength	AS 1289.6.4.1	≥ 75 kN/m^2

Note: The permeability and shear strength testing is to be undertaken on remoulded samples at 98% standard maximum dry density.

6.1.1.2 Embankment slope angles (internal and external)

Where embankments are constructed on relatively flat site and with adequate space the internal and external slopes shall range between 1v:4h and 1v:3h.

Where site constraints make it necessary to adopt steeper slopes than those above, SiD issues associated with the adoption of steeper slopes shall be considered, addressed, documented and agreed with SA Water.

6.1.1.3 Embankment design

The embankments shall be designed for the following load cases using slope stability software, with both internal and external slopes to be assessed.

Table 6-2 – Load Cases for Embankment Design

Load Case	Factor of Safety Requirements*
Short term total stress conditions	≥ 1.5
Long term effective stress conditions	≥ 1.5
Rapid Drawdown	≥ 1.3
Seismic Loading	≥ 1.0
Plant / Construction Loading	≥ 1.5

* The factors of safety values adopted in the table above are for deep seated failures. Lower factors of safety for shallow failures affecting only the embankment face shall be considered by the designer. Where crane lifts are required specific assessments shall be undertaken.

6.1.1.4 Embankment construction

The compaction requirements for embankment material are summarised below:

Table 6-3 - Compaction Requirements for Embankment Materials

Property	Acceptable Limits	Note
Maximum Dry Density	98%	Standard Maximum Dry Density, MMDD ratio of 98%. The material shall be compacted with a vibrating smooth drum roller or other approved equipment until the required density is achieved.
Optimum Moisture Content	+/- 2% OMC	The optimum moisture content of the material shall be the moisture content that is required to achieve the peak dry density when tested in accordance with the method given in AS 1289.5.2.1.
Max Layer Thickness	250 mm	The embankment material should be compacted in uniform horizontal lifts.
Unsuitable materials	hard clay lumps, organic matter and industrial by-products	Where these materials are encountered they shall be broken down or removed before being transported to the embankment.

Site compaction trials shall be undertaken on the proposed embankment material prior to the placement of any embankment material. The purpose of the trial will be to establish the suitability or otherwise of the compaction equipment proposed, the number of passes required and to determine the optimum layer thickness.

6.1.1.5 Embankment foundation preparation

- Pockets of weak or otherwise unsuitable material shall be removed below the general foundation level or as directed by the Client
- The foundation surface, immediately prior to receiving the embankment material, shall have all water removed from the depressions and the top 150 mm of foundation material shall be sufficiently moistened and compacted

- Where the foundation for the embankment material is the concrete encasement of the pipework, the surface for the fill to be placed on the concrete, contact material, shall be prepared by removing any loose and unbonded material that will prevent the bonding of the contact material with the foundation.

6.1.1.6 Earthworks issues encountered when undertaking renewal of existing EBS

There are a number of earthworks issues that should be anticipated when the works are primarily to reline an existing EBS, these issues are summarised below:

- Sites have shown cracking within the base and side of the EBS, due to shrinkage of the clay embankment fill. Prior to placing the new liner any cracking shall be remediate to provide a uniform surface for the acceptance of the new liner

- There may be weak / soft material within the base and sides of the EBS, where drainage has been ineffective or absent. This will reduce the trafficability of the material and where required the weak / soft material shall be removed and replaced with competent material, to allow plant / machines to access the EBS

- Careful consideration shall be given to the removal of the existing liner, as exposure of the base and side of the EBS to the elements can have significant impacts on its integrity. Uncontrolled surface run-off can cause significant damage to the embankments which shall be remediated prior to the placement of the new liner.

6.1.2 Erosion protection

It is essential that the downstream face of the EBS shall be protected from erosion. The minimum requirement for erosion protection shall be a layer of seeded topsoil nominally 150 mm thick. The grass shall be of an approved seed mixture and spread at a density not less than 10g/m^2. Maintenance of the topsoil layer may be required prior to the establishment of the grass cover and root system.

Where higher flows or drainage outlets are located on the downstream face then more robust erosion protection shall be required, such as rip-rap or a reno-mattress type structure.

The Contractor must plan and carry out the work to avoid erosion, contamination and sedimentation of the Site, surrounding areas and drainage systems. The Contractor shall maintain erosion control measures during the course of the work.

6.1.3 Excavation and backfilling requirements

6.1.3.1 Shoring of excavations

SA Work Health and Safety Act 2012 has specific requirements in respect to excavations exceeding 1.5 metres in depth and which permit the entry of a person. The Contractor shall ensure that all ground support systems are removed as the excavation is backfilled, in a manner which shall prevent damage to any persons, the main and/or any other adjacent structures, unless approval is obtained from the Principal for the support systems to remain in place during backfilling (i.e. for the support systems to be "lost").

6.1.3.2 Shoring of trenches and pits

The Contractor shall supply, put in place and maintain such shoring in accordance with the relevant statutory requirements and as may be required to support the wall of the excavation and to prevent any movement which can in any way injure personnel or endanger any adjacent pavements, buildings, conduits, or other structures. If the Principal considers that sufficient or proper shoring has not been provided, the Principal may order additional shoring put in at the expense of

the Contractor and the compliance with such orders shall not release the Contractor from its responsibility for the sufficiency of such shoring.

6.1.3.3 Trench backfill outside embankment

The material used for trench backfill outside the embankment shall be coarse, free flowing pit or beach sand, equivalent to SA Water Technical Standard TS 0620.

The material shall be clean with 100% passing a 4.75 mm sieve and not greater than 5% passing a 0.075 mm sieve, and such that it can be satisfactorily and economically compacted in the dry state. NOTE that sand backfilling can only be used on trenches outside the embankment.

6.1.3.4 Trench backfill within embankment footprint

The embankment footprint shall include the area on the plan that the embankment cut and fill occupies (after stripping the unsuitable materials), plus an influence zone which shall be determined using a horizontal distance outside of the embankment toe on either side which should be the greater of the following items:

- two times of the apparent height of the embankment
- the length of cut section (shown as "D" in following figure) in upstream side
- 5 m in downstream side.

Figure 6-1 below schematically shows the extent of embankment footprint for a typical cut/fill EBS for pipe embedment purposes.

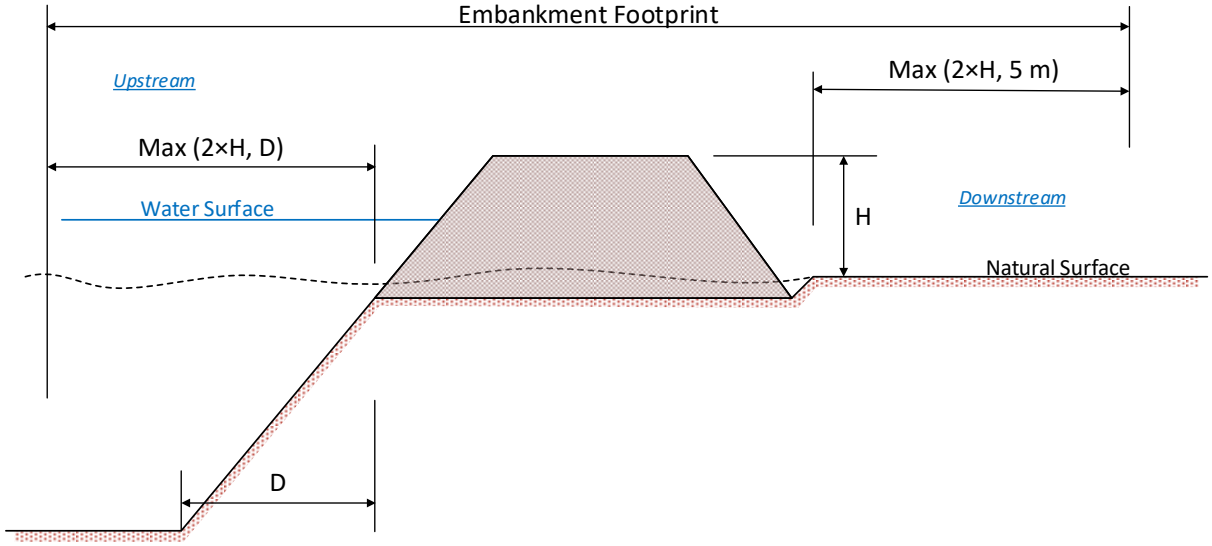

Figure 6-1: Extent of embankment footprint for a typical cut/fill EBS

Within the embankment footprint as determined above, the backfill of the material for embedment of the pipe shall be selected using a risk based approach.

Based on the risk profile of the EBS, the following trench backfill shall be provided within the embankment footprint:

For Low Risk: Cement stabilised sand.

The sand material shall be equivalent to SA Water Technical Standard TS4. The sand shall be stabilised with 5% w/w GP cement.

Cement stabilised sand shall be supplied and placed in accordance with DPTI Specification for Controlled Low Strength Material: Part R09 Supply of CLSM. Construction method shall be suitable to prevent floatation of pipe work during backfilling.

For Medium Risk: Reinforced Concrete.

The grade of concrete and the required reinforcement shall be designed based on applied construction loads (e.g. compaction impacts), internal and external pressure. As minimum requirements the concrete shall be at least 150 mm thick with grade S15 or higher.

If the pipeline is located on the floor of the foundation excavation, the side slopes of the concrete embedment shall be no steeper than 1H:10V to encourage high contact pressures against the concrete surface. If the pipeline is located in a trench excavated below the floor of the foundation excavation, the concrete embedment shall be poured to the sides and top of the trench, making sure that a proper bond of concrete and trench walls is achieved.

For High Risk: Reinforced Concrete, plus filter collar in the last 1/3 length of the encasement length at the downstream side of the bank.

The design of the reinforced concrete for High Risk shall follow the same principals as those outlined for the Medium Risk.

The filter collar consists of a zone of filter material (usually sand) that completely surrounds a specified length of conduit and shall be designed by an experienced Dams Engineer to satisfy the filtration criteria based on particle size distribution of the base soil in accordance with "Geotechnical Engineering of Dams" (Fell, MacGregor, Stapledon, Bell, 2015). The minimum thickness of the filter collar is 450 mm perpendicular to the pipe; the actual thickness depends upon design requirements.

In situations that placing the filter collar against the concrete encasement is not practical (e.g. due to pipe trench located below the foundation excavation floor, or in renewal of the existing EBSs), a filter diaphragm can be used instead of filter collar. The filter diaphragm shall be designed by an experienced Dams Engineer, as a minimum it should be 1m thick, extending 1.5 W beneath the embedment zone, 3 W above and each side of the embedment zone, and extending 0.6 m beyond the excavated trench width, where W is the width of the pipe embedment zone (concrete) in plan. A filtered drainage outlet from the bottom of the diaphragm shall be provided to the EBS toe, leading to a downstream collection chamber.

The risk profile can be best determined based on consequence category of the dam failure, determined in accordance with ANCOLD guidelines, based on population at risk (PAR) or incremental potential loss of life (PLL) and considering the severity of damage and loss. The following table can be used to correlate the ANCOLD consequence categories with risk profile of the EBS for trench backfill purposes.

Table 6-4 – Risk Profile in Accordance with ANCOLD Guidelines

Risk profile of the EBS for selection of trench backfill	ANCOLD consequence categories of dambreak
Low	Very Low and Low
Medium	Significant
High	High A, High B, High C, Extreme

A simple assessment of the risk profile may also be achieved using a high estimate of the potentials and consequences, using the following table.

