Assets Planning and Delivery Group
Engineering

DESIGN STANDARD DS 81

Process Engineering

VERSION 1
REVISION 6

JUNE 2024

FOREWORD

The intent of Design Standards is to specify requirements that assure effective design and delivery of fit for purpose Water Corporation infrastructure assets for best whole-of-life value with least risk to Corporation service standards and safety. Design standards are also intended to promote uniformity of approach by asset designers, drafters and constructors to the design, construction, commissioning and delivery of water infrastructure and to the compatibility of new infrastructure with existing like infrastructure.

Design Standards draw on the asset design, management and field operational experience gained and documented by the Corporation and by the water industry generally over time. They are intended for application by Corporation staff, designers, constructors and land developers to the planning, design, construction and commissioning of Corporation infrastructure including water services provided by land developers for takeover by the Corporation.

Nothing in this Design Standard diminishes the responsibility of designers and constructors for applying the requirements of the Western Australia's Work Health and Safety (General) Regulations 2022 to the delivery of Corporation assets. Information on these statutory requirements may be viewed at the following web site location:

Overview of Western Australia's Work Health and Safety (General) Regulations 2022 (dmirs.wa.gov.au)

Enquiries relating to the technical content of a Design Standard should be directed to the Senior Principal Engineer - Water Treatment, Engineering. Future Design Standard changes, if any, will be issued to registered Design Standard users as and when published.

Head of Engineering

This document is prepared without the assumption of a duty of care by the Water Corporation. The document is not intended to be nor should it be relied on as a substitute for professional engineering design expertise or any other professional advice.

Users should use and reference the current version of this document.

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Any interpretation of anything in the Standards/Specifications that deviates from specific Water Corporation Project requirements must be referred to, and resolved by, reference to and for determination by the Water Corporation's project manager and/or designer for that particular Project.

REVISION STATUS

The revision status of this standard is shown section by section below:

REVISION STATUS						
SECT.	**VER./REV.**	**DATE**	**PAGES REVISED**	**REVISION DESCRIPTION (Section, Clause, Sub-Clause)**	**RVWD.**	**APRV.**
1	1/0	24.05.19	All	New Version/Revision	DH	DH
1.4	1/1	19.03.20		Requirement for Process Safety Plans added.	DH	DH
2	1/0	24.05.19	All	New Version/Revision	DH	DH
2.1; 2.2	1/1	19.03.20		Requirement for Process Safety Plans added.	DH	DH
2.2	1/3	10.07.23	12	Clarification on need to do HAZOPs for designs using standards	NH	BM
2.1	1/4	12.02.24		Clarification on DP/DT envelope requirement	BM	BM
2.2	1/5	05/24	12-13	Requirement for Process Safety Plan(s) changed from pre-HAZOP to post-HAZOP.	NH	BM
2.3	1/5	05/24	13	New section 2.3 added	NH	BM
3	1/0	24.05.19	All	New Version/Revision	DH	DH
3.2	1/1	19.03.20		Document name change from PIR to Digital Engineering Manual	DH	DH
3.5.1	1/2	03.12.20		Clarified that electrical drawings have their own bundle numbering convention in DS80	DH	DH
3.5.1	1/3	10.07.23	15	Bundle numbering provided for Process Safety Plans	NH	BM
4	1/0	24.05.19	All	New Version/Revision	DH	DH
5	1/0	24.05.19	All	New Version/Revision	DH	DH
5.5	1/4	12.02.24		Equipment numbering convention revised to 6-digit tag numbers	BM	BM
5.5	**1/6**	**12.06.24**		**Equipment numbering convention reverted to normally use 5-digit tag numbers, and 6 digits by exception**	**BM**	**BM**
5.8	1/4	12.02.24		Interlock identification revised to 6-digit tag numbers	BM	BM
5.8	**1/6**	**12.06.24**		**Interlock identification reverted to 5-digit tag numbers (6 digits by exception)**	**BM**	**BM**
5.11	1/4	12.02.24		Pipe identification line numbering revised to 6-digit tag numbers and order of pipe material changed	BM	BM
5.11	**1/6**	**12.06.24**		**Pipe identification line numbering reverted to 5-digit tag numbers (6 digits by exception)**	**BM**	**BM**
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REVISION STATUS						
SECT.	**VER./REV.**	**DATE**	**PAGES REVISED**	**REVISION DESCRIPTION (Section, Clause, Sub-Clause)**	**RVWD.**	**APRV.**
7.2; 7.3	1/1	19.03.20		Document name change from PIR to Digital Engineering Manual	DH	DH
7.2,7.3	1/3	10.07.23	47	Minor changes associated with Process Safety	NH	BM
7.3.1	1/3	10.07.23	48	Further requirements added for alarm criticality	NH	BM
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8	1/1	19.03.20		Document name change from PIR to Digital Engineering Manual	DH	DH

DESIGN STANDARD DS 81
Process Engineering

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1 INTRODUCTION

1.1 Purpose

The purpose of DS81 is to describe the process engineering requirements for Water Corporation assets, including:

- the design process as it applies to process engineering;
- process engineering deliverables;
- drafting requirements, such as the presentation of Piping and Instrumentation Diagrams (P&IDs);
- the development of control logic; and
- the requirements when Building Information Management (BIM) engineering software is used on a project.

1.2 Scope

This Standard describes the minimum requirements for process engineering of Water Corporation assets. DS81 is to be read in conjunction with WCX CAD standard DS80 which describes the Water Corporation's general requirements for drawing production, and the suite of DS40 standards which describe the requirements for instrumentation and process control (SCADA).

DS81 defines symbolism and identification of instrumentation and equipment. Primarily, it does this by stating which parts of ANSI/ISA-5.1-2009 are adopted and by indicating selection of options presented in ANSI/ISA-5.1-2009. This standard and the associated standard P&IDs state requirements and make definitions that shall take precedence over ANSI/ISA-5.1. For the sake of simplicity this is often without explicit reference to ANSI/ISA-5.1. Note that ANSI/ISA-5.1 is only to be applied for the purpose of creating P&IDs. Refer to DS24 for electrical drafting requirements for other drawing types (e.g. logic diagrams).

DS81 provides guidance for designers / drafters on presentation and symbology for P&IDs. This guidance includes detailed sample drawings.

1.3 References

1.3.1 Water Corporation standards

DS 40	Design Process for SCADA Works
DS 40-01	Control Philosophy
DS 40-02	Naming Convention
DS 40-05	Scheme Control
DS 40-07	Electrically Actuated Valve Control
DS 40-08	Standard for the Control of Chemical Dosing
DS 40-09	Field Instrumentation
DS 41-03	ClearSCADA Configuration
DS 80	WCX CAD Standard

NOTE: The above list is not intended as an exhaustive list of all Water Corporation standards that have relevance to Process Engineering of Water Corporation assets.

1.3.2 External standards

ANSI/ISA-5.1-2009	Instrumentation Symbols and Identification
ISO 19650-2	Organisation and digitisation of information about buildings and civil engineering works, including building information modelling (BIM) – Information management using building information modelling – Part 2: Delivery phase of assets

1.4 Definitions

For the purposes of this standard, the following definitions shall apply:

Table 1: Definitions

Term	Definition
AMPS	Asset Management Planning System (AMPS) provides a single entry point or gateway to all asset management planning information in the Water Corporation's information systems.
bubble	The preferred term for the circle-based symbols, used to denote and identify the purpose of an instrument or function, that may contain a tag number.
Critical Safeguards	Instruments, equipment and interlocking provided to prevent or mitigate events that could lead to High Potential Incidents or reportable regulatory breaches. The term Safety Critical Elements is used to cover safety critical equipment and instruments.
Critical Safeguards Register (CSR)	A document that describes the key attributes of critical safeguarding instruments and equipment.
FAT	Factory Acceptance Testing
HAZOP	HAZard & OPerability study
High Potential Incident (HPI)	Any OSH incident that has the potential to result in a permanent disabling injury or life threatening outcome.
Process Safety Plan (PSP)	A schematic document that identifies the events capable of producing High Potential Incidents and reportable regulatory breaches, and the controls in place to prevent or mitigate them.
Safety Instrumented System	A system composed of sensors, logic solvers, and final control elements for the purpose of taking the process to a safe state when pre-determined conditions are violated.
SAT	Site Acceptance Testing
site	A collection of assets that are physically located together and typically has one (1) power supply source connection.
transmitter	A device that changes a sensor's output to a standard signal e.g. a temperature element [TE] connects to a temperature transmitter [TT]. The sensor can be an integral part or a separate part to the transmitter.

2 DESIGN PROCESS

2.1 General Design Sequence

Process engineering shall generally lead the overall design process. It shall be substantially completed first, and then used as the basis of design for all other engineering disciplines. Other engineering disciplines shall provide appropriate input to support the substantial completion of a robust process design.

Table 2: Design Process

Step	Activity
Engineering Design	
1. Identify Process Objectives	The first step in process design is to identify the process objectives (and constraints) – e.g. considering influent water quality and the target water quality as well as recovery of resources other than water.
2. Functional Description	A narrative describing the high level process flow.
3. PFDs (Note A)	Depict the process design in a Process Flow Diagram, which shall include: • a mass-flow and component balance (relevant components) • normal, maximum and minimum operating process conditions – pressures & temperatures • design pressures & design temperatures
4. P&IDs	Develop Piping & Instrumentation Diagrams to more fully describe the process, instrumentation and plant automation. Once the P&IDs are developed to a state of completion that is suitable for HAZOP, then they shall be "Issued for HAZOP" and "frozen".
5. Functional Control Description	A narrative describing the process control in detail.
6. HAZOP	The HAZOP shall be conducted as soon as the Process Design has progressed such that the P&IDs are "frozen" and the Functional Control Description is complete.
7. HAZOP Action Closeout	Actions from the HAZOP are addressed and closed out in a traceable manner to the satisfaction of the Water Corporation Design Manager. Design changes as managed, tracked, risk assessed and visible to the Water Corporation according to a documented management-of-change procedure. Significant changes may require a re-HAZOP or change HAZOP.
8. IFD P&IDs	P&IDs are "Issued For Design" (IFD) once the majority of HAZOP items have been closed out (with resulting changes reflected in the IFD P&IDs). At this stage, the IFD P&IDs may contain "HOLDS" for any un-resolved HAZOP actions or other process design uncertainties. HOLDS will be removed in subsequent P&ID revisions as the associated HAZOP actions or design uncertainties are resolved. The issue of IFD revision P&IDs releases other engineering disciplines to complete their Engineering Design scope & deliverables.

Step	Activity
9. Schedules	Equipment, valve, instrument and electrical schedules are produced in the engineering design phase once the P&IDs are issued for design.
10. Process Safety Plans	A PSP shall be developed for each chemical/hazardous process area that has had events identified which could lead to a High Potential Incident (HPI) or reportable regulatory breach.
Detail Design	
11. Functional Control Specification (Notes B, C)	A complete description of the process control in both narrative and diagrammatic format. It shall include all instrumentation and device details, plus shall describe the indicators, controls and alarms on HMI displays.
12. Critical Safeguard Registers	Each process that has had a PSP prepared shall have an accompanying CSR developed.
13. Coding	Programming of the PLC or RTU in accordance with the FCS (not normally performed by the process engineer).

Note (A): The process engineer shall clearly designate the DP/DT envelope for each section of process plant and piping. Once the process engineer defines this for each part of the plant and piping, the onus is on mechanical and instrument engineers to select valves, equipment and instruments that meet or exceed the DP/DT requirement.

Note (B): Towards the end of detail design phase, express the control system design as a functional control specification and possibly also as logic diagrams or sequential flow charts.

Note (C): The FCS shall include tables of alarms. While the nominated alarm severity will depend on process requirements, the response time will depend on site location/remoteness. Understanding the practical response time will influence the design (e.g. storage, redundancy requirements, etcetera).

2.2 Hazard and Operability Study (HAZOP)

A HAZOP would normally be undertaken during engineering design, and would also need to be performed during detail design if the P&IDs have been significantly revised.

The scope of the HAZOP shall include all P&IDs generated for the works and shall include their interface with existing assets and systems. It is normally not necessary to HAZOP the content within Water Corporation standard P&IDs if they have undergone a HAZOP study within the last 5 years. The Water Corporation design manager shall check the Standard P&ID HAZOP register (Nexus document # 141778649) to confirm whether the latest HAZOP of the standard P&ID is within the last 5 years. However, the nodes that should be included in the HAZOP are where standard systems interface with other systems or the rest of the plant. For example, a standard chlorination P&ID (if used unchanged) would not need to be included in the HAZOP study except for interfaces such as the chlorine dose point or loss of services such as service water supply (for the ejectors) or potable water supply (for the safety shower).

Pre-requisites for holding the HAZOP include:

1) Issued for HAZOP P&IDs have been prepared and frozen; and
2) a complete Functional Control Description is available

All of the above items shall be made available to the HAZOP invitees/participants at least one week prior to the HAZOP.

The HAZOP minutes shall indicate against all key words, for each node, whether there are:

- NSI No significant issues; or
- NCC No credible causes; or
- Issue(s) and shall indicate the action item(s) to address the issue(s).

Detailed requirements for the HAZOP are described in the HAZOP Study Work Instruction (https://nexus.watercorporation.com.au/otcs/cs.exe/app/nodes/58548409).

2.3 Process Safety Plan and Critical Safeguards Register Preparation

A Process Safety Plan and Critical Safeguards Register shall be prepared for each unit process where significant safety or environmental risks (e.g. Regulatory, death) have been identified in a HAZOP. Plans and Registers shall be prepared following completion of the HAZOP in accordance with the Process Safety Plan Work Instruction (Nexus document # 170242106).

