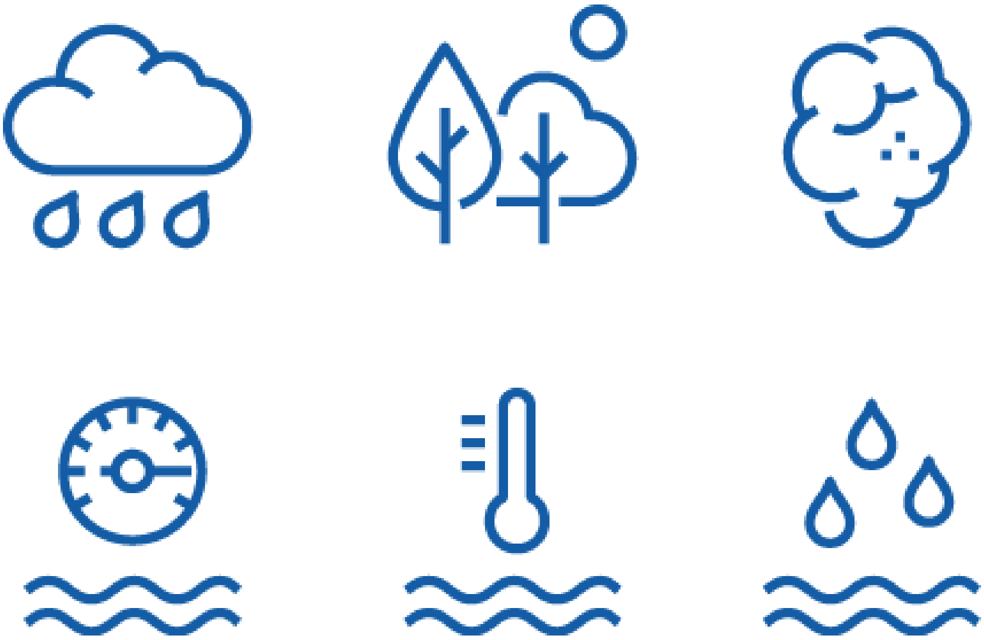
National Environmental Monitoring Standards

Guidelines for Hydrological and Meteorological Structures

Version: 2.0.0

Date of Issue: October 2023



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Change Register

Version Number	Date	Section	Significant Change
Version: 1.0.0	1 July 2016		Published
Version: 2.0.0	4 October 2023	Whole document	Significant changes throughout the document, including change of title

The National Environmental Monitoring Standards

The current suite of National Environmental Monitoring Standards (NEMS) documents, Guidelines, Glossary and Quality Code Schema can be found at www.nems.org.nz.

Implementation

When implementing these Guidelines and Standards, current legislation relating to health and safety in New Zealand and subsequent amendments shall be followed. The NEMS "*Safe collection of environmental data: Guidelines for safe working when undertaking environmental monitoring*" also provides useful support material for undertaking monitoring.

Limitations

It is assumed that, as a minimum, the reader of these documents has a basic understanding of environmental monitoring techniques, and a degree of competency in their application. Instructions for manufacturer-specific instrumentation and methodologies are not included in this document.

The information contained in these NEMS documents relies upon material and data derived from a number of third-party sources.

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Development

The National Environmental Monitoring Standards (NEMS) Steering Group has prepared a series of environmental monitoring standards on authority from the Regional Chief Executive Officers (RCEOs) and the Ministry for the Environment (MfE).

The development of this document involved consultation with regional and unitary councils across New Zealand, and the National Institute for Water and Atmospheric Research Ltd (NIWA). These agencies are responsible for the majority of continuous environmental-related measurements within New Zealand.

The lead writer of the original document was Jeremy Walsh of NIWA, with workgroup members Phil Downes of Environment Canterbury Region Council and John Porteous and Graeme Horrell of NIWA. The input of NEMS Steering Group members into the development of this document is gratefully acknowledged; in particular, the review undertaken by the NEMS Steering Group.

The most recent review (October 2023) of this document was undertaken by Colin Grace of NIWA.