Table 6-5 – Risk Assessment Profile

Risk profile of the EBS for selection of trench backfill	Potential loss of human life	Economic, environmental, lifeline losses
Low	None	Low, generally limited to owner
Medium	None	Yes
High	Probable	Yes, but is not necessary to fall in this risk profile

Around and on top of the pipe embedment zone, the rest of the trench backfill shall have properties that are compatible with the adjacent embankment. Ideally, the earth material adjacent to the pipe embedment in low permeable zone of the embankment should be reasonably well graded, have a maximum particle size no greater than 13 mm, including earth clods, a minimum of 50 percent by weight passing a No. 200 sieve, and a plasticity index between 10 and 30 percent. The water content of the material in this zone should be between 1 percent and 3 percent wet of optimum.

Trenching through embankment and underlying foundation shall be battered and not benched. Battered side slopes will promote acting positive pressures on the contact face and will lessen the potential for differential settlement, vertical cracking and hydraulic fracture or piping.

Figure 6-2 below show an example of battered slope in pipeline trench within an embankment footprint.

Unless an advanced numerical simulation shows otherwise, excavated slopes in soil for pipe trenches should be no steeper than 1 vertical to 2 horizontal to facilitate adequate compaction and bonding of backfill with the sides of the excavation. This recommendation is appropriate for favourable soil properties. Flatter side slopes should be used for less favourable conditions. Excavation slopes of 3H:1V to 4H:1V are commonly recommended for unfavourable situations.

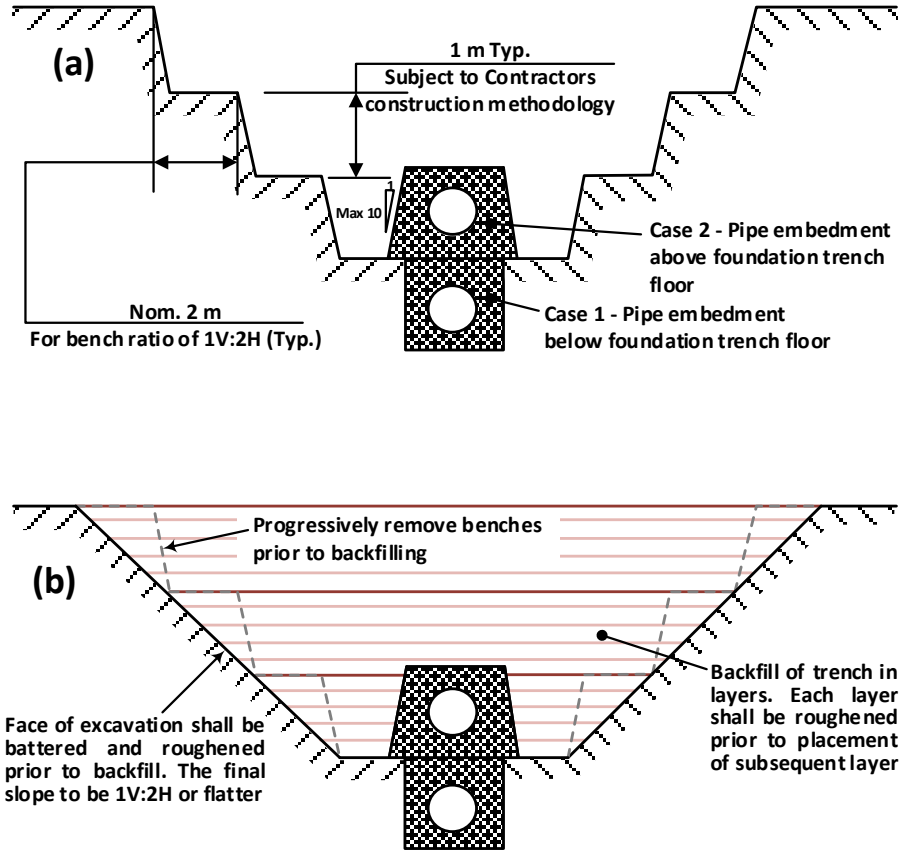

Figure 6-2: An example of (a) benched embankment excavation for pipe penetration, and (b) backfilling around and on top of the pipe embedment zone with progressive battering

The length of pipe lay within the embankment footprint shall be minimized, e.g. by setting the pipe alignments perpendicular to the embankment axis as much as practical. No bends, valves, or abrupt changes of pipe type or pipe diameter shall be allowed within the embankment footprint.

In all embankments, hoses or loose corrugated pipes without embedment shall not be laid, used or left active within the embankment footprint, as they pose unacceptable risk of burst, uncontrolled release of water, erosion, and potentially failure to the embankment.

Pipes laid in trenches within the embankment footprint shall be either welded or have solid joints, use of pipes which may require non-restraint joints (e.g. GRP with rubber joints) are not permitted.

6.2 Replacement of conduits (inlet & outlet pipework)

Generally, removal and replacement of existing inlet and outlet pipework through an EBS consists of draining the storage, excavating the embankment down to the existing pipework, stockpiling the material, removing the existing pipework, constructing a new inlet / outlet and possibly new entrance and terminal structures and reinstating the embankment material.

Note: *The guidance provided in this section is specific to covered and lined earth bank storages only and should not be used for embankment dam reservoirs; specialist advice should be sought for any works on embankment dam reservoirs.*

6.2.1 Excavation

Where excavations are required in soil foundations to replace existing inlet / outlet pipework, they should be wide enough to allow compaction of the backfilled material parallel to the pipework. They should also be approximately 2h:1v and stepped as per the Figure 6.1. The compaction of the back fill shall be undertaken with motorised compaction equipment, which is of suitable geometry to allow its load-transferring wheels or drum to work against the structure. The compaction requirements shall be the same as for a new embankment.

6.2.2 Removal of existing pipework

Once the embankment has been excavated to the invert of the existing pipework, the pipework can be removed. The removal of the existing pipework may also include the removal of the entrance and terminal structures due to deterioration or to ease the construction of the replacement structures.

Where the removal of the existing pipework and associated structures is considered difficult and expensive, the existing pipework may be abandoned by backfilling the pipework with grout and installing new pipework at a different location.

A suitably qualified engineer or engineering geologist should carefully observe and document the excavation required for the removal of the existing pipework to confirm that any damaged embankment or foundation material have been removed and / or treated prior to construction of the new pipework and replacement of embankment materials.

6.2.3 Reinstatement of the embankment

6.2.3.1 Compaction considerations

The soil removed from the embankment to allow the removal of the existing pipework is frequently re-used to backfill the excavation in the embankment. However, the excavated material should be subjected to the same compliance testing as would be required for imported material, prior to inclusion in the embankment.

The Designers and Contractors should evaluate the water content of the excavated material and determine if drying or wetting is required for acceptable re-use and placement of the material at optimum moisture content.

The excavated slopes in the embankment may remain exposed to the elements for a period of time before they are backfilled. During the works the weather may be hot and dry, which could lead to desiccation to considerable depths. Before backfilling of the excavation in the embankment, any desiccation cracks in the existing embankment shall be removed and the

embankment surface moistened. It is recommended that any remedial works to the excavated slope are undertaken immediately before backfilling is ready to take place. Likewise, if the excavated embankment is exposed to uncontrolled surface run-off during prolonged periods of rainfall damage may occur. Remediation of the saturated excavation will be required, prior backfilling.

6.2.4 Zoning

Generally EBS's are not constructed using zoned embankments. However, if the pipework is being placed in a zoned embankment where a central core is substantially different in properties than the embankment shoulders, the backfill for the pipe work should coincide with the zoning of the embankment.

6.2.5 Summary of design considerations

The following section summarises design considerations, when replacing existing pipework through / below an EBS:

- Earthworks materials used to reinstate the embankment should be tested by the same methods that would be used for a new embankment
- Earthworks materials used to reinstate the embankment should usually be placed slightly wet of optimum water content, to improve their flexibility and resistance to cracking and arching
- Where desiccation or saturation of the exposed excavation occurs, it is essential that any desiccation crack or low strength saturated materials are removed over their full extent
- Prior to placing embankment material adjacent to the reinstated pipe work, the encased concrete must have attained its design strength
- Earthworks material immediately adjacent to the reinstated pipe work should be compacted, so that no layers of material with permeability higher than in the adjacent material extend in an upstream and downstream direction along the pipe
- The elevation of the earthworks material should be maintained at approximately the same level on both sides of the conduit during backfilling. This will help to prevent lateral movement of the pipe caused by unequal compaction energy applied to the side of the pipe
- High trafficked areas need to be ripped prior to placement of earthworks materials. This will aid the removal of tension cracks and moistening of surface before placing subsequent lifts, to prevent smooth surfaces between lifts
- Compaction adjacent and over the encased pipework must proceed with caution as not to damage the pipework. Hand or remote operated compaction (tampers or wacker plates) may be required for the initial layers to cover the pipework.

6.2.6 Micro-tunnelling and Horizontal Directional Drilling

SA Water has a requirement for the inlet and outlet pipes to be encased in reinforced concrete. Therefore, micro tunnelling and horizontal directional drilling (HDR) are not suitable for use through the embankment. Micro-tunnelling and HDR are alternative methods that are sometimes used to install pipes below embankments. Both methods have difficulties with obtaining a watertight seal along the conduit and can potentially disturb the embankment during installation. Where these methods are used it is recommended that they are only installed in natural ground and not through the body of the embankment.

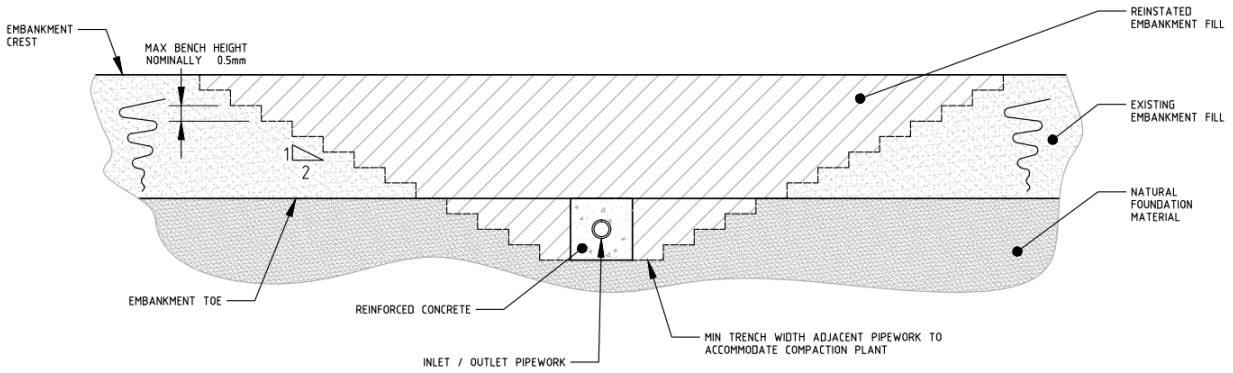

Figure 6-3 : Example excavation through the embankment to replace inlet / outlet pipework

6.3 Access road requirements

6.3.1 General

Unless stated otherwise instructed by SA Water, the Contractor shall include in the design documentation the modification of existing access roads or tracks including embankment crest roads of the existing storage. All new storage development shall include access road design suitable for SA Water's vehicular equipment, construction vehicle and any permitted vehicles specifically identified by SA Water.

Depending on the site specific requirements, the access road shall be granular pavements sealed with asphalt or equivalent bituminous surfacing. The design of pavement shall last for a minimum of 10 years.