Process Safety Plan(s) and Register(s) shall be reviewed and revised (refer section 8 Change Management) following completion of equipment procurement to ensure that Commissioning personnel can check the range (for instruments) and settings of Safety Critical Equipment.

Finalised Process Safety Plan(s) and Register(s) incorporating commissioning changes shall be completed following completion of Commissioning (refer section 8 CHANGE MANAGEMENT).

2.4 Process Calculations

The following types of process calculations, where required for design work, shall be submitted in native format to the Water Corporation at the end of the design job:

- Mass-Flow and Component Balance[1](prefer as dynamic model)
- Energy / Heat Balance
- Process Modelling & Simulations (e.g. UF, RO, WWTP models; water hammer/surge analysis)
- Equipment Sizing
- Line Sizing / Hydraulic Calculations
- Pump and Control Valve Sizing
- Relief Case Assessment & Relief Valve Sizing
- Process tank sizing & design calculations (covering process reaction tank Ct, process reaction time, etc.)

The Water Corporation design manager shall save the process calculations into AMPS against the site functional location number. Permanently retaining these calculations in a readily accessible location (AMPS) has value including informing plant optimisation and for reference in future upgrades/modifications.

3 DRAFTING REQUIREMENTS

3.1 General

All drawings produced shall conform to the requirements of DS80.

The original sheet size for all PFDs and P&IDs shall be A1.

[1] Provide for the overall plant and where complex sub-systems are involved then also for separate sub-systems.

The drafting must be of a sufficiently high quality to maintain legibility when reduced to A3 size.

Notes shall be sequentially numbered. Where a note is no longer required, it shall be replaced by the word “deleted”. That note number shall not be reused but shall remain in sequence in the notes list.

3.2 Digital Engineering/BIM

The Water Corporation is progressively adopting Digital Engineering. The term Digital Engineering (DE), when used as a noun, refers to digital models that represent asset information, and when used as a verb it describes a collaborative way of working, using digital processes, to enable more productive methods of planning, design, constructing, operating and maintaining of assets. It involves capturing engineering information digitally throughout the asset life cycle (design, construction and operational phases). The use of Building Information Modelling (BIM)/DE will support the creation of the Project Information Model (PIM) and Asset Information Model (AIM) as defined in ISO 19650-2.

The Digital Engineering Manual (also known as Principal’s Information Requirements, PIR) identifies the Employer Information Requirements (EIR) of the Water Corporation across all project types and all stages. The Digital Engineering Manual (refer section 10 (APPENDIX A)) shall be followed on those projects where BIM has been specified as a requirement by the Water Corporation. On projects where BIM is not expressly specified, then consultants/contractors may use BIM at their discretion and compliance with APPENDIX A would not be mandatory.

3.3 Holds

Items on hold shall be indicated with reverse clouding unless a note can clearly define the scope that is on hold.

Holds shall be shown on drawings for items that are:

- Incomplete;
- Likely to change (e.g. due to resolution of a HAZOP item);
- Not ready to be released for the purpose stated on the drawing revision (i.e. detail not released for design on an otherwise Issued for Design drawing revision).

Holds shall be numbered and briefly described in a list on the drawing which shall be located on the right side of the drawing where practical. Hold numbers may be reused once deleted and removed from the drawing.

3.4 Revisions

Revision clouds shall be used for all process drawings (including PFDs, P&IDs, Schedules and Control Logic Diagrams). Revision clouds shall be used to indicate amendments made in the current revision of the drawing. Remove revision clouds that relate to amendments made in previous drawing revisions.

3.5 Drawing Numbering

3.5.1 Bundle Numbering

Refer section 3 of DS80 for description of the normal bundle numbering convention for Water Corporation drawings, and note the following departures.

3.5.1.1 Concept Design Drawings

Concept design drawings are a proposal of a new asset or modifications of an existing asset, and therefore need to be distinguished from drawings which represent the asset as currently constructed. This is achieved by having bundle numbers that are dedicated to concept design drawings. An alternative is to use 900 series bundle numbers for concept design (except for electrical drawings which have their own bundle numbering convention – refer DS80). For example, the P&IDs would be in bundle 960 during concept design, which makes it very simple to truncate the prefix 9 when the drawing is updated for detail design. Where it is not practical to use the 900 series (e.g. if it has already been used for a

different drawing type, but if the existing drawing is the same process area then it would normally be appropriate to use the next revision), then revert to the normal DS80 requirement that concept design drawings for various disciplines (except electrical), including process engineering, be allocated in bundles 95 to 99. Where the same sheet number is to be used for different drawing types (e.g. a P&ID may have the same sheet number as an Equipment Schedule) then this potential conflict shall be avoided by allocating each drawing type to separate bundle numbers (e.g. if P&IDs were in bundle 95 then Equipment Schedules could be put in bundle 96).

3.5.1.2 Engineering Design Drawings

Similar to concept design drawings, the engineering design drawings have bundle numbers that are dedicated to engineering design drawings. An alternative is to use 800 series bundle numbers for engineering design (except for electrical drawings which have their own bundle numbering convention – refer DS80). For example, the P&IDs would be in bundle 860 during engineering design, which makes it very simple to truncate the prefix 8 when the drawing is updated for detail design. Where it is not practical to use the 800 series (e.g. if it has already been used for a different drawing type, but if the existing drawing is the same process area then it would normally be appropriate to use the next revision), then revert to the normal DS80 requirement that engineering design drawings for various disciplines (except electrical), including process engineering, be allocated in bundles 85 to 89. Where the same sheet number is to be used for different drawing types (e.g. a P&ID may have the same sheet number as an Equipment Schedule) then this potential conflict shall be avoided by allocating each drawing type to separate bundle numbers (e.g. if P&IDs were in bundle 85 then Equipment Schedules could be put in bundle 86).

3.5.1.3 Detail Design Drawings

DS80 requires:

- P&IDs in bundle 60;
- Control Logic Diagrams (if used) in bundle 61;
- Schedules in bundles 62 to 68;and
- Process Safety Plans in bundle 73.

3.5.1.4 Sheet Numbering

The sheet numbering convention applies to all design stages, which is especially important because equipment numbering depends upon the P&ID sheet number. Therefore, as a drawing progresses (typically being copied from the earlier stage and updated) through concept, then engineering and finally detail design, the sheet numbering would remain the same and only the bundle number would change between design stages. Sheet numbering for P&IDs (bundle 60), control logic diagrams (bundle 61), schedules (bundle 62), and process safety plans (bundle 73) shall be based on the process area number.

For complex plants the preference is to have separate schedules for each process area, and therefore the schedules have sheet numbering based on the process area numbering. For example, in bundle 62, an equipment schedule for chlorine would have sheet number 80 and part sheet numbers would be used to accommodate other types of schedules; hence, mechanical equipment could be in sheet number 80.1, instruments in 80.2, drives in 80.3, etcetera.

When allocating sheet numbers and part sheet numbers, designers should make generous allowance for the ultimate level of detail that will be required on each drawing sheet. This is often underestimated and results in over-crowded P&IDs or the need to later split P&IDs across multiple sheets. The designer shall also make provision for the ultimate plant by leaving gaps for any anticipated future processes and future expansion of capacity.

3.5.1.5 Conflict with existing sheet numbering

It is desirable for all sheet numbering to conform to this numbering scheme for reasons including that it allows efficient adoption of standard designs (the standard P&IDs, which come with correctly numbered tags, can be copied into the project specific plan set with minimal drafting modifications) and to provide a common system across the Water Corporation.

Where existing drawing numbering is not consistent with the process area numbering convention (refer section 3.5.1.6), then consider the following options (presented in order of preference) to manage this problem:

a) Re-number the existing P&ID but do not change the equipment tag numbers (as that may require a large amount of changes to PLC programming and PI tags). Note the need to cancel the old P&ID. This will allow the unused part sheets to be available for future use by the process area that matches the P&ID number; or
b) Use part sheet numbering so that the sheet number can be shared between the existing P&ID and the DS81 process area (note that the disadvantage is potential for confusion where two process areas share a sheet number); or
c) Sheet number to have a numerical prefix to the process area number to avoid conflict with existing drawings e.g. one hundred series or two hundred series, etcetera.

An example of above method "a" is at a wastewater treatment plant where the existing P&ID for digester gas may have sheet number 81 (equivalent to 81.01). If a new project is required to create a new P&ID for chlorine then the process designer would copy the existing digester gas P&ID to sheet number 75 (then cancel 81.01) and use the next available part sheet number (e.g. 81.02) for the chlorination P&ID.

To manage potential confusion where some P&IDs use an earlier/historic equipment numbering protocol while new P&IDs follow this standard, the process engineer shall include a note on P&ID sheet 00 that explains the earlier/historic numbering system.

The reason that use of a new plan set is not presented as an option is it leads to confusion where drawings in the old plan set do not get updated or people are unaware of the old plan set. This confusion can contribute to safety hazards and sub-optimal decision making during plant upgrades. Use of a new plan set should only be considered where all current drawings are to be migrated to the new plan set and the old plan set cancelled.

For advice on managing conflicts with existing sheet numbering, refer to the Senior Principal Engineer – Water Treatment.

3.5.1.6 Process area numbering - general

The plant has been divided into the following processes/facilities for the purposes of equipment and drawing numbering. Where applicable use the designated (reserved) process area number and otherwise use a non-allocated process area number in the relevant number range. If a process area described in Table 3 will not ever be required at a site, then that process area number may be used/re-purposed once all the non-allocated process area numbers in that number range have been used.

Advantages of using standard process area numbering include:

- Standard P&IDs can be used with minimal customising i.e. it will not be necessary to revise tag numbers;
- The tag number will identify what process area a piece of equipment belongs to, and similarly will indicate the P&ID sheet (and possibly also the schedule sheet) it belongs to.

Table 3: Process area numbers

AREA / SHEET NUMBER	PROCESS AREA
00 – 09 GENERAL SITE - items that apply site-wide rather than to a particular process area	
00 General	General P&IDs - such as for details of simplified representation of instrumentation; common notes; symbols; and legends. Refer section 5.4
01 PFDs	Process Flow Diagrams - refer section 4
02	reclaimed effluent services from effluent PS to ALL delivery points, including any downstream storage
03	power services
04	building services - fire and gas, PA, phone, security
05	compressed air supply (where a central system)
06	drainage system
07	water services from plant water supply main to ALL delivery points
08	plant - common control systems
09	odour control (scrubbers – biological; chemical; absorptive)
10-13 SOURCE	e.g. bores, dams, seawater intake
14-17 RAW WATER PUMPING	e.g. raw water pump station
20-29 INLET WORKS	
21	inlet flume(s), inlet channels up to inlet of screenings system
22	screening system from source to, and including, screenings disposal system
23	grit removal system from source to, and including, grit disposal system
24	odour control system from source to and including, odour treatment system
25	Inlet/feed pumping station
30-39 PROCESS NO. 1 / PRIMARY TREATMENT	e.g. in a WTP, primary sedimentation may be a clarifier or DAF
31	primary sedimentation tanks including feed lines from Inlet Works and delivery lines to Aeration System
32	raw sludge pumping system from source to delivery point of Sludge Treatment System
33	skimmings system from source to, and including skimmings treatment system
34	odour control (primary)
40-49 PROCESS NO.2 / AERATION SYSTEM	e.g. in a WTP, the second process may be filtration (including blowers and compressors)
41	aeration tanks including mixed liquor delivery pipelines to Secondary Sedimentation system/reactor
42	compressed air system from air inlet to delivery into aeration tanks
43	odour control (aeration)
50-59 PROCESS NO. 3 / SECONDARY SEDIMENTATION	e.g. in a WTP, the third process may be softening, desalination or MIEX (ancillary services would go in subsequent bundles within this range)
51	secondary sedimentation tanks including effluent delivery pipelines/channels to effluent PS or effluent outfall
52	return activated sludge system (RAS) from source to, and including, pumping station and beyond to Aeration System
53	excess activated sludge system (EAS) from source to, and including, pumping station and beyond to Sludge Treatment System
54	odour control (secondary)

AREA / SHEET NUMBER	PROCESS AREA
60-64 PROCESS NO. 4 / EFFLUENT SYSTEM	
61	effluent pumping station
62	effluent pressure main/land pipeline external to pump station
63	effluent ocean outlet
64	balancing dam and outfall
65	emergency overflow
66	filtration system
67	UV system
68-69 PUMP STATIONS	e.g. clearwater PS, backwash pumping, surge vessels
70-77 SLUDGE TREATMENT	
70	Washwater system & recovery
71	sludge thickening (where applicable) including delivery to digesters and odour control
72	sludge digestion tanks including raw sludge feed where integral with recirculation, sludge heating
73	Energy recovery system
74	sludge recirculation where a central system
75	gas collection and storage (LP)
76	gas mixing system
77	Sludge drying; digested sludge storage system
78-79 CLEARWATER STORAGE	Clearwater tanks & reservoirs
80–99 CHEMICAL SYSTEMS	
80	Chlorine storage (gas)
81	Chlorination system 1 (gas only)
82	Chlorination system 2 (gas only) or (hypochlorite storage & system)
83	Fluoride
84	Lime systems (mixing)
85	Lime systems (dosing)
86	Alum/ACH
87	Polyelectrolyte
88	Ammonia
89	Carbon dioxide
90	Sodium hydroxide (caustic soda)
91	Powdered/granulated activated carbon
92	Potassium permanganate
93	Hydrochloric acid
94	Sodium carbonate (soda ash)
95	Anti-scalant
96	Ferric chloride/sulfate
97	Sulfuric acid
98	Sodium metabisulfite/bisulfite
99+	Other Chemical Systems

3.5.1.7 Process area numbering – small simple sites

Where standard designs exist, the process area numbering shall be used unchanged from the standard P&IDs. For the other P&IDs at small sites, although generally not preferred it may be considered impractical to have a separate P&ID for each process area (i.e. if the separate P&ID sheets were to be predominantly unused space). In such circumstances related process areas such as a water storage tank (process area 78) and a small pump station (process area 68) could be combined onto one drawing sheet. In this instance, select the dominant (or primary) process area for the P&ID number, then all the tag numbering is to be based on this adopted process area number.