Funding

The primary funders of the National Environmental Monitoring Standards project are Ministry for the Environment and New Zealand regional councils and unitary authorities. Other financial and in-kind support to the overall NEMS project has been provided by the following organisations:

- National Institute of Water and Atmospheric Research Ltd (NIWA)
- GNS Science
- StatsNZ
- Meridian Energy
- Ministry of Business, Innovation and Employment – Science and Innovation Group
- Genesis Energy
- Contact Energy
- Mercury New Zealand Limited

Review

This document will be assessed for review approximately once every two years. Further details on the review process can be found at www.nems.org.nz. Feedback from users of the previous version of this document has been incorporated into this version

Users of this document are encouraged to provide feedback via the NEMS website.

Contents

Terms, Definitions and Symbols

Relevant definitions and descriptions of symbols used in these guidelines are contained within the NEMS Glossary available at nems.org.nz.

Normative References

These Guidelines should be read in conjunction with the following references:

- AS/NZS 1664.1:1997 *Aluminium structures – Limit state design*
- AS/NZS 1170:2002 *Structural design actions Standard*
- Health and Safety at Work Act 2015
- NEMS *Glossary*
- NEMS *Open Channel Flow Measurement*
- NEMS *Water Level*
- (New Zealand) Building Act 2004
- (New Zealand) Building Regulations 1992, Schedule 1 (The Building Code)
- NZS 3109:1997 *Concrete construction*
- NZS 3404 Part1:1997 *Steel structures Standard*
- NZS 3603:1993 *Timber structures Standard*
- Resource Management Act 1991.

About these Guidelines

Background

These Guidelines have been developed following discussion and consultation with regional and unitary councils within New Zealand as well as the National Institute for Water and Atmospheric Research Ltd (NIWA). Between them, these agencies undertake the majority of environmental data acquisition within New Zealand.

Objective

The objective of these Guidelines is to document or reference commonly used designs of hydrological and meteorological structures, and considerations in implementing these designs, including:

- suitability for use in new construction (covering compliance with the New Zealand Building Code)
- design considerations; for example, loading and stability, and
- construction techniques.

Scope

The scope of the Guidelines covers construction of hydrological and meteorological structures that are likely to be built in future, including:

- ‘standard’ steel stilling wells
- slack-line cableways
- catwalks
- stairways and access ladders, and
- meteorological masts.

Exclusions

The following structures are excluded:

- manned cableways
- concrete stilling wells
- weirs and flumes.

1. Legislative Requirements

1.1. Background

All building works should comply with the most recent Building Act requirements and related standards and the Resource Management Act. The Building Act establishes the regulatory regime covering building work in New Zealand.

Under the Building Act, key requirements for building work are:

- All building work, regardless of whether a building consent is required, must comply with the New Zealand Building Code.
- All building work, unless exempt, requires a building consent.

Note: The most recent Building and Resource Management Acts are available from the New Zealand Legislation website http://www.legislation.govt.nz.

In order to build a new hydrological structure or meteorological mast, it may be necessary to obtain a resource consent from the relevant consenting authority.

1.2. Hydrological Structures

Some consenting authorities have a clause in their regional plan that classes the installation of structures for river monitoring purposes as a permitted activity.

Note: The permitted activity rule may have provisos relating to, for example:

- *safe passage of fish;*
- *limits on the restriction imposed on the cross-sectional area;*
- *adequate maintenance of the structure.*

1.3. Meteorological Masts

The need for a consent to construct a mast, and any requirements imposed by the consenting authority may depend on the location (urban or rural) and height of the mast.

1.4. Resource Consent

For all new building work, the relevant consenting authority should be consulted:

- as to whether a resource consent is required, and
- on any conditions imposed with or without consent.

2. Stilling Wells

2.1. Background

Stilling wells are commonly built to what was a 'standard' Ministry of Works and Development (MWD) design. Figure 1 (below) illustrates the design.