6.3.2 Typical road section

The access road and embankment crest tracks, as a minimum shall be provided with a minimum carriageway width of 4m suitable for single lane roadway, clear of any liner or cover system including anchor beams and signage. The road base materials shall be conforming to the requirements of AUSTROADS and as a minimum shall be equivalent to DPTI PM1/20QG base-coarse with the properties included in the table below.

A minimum cross-fall of 2% shall be provided to facilitate free draining of the road surface.

Table 6-6 – DPTI PM1/20QG Base-Coarse Road Base Materials Properties

TEST PROCEDURE	MANUFACTURING TOLERANCE [Grading based]	
QUALITY CONTROL TESTS		
Particle Size Distribution **TP134**	Sieve Size (mm)	Percentage Passing
	53	
	37.5	
	26.5	100
	19	95 – 100
	13.2	77 – 93
	9.5	63 – 83
	4.75	44 – 64
	2.36	29 – 49
	0.425	13 – 23
	0.075	5 – 11
AS 1289.3.1.2	Liquid Limit	Maximum 25%
AS 1289.3.3.1	Plasticity Index	Minimum 1% Maximum 6%
AS 1289.3.4.1	Linear Shrinkage	Maximum 3%
AS 1141.23	LA Abrasion Grading 'A'	N.A.
AS 1141.23	LA Abrasion Grading 'B'	Maximum 30%

The figures below show the example typical road cross-section of the embankment crest road with one section showing the interface with the new and existing site services.

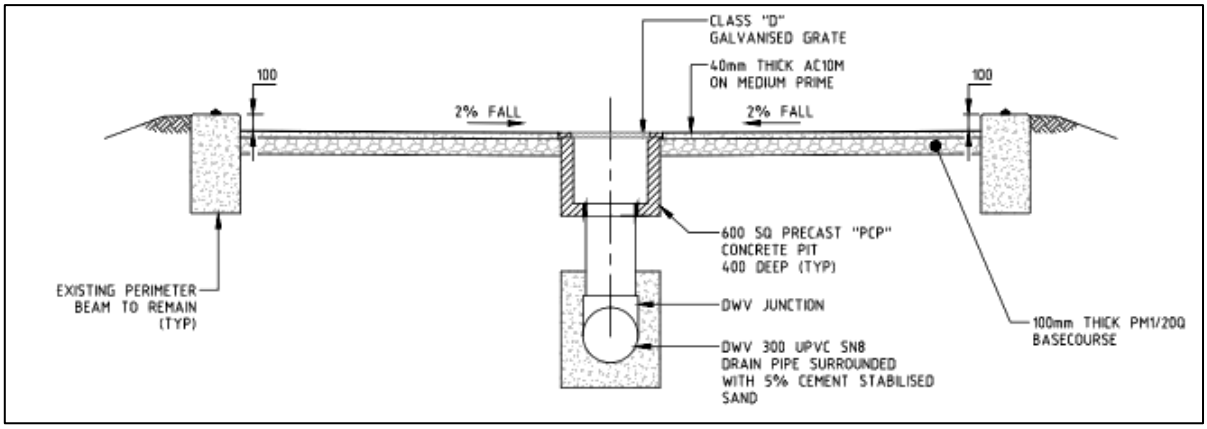

Figure 6-4 : Example embankment crest road section between storages.

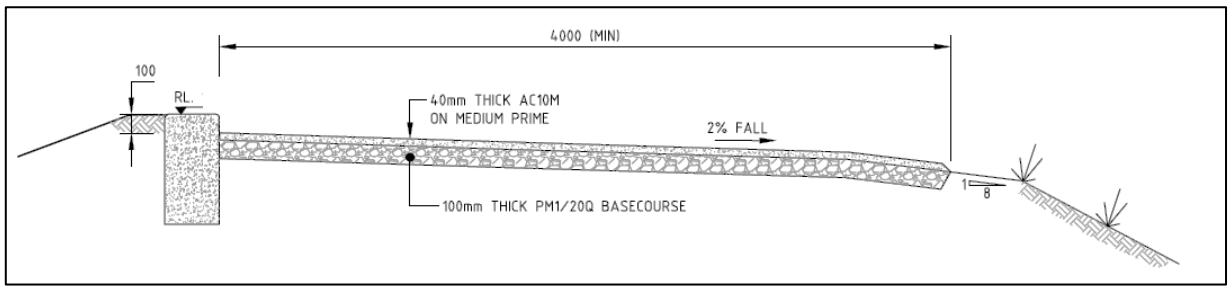

Figure 6-5 : Example embankment crest road section

6.3.3 Design for vehicles

All vehicles expected to access the storage site shall be able to safely negotiate without damaging the site infrastructure such as pavement, kerbs and similar roadside furniture. The design vehicle to be considered for the access road pavements shall be in accordance with AUSTROADS and as a minimum includes the following:

- Passenger vehicles
- Service Vehicles
- Single unit truck
- Construction equipment

The access of prime mover or semi-trailer including B-doubles shall be confirmed with SA Water prior to commencing design documentation and shall form part of the basis of design.

6.3.4 Requirements for asphalt pavements

The supply and construction of asphalt pavements shall comply in strict accordance with the requirements of the DPTI Specification Part R27 and Part R28, respectively including all future amendments current at the time of project delivery.

6.4 Drainage requirements

6.4.1 Rainwater removal system

Floating covers require rainwater removal systems to prevent build-up of water on the covers. It is SA Water's preference that off cover self-priming pumps are used, where head differences permit their use. However, on cover submersible pumps have historically been adopted for EBSs on the SA Water system.

The rainwater removal system shall be adequate to remove rainwater during 20% Annual Exceedance Probability rainfall events such that there is no dispersed ponding greater than 25 mm deep 5 days after the rainfall event.

Access to this rainwater removal system shall be easily accessible at all storage levels. Consideration shall be given during design to minimise the need for personnel to access the cover to maintain the rainwater removal system. Consideration shall also be given to the safe maintenance of drainage channels in the cover.

Covers for rectangular storages should typically drain via in-built channels to a central channel. This central channel shall have a sump / pump well fixed into a buoyant float platform in the cover at either end. These sumps shall be suitable to secure the pump suction line or submersible pump.

Where the pumping system includes off cover pumps (heavy duty diaphragm pump or approved equivalent), complete with all suction and discharge pipework, and fittings. The pumps will be controlled via the PLC. Each pump unit shall be able to operate independently of the other and automatically when the storage is at any level above minimum operating level. Stormwater sump level set points shall be confirmed with the Superintendent's Representative during the detailed design phase. All storm water pumps shall have separate individual manual start and stop controls at the local switchboard (Refer to Section 8.1and 9.4.4 for details).

The suction line shall be flexible, and laid on the floating cover with suitable measures to prevent chafing of the cover. Any protrusions (joints, fittings etc.) shall be suitably wrapped to further protect against chafing of the cover.

Where off cover pumps are adopted they shall be located adjacent the top of bank / access road for easy access. Pumps and associated controls, power cables and pipework shall be adequately protected from exposure to the elements.

However, if on-cover pumps are adopted the system shall include submersible pumps (with integral float level switches), complete with separate discharge hoses, hose couplings, and submersible power cables. Each pump unit shall be able to operate independently of the other and automatically when the storage is at any level above minimum operating level. Stormwater sump level set points shall be confirmed with the Superintendent's Representative during the detailed design phase. All storm water pumps shall have separate individual manual start and stop controls at the local switchboard.

The discharge hose shall be an approved flexible tube or hose laid on the floating cover. Any jointing clamps shall be suitably wrapped to prevent chafing of the cover.

Where on cover submersible pumps are adopted the electric cable providing power to the pumps and the discharge hose shall both be in a continuous length without jointing, and shall be suitable for exposure to the elements.

Stormwater shall be discharged to the site stormwater system for reuse or disposal (refer Section 6.4.4).

6.4.2 Underdrain system requirements

Storage liner underdrain systems are required to drain water from under the liner due to liner leaks or groundwater intrusion. The underdrain system shall be designed in segments that are independently drained in order to isolate potential leaks in the liner system.

The design flow rate for the underdrain system is to be assessed by the designer during design development and approved by the Principal prior to final detailed design. Factors influencing design flow rates for the underdrain system include:

- Liner design
- Liner material
- Local hydrogeology
- Geotechnical conditions

Each segment's underdrain system shall be self-contained and may consist of slotted pipe connected to a discrete underdrain delivery pipe to a pump system delivery pipe containing a submersible withdrawable pump complete with discharge hose, hose couplings and submersible power cable. The submersible pumps shall be accessible from access track level via hauling up through a duct or similar arrangement.

Each submersible pump unit shall be able to operate automatically via sensor control or other mean of mechanism to discharge water in the pipe. (Refer to Section 8.2 for details)

Discharge shall be to a sampling pit at access track level through a duct under the liner extending up to and through the concrete ring beam. At a minimum the discharge line from each segment shall have fittings suitable to measure and sample the flow at the access track level. The sampling pit shall drain to sewer if available. If a suitable sewer connection is not available discharge to the stormwater system may be appropriate as approved by the Principal, the relevant environmental agency and local government authority.

The electric cable providing power to the underdrain system pumps and the discharge hose shall be submersible (refer to pump manufacturer for IP Rating) and of continuous length without jointing (Refer to Section 9.4.6 for details).

6.4.3 Embankment crest and toe drainage requirements

Stormwater shall not be left to pond on the embankment crest and should be captured and discharged to the wider stormwater network of the site. Where there is an embankment crest road between storages the road shall be graded to a central drain and picked via grated inlet pits (See Figure 6-3). On embankment crest roads adjacent batters the road shall be constructed of suitable material and camber to ensure stormwater drains freely across it and down the batter (See Figure 6-4). Care should be taken not to concentrate the flow. Where concentration of flows cannot be avoided care should be taken to provide adequate erosion protection to the batter face (See Section 6.1.2).

Stormwater runoff shall be collected at the toe of the embankment where necessary to prevent erosion of site access roads or damage to infrastructure.

6.4.4 Storm water management

Where possible site stormwater should be contained within the SA Water site.

Designers shall work with SA Water to identify potential on site storage options for possible reuse, including but not limited to;

- detention basins
- abandoned reservoirs
- storage tanks
- storage cells.

Should no storage and/or reuse options be deemed viable, stormwater shall be either disposed of via infiltration trenches or discharged offsite in a controlled manner in consultation with, and with the approval of adjacent landowners as required.

6.5 Inlet and outlet work system requirements

6.5.1 General

Grates are to be installed at inlets and outlets, and should be constructed of GRP or other durable material not susceptible to corrosion. Grates are to be designed based on reducing safety risk to personnel, and to prevent damage to the cover in the case where the cover comes into contact with the inlet/outlet.

Pipework that is constructed through embankments must be fully concrete encased with reinforced concrete. The minimum cover to any side of the pipe is to be selected based on the size of the pipe and the expected loading of the embankment, but is to be a minimum of 200 mm.

The pipework shall be designed such that the liner can be fixed and sealed to a reinforced concrete surround.

Pipe materials are to be selected in line with SA Water TS 0522 and Authorised Items for Water Reticulation Systems. MSCL and Polyethylene should be considered as preferred due to their ability to take small amounts of movement without failure and the ability to form welded joints. Pipe joints are to be proved to a high level of certainty to minimise the risk of leaks at joints, for instance NDT of every welded joint prior to pressure testing.

Appropriately designed cutoffs are to be included to reduce any flow paths created by the presence of pipework.

Inlet or outlet structures are to be positioned no closer than 2m to the toe of the embankment.