4 PROCESS FLOW DIAGRAMS (PFDs)

Process Flow Diagrams provide a summary of the overall process. Their purpose includes:

- Defining major items of equipment and the process connections between them;
- Providing a mass-flow and component balance;
- Determining and detailing design conditions (flow, pressure, temperature) for equipment, piping and inline instruments; and illustrating basic control strategies.

The designer shall develop PFDs that:

- Clearly define the basic processing scheme;
- Provide schematic representation of the type of process equipment;
- Illustrate the main conditions for normal operation;
- Provide information showing the continuity of mass-flow and component balances; and
- Provide the design flow, pressure and temperatures for each flow stream.

The designer shall develop the number of PFDs as required depending on the magnitude and complexity of the process functions. Drawing sequence shall correspond to order of the main process steps.

The designer shall develop separate PFDs for different design cases (such as staging) or modes of operation.

An additional purpose of the PFD is to provide guidance to the Coder as to how the process should be represented on the SCADA / HMI process overview screen.

4.1 Layout

Equipment Description Blocks shall be presented in the top part of the drawing sheet.

The Flow Diagram shall be presented in the centre of the drawing sheet.

Stream data shall be presented as a table in the lower part of the drawing sheet.

4.2 Equipment Blocks

Equipment blocks shall present key design parameters such as design capacity, pump duty flow and pressure, dimensions, primary materials of construction and power rating. Equipment blocks shall be ordered alphabetically left to right (and top to bottom in multiple rows if necessary) according to equipment tags. The blocks for like types of equipment (e.g. pumps) shall be grouped together.

4.3 Content

The following guidelines shall be used in the development of PFDs.

a. Show the significant process flow lines.
b. Show normal operating lines.
c. Do not show minor lines, such as minor intermittent flows, instrument air, maintenance piping (e.g. flushing lines), startup lines, shutdown lines, blowdowns, and pumpouts.
d. Do not show relief valves.
e. Do not show vents and drains, except to clarify a process description.
f. Show only block and isolation valves that are required for manual control.
g. Show control valve stations as a single generic valve with a generic valve operator. Do not show drain, isolation, or bypass valves.

h. Simplify controls to illustrate the fundamental control scheme only. Do not show transmitters, relays, recorders, alarms, and switches. Show only controllers and their interconnection (e.g., cascaded set points). Location or type of controller is not indicated, (e.g., computer versus local panel).
i. Generally, do not repeat control functions from one PFD to another. If clarity is gained, control functions may be duplicated on the associated utility PFD by showing inside a dashed box to indicate it is shown elsewhere.
j. Show only critical instrument indicators not associated with a controller. In general, do not show most instrument indicators.
k. Show process analysers only if associated with controllers or critical control points.
l. Do not show spare equipment, but indicate it by equipment number, i.e. "PU11101A/B".
m. Pump types shall be identified by symbols representing the type, but driver types shall not be indicated.
n. Show trays for columns in a simple line only.
o. Show vessels and towers in basic outline. Special internals with specific process functions such as baffles and packing may be illustrated in a basic manner. Components having process connections shall be shown and numbered or otherwise identified to indicate the relative position of the connection.
p. Do not show equipment nozzles and supports.
q. Show package units that are yet to be designed by the Vendor as a "black box" with a basic (typical) scheme inside and showing the interface connections. A Vendor PFD shall be supplied (or the detail added inside the black box on a later revision) when the Vendor's process design is complete.
r. Refer long or repeated notes to a numbered list of notes on the right side of the drawing. Short notes (2-3 words) may be included in the main body of the PFD.

4.4 Stream Flow Information

All process streams required during normal operation shall be shown with the direction of flow indicated. Show utility streams only if they are required during normal operation or of significance to the mass and component balance. A diamond with a number inside shall be used to identify the stream number and used to cross-reference the properties listed in the Mass and Component Balance table.

Stream numbering shall be unique for each stream at the site. Very simple PFDs (e.g. with no more than 20 flow streams for the whole site) may simply use sequential numbering. More complex PFDs shall use the process area number as the prefix with the stream numbering within each process area as a two-digit sequential number.

Thus flow stream 4001
would be 40 = Process area number for Filters
01 = Sequential number 1 – i.e. the 1st flow stream in that process area

The stream flow properties shall be displayed in the Mass and Component Balance with the following accuracy (typical).

Table 4: Stream Data Accuracy

Property	Units	Accuracy
Flow Rate	L/s	2 decimal places
	kL/Day	0 decimal places
Pressure	kPag	0 decimal places
Temperature	℃	1 decimal place
Concentration	mg/L	2 decimal places

4.5 Mass and Component Balance

The Mass and Component Balance describes normal operating conditions. It shall be presented as a table in the lower part of the PFD. Choice of parameters to display shall be based on the process to be illustrated. Illustration of the operating conditions shall as a minimum include:

- Flow Rates –
  - Minimum capacity (turn down)
  - Maximum capacity (instantaneous)
  - Nominal (guaranteed) capacity
  - Daily (24 hour production at nominal capacity)
  - Average daily guaranteed (as expected over 30-90 days)
- Pressure – typical; design.
- Temperature – typical; design.
- Concentration – include key components of interest to the design e.g. suspended solids (typical units of mg/L and also kg/day); TDS (if the process significantly alters TDS); and chemical dose rates in mg/L. The list of components to be included in the mass balance table may be discussed in advance with the design manager.
- Phase (Liquid; Vapour; or if two phase then Liquid/Vapour) – note that in simple PFDs the phase may be obvious from the heading (e.g. backwash air) and therefore not require a row in the table to identify phase of each flow stream.
- Raw water feed characteristics
- Product water feed characteristics

For complex plant, it may not be possible to display all of the above on the PFD. In this instance a model will need to be provided to complement the PFD. The model shall preferably be in a publicly available application.

5 PIPING & INSTRUMENTATION DIAGRAMS (P&IDs)

Uses for P&IDs include:

- Basis for mechanical design including materials selection;
- Basis for control logic design;
- Basis for process hazard assessments such as HAZOP studies;
- Basis for equipment, pipe, valve, instrument and other lists;
- Basis for capital cost estimation;
- Reference for operation;
- References for future upgrade projects;
- The basis for developing the Functional Control Description (in which the P&IDs shall be referenced);
- Basis for equipment naming and tagging on-site and referencing in construction, commissioning and O&M documentation & systems; and
- Reference for maintenance, including start-up and shutdown planning.

P&IDs shall define the hydraulic and process requirements by showing the following:

a) The pipework (diagrammatically);
b) The electrically driven loads, i.e. pumps, fans, control valves, etc.;
c) The instrumentation measuring process non-electrical variables, including the required measuring ranges for each variable;
d) The signals from the above instruments;
e) Incoming process control signals;
f) Electrically driven load control signals;
g) Which instrumentation and input control signals are combined in the various “interlocks” in order to derive each particular control signal; and

h) Outgoing process related critical indicators and critical alarms.

P&IDs shall show all machine elements and associated equipment such as piping, valves, and instrumentation that are needed for accomplishing detailed mechanical design. Table 5 defines the minimum level of detail required on P&IDs at each stage of developing design. Piping shall be completely specified indicating material, nominal diameter, and pressure rating. Heat tracing and insulation shall also be shown.

Table 5: Information required on P&IDs

P&ID Content / Details Requirements	P&ID ISSUE							References / Notes
	Issued for Consultant Internal Reviews	Issued for Client Comment	Issued for HAZOP (Frozen)	Issued for WC Acceptance	Issued for Use / Issued for Design	Issued for Construction	As Built	
Designer Issue	consultant's system	designer's system	designer's system	designer's system	designer's system	designer's system	designer's system	As per designer's drawing management system.
Formal / Informal Issue to WC	Informal	Informal	Informal	Formal	As per contract	As per contract	formal	
Saved in DMS	No	No	No	Yes	As per contract	As per contract	Yes (once accepted)	
WC Issue	none - leave empty	0,1,2,3… (note 1)	0,1,2,3... (note 2)	A (notes 3,4,5)	B,C,D… (notes 6,7,8)	B,C,D… (notes 6,7,8)	B,C,D… (note 8)	
Equipment (named & tagged)	x	x	x	x	x	x	x	
Equipment Summary Information			x	x	x	x	x	
Process Lines & Fittings	x	x	x	x	x	x	x	
Flow direction arrows	x	x	x	x	x	x	x	
Line sizes, material & identification			x	x	x	x	x	
Process piping reducers, increasers etc.			x	x	x	x	x	
Utility Lines (instrument air, water etc.)	x	x	x	x	x	x	x	
Lines Numbered			x	x	x	x	x	
Below ground lines shown as dashed lines			x	x	x	x	x	
Drain, vent & flushing points			x	x	x	x	x	
Valves - manual and actuated	x	x	x	x	x	x	x	
Valve types identified			x	x	x	x	x	
Valves numbered			x	x	x	x	x	
Valve failure position (where not fail last)			x	x	x	x	x	
Instruments (tagged)	x	x	x	x	x	x	x	
Pressure / Flow Regulating Valves	x	x	x	x	x	x	x	
Pressure / Flow Regulating Valve Setpoints				x	x	x	x	
Control Loops	x	x	x	x	x	x	x	
HH, H, L, LL etc. Alarms			x	x	x	x	x	
Locations for Instruments and Controls			x	x	x	x	x	
Control Interlocks (Functional Description Tables)			x	x	x	x	x	Show in Functional Description table(s)
Tie-in and Termination Points (numbered)			x	x	x	x	x	
Pipe material specification breaks			x	x	x	x	x	
Pipe slope process requirements			x	x	x	x	x	
Straight pipe length requirements				x	x	x	x	
Maintainability requirements (isolations, dismantling joints, removable spools etc.)			x	x	x	x	x	
P&ID legend sheets			x	x	x	x	x	
Holds			x	x	x	x	none	
Spider diagrams (safeguarding functions)			x	x	x	x	x	
Off page connectors (numbered)			x	x	x	x	x	
Revision Clouds (for WC revision)					x	x	x	
Sample Points	x	x	x	x	x	x	x	
Sample Point Tags			x	x	x	x	x	
Nozzle Numbers to Tanks & Vessels					x	x	x	
TWL of water storage tanks					x	x	x	
Manways, hand holes etc.			x	x	x	x	x	
Special piping items (tagged)				x	x	x	x	
Commissioning and startup special requirements			x	x	x	x	x	

NOTES

1) Drawing to be stamped "preliminary"
2) Drawing to be stamped "for HAZOP"
3) Revision box in title block to be empty.
4) If it is necessary to re-issue drawings for Water Corporation approval (ie. initial approval fails) the drawing issue shall remain as A.
5) Once issued for Water Corporation acceptance, P&ID's shall be "frozen" ie. all future changes shall be managed in compliance with the agreed management of change process.
6) Formal WC issue is not mandatory.
7) Only increment WC issue if drawings are to be formally issued to the Corporation.
8) Revision box to be populated if drawing is formally re-issued to WC.
9) Ref. DS 80 - WCX CAD Standard

5.1 Drafting

Standard symbols are presented in the Standard Symbols sheets in plan set GB72. These Standard Symbols take precedence over the symbols in ANSI/ISA-5.1. Generally, the mechanical symbols were taken from BS1553 and all other symbols (e.g. sensing symbols) were taken from ANSI/ISA-5.1.

Note that the Connector (for Exit and Entry) shown on GB72-60-0-1 shall be used for pipe and signal connections between drawings (i.e. do not adopt items 17 through to 21 of Table 5.3.2 in ANSI/ISA-5.1).

Arrow heads shall be used to identify the direction of a signal.

Wherever equipment, cabinets, pits, dosing panels, etcetera have names (or even a description e.g. “valve pit”), this shall be included on the P&ID in addition to any tag number. The name of equipment shall be shown in the equipment block.

5.1.1 Data extractable attributes

All P&ID symbols shall have data extractable attributes which are to be populated (and maintained) with the data required for the Equipment Schedules (refer section 5.15). Note that the Water Corporation standard P&ID symbols (refer drawing GB72-60-0 part sheets 1 & 2) have been set up with the attributes required by the Water Corporation. The steps of the process are described in full in section 9 (APPENDIX A - P&ID symbols – data extraction). The typical process is:

1. Create the P&ID.
2. Extract data from P&ID to spreadsheet (preferred format is the Equipment Schedule Template, https://nexus.watercorporation.com.au/otcs/cs.exe/app/nodes/58648907).
3. Discipline engineers to review and advise drafter of incorrect or missing data.
4. Create equipment, valve, instrument and drive schedule drawings on Water Corporation title blocks for upload to the Drawing Management System.
5. Submit completed Equipment Schedule spreadsheet and CAD drawing schedules to Water Corporation.

[Note: As at December 2018, the extraction process requires modification to function with the current version of Excel. This modification will be done in 2019.]