All pipework is to be graded at a minimum grade of 1% to aid draining of pipes. Where significant settlement is expected, this is to be taken into account for the final pipe grades.

Disinfection of all pipework and valving is to be undertaken as per usual SA Water new assets. Refer to WQ_G35: Code of Practice – Disinfection of Water Supplies and WQ_P034: Mains, Valves & Fittings – Disinfection.

6.5.2 Existing inlets or outlets

Where inlet and outlet pipework or other structures exist, their suitability to work with the proposed liner and cover is to be assessed early in the project.

New connections to existing live mains should be made only when the new works have been constructed and satisfactorily pressure tested to SA Water approval. A 'Link-in Plan' shall be provided to SA Water to provide assurance that there is a robust system in place to ensure continuity of supply to customers, with contingency plans in place for unlikely incidents that could occur.

6.5.3 Hydraulic requirements

Inlets are to be designed for maximum flows. Depending on water quality considerations, a diffuser may be included on the inlet. The design maximum velocity at the inlet is not to exceed 2.0 m/s.

Outlets are to be designed for maximum outflows and sized such that the design maximum velocity does not exceed 2.0 m/s for a gravity outlet, and reduced to 1.2 m/s for a pumped outlet, dependent on specific pump requirements. Should an outlet riser / tower be required, special consideration must be given to how damage to the cover will be prevented during storage emptying. As such, this is generally not preferred. Where air entrainment is considered a risk, anti-vortex structures are to be incorporated, and designed to integrate with the liner without any increased risk of leakage at this point.

A separate scour is to be provided where possible to enable complete emptying of the storage. The scour should be designed to enable emptying from minimum water level within 8 hours, or as specified by SA Water depending on the size of the storage and location specific requirements. Scours must discharge to an approved location with appropriate erosion protection designed for the discharge of the full volume of the storage.

6.5.3.1 Valve requirements

Accessibility of all valves and associated equipment is to be considered as part of the safety in design process. Where possible, access points are to not be located within the embankment zone. Access points, pits and covers are to be installed to SA Water standards. Security of valves and

especially security considerations for above-ground valving are to be included to meet SA Water standards.

Valves for throttling flow are to be resilient seated butterfly valves in accordance with SA Water's approved valve list. Isolation valves are to be gate valves. Where risk of backflow exists, a suitable non-return valve is to be included on the outlet.

Flowmeters should be included on both inlets and outlets to provide an additional check for any major leakage. Flowmeters are to be selected to meet SA Water standards.

6.6 Overflow system requirements

Overflows are to be designed to pass a minimum of 120% of the maximum expected inflow rate, or as agreed with SA Water. Level sensors will trigger the full level alarm prior to the overflow operating with an appropriate allowance for operator attendance. The overflow must discharge to an appropriate area based on environmental and safety considerations.

6.7 Perimeter ring beam requirements

6.7.1 General

Given that all storages are exposed to wind action, the cover and liner shall be provided with suitable anchorage system to protect them from the tension force that could develop in the geomembrane. The perimeter ring beam is typically provided to resist sliding and uplift against the tension force developed in the geomembrane during high wind conditions. The interface between geomembrane and concrete when effectively sealed prevents air going to the underside of the liner, hence eliminating instability of the liner and cover.

6.7.2 Strength and serviceability design

The perimeter ring beam if provided shall be designed in accordance with the minimum requirements of AS3600 Concrete Structures for both strength and serviceability limit states. Any reuse of existing perimeter beams shall be assessed to confirm that residual capacity is adequate for new liner and cover.

The concrete shall have the minimum durability conforming to the requirements of SA Water Technical Standards TS 0710.

The beam reinforcement shall be determined based on the applied actions and the requirements for shrinkage and temperature reinforcement shall be added accordingly.

The perimeter ring beam shall be provided with expansion joint at a spacing determined from the thermal behaviour of the concrete structure. The joint shall be provided with sealant and galvanised dowels for load transfer across joint and to maintain beam alignment.

The figure below shows an example cross-sectional and elevation views of a typical perimeter ring beam.

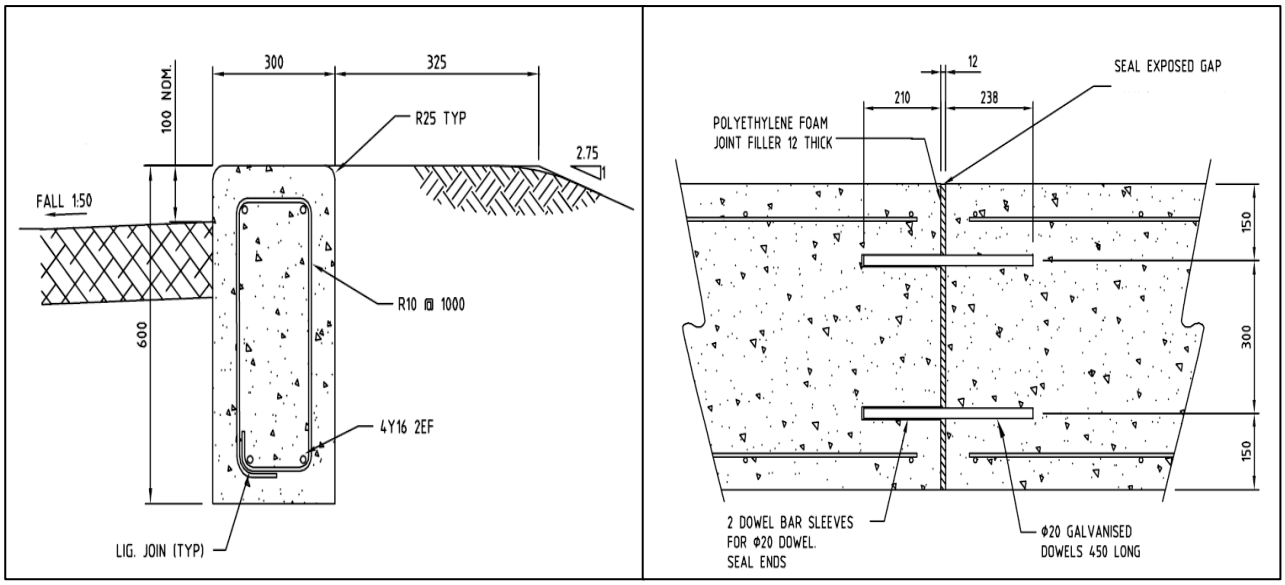

Figure 6-6 : Example perimeter ring beam section and joint detail

6.7.3 Stability

To resist sliding and uplift instabilities caused by the wind action, the size of the perimeter ring beam shall be adequately determined based on the calculated tension force in the geomembrane. The anchor resistance for instabilities are typically provided by gravity or self-weight of the perimeter ring beam.

A global factor of safety of 1.5 shall be applied when sizing the concrete perimeter beam to secure the liner and cover.

When excessive size of concrete is required, the Contractor may consider the use of tensile members that are driven or screwed into the ground as anchoring system.

6.7.4 Fixing bar and fasteners

The ends of liner and cover shall be securely attached to the concrete beam with the use of stainless steel anchors where the size, embedment and spacing are determined based on the calculated tension force in the geomembrane. The edge treatment of the liner and cover shall be in accordance with the Manufacturer's recommendations to prevent tearing of geomembrane during pull-out. A continuous strip of stainless steel plate with rubber strip shall be used to tightly seal the interface between concrete and geomembrane preventing ingress of air to the underside of the liner.

The figure below shows the typical anchorage system of a liner and cover securely fastened to the perimeter ring beam.

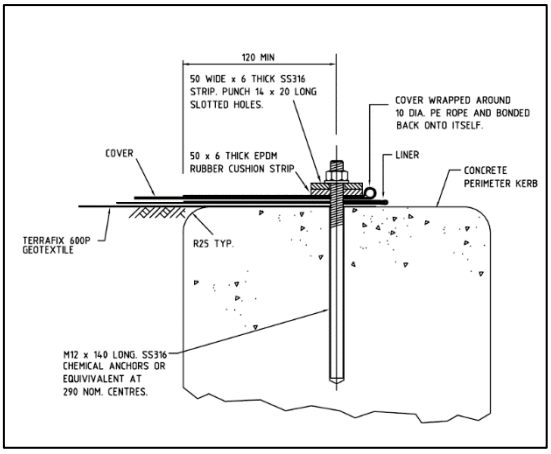

Figure 6-7 : Example anchorage detail

7 Water Quality

7.1 General considerations

The Designer shall consider the preservation of stored water through all stages of the design, manufacture, installation and commissioning process as well as through expected long term future operational and maintenance activities so that the water can remain fit for its intended use.

Key issues to be considered by the Designer include materials selection, elimination of contamination risks as well as management of potential changes in water quality whilst in storage, primarily those associated with water age including temperature and stratification, loss of residual and potential growth of both non- pathogenic and pathogenic microbiological organisms.

7.1.1 Material selection

All materials that may come in contact with the stored water shall be selected to ensure that the water quality is not adversely affected. In this context materials include the liner and cover, associated appurtenances, factory and field jointing materials including adhesives, fusion agents, solvents or cleaners as well as repair materials that may be needed after practical completion.

The materials

- Should be impermeable under normal operating conditions
- Should not include extractable components that, when dissolved in water could exceed the applicable water guidelines, or create and adverse aesthetic effect (i.e. colour, taste or odour) due to reaction with the water, including in any chlorine or chloramine residual disinfectants that may be present
- Should not support the growth of bio-films, harbour bacteria or promote the growth of fungi or similar biological species.

As a minimum for drinking water applications, the membrane liner and cover and appurtenances shall be compliant with AS/NZS 4020.

All hatch and sample port covers, including support frames, hinges and locking mechanisms, shall be fabricated of 316SS.

In selection of the materials, the designer shall consider the range of water qualities expected. This shall include the range of disinfection type and ranges expected for initial disinfection, normal operation as well as disinfection of equipment and diver suiting that may lead to abnormally high local concentrations of chlorine.

7.1.2 Preservation of water quality

The Designer shall consider the following aspects to maintain water quality within the storage and / or modify it prior to re-entering the downstream water network.

- Separation of the inlet and outlet
- Orientation of inlet and outlets to naturally enhance mixing within the storage
- Use of internal flexible hanging baffles to direct flow within the tank and prevent short circuiting
- Provision of mechanical or hydraulic recirculation and mixing systems to prevent thermal stratification and to prevent dead zones from occurring
- Disinfection dosing within the reservoir and / or at the reservoir outlet.

7.1.3 Contamination prevention

Attention shall be given to identify and mitigate contamination risks; the Designer shall consider risks and design to eliminate or mitigate risks from:

Surface water flow flows (Watertight liner cover edge seal design,

- Rainwater ingress (design of cover hatches and vents)
- Vermin / backflow (overflow and cover vents)
- Inspection and maintenance activities (diver entry, ROV, sampling, in situ repairs).

Air vents and supporting floats shall be designed to ensure the vent ports and hatch lids remain above water level, including surface water, at all times. Vents shall inhibit the introduction of air beneath floating covers, and be fitted with screens to prevent the ingress of vermin and insects.

Designer shall consider inverted syphon overflows with water seals where practical.

7.2 In storage mixing requirements

7.2.1 General

In storage mixing will be required to reduce the risk of stagnant zones or short-circuiting pathways, age of water / loss of chlorine residual that typically occur in large reservoirs as exacerbated by the geometry of the system and temperature stratification. Effective mixing/circulation throughout the EBS can significantly extend the life of the water by maintaining water quality over time while reducing treatment and storage costs.

7.2.2 Computational fluid dynamic modelling

Computational Fluid Dynamic (CFD) modelling is the preferred analysis and predictive tool to model flow of water within the EBS and demonstrate the level of mixing/circulation achieved. CFD model outputs shall include water age variations through the reservoir which may be used to infer chlorine decay and predict chlorine variability in outflows. CFD modelling outputs shall be used to demonstrate that chlorine residuals can be maintained within the reservoir, and that target chlorine levels will be achieved at the outlet.

CFD modelling shall be undertaken at the detailed design stage to demonstrate that the preferred mixing method will be effective and meeting the requirements of SA Water. The following operational scenarios are to be included in the CFD modelling:

- Reservoir at TWL and minimum and maximum flow
- Reservoir at MOL and minimum and maximum flow
- Modelling the effects of chlorine boosting.

CFD models shall include the geometric protrusions caused by rainwater channels and associated ballasted weights. The CFD modelling will also be used to understand the following aspects within the EBS.

- The effect of the mixing system to avoid stagnant zones associated with stratification and low mixing velocities
- To understand how quickly the operator can expect to return the disinfectant concentration in the EBS back to acceptable levels
- A tracer model shall be undertaken to enable the operator to predict the dose/response following an 'out of control' event
- A tracer CFD shall be performed to provide an indication of the deviation from an entered setpoint over the course of time. The entered setpoint, deviation tolerance and acceptable timeframe to achieve this setpoint will be defined in the Technical Specification.

While at times it can be difficult to predict what a suitable mixing velocity should be to achieve the above objectives, SA Water experience indicates that average mixing velocities > 1 cm/s throughout the entire storage volume is deemed sufficient. A successful CFD output would incorporate a timeline of outputs and demonstrate that > 90 % of the velocity exceeding 1 cm/s.

Note: *CFD modelling is not required for recycled water storages; this is specific to potable water storages only.*

7.2.3 Passive mixing (baffles)

Internal baffle curtains combined with directed inlet flows can be used to extend flow paths between the inlet and outlet and provide effective mixing of smaller EBS. However, this method becomes less effective as the size of the EBS increases.

7.2.4 Active mixing (powered mixers)

Powered submersible mechanical mixers shall be used for larger EBS structures where CFD modelling has indicated that baffles alone would be ineffective. Mixers shall be of proven effectiveness in similar structures, and shallow geometries.

7.3 Disinfection injection and monitoring requirements

7.3.1 Disinfection considerations

Reservoirs shall incorporate provision for disinfection. In selecting the type of disinfectant and disinfectant system the Designer shall take the following into consideration:

- Initial disinfection by disinfectant after liner / cover installation and testing and prior to the reservoir being brought into service
- Maintaining or boosting disinfection levels (chlorine or chloramine systems) during normal operation (i.e. if there is a need for permanent facilities)
- Potential need for breakpoint chlorination (chloraminated systems only), which would normally be done with the reservoir off line.

The disinfection method shall take into account:

- The maximum allowable chlorine/chloramine levels permitted to come in contact with the liner, cover and appurtenances, which if exceeded could cause damage or void warranties as well as
- Capacity of reservoir, reservoir characteristics and mixing design
- Likely dose frequency and duration.

Disinfection is required for all new or refurbished storages / tanks prior to collecting analytical samples. Unless approved otherwise by the Superintendent all commissioning activities should be done with the storage / tank isolated from the distribution network and all commissioning water held whilst awaiting analytical results.

7.3.2 Disinfectant types

SA water typically uses un-stabilised calcium hypochlorite, sodium hypochlorite and chlorine gas in various applications.

Table 7-1 – Disinfectant Types

Chlorine form	Application	Comment
Calcium Hypochlorite Tablets	Irregular in reservoir boosting, breakpoint chlorination	Requires mechanical mixing
Sodium hypochlorite	Irregular or regular in reservoir boosting at mixer(s) or recirculation systems, breakpoint chlorination outlet booster chlorination	Scaling risk if dilution / carry water is provided Compatible with recirculation mixing and reservoir outlet boosting Compatible with permanent or portable considerations Loss of strength when stored for long periods in hot conditions
Chlorine gas	Outlet booster chlorination In reservoir boosting by recirculation	Only suited for permanent facilities. Only suited for recirculation mixing and reservoir outlet boosting Gas risk attended / remote sites

On some occasions SA Water may need to boost ammonia levels in reservoirs and may use anhydrous or aqua ammonia for this purpose. SA Water will confirm whether the design needs to incorporate permanent or provision for temporary ammonia boosting facilities.

Table 7-2 – Ammonia Types

Ammonia Form	Application	Comment
Anhydrous gas	Regular in reservoir boosting at mixer(s) or recirculation systems, breakpoint chlorination outlet booster chloramination	Scaling risk if dilution / carry water is provided. May require softened water/ duplicate dosing lines. Only suited for permanent facilities
Aqua ammonia	Irregular or regular in reservoir boosting at mixer(s) or recirculation systems, outlet booster chloramination	Scaling risk if dilution / carry water is provided; may require softened water/ duplicate dosing lines. Compatible with recirculation mixing and reservoir outlet boosting Compatible with permanent or portable considerations

Chloramination is also an area where rapid mixing can be very important, and the designer must consider the specific form of chlorine, pH, the order of chemical dosing and the degree of mixing required.

At lower pH, the formation of di-chloramine is much faster, and consequently low pH should be avoided.

In particular, adding chlorine gas solution (which has low pH) to water after ammonia has been added, or to chloraminated water, can result in excess chlorine concentrations locally near the point of injection resulting in the formation of di- and tri-chloramines, which leads to risk of unpleasant odours (tri-chloramine is very objectionable and highly volatile) as well as excessive chlorine use; further reactions with chlorine may proceed through to breakpoint chlorination yielding nitrate and nitrogen gas by different pathways. These reactions are irreversible and lead to an increase in the amount of chlorine and ammonia required to achieve the target mono-chloramine residual.

Rapid mixing of chlorine gas (solution) is essential to mitigate these risks.

For a chlorinated system, a minimum C.t of 150mg.min/L is required to achieve disinfection. Free chlorine residual of drinking water being supplied to consumers must not exceed the ADWG health value of 5.0 mg/L.

For chloraminated supplies where there is evidence of a secure source water supply (e.g. groundwater with no previous history of contamination and evidence of a secure catchment) or a filtered chloraminated supply, a minimum C.t of 300 mg.min/L can be applied. Chloramine residual of drinking water being supplied to consumers must not exceed the ADWG health value of 4.1 mg/L.

Where unfiltered chloraminated water is used or where the above restrictions cannot be achieved, a minimum C.t of 2000 mg.min/L must be achieved to achieve inactivation of Giardia.

Note: *This section is specific to potable water storages only. Disinfection requirements for recycled water storages shall be confirmed by SA Water.*

7.3.3 Monitoring

Where agreed or required by SA water quality monitoring stations shall be installed to continuously monitor free or total chlorine. Where chloramine is used the analyser(s) shall continuously monitor

free and total chlorine as well as free ammonia present. Unless specified by SA Water, continuous monitoring of recycled water is not required.

7.4 Water quality sampling requirements

7.4.1 Sample point locations and type

In selecting the number and position of sampling points the Designer shall consider the reservoir retention time, incoming chlorine levels, chlorine decay rates as well as the reservoirs specific geometric configuration such as its shape/ area, operating depths, inlet and outlet location, potential stratification, internal baffling, mixing and disinfection top up dosing.

As a minimum sampling points shall be provided to the inlet and outlet, and at least two locations within the reservoir for reservoir capacities up to 100ML. An additional sample location shall be provided for each 50ML capacity increment or part thereof.

Sampling provisions will include facility to enable grab samples by a manual device, grab samples by portable pump, as well as sampling at on- line analysers. Permanent sampling points shall enable aseptic techniques to be used for bacteria sampling and incorporate an isolation ball valve and tail pipe suitable for sterilisation by flaming prior to sample collection. The location and type of sampling and monitoring stations shall be as agreed with SA Water.

The Designer shall document the agreed sample stations including locations, type, suction depth below cover etc.

7.4.2 Sampling prior to entry into service

After cleaning, leakage testing and disinfection, water quality shall be tested prior to being put back into service.

The water quality within the EBS shall meet the SA Water standards and testing shall be undertaken by Australian Water Quality Centre (AWQC). This will also include organic testing (such as BTEX or NDMA) that the reservoir fabrication or jointing material is not leaching chemicals. Should the liner or cover fail any of the tests, flushing, cleaning refilling and re-testing of the reservoir may be required at the Contractor's expense.

If water quality results indicate the water is not suitable for distribution, the water will need to be drained and flushed and not put into distribution.

7.4.3 Water quality

The general water quality to be provided to the liner / cover Contractor should reflect the expected range of potable or recycled water from the source supply. SA Water will provide the designer with typical / expected feed water quality parameters. These may include parameters that impact on materials selection (corrosion), or liner life (oxidants).

Table 7-3 – Water Quality Parameters

Parameter	Unit	Expected Incoming Quality	
		Range*	Typical*
Alkalinity as ($CaCO_3$)	mg/L		
Chloride	mg/L		
Chlorine – Free	mg/L		
Chlorine – Total	mg/L		
Monochloramine	mg/L		
Free Ammonia	mg/L		
Conductivity	µScm		
Sulphate	mg/L		
Fluoride	mg/L		
pH	pH units		
Calcium Hardness as $CaCO_3$	mg/L		
Total Hardness as $CaCO_3$	mg/L		
Turbidity	NTU		
Dissolved Organic Carbon	mg/L		
E.coli	No/100mL		
Coliforms	No/100mL		
Temperature	°C		

* SA Water to provide expecting incoming water quality parameters to the designer and manufacture of the floating cover and liner.

7.4.4 Testing

Prior to an EBS entering into service the water shall be tested for the following parameters (as a minimum). Additional parameters may be tested for as requested by SA water or as required to support the Contractors warranties. Both the inlet water quality and in-reservoir water quality are to be sampled.

Table 7-4 – Water Testing Parameters

Parameter	Unit	Application		
		Potable - Chlorinated	Potable - Chloraminated	Recycled
Chlorine – Free	mg/L	x	x	
Chlorine – Total	mg/L	x	x	
Monochloramine	mg/L		x	
Free Ammonia	mg/L		x	
Conductivity	µScm	x	x	x
Dissolved Organic Carbon	mg/L			x
Fluoride	mg/L	x	x	
pH	pH units	x	x	x
Turbidity	NTU	x	x	x
Colour	TCU	x	x	
Taste and Odour		x	x	
E.coli	No/100mL	x	x	x
Coliforms	No/100mL	x	x	x
Benzene, Toluene, Ethylbenzene, and Xylenes	mg/L	x	x	
NDMA	ng/L		x	x

8 System Functionality

This section outlines the minimum requirements for the functionality of the systems. This is to be further developed as per the project specific requirements.

8.1 Rain water removal pumps

The rain water removal system on the floating covers is to prevent build-up of water. Each system shall include a self-priming pump.

The rain water pumps are to operate independently from one another. The automatic start and stop operation is based on the level in the sump.

Each unit shall be able to operate in automatic mode when the storage is at any level above minimum operating level. Each unit will also be able to be operated in local manual mode.

The forms of control to operate the rain water removal pumps will include:

1) Automatic
2) Remote Manual
3) Local Manual

The rule of operation for the rainwater pump is outlined below as a guide for detail design. This is to be further developed to suit the design and specific site requirements.