If Intelligent P&IDs are used, then instead of the above data extraction procedure the Intelligent P&IDs allow tagged lists with fields to be exported, populated by the engineers and the information imported back into the design model. This has benefits of avoiding a piecemeal approach to entering the data attributes, thereby reducing errors, and since the information will often be in a spreadsheet anyway it avoids double-handling.

5.2 Layout

The top part of the drawing shall contain the Equipment Description Blocks, and the remainder of the drawing will contain the diagram, notes, etc.

Avoid crowded drawings by minimising clutter and maintaining blank space. This shall be achieved through use of additional part-sheets. Each drawing sheet would typically show up to two pieces of major equipment (generally, one item of major equipment is shown on each Intelligent P&ID); however, up to four pieces may be shown for simple process units if space permits (e.g. four clearwater transfer pumps). To ensure that drawings do not become over-crowded, allow sufficient space between

equipment in the initial drawing layout for the inevitable piping, instrumentation, controls and notes that will need to be shown.

Layout shall be in a semi-geographical/spatial arrangement to aid interpretation of the drawing. For example:

- if a tank has an over-the-top inlet pipe then the pipe connection shall be shown at the top of the tank;
- if items are within a bund, then those items shall be drawn over a representation of the bund; and
- chemical dose panels with horizontal and vertical sections of pipe shall be drawn that way.

For the sake of readability, wherever practical, flows shall enter the drawing sheet from the side of the sheet at top left and exit at bottom right i.e. the reader will easily find flows when they enter and leave from known positions. Variation of this requirement may only be accepted if it significantly reduces clutter/complexity on the drawing sheet.

Notes shall be at the bottom of the drawing (above the title block) where practical.

5.3 Content

Where a process unit has a significant number of identical process trains, the Design Manager may approve that only one set of typical P&IDs is required to be prepared to represent all trains.

P&IDs shall include the following items:

a. Equipment Description Blocks shall present key design parameters such as tag (i.e. tag of the major item), name, design capacity, pump duty flow and pressure, dimensions, primary material of construction and power rating.
b. Symbols shall have their location identified (refer section 5.10.2).
c. Pressure/Vacuum Safety Relief Valves (PSVs) shall be shown with their set pressure (kPag) and size.
d. Pressure/Vacuum Regulating Valves (PCVs) shall be shown with their normal set pressure (kPag) noted.
e. Indicate fail-safe and power off status of control valves.
f. Indicate lockable valves and indicate their normal position (e.g. text label of LC (locked closed) or LO (locked open)).
g. Show all controllers (feedforward, feedback and cascade) with their associated signal connections to the process, setpoint inputs and alarms. Use annotations to make controller functions clear.
h. Show safety critical interlocks.
i. Show control links external to the site (e.g. a controlling level signal from an offsite destination tank).
j. Show all process lines in full and also show connections to and from utilities. Note: instrument air connections to pneumatic valve actuators do not need to be shown.
k. All process and signal flow directions shall be indicated.
l. Process and signal flow lines entering or exiting the drawing shall do so with an arrow box labelled inside with the connecting drawing number and grid reference , plus a label underneath with a brief process description (or process area) e.g. “To drying beds”. An acceptable alternative to a grid reference is a unique interconnection cross reference number if that is the native system in the drawing software being used.

m. Show vents and drains.
n. Show all piping flanges including blank flanges for future connections.
o. Show line numbers including: service, size, specification including pressure rating, insulation requirement. (refer section 5.11)
p. Clearly show specification breaks that define changes in piping materials or class.
q. Show module breaks which identify the change in module and module identification code.
r. Show heat tracing of process systems. Note special precautions to prevent damage or deterioration of instruments due to freezing or heating.
s. Provide P&IDs for vendor packaged units or equipment. These shall be drawn in the same drafting package as the main P&IDs and with identical symbology and appearance unless approved otherwise by the design manager. The limits of the package vendor's responsibility shall be clearly indicated on the P&IDs.
t. When the equipment is a specialty item (e.g. special piping), for which details are not known, the CONTRACTOR shall illustrate the item only by a box with a specialty item symbol used.

Note that P&IDs shall not include binary logic or electrical schematic representations. Where these are required they are defined in electrical drafting design standard DS24 and Australian Standard AS1102, not ANSI/ISA-5.1.

5.4 General P&IDs

There shall be a series of General P&IDs at sheet 00 which represent all process areas. The General P&IDs define symbols, simplified representations, common notes, and pipe line nomenclature/service codes. There is a standard General P&ID GB72-60-0 (with various part sheets) which the designer shall copy and then revise as required to suit their project. Use part sheets within sheet 00 so that all the General P&ID information is presented at sheet 00.

Include a note on the General P&ID stating that detailed description of interlocks is contained in the Functional Control Description/Specification (provide the Nexus number).

To avoid overcrowding, consider use of simplified representation (refer section 5.10.4) of instrumentation, sample and analyser connections with notes referring to the drawing number(s) with the details of each simplified representation. These typical details are to be presented in the General P&IDs of sheet 00. Any exceptions from typical details shall be explicitly stated in the notes area on the P&ID where the exception occurs.

5.5 Equipment Numbering

The numerical part of equipment tag numbering shall ordinarily be 5 digits; however, on large complex plants it may be more practical to use 6 digits if some process areas need more than nine part sheets for the P&IDs. Approval to use a 6-digit tag numbering scheme at a particular plant shall be sought from the Senior Principal Engineer – Water Treatment.

Equipment numbering/identification (using 5-digit tags)[2] shall be based on the following scheme:

Equipment type + Process Area number + Part sheet (1 to 9) + Sequential number (01 to 99)

[2] At sites with dispensation for a 6-digit tag numbering scheme, then equipment numbering shall be like the 5-digit scheme except the part sheet will be two digits (01 to 99) i.e.
Equipment type + Process Area number + Part sheet (01 to 99) + Sequential number (01 to 99)

Do not include punctuation or spaces in the tag number. For general equipment use the prefixes listed in section 5.5.1 and for instruments refer to the below section 5.6.
Sequential numbering shall operate in parallel for each of the following types of equipment:

- Instruments;
- Valves;
- Mechanical equipment (including pumps).

Exceptions to the numbering sequence are required for instrumentation attached to an item of equipment (such as limit switches on a valve) or associated with the control loop for an item of equipment, in which case the instrumentation shall have the same number as the item of equipment it is associated with.
A further exception to the equipment numbering is where conveyance infrastructure has been assigned an equipment number that is unique within the Water Corporation (refer DS80), whereas DS81 assigns numbers that are only unique within the site/plant. In these circumstances, follow the conveyance equipment numbering convention in DS80 for those items of equipment, but for all other items of equipment follow the DS81 equipment numbering scheme.

The Process Area Number is described in section 3.5.1.6. This number is also used to set the drawing sheet and part-sheet numbers for P&IDs, Control Logic drawings and Schedules.

Example 1: VA40102 would be:
VA = Valve
40 = Process area number for Filters
1 = Drawing Part-Sheet number
02 = Sequential number 2 – i.e. the 2nd valve in that process area
This valve would appear on:

P&ID drawing	AAnn-60-40-1A
Control logic drawing	AAnn-61-40-1A
Equipment Schedule	AAnn-62-40-1A
GA Drawing	AAnn-70-40-1A

Example 2: PU81103 would be:
PU = Pump
81 = Chlorination system 1
1 = Drawing Part-Sheet number
03 = Sequential number 3 – i.e. the 3rd pump in that process area
This pump would appear on:

P&ID drawing	AAnn-60-81-1A
Control logic drawing	AAnn-61-81-1A
Equipment Schedule	AAnn-62-81-1A
GA Drawing	AAnn-70-81-1A

If for some reason the tag number is too long to fit within the instrument symbol, then one option to manage this problem is to omit the process area when the tags are shown on the P&ID and have a general note on that drawing explaining that every equipment identification number shown on the drawing is prefixed with the process area number.

5.5.1 Equipment Types

The normal equipment used and the designated prefix for it are listed hereunder.

AB	air break
AC	access chamber
ACO	air conditioner
AE	analysis element
AG	agitator
AP	air separator

AR	air receiver
AS	air scrubber
AT	analysis transmitter
AU	auger / screw
BL	blower
BM	bell mouth
BN	bins and hoppers
BS	bar screen
BT	battery
BU	burner
CA	clarifier
CB	circuit breaker
CC	control cubicle
CF	centrifuge
CH	chamber / manifold
CL	chlorinator
CN	conveyor
CO	condenser
CP	compressor
CR	crane
CT	chute
CV	cover
CY	cyclone
DG	digester
DP	dampener
DR	drier
DT	density transmitter
EBV	electrically actuated butterfly valve
EJ	ejector/injector/eductor
EP	electrostatic precipitator
EV	evaporator
FA	flare
FD	feeder
FE	Flow element
FL	fluoride saturator
FN	fan
FP	filter belt press
FR	filter
FT	flow transmitter
FX	flame arrester
GE	generator
GR	grinder
GS	gas scrubber
HE	heat exchanger/boiler/heating coil
HG	hot gas generator
IC	irrigation controller
LC	local controller (PLC, RTU etc.)
ME	miscellaneous equipment

MCC	motor control centre
MF	motor fixed speed
MH	manhole
MV	motor variable speed
MR	monorail
MSF	microscreen filter
MX	mixer
NE	network equipment
PC	computer / server
PH	preheater
PL	plant / station
PN	penstock
PCV	pressure control valve
PSV	pressure safety valve
PT	pressure transmitter
PU	pump
RA	radio
RC	roll crusher
RD	rupture disc
RE	reciprocating engine
RR	reactor
RWH	retractable wash-down hose
SC	screen
SE	scum ejector
SG	stop log
SK	stacks
SL	silencer
SP	screen press
SQ	sequence
SR	shredder
SS	sludge scraper
SSE	safety shower and eyewash
ST	strainer
TA	tank/storage
TB	turbine
TF	transformer
TR	skimmings troughs
UPS	uninterruptible power supply
UV	ultraviolet reactor
VA	valve
VE	pressure vessel/ surge vessel/pulsation dampener/hydro-pneumatic accumulator
WE	well
WP	wash press
WS	wet scrubber
XE	sampler
ZSH	position switch High
ZSL	position switch Low
ZZ	positioner

Equipment types for other equipment can be nominated and referred to the relevant Design Manager for approval.

5.6 Loop and Functional Identification

Electrical and control system symbols shall be consistent with Instrument Society of America (ISA) standards (refer ANSI/ISA-5.1: Instrument Symbols and Identification). Each instrument item shall be identified by two, three or four letter prefix i.e. FCV, ZZ, etc. together with the Process Area Number and the drawing part-sheet number and the sequential number as for the equipment e.g. FCV40102. ISA Standard S5.1 has both mandatory letter designations and those available for the User's Choice. Where Water Corporation has a standard designation for a User's Choice, these are shown with yellow shading in Table 6. Letter combinations that are commonly used in Water Corporation P&IDs are presented in Table 7.Where there is need for a project specific User's Choice then this identification tag needs to be defined on the project P&IDs (P&ID sheet 00) after being agreed to by the Water Corporation's Design Manager.

Instrumentation tags shall be based on function rather than form. An example of this is where a pressure transducer is used to measure fluid level then it would be described as a level element (LE). If that level instrument has indicating and transmission functions then it would be labelled as LIT.

The instrumentation tags associated with, for example valves, should have the same number as the valve; hence, the valve VA40102 should have open limit switch ZSO40102 and position transmitter ZT40102.

If an item of equipment or control loop has more than one instrument with the same functional identification tag a suffix shall be appended (e.g. HS40101A, HS40101B, HS40101C, etc.).

The Measuring (or Initiating) Variable (refer Column 1 in Table 6) and, where applicable, a Modifier (refer Column 2) is selected such as pressure (P), pressure differential (PD), etcetera. The loop number shall be the same as the instrument if measured directly (e.g. pressure differential transmitter, PDT) as opposed to one that is mathematically derived (e.g. two pressure transmitters PT40101 and PT40102 from which PDI40103 would be the indicator for the computed Pressure Differential). However, this could be confusing where there are multiple vessels for which differential pressure is calculated; hence, a more convenient scheme is to number the two separate pressure transmitters as A and B (e.g. PT40101A and PT40101B) so that the origin of the calculated differential pressure is obvious (i.e. PDI40101).