Table 8-1 - Rule of Operation for the Rainwater Pump

Item	Operation	Action
1	Rainwater Pump Level Transmitter (High/Low)	Determines rainwater pump cut in and cut out operation.
2	Rainwater Pump Level Transmitter (High High)	Raises an Alarm on SCADA.
3	Thermal Overload	Thermal Overload will trip the pump in both Manual and Auto modes. The fault can be reset via Local Reset Button and remote reset via the PLC.
4	Reset Local and via PLC	Reset allows the pump to be started after a trip. (Thermal Overload)

Operators shall be able to adjust the alarm set points.

8.2 Underdrain pumps

The drainage system under the liner is designed to remove any water leakage from the liner or ingress of groundwater. The underfloor drainage system shall divide the storage into segments so that the location of the leakage, if any, can be identified and monitored easily.

Each underfloor drainage pump unit shall be controlled via the PLC based on the Hydrostatic Level. Each discharge pipe will also have a magnetic flow meter to calculate to the total discharge flow and volume.

Each unit shall be able to operate in automatic mode when the storage is at any level. Each unit will also be able to be operated in local manual mode.

The forms of control to operate the underdrain pumps will include.

1) Automatic - Controlled by PLC can be initiated by operators from the control room or on local HMI
2) Remote Manual - In remote mode the pump can be started via the HMI. This will operated continuously until stop signal is presented
3) Local Manual - In local mode the pump can be started and stopped via the push button on the local control station or at the Switchboard. It will appear as unavailable on SCADA.

The rules of operations for the underdrain pump are outlined below.

Table 8-2 - Rules of Operations for the Underdrain Pump

Item	Operation	Action
1	Underfloor Pump Level Transmitter (High/Low)	Determines underfloor pump cut in and cut out operation.
2	Underfloor Pump Level Transmitter (High High)	Raises an Alarm on SCADA
3	Underfloor pump Flow meter (High Volume)	When pumping volume exceeds a pre-set volume an Alarm is to be raised on SCADA.
4	Underfloor pump Flow meter (High and Low Flow)	When the underfloor pump is running, at minimum flow the pump will be tripped after an adjustable time delay. An alarm is raised on the SCADA.
5	Thermal Overload	Thermal Overload will trip the pump in both Manual and Auto modes. The fault can be reset via Local Reset Button and remote reset via the PLC.

Operators shall be able to adjust the alarm set points.

8.3 Mixers / Recirculation Systems

The Mixers / Recirculation system will generally be run in continuous mode. The operations of these systems are to be finalised based on the vendor provided operational requirements. Only the following signals are required to be configured in the PLC:

- Running and Fault conditions provided by the vendor package
- Start and Stop signals from the PLC to the vendor package
- Start and Stop signals from the Local Control Station to the vendor package
- Speed input (where applicable) via PLC and /or manual via VFD Driver
- Flow rate (where applicable) via PLC.

The forms of control to operate the mixer / recirculation system will include.

1) Automatic - Controlled by PLC can be initiated by operators from the control room or on local HMI
2) Local Manual - In local mode the mixer / recirculation system can be started and stopped via the push button on the local control station or at the Switchboard or at the relevant valve if hydraulically operated. It will appear as unavailable on SCADA.

8.4 Health monitoring and alarming

The following information shall be monitored and collected:

1) The operational mode and status of all field devices

2) The health of all communications networks and devices

3) The health of all analogue inputs

4) The health of all battery chargers

5) The health of all power supplies

6) The hours run.

The Contractor shall liaise with SA Water on which of these signals is to be treated as alarms and sent to the Central SCADA System.

9 Typical mechanical and electrical requirements

9.1 Approval process

The approval process is as per Section 2.5.

Evidence of regulatory compliance needs to be documented through:

- Electrical Safety Certificates for Equipment
- Proof of protective device co-ordination as per AS3000.

The SA Water reserves the right to engage a third party auditor to verify compliance with this Technical Standard during the design process.

9.2 Standards and general requirements

All electrical equipment, systems and installation methods shall comply with Australian Standards, the requirements of relevant statutory regulations, and the requirements of any relevant Codes of Practice.

All Electrical, Instrumentation and Control works are to conform to the requirements of SA Water's standard electrical specification - TS 0300 - The Supply and Installation of Low Voltage Electrical Equipment

9.3 General control and SCADA requirements

This section outlines the general control and SCADA requirements for Floating Covers and Liners of Earth Bank Storages.

9.3.1 System Architecture Requirements

The following as a minimum are required to develop the system architecture:

1. The system shall consist of the following key components:
    a. PLC
    b. RTU
    c. HMI
    d. Ethernet hubs.

    A RTU is to be installed in the situation where a new Switchboard is installed in a remote location. Configuring the RTU to connect to the existing telemetry system (if RTU is required);
2. If a new PLC is required, the Contractor shall configure the existing telemetry System to communicate with new PLC and RTU.
3. The architecture is to be developed by the Contractor and to be submitted to the SA Water prior to implantation and purchase of equipment.
4. The HMI communication is to be directly via the RTU back to the main SCADA. **SA WATER TO CONFIRM PREFRENCE**
5. The configuration, screens and function of the local SCADA system shall conform to the requirements of the Contractors prior approved Control Narrative.
6. Full information on the requirements for instrumentation, communication and control cabling is found in the standard electrical specification - TS 1000 - SCADANet SCADA and DCS systems.

7. Modbus communication is required to the flowmeters. If an RTU is installed the Modbus communication shall be via the RTU to the main PLC.

9.3.2 Logic system programming works

The Contractor shall engage a SA Water approved Automation Panel Integrator for all the software, graphics development and integration of the new PLC, RTU to the existing system.

9.3.3 Logic controller software programming

The logic controller systems shall operate in the manner described in the drawings and Control Narrative.

The programming structure and format shall comply with the Principal's standard requirements.

The operation and performance of all equipment and software shall be tested prior to delivery to site. Documented evidence of testing must be made available to the Principal on request. The program shall include tests to sufficiently verify that all equipment is complete and that it operates and performs in accordance with the requirements of the Specification. Completed test report sheets shall be provided to the Superintendent.

The logic controller program shall be fully documented with comments for each input/output, data address and rung etc. A copy of the completed program, with all documentation, shall be submitted to the Principal on CD or USB, and in hard copy, as soon as practical but not less than 3 weeks prior to commencement of commissioning. A further copy will be given to the Principal as on a USB key and attached with a keychain to the cubicle.

The logic controller shall be programmed using a version of the programming software fully compatible with that owned by the Principal.

9.3.4 General programming requirements

The Contractor shall specify and develop all software and graphics as per SA Water Standard TS 1000 SCADANet SCADA and DCS systems.

All software programming for both the PLC and SCADA systems shall be done in a software environment version that is accepted and compatible with the environment versions used by the Principal.

9.3.5 Documentation

All relevant documentation pertaining to the type of equipment to be installed and the methods and configuration of how the equipment will be installed, shall be submitted to the Principal for prior approval before any onsite works commence. This documentation should include the Contractors drawings and, where applicable, be to the Principal's standard drawing format.

Refer work instruction TS 0100 Requirements for Technical Drawings and TS 1000 SCADANet SCADA and DCS systems.

All documentation, including drawings, shall be supplied as per the Principal's work instruction

9.4 Instrumentation and Electrical Equipment

All instrumentation and electrical equipment shall be designed and installed as per TS 0300 - The Supply and Installation of Low Voltage Electrical Equipment, unless otherwise specified in this specification or with prior approval from SA Water.

9.4.1 Flow meters

The flow meters are to be magnetic induction flow meters and supplied from a 24 Vdc Supply.

The flow meters are to be provided with an Analogue 4-20 mA for instantaneous flow connected to the PLC and a Modbus Connection to be used for totalised flow.

The Modbus connections are to be daisy chained to the RTU or Ethernet switch back to the main PLC.

Table 9-1 - Magnetic induction flow meter requirements

Item	Description	Requirement
General		
1	Measurement Type	Magnetic induction
2	Operating Range	As per Control Requirement
3	Unit of Measure	Instantaneous - L/s Totalised - kL
4	Power Supply	24 Vdc
5	IP Rating	IP65 or higher
Output Signal		
6	Output Signal	4-20 mA
7	Communication Protocol	Modbus
8	Zero Adjustment	Required
9	Span Adjustment	Required
10	Lighting Requirement	Required
Mounting Detail		
11	Process Connection:	Flanged
12	Mounting	Transmitter – Inside Switchboard or Local Junction Box Sensor - In-Line
13	Lifting Lugs	Required
Other		
14	Electrodes	Self-Cleaning Electrodes

9.4.2 Level meters

Hydrostatic Level Sensors are to be used in underfloor level measurement application. The level sensors are to be mounted inside a stilling well. Table 9-2 identifies the minimum requirements for a hydrostatic level transmitter.

Table 9-2 - Hydrostatic Level Transmitter Specification

Item	Description	Requirement
General		
1	Measurement Type	Hydrostatic
2	Operating Range	Length of Insertion
3	Unit of Measure	m
4	Power Supply	24 Vdc

5	IP Rating	IP65 or better
Output Signal		
6	Output Signal	4-20 mA
7	Communication Protocol	HART TO BE CONFIRMED BY SA WATER
8	Zero Adjustment	Required
9	Span Adjustment	Required
10	Lighting Requirement	Required
Mounting Detail		
11	Process Connection:	Straining Clamp
12	Mounting	Stilling Well
Other		
13	Diaphragm	Ceramic

The rainwater levels are to be measured using a capacitive level measurement. Table 9-3 identifies the minimum requirements for a capacitive level transmitter.

Table 9-3 - Capacitive Level Transmitter Specification

Item	Description	Requirement
General		
1	Measurement Type	Capacitive
2	Operating Range	Length of Insertion
3	Unit of Measure	m
4	Power Supply	24 Vdc
5	IP Rating	IP68 or higher
Output Signal		
6	Output Signal	4-20 mA
7	Communication Protocol	Not Required **TO BE CONFIRMED BY SA WATER**
8	Zero Adjustment	Required
9	Span Adjustment	Required
10	Lighting Requirement	Required
Mounting Detail		
11	Process Connection:	Straining Clamp
12	Mounting	Stilling Well

9.4.3 Disinfection injection and monitoring

The disinfection injection and monitoring if required shall be in accordance with relevant SA Water Standards,

9.4.4 Switchboard

A new switchboard shall be designed as per TS-79 Supply and Installation of Low Voltage Electrical Equipment, if any modifications or new switch boards are required as part of the works.

The following are the minimum requirements that shall be incorporated:

1) Separation between 24Vdc and 400/230Vac power;

2) The escutcheon cover shall have as a minimum:

   a. LED indication for Status (Fault and Running) for each Pump and Mixer

   b. Start, Stop and Reset Button for each Pump and Mixer

   c. Lockable Device Mode Selection Switch for each Pump and Mixer.

      The Device Mode Selection Switch is either a three way or a four way switch pending requirements of the Local Control Station.

3) Remote/Off/MCC Local/LCS Local for each Pump and Mixer; or

4) Remote/Off/ Local for each Pump and Mixer

   a. One Lamp Test Button (to test all LEDs)

   b. HMI Panel

   c. Ammeters are NOT required

   d. Hour Run meters are NOT required and is to be configured within the PLC.

5) Space to be allocated for a control link radio which will communicate to the main PLC if required.