Table 6: Identification Letters

	FIRST LETTERS		SUCCEEDING LETTERS		
	Column 1	**Column 2**	**Column 3**	**Column 4**	**Column 5**
	MEASURING OR INITIATING VARIABLE	**MODIFIER**	**READOUT OR PASSIVE FUNCTION**	**OUTPUT FUNCTION**	**MODIFIER**
A	ANALYSIS (5,18)		ALARM		
B	BURNER, COMBUSTION		USER'S CHOICE (1)	USER'S CHOICE (1)	USER'S CHOICE (1)
C	USER'S CHOICE (1)			CONTROL (13)	CLOSED (15)
D	USER'S CHOICE (1)	DIFFERENTIAL (4)			DEVIATION
E	VOLTAGE		SENSOR (PRIMARY ELEMENT)		
F	FLOW RATE	RATIO (FRACTION) (4), FIXED			
G	USER'S CHOICE (1)		GLASS, VIEWING DEVICE (8), GAUGE		
H	HAND				HIGH (15)
I	CURRENT (ELECTRICAL)		INDICATE (9)		
J	POWER	SCAN			
K	TIME, TIME SCHEDULE	TIME RATE OF CHANGE (4,20)		CONTROL STATION (21)	
L	LEVEL		LIGHT (10)		LOW (15)
M	MOTOR, MOISTURE/HUMIDITY, MISCELLANEOUS	MOMENTARY (4)			MIDDLE, INTERMEDIATE (15)
N	USER'S CHOICE (1)		USER'S CHOICE (1)	USER'S CHOICE (1)	USER'S CHOICE (1)
O	USER'S CHOICE (1)		ORIFICE, RESTRICTION		OPEN (15)
P	PRESSURE/VACUUM		POINT (TEST) CONNECTION		
Q	QUANTITY	INTEGRATE, TOTALISE (4)			
R	RADIATION		RECORD (16)		
S	SPEED/FREQUENCY	SAFETY (7)		SWITCH	STOP
T	TEMPERATURE			TRANSMIT (17)	
U	MULTIVARIABLE (6)		MULTIFUNCTION (11)	MULTIFUNCTION (11)	MULTIFUNCTION (11)
V	VIBRATION MECHANICAL ANALYSIS (18)	VARIABLE		VALVE, DAMPENER, LOUVRE (13)	
W	WEIGHT, FORCE		WELL		
X	UNCLASSIFIED (2)	X AXIS	UNCLASSIFIED (2)	UNCLASSIFIED (2)	UNCLASSIFIED (2)
Y	EVENT, STATE OR PRESENCE (19)	Y AXIS		RELAY, COMPUTE CONVERT (13,14)	
Z	POSITION, DIMENSION	Z AXIS, SAFETY INSTRUMENTED SYSTEM		DRIVER, ACTUATOR UNCLASSIFIED FINAL CONTROL ELEMENT	

Notes for Table 6:

General Note. Water Corporation standard "user's choice" designations are highlighted yellow.

1. A "user's choice" letter is intended to cover unlisted meanings that will be used repetitively in a particular project. If used, the letter may have one meaning as a first-letter and another meaning as a succeeding-letter. The meanings need to be defined only once in a legend, or other place, for that project. For example, the letter N may be defined as "torque" as a first-letter and "oscilloscope" as a succeeding-letter.
2. The unclassified letter X is intended to cover unlisted meanings that will be used only once or used to a limited extent. If used, the letter may have any number of meanings as a first-letter and any number of meanings as a succeeding-letter. Except for its use with distinctive symbols, it is expected that the

meanings will be defined outside a tagging bubble on a flow diagram. For example, XR-2 may be a stress recorder and XX-4 may be a stress oscilloscope.

3. The grammatical form of the succeeding-letter meanings may be modified as required. For example, "indicate" may be applied as "indicator" or "indicating", "transmit" as "transmitter" or "transmitting", etc.

4. Any first-letter if used in combination with modifying letters D (differential), F (ratio), M (momentary), K (time rate of change), Q (integrate or totalise), or any combination of these is intended to represent a new and separate measured variable, and the combination is treated as a first-letter entity. Thus, instruments TDI and TI indicate two different variables, namely, differential-temperature and temperature. Modifying letters are used when applicable.

5. First-letter A (analysis) covers all analyses not described by a "user's choice" letter. It is expected that the type of analysis will be defined outside a tagging bubble e.g. turbidity.

6. Use of first-letter U for "multivariable" in lieu of a combination of first-letters is optional. It is recommended that non-specific variable designators such as U be used sparingly.

7. The term "safety" applies to emergency protective primary elements and emergency protective final control elements only. Thus, a self-actuated valve that prevents operation of a fluid system at a higher-than-desired pressure by bleeding fluid from the system is a back-pressure-type PCV, even if the valve is not intended to be used normally. However, this valve is designated as a pressure safety valve PSV if it is intended to protect against emergency conditions, i.e. conditions that are hazardous to personnel and/or equipment and that are not expected to arise normally.

   The designation PSV applies to all valves intended to protect against emergency pressure conditions regardless of whether the valve construction and mode of operation place them in the category of the safety valve, relief valve, or safety relief valve. A rupture disc is designated PSE.

   NOTE: Within Water Corporation it has been historically common to colloquially refer to pressure sustaining valves used for general water distribution as "PSVs". This use shall not occur on P&IDs. All such valves shall be designated as PCV (pressure control valve) and the symbol shall clearly illustrate the type and function of the valve.

8. The passive function G applies to instruments or devices that provide an uncalibrated view, such as sight glasses and television monitors. Note: For bourdon tube type and similar pressure gauges use PI (not PG).

9. "Indicate" normally applies to the readout (analog or digital) of an actual measurement.

10. A succeeding letter L may be used to designate an indicator light but is also often used for a digital status indicator (even where no indicator light is used). For example, an indicator light that indicates an expired time period should be tagged KQL. If it is desired to tag an indicator light that is not part of an instrument loop, the light is designated in the same way. For example, a running light for an electric motor is tagged as YL (note: for running lights use status YL rather than power KL, current IL or voltage EL).

11. Use of a succeeding-letter U for "multifunction" instead of a combination of other functional letters is optional. This non-specific function designator should be used sparingly.

12. A device that connects, disconnects, or transfers one or more circuits may be either a switch, a relay, an ON-OFF controller, or a control valve, depending on the application.

13. If the device manipulates a fluid process stream and is not a hand-actuated ON-OFF block valve then it is to be designated as a control valve. It is incorrect to use the succeeding-letters CV for anything other than a self-actuated control valve. For all applications other than fluid process streams, the device is designated as follows:

    a) A switch, if it is actuated by hand.

    b) A switch or an ON-OFF controller, if it is automatic and is the first such device in a loop. The term "switch" is generally used if the device is used for alarm, pilot light, selection, interlock, or safety.

c) The term "controller" is generally used if the device is used for normal operating control.

d) A relay, if it is automatic and is not the first such device in a loop, i.e. it is actuated by a switch or an ON-OFF controller.

14. It is expected that the functions associated with the use of succeeding-letter Y will be defined outside a bubble on a diagram when further definition is considered necessary. This definition need not be made when the function is self-evident, as for a solenoid valve in a fluid signal line.
15. The modifying terms "high" and "low", "open" and "closed", and "middle" or" intermediate" correspond to values of the measured variable, not to values of the signal, unless otherwise noted. For example, a high-level alarm derived from a reverse-acting level transmitter signal should be an LAH, even though the alarm is actuated when the signal falls to a low value. The terms may be used in combinations as appropriate. (See Section 6.9A, ISA S5.1). A high vacuum alarm would be tagged as PAL and *vice versa* (ie. alarm terms relate to absolute pressure).
16. The word "record" applies to any form of permanent storage of information that permits retrieval by any means. It is not required for the normal data storage in the SCADA system because the record function is implied. Clarification: note that indicating data is stored in PI is not done using the letter R but can be done using the Location Legend and also in the I/O List and is required by the SCADA template for that equipment.
17. For use of the term "transmitter" versus "converter", see the definitions in Section 3, ISA S5.1.
18. First-letter V, "vibration or mechanical analysis" is intended to perform the duties in machinery monitoring that the letter A performs in more general analyses. Except for vibration, it is expected that the variable of interest will be defined outside the tagging bubble.
19. First-letter Y is intended for use when control or monitoring responses are event-driven as opposed to time or time schedule-driven. The letter Y, in this position, can also signify presence or state.
20. Modifying-letter K, in combination with a first-letter such as L, T or W signifies a time rate of change of the measured or initiating variable. The variable WKIC, for instance, may represent a rate-of-weight-loss controller.
21. Succeeding-letter K is a user's option for designating a control station, while the succeeding-letter C is used for describing automatic or manual controllers. (See Section 3, ISA-S5.1 Definitions).

Table 7: Common letter combinations for tags

Letter combination	Description
Pressure	
PCV	Pressure Control Valve
PE	Pressure Element
PI	Pressure Indicator – analog (pressure gauge) or digital
PT	Pressure Transmitter
PIT	Pressure Indicating Transmitter
PSH	Pressure Switch High
PSV	Pressure Safety (relief) Valve
PAH	Pressure Alarm High
PDT	Pressure Differential Transmitter
Level	
LE	Level Element
LT	Level Transmitter
LIT	Level Indicating Transmitter
LSH	Level Switch High
LAH	Level Alarm High
LSHH	Level Switch High High
LAHH	Level Alarm High High

Letter combination	Description
Flow	
FE	Flow Element
FT	Flow Transmitter
FIT	Flow Indicating Transmitter
FQT	Flow Totalised Transmitter
FSH	Flow Switch High
FAH	Flow Alarm High
Analyser	
AE	Analyser Element
AT	Analyser Transmitter
AIT	Analyser Indicating Transmitter
AI	Analyser Indicator
Weight	
WE	Weighing Element
WT	Weight Transmitter
WIT	Weight Indicating Transmitter
WQT	Weight Totalised Transmitter
WQI	Weight Totalised Indicator
Other	
MF	Motor Fixed (i.e. fixed speed motor)
MV	Motor Variable (i.e. variable speed motor)
KQT	Hours run Total Transmitter
HS	Hand Switch (e.g. A/O/M)
HC	Hand Controller (e.g. dose rate)
SC	Speed Controller
YS	Event Switch (e.g. available, in service)
IY	Current Relay: run signal
ESL	Voltage Switch Low: power failure
JT	Power Transmitter
YL	Event Light (e.g. the indicator for available signal)
XA	Transmitter Fault (i.e. alarm for transmitter malfunction)
YA	Event Alarm (e.g. alarm for Bin Full; or Motor Fault)
NZ	<User's Choice> Driver. This is used as the drive element for a motor.
ZZ	Position Actuator. This is used as the drive for a valve actuator.

5.7 Valves

The preferred designation for two-way valves is to use the identification letters "O" for Open and "C" for Closed on P&IDs. Thus limit switches should be tagged as ZSO and ZSC. Alternatively, the terms "high" and "low", when applied to positions of valves and other open-closed devices, are defined as follows: "high" denotes that the valve is in or approaching the fully open position, and "low" denotes that it is in or approaching the fully closed position. It is preferred that ZSO and ZSC be used for two-way valves whereas ZSH and ZSL be used for three-way valves.

Simple valves only require the tag ZZ inside a single bubble to represent the valve actuator. Valves with complex control require additional bubbles to represent all the different signal conditions associated with the control of the actuator and its feedback conditions.

5.7.1 Pressure Safety (relief) Valves

Pressure Safety (relief) Valves shall be given an instrument tag (bubble) with the letter combination PSV. The set pressure and orifice sizing shall be shown on the P&ID and sizing calculations showing relief case(s) and backpressure calculation shall be provided to the Water Corporation.

5.7.2 Pressure Control Valves

Pressure control valves of all types (mechanical, hydraulic, electric, pneumatic, etc.) shall be given an instrument tag (bubble) with the letter combination PCV in all instances. The valve symbol shall clearly illustrate the type of pressure control valve and actuator (sustaining, reducing, hydraulic, electric, etc.).

5.8 Interlock Identification

Interlocks shall be shown on the P&IDs for critical safety systems (Safety Instrumented Systems) including process safety (e.g. protecting water quality for health reasons; or protecting the environment) and personnel safety.

The numbering scheme for interlocks shall be based on the following scheme:
Process Area number + Part sheet number (1 to 9) + Sequential number (01 to 99)

Figure 1: Example of an Interlock Symbol (on chlorine storage P&ID sheet 80.1)

5.9 Instrumentation

The following guidelines shall be used for showing instrumentation on P&IDs:

- Show all instrument tag numbers.
- Safety valves and control valves of all types shall be classed as instruments and tagged accordingly.
- Show alarm states of each device. Use an abbreviation next to the instrument tag. Refer section 5.10.5.
- Show push buttons, resets, switches, and operational overrides (where permitted) associated with logic systems.
- Instrument lines shall break when crossing a major piece of equipment.
- Show a bold dot (small circle) for instrument lines that join at crossovers or intersections.
- Show status indicators and controls where applicable for motor drives.
- Show critical safeguarding interlocks using spider diagrams on the P&IDs to show the inputs and outputs associated with each safeguarding interlock (refer section 5.10.6).
- Show PID and non-PID (feedforward or calculation based) controllers with all associated set-points, user inputs, alarms, etc.
- Secondary instrumentation (such as pressure gauges) shall be represented with unique tag numbering the same as primary instrumentation i.e. do not apply generic identification based on instrument range (refer A.13.1.b in ANSI/ISA-5.1).
- Instrumentation assembled into systems shall not have standard codes (i.e. do not adopt standard codes for these systems – refer A.14.2 and A.14.3 in ANSI/ISA-5.1); however, if this is to be adopted on a project specific basis then include a code schedule in the General P&IDs at sheet 00. Note that instrumentation systems may better be shown using Simplified Representation (refer section 5.10.4)
- Two instruments with the same purpose (e.g. redundant instruments) shall be numbered with the same tag number and be distinguished by alphabetic numbering as a suffix to the tag. For example, LIT78101A and LIT78101B (i.e. not LIT78101 and LIT78101A).

- Instrumentation shall be drawn the same as it is physically arranged e.g. PDT if the pressure transducer has a pilot tube from each of the two points having pressure compared, but two pressure transmitters (each shown as a PT) if there are two pressure transducers installed, from which differential pressure (PDI) is then calculated.

5.10 Symbols

Section 5.4 explains that standard P&ID symbols are available in plan set GB72. Lettering fonts shall match those in the plan set GB72 standard P&ID symbols rather than the dimensions in B.2.5 of ANSI/ISA-5.1. Minimum graphic dimensions shall match those in the plan set GB72 standard P&ID symbols rather than those of section 6 in ANSI/ISA-5.1. It is generally preferred not to use larger symbols (refer 5.10.3) since they take more space and they appear quite large when printed at A1.

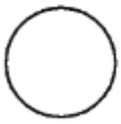
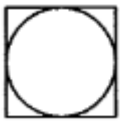
Symbols shall be shown for all devices and functions that are to be included in schedules or require data sheets. This will allow linkage of the symbols on the P&ID to the instrument schedule and the data sheets.

Examples of typical instrument assemblies may be found within the Typical Arrangement drawings referenced in section 5.12.

5.10.1 Instrumentation Device and Function Symbols

Table 8 describes symbology adopted by the Water Corporation. Note that location identifiers (refer section 5.10.2) shall be used to distinguish between the different functions and devices each symbol can represent.

Table 8: Instrumentation device and function symbols

Symbol	Description
	Discrete devices (such as instruments) or functions
	Control Logic Processor (e.g. PLC or RTU)
	Interface e.g. OIP/HMI/SCADA
	Safety Instrumented System

5.10.2 Location Identifiers

Symbols, except field instruments, shall have a numeric location code superscript to the right of the bubble. This code shall be identified in a Location Legend on the drawing. The code identifies the location of the equipment/instrument/indicator/control/software etcetera by specifying:

- if hardware, the name of the cubicle or panel;
- if software, specifying the RTU or PLC location; or
- If a user input, setpoint, control or switch, specifying the input location as OIP and/or SCADA.

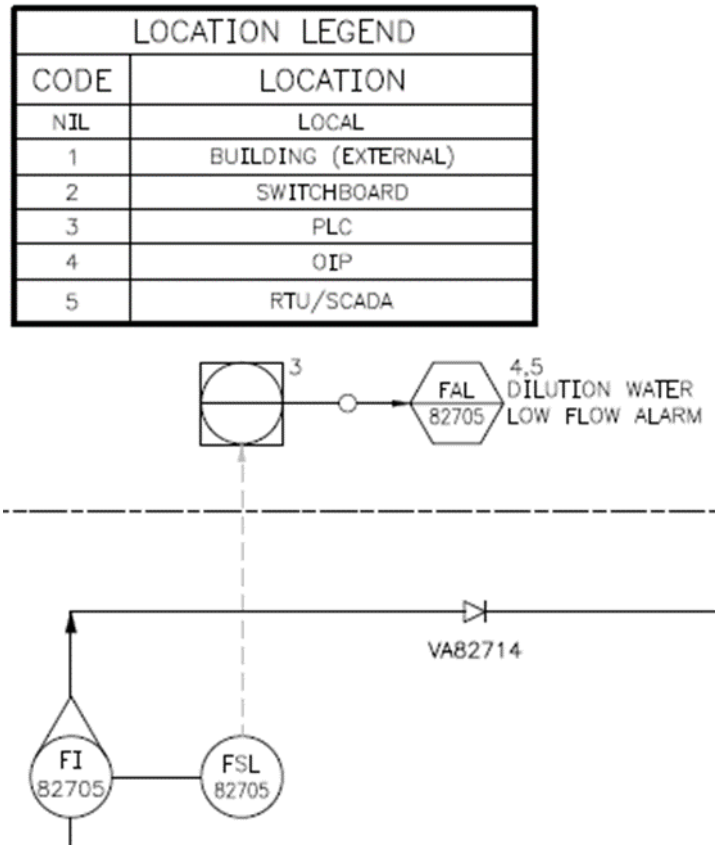


Figure 2: Example of a Location Legend

The ordinary requirements for location legends need not be specific (refer Table 9) about which switchboard, which PLC, etcetera, because the process designer is not generally trying to represent that level of electrical detail. Table 9 indicates Location Identifiers (Nil to 3) that should be adopted at all sites, whereas higher numbers can be site specific. It is preferred that the location legend be consistent across all drawing sheets for a site wherever practical.

Table 9: Recommended codes for use in a Location Legend

LOCATION LEGEND	
CODE	LOCATION
NIL	LOCAL
1	BUILDING (EXTERNAL)
2	SWITCHBOARD
3	PLC
4	OIP
5	RTU/SCADA

5.10.3 Symbol Dimensions

In circumstances where tags are longer (such as where there are alphabetic suffixes to the tag number) than can be accommodated by standard diameter bubbles, then consider whether the tag number can be abbreviated by omitting the prefix (Process Area Number, and if necessary also omitting the Part Sheet Number), rather than the options in ANSI/ISA-5.1 of relieving sides of bubble or elongating the bubble; this will require an explanatory note on the drawing. Note that the prefix shall only be omitted where it is strictly necessary, and the tag number must be stated in full everywhere else it is used (such as in the Functional Control Specification). The order of preference for managing long tags is:

- Abbreviate by omitting the prefix;
- Larger diameter bubbles; or
- Bubbles with sides relieved/broken.

5.10.4 Simplified Representation

Simplified representations may be used to minimise clutter on drawings and are especially useful where similar detail is repeated. If the detail description is only relevant to a single process area then it shall be shown on a P&ID for that process area, or if similar details occur across the plant then show the standard detail on the General P&ID (P&ID sheet 00 - refer section 5.4). An example (from a multiple chlorine drum P&ID) is shown in Figure 3.

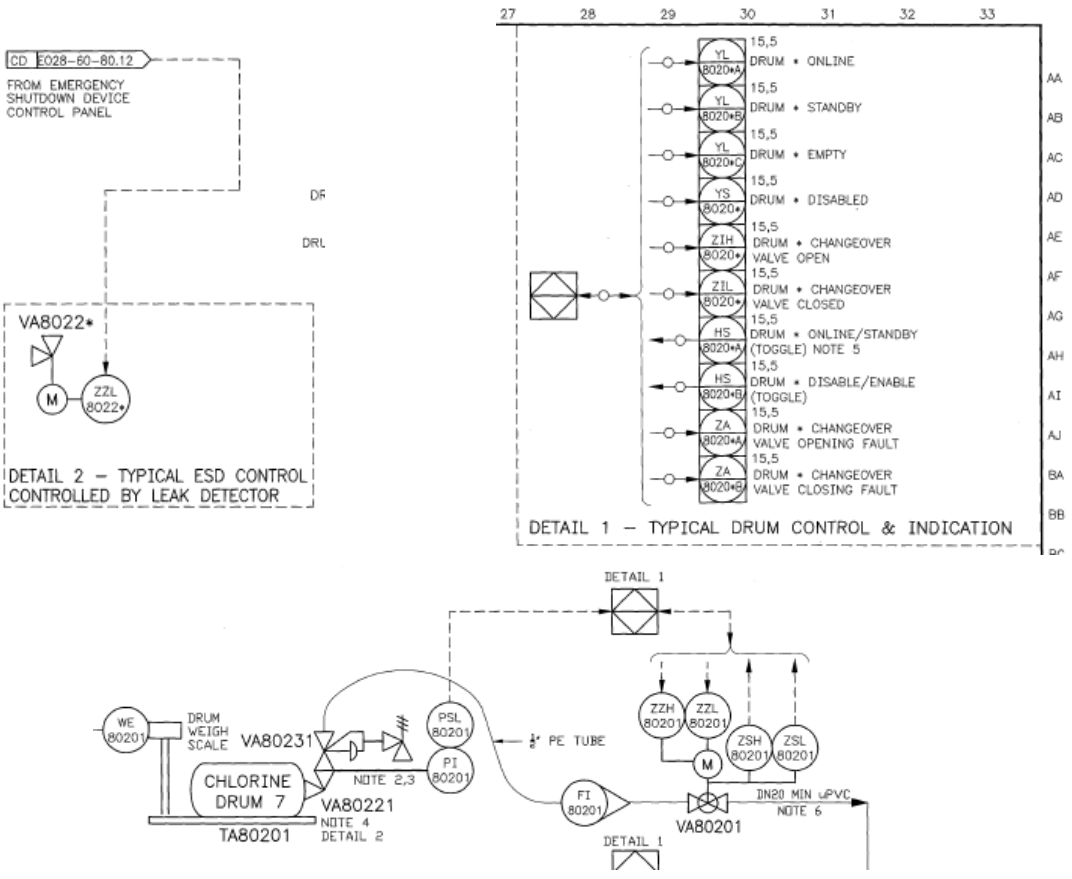


Figure 3: Example of simplified representation using details

5.10.5 Alarms

Show alarm states of each device and indicate alarms that are switched (i.e. interlocked) – these interlocks must be referenced in the Functional Control Description. Alarms with complex names are best represented as illustrated in Figure 4.

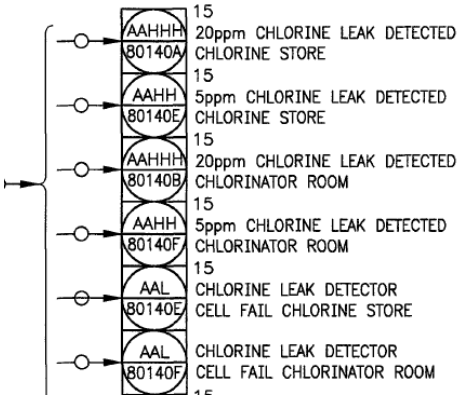


Figure 4: Example of typical representation of alarms with complex names

To avoid clutter on the drawing, multiple function attributes can (at the discretion of the designer) be applied to a single symbol to identify multiple functions. For example, multiple alarm states of instruments may be shown in shorthand on the right-side of the instrument symbol e.g. Figure 5 illustrates that LIT86101 would have the alarm states written in short form as HH, H, L, and LL (whereas the full tag for each alarm would be LAHH86101, LAH86101, LAL86101, and LALL86101). Note that Figure 5 is an abbreviation (since showing the alarms at the transmitter rather than their actual location in the control system) of the instrument diagramming in B.11.3.a of the ANSI standard.

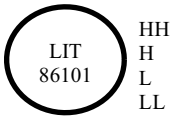


Figure 5: Example of short form depiction of alarm states

In circumstances where alarms trigger an interlock to a control function (as opposed to SIS which would have a different designation), the "switch" function can be shown as in Figure 6 which has the alarm states written in short form as HH, H(s), L(s), and LL where the high and low alarms also trigger control functions (e.g. start and stop a pump). Note that in this example, the high and low alarms would normally be supressed.

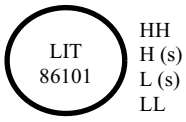


Figure 6: Example of short form depiction of alarm states with interlocks

5.10.6 Critical Safeguarding Logic

Definition of Critical Safeguards:

- The final level of protection (safeguard) against uncontrolled loss of containment of hazardous materials in a process plant/facility;
- Primary machinery instrumented safeguards that protect personnel from injury or death;
- Safeguards that protect against serious injury or death. This includes safeguards that prevent the distribution of off-spec water or wastewater that would likely cause a public health issue;
- Critical Control Point interlocks.

Interlocks associated with critical safeguarding shall be shown on the P&ID. The preferred method is to use a spider diagram (refer section 5.14) for each process safeguard.

To reduce clutter on the P&IDs, all other interlocks can have the detail regarding their control and data signals described in the Functional Control Specification with cross reference (tag shown on the interlock) to the final controlled element(s).

5.10.7 Controllers

Show control loops for both PID-based controllers and math-based analog controllers (e.g. flow-paced chemical dose rate control). Derived controllers (e.g. look-up tables) shall have a note reference at the equipment and a note on the P&ID which references the Functional Control Description for full detail of the derived controller.

Loop numbering shall be based on the same numbering scheme used for the device being controlled:
Prefix - Process Area number – Part sheet number – Sequential number
Where the Prefix is the Variable (parameter) being controlled e.g. Flow, Pressure, Speed, etc.

Interlock numbering requirements are described in section 5.8.

5.10.8 Function blocks

Function block symbols (refer B.10 in ANSI/ISA-5.1) are not used on Water Corporation P&IDs, particularly because nowadays signal processing is done in a PLC or SCADA rather than a device for each function. Functional details for interlocks etcetera shall instead be defined in the Functional Control Specification with cross reference to the final control element for that function.

5.10.9 Functional diagramming

Table 5.5 in ANSI/ISA-5.1 is not used for Water Corporation P&IDs.

5.11 Pipe Identification - Line Numbering

Pipe identification is to be shown for each line with detail progressively added as the relevant design decisions are made. When some of the detail is unknown early in the design process, missing values can be substituted with '***' for completion later in the design (note: for unknown detail use asterisks rather than X i.e. to avoid confusion with identification letter X).

Allocate consecutive line numbers first for main process lines and then for secondary/minor process lines. Maintain the same line number until reaching a piece of equipment, header, change in material, change in class, or a battery limit. Unique line numbers are also required for a line from an equipment item to the same equipment item (e.g. pumped recirculation lines). New line numbers shall be assigned after a control valve or piping specialty item if the item requires a different line size, pipe specification, or after a change of fluid service.

If utility lines on a process P&ID originate on a utility P&ID, then they shall carry the utility line number.

Pipe numbering/identification shall be based on the following scheme:
Pipe ND – Pipe Specification – Service Designation - Process Area + Part sheet (1-9) + Sequential No. (01-99)
Note that:

- Process Area numbering is defined in section 3.5.1.6.
- Piping Specification – the minimum requirement is to state the material and pressure class or schedule (e.g. uPVC SCH80). Alternatively, project/site specific piping specification designations may be developed and shown on the Line Numbering drawing (i.e. site plan set, bundle 60, sheet 0, part sheet 4).

- Service Designation is defined in Table 1 on standard drawing GB72-60-0-4.

Since the line number incorporates the P&ID part sheet number, then the line number can be used to identify the P&ID that the line features upon. Also, this makes the line number unique to the P&ID, which has the benefit of avoiding duplication of existing line numbers elsewhere in the plant. Base line numbering on the sheet and part-sheet that the line commences from i.e. even if it traverses multiple sheets.