An outdoor switchboard material shall be 316 stainless steel and to be mounted on a stainless steel plinth.

9.4.5 Mixers

The mixers are to be submersible type and are required for continuous use while submersed in the reservoir. Each mixer shall have the ability to function continuously on a year-round basis. Each mixer shall consist of a submersible motor, an impeller and a non-submersible control centre that houses all control electronics, located external to the main switchboard, the switchboard to house the circuit breaker and device mode selection switch, unless otherwise requested by SA Water.

9.4.5.1 Mechanical Requirements

The need for, and the number, size, type and location of the mixers may be determined by SA Water. If not, it will be the Contractor's responsibility to fully design the mixing system, to ensure uniform storage temperature and full distribution of disinfectants, as per the requirements of Section 7 of this Standard.

The mixers shall be floor mounted active (powered) mixers, of a type accepted by SA Water.

All metallic components of the mixer that will be in contact with the water shall be SS316. Rubber components and wiring shall be certified to AS4020 or NSF61.

The mixers shall be entirely suitable for operation within the reservoir, from the maximum through minimum operating water levels and shall not place the cover (or liner) at risk of damage.

Mixers shall be supplied complete with load distributing base or feet, a stand, a submersible motor and an impeller.

9.4.5.2 Electrical Requirements

The mixers as a minimum shall be equipped with:

1) Motor Type –
    a. Single Phase (230Vac /50Hz) if Mixer Size is below 1.5kW
    b. Three Phase (400Vac/50Hz) if Mixer Size is greater than 1.5kW
2) GPO connection
3) Field Isolation
4) Locally mounted VFD Starter
5) MCC Lockable Device Mode Selection Switch

    The Device Mode Selection Switch is to be three way or four way switch pending requirements of the Local Control Station

    a. Remote/Off/MCC Local/LCS Local for each pump and mixer; or
    b. Remote/Off/ Local for each pump and mixer.
6) MCC Local Controls with Start, Stop and Reset Pushbuttons
7) Local Control Station with Start and Stop pushbuttons.

The mixers are to be able to be operated in both manual and auto modes. Mixers shall also be provided with a Local Control Centre, which is to be located on the embankment and as close as practicable to the mixer. For mixer functionality refer to Section 7.2

9.4.6 Rainwater removal pumps

The rain water pumps shall be off cover suction pumps where suitable or submersible, complete with discharge hose, hose couplings, and GPO power connection.

9.4.6.1 Mechanical Requirements

Rainwater removal pumps shall be sized to meet the requirements contained within Section 6.4.1.

The location and number of pumps shall be determined from the size and geometry of the cover and its ballast system. At minimum there shall be one pump located at opposing ends of the cover ballasting system.

The pump suction line is to be located in coarse screened polyethylene baskets, with screening achieved by a uniform array of drill holes through the basket. The size of the holes in the basket is to be determined based on avoiding pump blockage, but without creating excessive blinding of the basket.

The basket shall be suitably ballasted to hold the baskets upright at all times.

The pumps are to have single or three phase submersible motors, suitable for DOL operation.

Pump operation is to be controlled at the main switchboard, with the contactor being under PLC control, closing when the level sensor reaches the high level cut-in and opening when the level sensor reaches the low level cut-out.

The pumps are to include an internal low level cut-out to prevent dry running of the pumps. The low level cut-out from the level sensor is to be set above the pumps internal low level cut-out.

All metallic components in contact with the surface water shall be SS316. All exposed plastic and rubber components shall be suitable for outdoor operation in direct sunlight and full UV exposure.

Power supply to the pump shall be by a submersible cable, terminated at a local GPO complete with a lockable isolation switch.

9.4.6.2 Electrical requirements

The rain water removal pumps as a minimum shall be equipped with:

1) Motor Type: Three Phase (400V/50Hz)

2) GPO connection

3) Field Isolation

4) Thermal Overload Protection

5) DOL Starter

6) MCC Lockable Device Mode Selection Switch

   The Device Mode Selection Switch is to be three way or four way switch pending requirements of the Local Control Station:

   a. Remote/Off/MCC Local/LCS Local for each pump and mixer; or

   b. Remote/Off/ Local for each pump and mixer

7) MCC Local Controls with Start, Stop and Reset Pushbuttons

8) Local Control Station with Start and Stop pushbuttons.

The rainwater removal pumps are to be operated in both manual and auto modes. For pump functionality refer to Section 8.1.

9.4.7 Underfloor Drainage Pumps

9.4.7.1 Mechanical Requirements

Underfloor drainage pumps shall be submersible bore type pumps capable of ongoing cut-in and cut-out operation to maintain the water level in the sump within a set range.

The pumps are to be suitable for operation on any inclination (including vertical).

The pump impellers are to be selected to suit the required delivery head. Pumps should be sized for nominally 1m^3/hr capacity. Multiple pumps are to be used for large storages. One spare pump is to be provided to allow SA Water to change out a pump in the event of a fault.

The size of the bore / pit and the cut-in and cut-out levels shall be selected to ensure that the number of starts does not exceed that recommended by the pump supplier.

The pumps are to be of SS316 construction.

The pumps are to be provided with:

- Dry run protection
- Over-temperature protection

The controller shall include a relay for external alarm annunciation.

9.4.7.2 Electrical Requirements

The underfloor drainage pumps as a minimum shall be equipped with:

1) Single Phase (230V/50Hz)

2) Field Isolation

3) Thermal Overload Protection

4) DOL Starter

5) MCC Lockable Device Mode Selection Switch

   The Device Mode Selection Switch is to be three way or four way pending requirements of the Local Control Station

   a. Remote/Off/MCC Local/LCS Local for each pump and mixer; or

   b. Remote/Off/ Local for each pump and mixer

6) MCC Local Controls with Start, Stop and Reset Pushbuttons

7) Local Control Station with Start and Stop pushbuttons.

The Pumps will be controlled via the PLC and are **NOT** to be supplied with integral floats. The underfloor drainage pumps are to be operated in both manual and auto modes. For pump functionality refer to Section 8.2.

9.4.8 Local control station

The Local Control Station is to be located within close proximity to the allocated equipment. If the switchboard is located within an acceptable distance the Local Control Station is not required. The requirements for a local control station shall be confirmed by an SA Water Representative prior to final design.

10 Operation and Maintenance

10.1 Operation, maintenance, training and manuals

The Contractor shall provide training to SA Water or their Operator's personnel in all operation and maintenance facets of the reservoir liner and floating cover. Appropriate information shall be provided in an Operation and Maintenance (O&M) Manual. This will include the total project scope, i.e. civil, cover and liner, electrical, SCADA, etc.

The Operation and Maintenance Manual shall conform to the requirements of Technical Standard - TS 0132. This specifies the format, structure, and content of the O&M Manual and its relationship with other documentation and records. It is essential that special characters are not used in the creation of the O&M manual.

Issues to be addressed in the O&M Manual shall include the following with further guidance on the content included in TS 0132:

- Scope of manual
- Description of operation
- Emptying procedure
- Filling procedure
- Safety issues
- Maintenance (including cleaning) procedures and schedules
- Inspection procedures and schedules
- Drainage of rainwater sump
- Floating cover inflation procedure
- Interior inspection
- Data sheets
- Repair procedures
- Warranty details
- Contact details for the manufacturer, fabricator and installer
- MSDS for materials recommended to clean and maintain the cover and liner.

10.2 Future repair works

Material for use in future repair work shall be supplied to SA Water by the Contractor.

A repair kit including a roll of liner and cover material, to a size agreed with SA Water, but at least 20m^2, without welds and wrapped securely, shall be supplied by the Contractor to SA Water for future repair work and as a control sample for future testing. The spare material shall be the same as the material used for the construction of the new liner and cover, and shall be from the same batch as the majority of the cover and liner.

Any other necessary equipment (e.g. tools) and materials (e.g. adhesives) sufficient to effect patching on site shall be supplied to SA Water in the repair kit for storage.

11 Security Requirements

11.1 General

The final security equipment to be installed at each EBS site shall be determined by a security risk assessment conducted by SA Water security and emergency management group.

EBS installations have significant inherent risks associated with them, consequently, SA Water have minimum security requirements that shall be provided at all EBS installations. All security requirements (minimum and optional) required at a site shall be determined using this security risk assessment.

11.2 Equipment Requirements

11.2.1 Minimum Requirements

The following security equipment shall be provided as a minimum:

- A perimeter spear top security fence in accordance with TS 0121 – on property boundary,
- Camera monitoring in accordance with TS 0120 – number, type, locations etc. of cameras to be determined by security risk assessment,
- DVR video recorder in accordance with TS 0120,
- An intruder detector system in accordance with TS 0120 – type, configuration to be determined by security risk assessment.

11.2.2 Optional Requirements

The following option may be required as determined during the security risk assessment, which may include:

- Electric fence on top of storage bank immediately adjacent to storage.

11.3 Security Risk Assessment Process

The security risk assessment process may vary depending on the nature of the project delivery model (e.g. concept design by SAW, detailed design by Contractor, all design by Contractor, etc.). Irrespective of the delivery model, the detailed designer is responsible to ensure that the process described in this clause is (or has been) undertaken and security design for the site is finalised and approved by SA Water prior to construction. Designer shall hold a current SA Security Agents License, scoped for issuing security advice

The security design shall be developed as follows:

- A security drawing (showing all equipment to be installed) of the site shall be prepared by designer and submitted to SA Water's Representative
- SA Water will conduct the security risk assessment using the security drawing
- The outcomes of the security risk assessment will be documented by SA Water and submitted to the contractor by way of red pen mark-ups on the security drawing. These make ups will show the final security equipment required and locations of equipment to be installed

- The Contractor shall:
    - Update the security drawings showing all security equipment identified in the security risk assessment and any other relevant information require for construction
    - Submit the proposed security construction drawings to SA Water security for approval (via SA Water's Representative) prior to construction of security equipment.
    - Engage an SA Water authorised security contractor to install all security equipment
    - Install the required equipment (as per the approved security drawing) in accordance with the drawings and SA Water security standards, refer to clause 10.4
    - Update the construction drawing to include all "as built" details of all security equipment installed
    - Provide the "as built" drawing to SA Water with all other As Built drawings for the project/site.

11.4 Access to SA Water security standards

SA Water Security Standards TS 0120 and TS 0121 are generally only available to SA Water authorised security contractors. Information in these standards may be made available upon request to a contractor via SA Water's Representative if considered necessary by SA Water.

Appendix A Performance Specification

Specification for Flexible Geomembrane Materials for Liner and Floating Covers for the Storage of Disinfected Drinking Water

A1 Preface

This Specification was prepared in response to the increasing use of flexible liner and cover geomembrane materials for the storage of drinking water. Materials which are used for these applications are generally supplied to AWWA, Geosynthetic Research Institute (GRI) specifications and ASTM testing standards.

Recent issues with liner and cover geomembrane materials have shown that the influence of disinfectants such as chlorine or chloramines have had a direct effect on the performance of these materials. This aspect has been recognised in Geosynthetic Research Institute (GRI) GM 18 – (flexible reinforced and non-reinforced polypropylene geomembranes) where increased UV resistance has been specified which has shown to have provided increased resistance to disinfectants. While this has some validity there are no specified tests which can be used validate this and no QC tests which provide confidence that the material meets the UV type test.

This Specification introduces specific tests in addition to the requirements specified in GRI, AWWA standards and other specifications to demonstrate resistance to disinfectants.