The project specific requirement for a Piping Line List (i.e. schedule) as a design deliverable will be determined/specified by the Water Corporation design manager.

5.12 Typical Arrangements

Wherever standard designs exist (refer Table 10), the job specific P&IDs shall be developed from standard P&IDs. For all other situations, P&IDs shall be prepared using the typical arrangements (refer Table 11) in plan set GB72. This will allow the designer to copy relevant blocks (typical arrangements) into the P&IDs they are preparing. The benefit of doing this is that it enables efficient preparation of P&IDs that comply with DS81.

Table 10: Standard designs with P&IDs

Process Area	Plan set
Chlorination	EO28
FSA	GT36
Sodium Hypochlorite	JD71-60-82 series
Lime	JD71-60-84 series
Safety shower using non-potable water supply	JD71-60-07

Table 11: Typical Arrangements

Process Area/facility	Drawing
Submersible Sewage Pump Station	GB72-60-14
Bore	GB72-60-10
Water Tank	GB72-60-78
Transfer Pump	GB72-60-68
IBC (Bulki-box) Chemical Storage	GB72-60-86.1
Single chemical storage tank	GB72-60-86.2
Twin chemical storage tanks (i.e. 2 x 50%)	GB72-60-86.3
Chemical Dose Panel – Panel 1	GB72-60-86.4
Chemical Dose Panel – Panel 2	GB72-60-86.5

5.13 Control Valve Installations

At concept design stage, complex valves shall be represented by simple symbology, especially if there is risk of selecting an inappropriate typical detail. Then at detail design stage, the project specific valve details shall be transferred onto the P&ID.

5.14 SIS Functional Logic Arrangements – Spider Diagrams

The Safety Instrumented System (SIS) shall have its inputs and outputs indicated on the P&ID in a functional logic representation called a spider diagram (refer Figure 7). This spider diagram shall show all process and manually activated initiators (inputs) and final control elements (outputs) associated with a particular safety function. The preferred arrangement of spider diagrams is:

a. Initiators (Inputs)
Arrange inputs on the left side of the spider diagram between the 7 o'clock position and the 11 o'clock position.
The 12 o'clock position is reserved for the Manual Reset Soft Switch where applicable.

b. Final Control Elements (Outputs)
Arrange outputs on the right side of the spider diagram between the 1 o'clock position and the 5 o'clock position.

c. Location
The preferred location for the spider diagram is on the same P&ID sheet as the equipment the associated SIS interlock is protecting. If it is too large or if there are several spider diagram associated with a single P&ID then a separate part-sheet may be used.

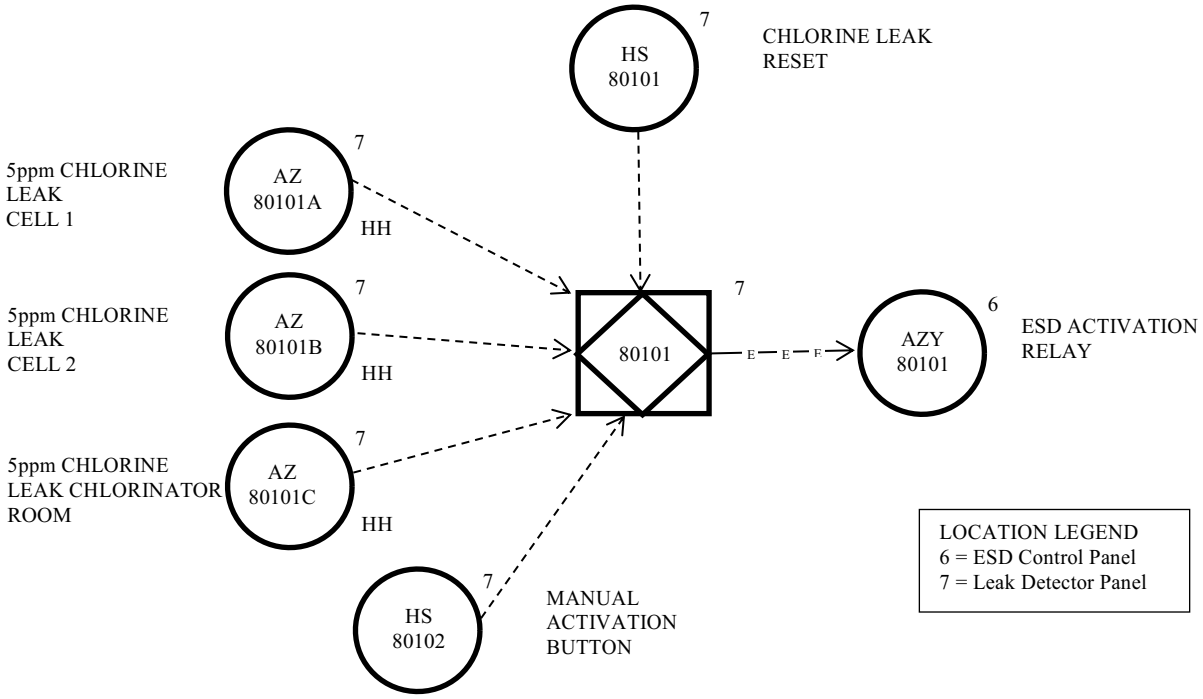


Figure 7: Example of a spider diagram

5.15 Schedules

Provide schedules of all equipment, valves, instruments and drives that feature in the P&IDs. Typically, a schedule is required for each category i.e. an equipment schedule, a valve schedule, an instrument schedule, etc. For complex plants, it is preferred to further sub-divide schedules to be specific to each process area e.g. chlorination equipment schedule, chlorination valve schedule, etc.

Equipment (i.e. mechanical equipment other than valves), valve, instrument, and drive schedules are initially developed in spreadsheet format using the Equipment Schedule template (https://nexus.watercorporation.com.au/otcs/cs.exe/link/58648907) which has separate worksheets for each schedule type. The Equipment Schedule spreadsheet shall be forwarded to the Asset Registration team so they can assign Functional Location numbers to each item of equipment and incorporate them into the Functional Location Equipment Register (FLER). As-constructed details shall be recorded by updating the Excel workbook. It is optional (based on Region's preference) for these schedules to also be pasted into Water Corporation drawing sheets for archival of the as-constructed details. The minimum required content and format for these drawings is illustrated in:

- Figure 8 for Equipment Schedules;
- Figure 9 for Valve Schedules;
- Figure 10 for Instrument Schedules; and
- Figure 11 for Drive Schedules.

Note that section A.2.2 in the ANSI/ISA-5.1 standard requires Instrument Schedules to reference the P&ID drawing number; however, if all the tag numbers have been based on the P&ID number, then it will be optional to show the P&ID drawing number (i.e. this column shall be included in the spreadsheet but not transferred to the drawing if needing to rationalise the number of columns to fit the schedule on a drawing sheet).

For each item of equipment whose procurement requirements are not able to be completely specified by the data fields in the schedules, then data sheets shall be provided. Note that templates of data sheets for commonly used instruments are available in DS40-10. Further datasheet templates are contained in many Water Corporation Strategic Product Specifications.

Pressure vessels and pressure equipment shall have procurement data sheets created during engineering design phase. Ensure that any pressure vessel licensing requirements are included in the capital project's External Approvals tracking spreadsheet, and during construction phase the licence information shall be recorded in SAP.

EQUIPMENT SCHEDULE							
EQUIPMENT No. (TAG)	DESCRIPTION/ FUNCTION	MANUFACTURER/ SUPPLIER	BRAND/ MODEL/ SPECIFICATION	MODEL NUMBER/ TYPE	OPERATING VOLTAGE	POWER RATING	REMARKS

Figure 8: Equipment Schedule – drawing format

VALVE SCHEDULE											
VALVE No. (TAG)	FUNCTION	VALVE TYPE	SPS	RATED PRESS. kPa	DE-RATING TEMP ^{O}C	SIZE	MATERIAL	SERVICE	CONNECT	ACTUATOR	SUPPLIER, MAKE & MODEL No. OR SIMILAR APPROVED

Figure 9: Valve Schedule – drawing format

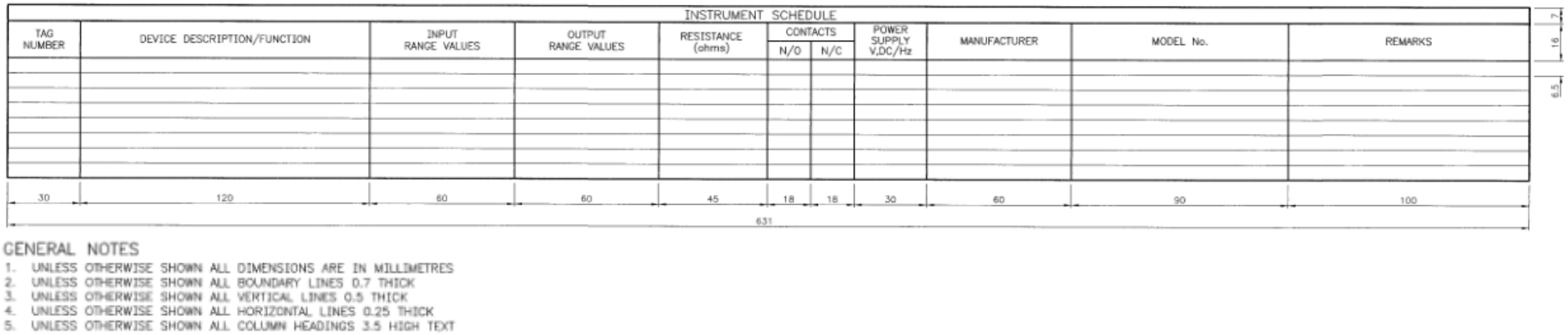


Figure 10: Instrument Schedule – drawing format

		DRIVE SCHEDULE							
EQUIPMENT No. (TAG)	DESCRIPTION/ FUNCTION	MANUFACTURER/ SUPPLIER	BRAND/ MODEL/ SPECIFICATION	MODEL NUMBER/ TYPE	OPERATING VOLTAGE	RATED LOAD (kW)	ACTUAL LOAD (kW)	DUTY	REMARKS (include starter type and whether fixed or variable speed)

Figure 11: Drive Schedule – drawing format

6 CONTROL LOGIC

Note that DS40 requires that, wherever possible, standard code modules, as supplied by Water Corporation, shall be used. PLC code development shall only occur when there is not an existing standard code module that satisfies the requirement.

Control logic shall conform to Scheme Control design standard DS40-05, which specifies:

- the inputs and outputs required for various assets;
- standard logic functions that shall be used (refer Table 12);
- alarming requirements;
- data capture and storage range and accuracy information;
- frequency of data capture; and
- data sent to the data historian.

Table 12: Standard Logic

Process Area/facility	Notes
Various types of equipment	• Standard/typical logic diagrams - plan set FQ11 (bundle 61).
Major pump stations	• Control system requirements – refer Appendix of DS21. • Standard logic diagrams –plan set FS00. • Standard logic modules shall be coded into the PLC program in accordance with the instructions on drawing FS00-1-2.
Minor pump stations (and wastewater pump stations)	• Control system requirements – refer Appendix of DS22. • Standard logic diagrams –plan set FS01. • Standard logic modules shall be coded into the PLC program in accordance with the instructions on drawing FS01-1-2.
FSA	• Refer GT36-61-83.
Chlorine	• Standard logic diagrams - plan set EO28 (bundle 61). • In addition, there is a standard chlorination PLC program.
Electrically-actuated valves	• Control system requirements in DS40-07.
Chemical dosing	• Control system requirements in DS40-08.

Control logic shall be developed based on requirements in the design standards relevant to each asset type. For example, pump station design standard DS32 and bore mechanical design standard DS32-01 have requirements for condition monitoring and protection. Power monitoring requirements and treatment plant control philosophy (refer s2.3 in Appendix 1 of DS28) are described in DS28.

Some design standards have standard logic drawings associated with them. The Functional Control Specification shall reference these logic diagrams and they shall be copied into the site-specific plan set. This avoids uncertainty regarding what version of the standard logic drawings were used in the design, and also provides a place to record any site-specific modifications during the life of the asset. In the case of chlorine, in addition to standard logic drawings, there is standard PLC code for Water Corporation's preferred PLCs.

If Logic Diagrams are prepared, then they shall comply with Electrical Drafting design standard DS24.

7 FUNCTIONAL CONTROL SPECIFICATIONS

Documentation of the control system design needs to be understood by a diverse audience, which includes operators, maintainers, designers, and programmers. It is generally preferred that the control system design is documented in the form of a Functional Control Specification (FCS). This preference

is because FCSs describe control system design in text and tables, and therefore do not present a barrier to readers unfamiliar with interpreting logic diagrams or sequential flow charts.

Note that logic diagrams may exist for some standard designs. If the asset consists of multiple process areas (e.g. a treatment plant) then a FCS is required but would refer to the standard logic drawings for that process area instead of using flow charts to describe the control logic. However, if the asset is a single process area (e.g. a sewage pump station) then a FCS would not normally be required because the control logic would be fully described by the standard logic drawings.

Note also that Functional Control Descriptions exist for some standard designs (e.g. chlorine; FSA; lime; and sodium hypochlorite). These template documents should be adapted with project specific information, particularly where the template FCD includes options. It is intended that the site-customised FCD for that process area would become a companion volume referenced in the overall plant Functional Control Specification, rather than attempting to merge the documents.