A2 Scope

This document specifies additional requirements for flexible geomembrane polymers for use in drinking water. The specification has been developed for the following materials in both reinforced and unreinforced forms, where available

- Flexible polypropylene (fPP),
- Thermoplastic Olefins (TPO)
- Chlorosulphonated Polyethylene. (CSPE or Hypalon®)

The specification is not applicable to geomembrane materials intended for use in the storage of waters or other fluids which are not subjected to disinfection.

A3 Reference Documents

The following documents are referred to in this Specification:

AS/NZS

4020 Testing of products for use in contact with drinking water

GRI

GM 13 High Density Polyethylene (HDPE) Smooth and Textured Geomembranes

GM 17 Linear Low Density Polyethylene (LLDPE) Smooth and Textured Geomembranes

GM 18 fPP and fPP-R Geomembranes

GM 25 LLDPE-R Geomembranes

GM 28 CSPE-R Geomembranes

ASTM

D 638 Standard Test Method for Tensile Properties of Plastics

D 751 Standard Test Methods for Coated Fabrics

D 1004 Standard Test Method for Tear Resistance (GMaves Tear) of Plastic Film and Sheeting

D 1693 Standard Test Method for Environmental Stress Cracking of Ethylene Plastics.

D 3895 Standard Test Method for Oxidative Induction time of Polyolefins by Differential Scanning Calorimetry

D 4833 Standard Test Method for Index Puncture Resistance of Geomembranes and Related Products

D 5199 Standard Test Method for Measuring the Nominal Thickness of Geosynthetics

D 5885 Standard Test Method for Oxidative Induction Time of Polyolefin Geosynthetics by High-Pressure Differential Scanning Calorimetry.

AWWA

D130-11 Standard Test Method for Oxidative Induction Time of Polyolefin Geosynthetics by High-Pressure Differential Scanning Calorimetry.

A4 General requirements

A4.1 Operating environment

The liner and floating cover will be exposed to drinking water meeting the Australian Drinking Water Guidelines and the specific environmental exposure conditions for the site as detailed below. The floating cover will be designed using weighted channels and floats to maintain the cover in a taught condition. This can induce high localised strains in the geomembrane materials where it is folded or creased.

Specifically the operating environments are: [data to be inserted for each specific site]

	Min (mg/L)	Max (mg/L)	95% ile (mg/L)
TDS			
Chloride			
pH			
Manganese			
Copper			
Iron			
Free Chlorine			
Chloramine as free Chlorine			
Bulk Water Temperature*			
Atmospheric Temperature			
Hours of sunlight per day			

*The surface temperature of the boundary water layer directly beneath a floating cover will be elevated during daytime periods where it is expected the temperature could increase by 20-30 °C

depending on the colour of the cover and daytime temperature. Higher temperatures could be expected if there are air pockets under the cover.

A4.2 Freedom from defects

Defects shall not affect the performance or function of the geomembrane in service. Membrane surfaces shall not have any gels, blisters, voids, burnt particles or heat marks. Where defects are present and the product is submitted for acceptance, the manufacturer shall be able to demonstrate its conformance to this Specification.

A4.3 Effect on water

Geomembrane materials shall comply with AS/NZS 4020.

A5 Performance requirements

A5.1 General

CSPE, TPOs and fPP Membrane materials shall meet the performance requirements detailed in GRI GM13, GM-17, GM-18, GM-25 or GM-28.

A5.2 Resistance to disinfectants

The following tests shall be carried out where geomembranes are to be exposed to disinfected waters. This testing is based on the use of a long term type or formulation test to demonstrate the resistance of a polymer formulation to disinfectants and is not a quality control test.

Polymer formulations which meet the long term type tests shall also be tested for their initial HP-OIT or OIT and these test results shall be used as a basis for manufacturing QC testing as a surrogate test for resistance to disinfectants.

A5.3 Resistance to chlorine

Membrane compounds shall be tested in accordance with modified ASTM D1693, using 3mm thick polymer samples exposed to a solution of 1% sodium hypochlorite at 50˚C for a minimum exposure period of 4800 hours. The membrane materials shall exhibit no surface cracking when viewed at 10x magnification after 4800 hours of exposure. The manufacturer shall provide details of the tests and results and shall declare the minimum initial HP-OIT or OIT time required by the polymer to achieve compliance to modified ASTM D1693 as detailed above. The declared initial HP-OIT or OIT test method and time shall be adopted as a quality control test measure by the manufacturer to ensure batch to batch performance.

A5.4 Resistance to chloramines

Membrane compounds shall be tested in accordance with modified ASTM D1693, using 3mm thick polymer samples exposed to a solution of 1% chloramine solution (as NH2Cl) at 50°C for a minimum exposure period of 4800 hours. The membrane materials shall exhibit no surface cracking when viewed at 10x magnification after 4800 hours of exposure. The manufacturer shall provide details of the tests and results and shall declare the minimum initial HP-OIT or OIT time required by the polymer to achieve compliance to modified ASTM D1693 as detailed above. The declared initial HP-OIT or OIT test method and time shall be adopted as a quality control test measure by the manufacturer to ensure batch to batch performance.

A5.5 Effects of disinfectants on welded polymer

Fusion welded joints of the geomembrane material shall be carried out and tested in accordance with modified ASTM D1693 using fusion welded sections of the manufactured geomembrane material and exposed to a solution of 1% sodium hypochlorite or 1% chloramine solution at 50◦C for

a minimum exposure period of 4800 hours. The test specimens shall be orientated such that all sections of the weld and heat affected areas are subjected to the bending stresses. The weld and heat affected areas of the geomembrane shall exhibit no surface cracking when viewed at 10x magnification after 4800 hours of exposure.

A5.6 Frequency of tests

QC testing for resistance to disinfectants shall be assessed by HP-OIT or OIT testing as detailed in A.4.2. The testing frequency shall be carried out in accordance with the following:

- Master batched product. Polymer produced using master batching shall be tested at the start, midway through and at the completion of each batch
- Pre-compounded product. Polymer supplied as pre-compounded material shall be tested at the start of each batch.

A batch is defined as the least of the manufacture of 1500 kg of geomembrane or the duration of a single shift (12 hours maximum). A change in shift is when there is a change of manufacturing personnel.

A5.7 Retesting

Testing to modified ASTM D1693 is a type or formulation test and needs only to be carried out to demonstrate the resistance of the formulated polymer. Retesting is required where there is a change in the compound formulation.

For the purpose of this Specification, re-testing to modified ASTM D1693 is required if the following changes to compound formulation, as defined below, occurs:

a) Change of base polymer type, change of polymer manufacturer, polymerization process or chemical nature of co-monomer

b) Change of Polymer Grade:

(i) Any change of nominated density where the change in density is more than 3 kg/m3

(ii) Production of the same base polymer at a different site

c) Change of pigment:

(i) Change of chemical nature or colour of pigment

(ii) Change of pigment level >10%

d) Change of additives other than pigments:

(i) Change of chemical nature or addition or deletion of any additive

(ii) Change of any additive (other than UV stabilizers) level >20%

(iii) Decrease of UV stabilizers by >10% or increase by >30%.

The percentage changes as detailed above are changes from the nominal percentages present in the original type tested material.

A6 Warranty

The Contractor and Manufacturer shall provide the following minimum warranties:

a) The liner and cover material shall each have a Manufacturer's certified 25 year defects and performance warranty in the nominated operating environment

b) The liner and cover shall each have a certified minimum 25 year warranty on all factory fabrication workmanship and on all field seaming and installation work.

Appendix B Schedule of Membrane Properties

Schedule of Membrane Properties			
General			
Membrane thickness / type			
Manufacturer			
Membrane type			
Product name			
Manufacturing plant - full address			
Proposed size of each formulated resin batch, (tonne)			
Production method – round die (blown film), flat bed, slot bed, flat die			
Sheet width, (mm)			
Number of plies, (#)			
Surface finish, (gloss / matte / textured)			
Roll length (standard), (m)			
Roll width (standard & options), (mm)			
Roll core diameter, (mm)			
Details of Upper Ply / Film			
Upper ply base resin manufacturer			
Upper ply base resin type			
Upper ply base resin name			
Upper ply colour, (& colour options)			
	Standard / Type	**Typical Value**	**Minimum Value**
Upper ply thickness, (mm)	ASTM D-5199		
Upper ply base resin Density, (g/cm^3)	ASTM D-792 or D-1505		
Upper ply base resin Oxidative Induction Time, (minutes)	ASTM D-3895		
Upper ply base resin High Pressure Oxidative Induction Time, (minutes)	ASTM D-5885		

Schedule of Membrane Properties			
Upper ply Main UV blocking pigment, (type, %w/w)			
Details of Lower Ply/Plies	Note: - "Lower ply(s)" refers to the core ply (if any) and the lower ply. The Tenderer is to include separate details for these ply(s) if their constituents or properties differ.		
Lower ply(s) base resin manufacturer			
Lower ply(s) base resin type			
Lower ply(s) base resin name			
	Standard / Type	**Typical Value**	**Minimum Value**
Lower ply(s) base resin Density, (g/cm^3)	ASTM D-792 or D-1505		
Lower ply(s) base resin Oxidative Induction Time, (minutes)	ASTM D-3895		
Lower ply(s) base resin High Pressure Oxidative Induction Time, (minutes)	ASTM D-5885		
Lower ply(s) Carbon Black, (type, %w/w)	ASTM D1603 or D4218		
Lower ply(s) Carbon Black Dispersion	ASTM D5596		
Membrane Properties			
Mass per unit Area (kg/m^2)	ASTM D5261		
Thickness	ASTM D5199		
Tensile Strength at Yield (MD), (kN/m), (MD - Machine direction)	ASTM D6693		
Tensile Strength at Break (MD), (kN/m)	ASTM D6693 or D7004		
Elongation at Yield (MD), (%)	ASTM D6693		
Elongation at Break (MD), (%)	ASTM D6693 or D751A		
Tensile Strength at Yield (TD), (kN/m), (TD - Transverse / machine cross direction)	ASTM D6693		
Tensile Strength at Break (TD), (kN/m)	ASTM D6693 or D7004		
Elongation at Yield (TD), (%)	ASTM D6693		
Elongation at Break (TD), (%)	ASTM D6693		
Tear Resistance (MD), (N)	ASTM 1004 or D5884		
Tear Resistance (TD), (N)	ASTM 1004 or D5884		
Puncture Resistance, (N)	ASTM D4833		

Schedule of Membrane Properties			
Ply Adhesion (N)	ASTM D6636		
Melt Flow Rate, (g/10 minutes)	ASTM D 1238, FR-190°C / 2.16kg		
Membrane Specific Gravity, (g/cm^3)	ASTM D792 or D1505		
Oxidative Induction Time, (minutes) which meets Appendix A requirements	ASTM D-3895 Appendix A of this specification		
High Pressure Oxidative Induction Time, (minutes) which meets Appendix A requirements	ASTM D-5885 Appendix A of this specification		
HP-OIT Retention (Oven Aging), (%)	GRI GM-13 ASTM D5721 ASTM D5885		
HP-OIT Retention (UV with condensation), (%)	GRI GM-13 ASTM D5885		
Dimensional Stability, (%)	ASTM D1204 100°C 1hr		
Coefficient of Thermal Expansion, (%/°C)	ASTM D696		
Axial-symmetric Break Resistance Strain, (%)	ASTM D5617		
Low Temperature Brittleness, (°C)	ASTM D1790		
Low Temperature Flexibility (°C)	GRI GM28 ASTM D2136		
UV Light Resistance	GRI GM28 ASTM D7238		