Table 13: Standard Functional Control Descriptions

Process Area/facility	Document
Small chlorination systems (water)	DS70-20: FCD
Small chlorination systems (wastewater)	DS70-30: FCD
Chlorine sequenced gas vacuum system	DS70-25: FCD
FSA	DS71-02: FCS
Lime	DS72-02: FCS
Sodium hypochlorite (bulk)	DS73-02: FCS

The Functional Control Specification shall be developed (initially by the process designer) from the standard template (T 40-02 - Functional and Control Description Template, which is available in the list of SCADA/OT template documents). Further requirements for the content of FCDs and FCSs are described in the Detailed Design Outputs section of DS40. It is intended that the same document will be used at each stage of the design process so that it is progressively revised and expanded as illustrated in Figure 12. During construction phase, the control system design will be converted to code (program).

Figure 12: Development of the Functional Control Specification

7.1 Functional Description

The Functional Description is a narrative description of the overall process. The Functional Description shall be prepared by the process designer (normally a process engineer).

7.2 Functional Control Description

The Functional Control Description (FCD) describes how the requirements of the Functional Description will be met by the design. It is a narrative description of the basic control functions of the whole asset system which provides information regarding the process operation, control, monitoring, protection/safeguarding, and configuration of hardware and software.

Provide a detailed control description of process areas that do not have standard designs, whereas for process areas with standard designs the standard documentation shall be used.

The Functional Control Description is primarily prepared by the process designer. Sections relating to the hardware and software configuration would normally be prepared by a controls / SCADA engineer.

The preparation of Functional Control Description Overview spreadsheets is encouraged for complex and/or unfamiliar processes. FDOs have value for briefing Operations (such as during a HAZOP) on equipment function and also serve as a useful cross-checking tool during design. The FDO would be referenced in the FCD (and subsequently in the FCS). Note that FDOs exist for the standard designs for chlorine, sodium hypochlorite, lime and FSA.

The FCD shall contain a dedicated section that details the process safety critical safeguards required to prevent or mitigate high potential incident (HPI) risks or reportable regulatory breaches. These critical safeguards shall be incorporated into the FCD, in parallel with the development of the Process Safety Plan for each chemical/hazardous process area.

7.3 Functional Control Specification

The Functional Control Specification (FCS) describes how the requirements of the FCD will be met by the design. It provides a detailed statement of the function and control of each item of equipment and each instrument and identifies critical safeguards. The control system is described using engineering data and information relevant to user objectives and application requirements, performance criteria, environmental constraints and functions and tasks to be performed that includes flows charts, logic diagrams and function and event diagrams. It shall include all instrumentation and device details, plus shall describe the indicators, controls and alarms on HMI displays. Tables of alarms shall include their prioritisation (alarm severity). While the alarm severity will depend on process requirements, the response times will depend on site location. Understanding the practical response time will influence the design (e.g. storage, redundancy requirements, etcetera). In addition to narrative, the FCS includes diagrams and tables to provide the level of detail required for programming. The FCS shall be finalised prior to commencement of Factory Acceptance Testing (FAT) of the control system.

The Functional Control Specification is normally prepared by a controls / SCADA engineer with significant input and review by the process designer and also review by other engineering disciplines.

7.3.1 Alarm criticality

The FCS shall have tables of alarms which include the category of each alarm.

Scheme Control design standard DS40-05 defines the following categories of alarm severity:

- Critical – For alarms that require immediate action
- Urgent – For alarms that require action within a limited period (less than an hour).
- Warning – For alarms that do not require immediate action
- Routine – Event only
- Maintenance – for maintenance use. These alarms are not displayed on the Operation Centre HMIs.

Critical alarms include those required for:

- Process safety – i.e. protection of personnel, the public, the environment and equipment; and
- Critical Control Points.

For process areas for which standard designs exist, use the alarm criticality described in the relevant standard functional control description.
However, for all other process areas the Design Manager shall liaise with stakeholders for input on alarm priority and timer settings (i.e. time between initiating event and control actions).
This will include Critical Control Points and may include Process Control Points and safety systems.

Potential stakeholders that the Design Manager shall consult include those with responsibility for defining requirements for and/or operational responsibility for:

- Continuity of water supply
- Water quality
- Public Safety
- Worker Safety
- Regulatory Compliance
- Wastewater Overflow events

7.3.2 Process Safety Critical Safeguards

The FCS shall contain a dedicated section that details the process safety critical safeguards required to prevent or mitigate high potential incident (HPI) risks or reportable regulatory breaches. These safeguards shall be consistent with those contained within the Process Safety Plans and Critical Safeguards Registers.

7.3.3 FCS Change Management

In addition to the Software Change Control requirements of DS40-06, a separate change control process shall be implemented for the Functional Control Specification. The FCS shall be used as the basis for Factory Acceptance Testing of the control system, to confirm that the required process has been implemented correctly. For the FCS to remain relevant as the basis for assessing test outcomes, any changes to the process control need to be documented using a formal process. This will allow all participants in the FAT and SAT to have access to the updated version of the FCS. It is acknowledged that continuous update of the FCS document may not be practical during code development, but the changes / deviations from the described control need to be captured and recorded for the purposes of FAT testing. This can be done using a conventional feedback / response spreadsheet, which ensures changes can be tracked and approved as required. The spreadsheet can then be referenced for subsequent update of the FCS document prior to handing it over for operational use. Any proposed changes to the FCS document that affect Critical Safeguards shall be referred to the Senior Principal Engineer - Water Treatment for approval **before** being implemented. Approved changes shall be incorporated into the relevant Process Safety Plan and Critical Safeguards Register.

8 CHANGE MANAGEMENT

The designer shall implement a change control process for the overall process design once drawings have been issued for HAZOP. This shall include changes as a result of actions in the HAZOP as well as other changes made post HAZOP (i.e. which did not get HAZOPed). Note that significant post-HAZOP design changes, including those that result from the HAZOP itself shall be subject to further HAZOP review and if they affect Process Safety Critical Safeguards, the Process Safety Plan and Critical Safeguards Register shall be revised.

An important element of managing this change is lodging the Issued for WC Acceptance P&IDs into the Drawing Management System.

The change management register shall maintain traceability on all process design changes. Revised drawings (with revisions shown in clouds) shall be in accordance with section 3.4. The designer shall have the change management register on hand for review on request and provide an updated copy at all progress meetings.

9 APPENDIX A - P&ID symbols – data extraction

Note that the Water Corporation standard P&ID symbols (refer drawing GB72-60-0 part sheets 1 & 2) have been produced as 'blocks' in AutoCAD and are provided in a symbol library. Each symbol has been created with attributes to allow data stored on the symbol to be extracted to an Excel spreadsheet if required. The symbol library, together with a data extraction routine, is provided on the WCX CD/download. To access these symbols from within AutoCAD, select the WCX pull-down menu and select the 'Load WC PID Menu' menu item.

Only Water Corporation symbols for P&IDs located in the symbol library on the WCX Download shall be used in the production of P&IDs for the Water Corporation. Symbols other than those supplied from the symbol library shall not be used without the expressed approval of the Senior Principal Engineer-Water Treatment, Engineering of the Water Corporation.

All symbols shall be used as supplied. They shall not be exploded and rebuilt, re-scaled or modified in any way. If a new symbol is required, the following procedure shall be followed:

a) The person requiring a new symbol shall provide a drawing of the proposed symbol to the Drawing Management System Manager, who will arrange for the Senior Principal Engineer-Water Treatment in Engineering to comment and approve.
b) Once the new symbol proposed has been agreed upon, a provisional approval for the use of the symbol shall be provided by the Senior Principal Engineer- Water Treatment in Engineering for use on the current project only.
c) If considered appropriate by the Senior Principal Engineer- Water Treatment in Engineering, the symbol will be adopted for use by the Water Corporation and added to the symbols library.

P&IDs are developed in stages from initial concept through to final design. As the design progresses data should be inserted into the relevant symbol attributes as it becomes available. At the stage of 'As Constructed' drawing production, all data attributes shall be complete.

9.1 Drawing Production Procedure

9.1.1 Asset Identification

An important piece of data to be added to a symbol is the 'asset ID' located on the 'Field Location' attribute. This asset identification number should be obtained from the Water Corporation prior to commencing the creation of the P&I diagram.

9.1.2 Order of Detail Arrangement

It is recommended that hydraulic detail (e.g. pipes, tanks, valves etc) be placed on the P&I diagram first. This determines the size of the P&ID and the number of drawing parts required. If the process to be represented is large and cannot be fitted on one drawing, then the diagram can flow across as many parts as necessary. The data extraction process will extract from any number of drawings.

9.1.3 Note on Drawing

All P&ID drawings shall carry the note 'THIS DRAWING CREATED WITH SYMBOLS HAVING ATTRIBUTE EXTRACTABLE DATA'. The preferred location for this note is in the bottom right corner of the drawing. The note should have a text height of 5mm and be placed on layer 24.

9.1.4 Attribute Data

As symbols from the WC P&ID library are selected and inserted onto the drawing the 'enter attributes dialog box' is displayed, data should be added to as many attributes as possible at this time, to reduce time consuming re-editing later.

9.1.5 File Delimiters

The text to be stored on the symbol attribute must not contain any commas (,) or single quotes (‘) as the data extraction process uses these characters as delimiters to create extract files. If these characters are left in the symbol attribute, the resultant spreadsheet column data for that symbol will be misaligned and require extra editing.

9.1.6 Use of Grids and Snaps

P&ID drawings shall be created with AutoCAD Grid and Snap settings turned on. All P&ID symbols have been created with the origin of the symbol at the centre of the symbol, with a recommended Grid setting of ‘6’ displayed and Snap setting of ‘1’, the symbol is placed accurately on a grid point. To connect pipe and signal lines to a symbol use a Snap of ‘1’ this will allow correct placement of line work to touch the symbol without requiring extra trimming or extension of lines.

9.1.7 Layer and Linetypes

Symbols shall be connected together with lines to represent piping and signal paths. To facilitate the connection of symbols, linetypes for both short distance connections and longer distance connections are made available by selecting ‘P&ID layers/linetypes’ from the ‘WC P&ID’ pulldown menu. By selecting ‘P&ID layers/linetypes’ the AutoCAD drawing is loaded with the extra layers and linetypes. Refer drawing GB72-60-0-2 to establish the correct layer and linetype to be used.

9.2 Extract Procedure

9.2.1 Attribute Extraction

Upon completion of symbol and data allocation to the P&I diagram, an extract of the attribute data can be obtained.

a) Start in an AutoCAD P&ID drawing.
b) Locate and select the ‘WC_P&ID’ pull-down menu. If this is not visible, select the WCX pull-down menu and select the ‘Load WC_P&ID Menu’ menu item.
c) Locate and select the ‘P&ID attribute extraction’ menu item.
d) A ‘Select any other drawing files for attribute extraction’ file dialogue box will appear, allowing you to select other drawings to include in the extraction. More than one drawing can be selected at a time using Ctrl and/or Shift in the usual Windows way. If there are no other drawings to include, just pick Cancel and just the current drawing will be extracted. If you pick other drawings, they will temporarily be attached as Xrefs and then detached again after the extract. The routine will create a file ready to import into Excel, and display the filename in the Command prompt area. The file will be called the same as the current drawing file, with ‘Extracted Data.txt’ appended.

9.3 Spreadsheet Procedure

a) Start a new Excel spreadsheet
b) Select ‘File’ and then ‘Open’, set the ‘Files of type’ box to ‘All Files (*.*)’, browse the path of the current P&ID drawing and select the file called the same name as the current drawing filename with ‘ Extracted Data.txt’ appended. Double-click on it or pick Open.
c) The Text import Wizard – step 1 of 3 dialog box appears.
    - In the ‘Original data type’ box select ‘Delimited’.
    - ‘Start import at row’ should be set to ‘1’
    - ‘File origin’ should read ‘Windows (ANSI)’ or ‘MS-DOS (PC-8)’.
      Select ‘Next >’
d) The Text import Wizard – step 2 of 3 dialog box appears.
    - In the ‘Delimiters’ box turn on the ‘Comma’ toggle.
    - ‘Text qualifier’ should be set to a single quotation mark.
    - Turn off the ‘Treat consecutive delimiters as one’ toggle.
      Select ‘Next >’

e) The Text import Wizard – step 3 of 3 dialog box appears.
   - 'Column data format' box select 'General'.
     Select 'Finish'

f) Checking for errors
   Scan through the columns of information to see if any information is in the wrong column. This is usually caused by commas (,) in the symbol attributes. If there is misalignment of data go back to the drawing, fix the problem and then repeat the extract.

g) Spacing of columns
   Increase or decrease the spreadsheet column widths as necessary to display all text within the columns.
   - Highlight all cells.
   - Select 'Format' pulldown menu.
   - Select 'Column' menu.
   - Select 'Autofit Selection'.

h) Spreadsheet title
   Insert the spreadsheet title and date in the spreadsheet header
   - Select 'View' pulldown menu.
   - Select 'Headers and Footers.
   - Select 'Custom Header'
   - Type in title and date into 'Centre section'. Select 'OK'

i) Borders
   Apply borders to all cells containing data.
   - Highlight all cells containing data.
   - Select 'Borders' menu.
   - Select 'All borders'.

j) Save as *.xls file
   Save the modified spreadsheet in the form *.xls

k) Print or exit
   Print a hard copy of the spreadsheet or save and exit as required.

10 APPENDIX B – Digital Engineering Manual

Digital Engineering Manual
(https://nexus.watercorporation.com.au/otcs/cs.exe/link/49104062)

END OF DOCUMENT