The stilling well itself is made of standard rolled sections, 1200 mm in length and 600 mm in diameter, with a wall thickness of about 2.3mm. It incorporates a hatch in the top section for inspection and levelling of instrumentation. A hatch is also provided at the bottom of the stilling well for inspection of the float and counterweight system and flushing of sediment.

A steel recorder housing bolts to the top section. A platform or catwalk may be required to provide access to the recorder housing.

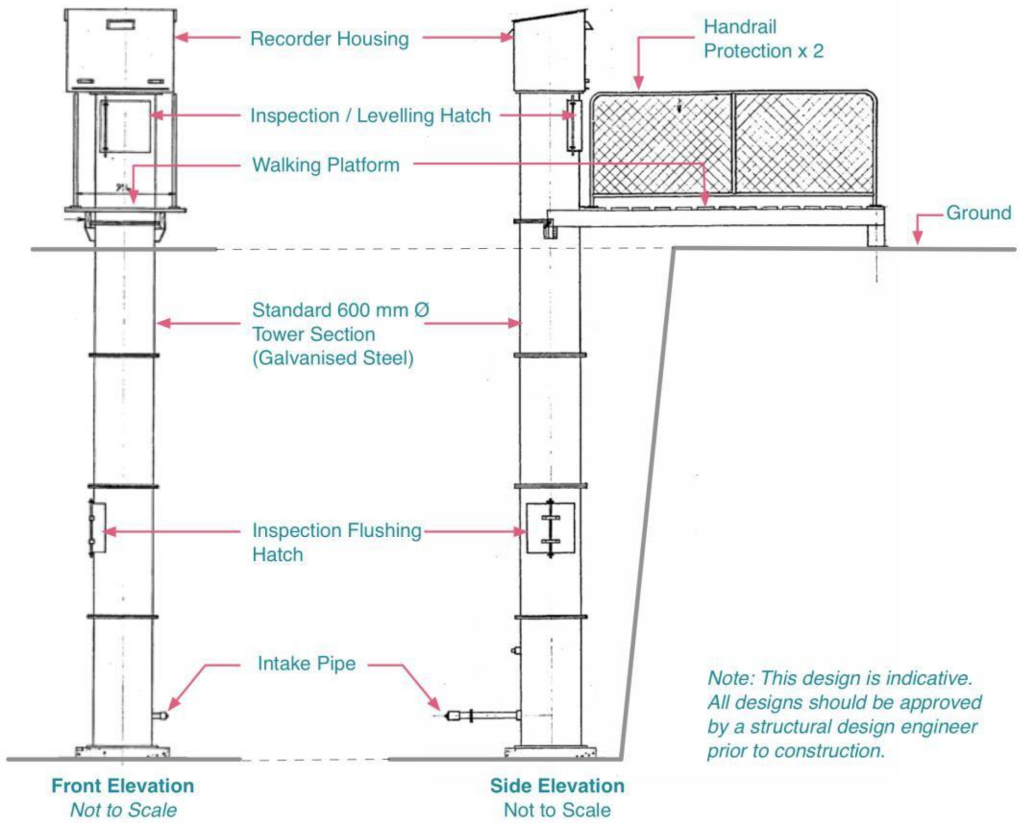

Figure 1 – Typical stilling well and housing setup – MWD 'standard' steel stilling well

Source: NIWA Field Manual.

Note: Other designs and materials may be as good or better in certain situations. The MWD design is a network design which has proved to be effective and cost efficient on a network scale. Alternatives include pipes made of concrete or spiral-welded steel, or for smaller installations, plastic (PVC) with a low coefficient of thermal expansion, or fibreglass and corrugated culvert pipes.

2.2. Acceptable Design

2.2.1. Steel Stilling Well Design Drawings

The MWD steel stilling well design is documented in the Ministry of Works and Development design drawings listed in Table 1 below. The design drawings themselves can be found in Annex C.

Table 1 – MWD steel stilling well design drawings

Drawing	Title
6/721/6/7603/601	General Assembly
6/721/6/7603/602/R1	Instrument Housing
6/721/6/7603/603/R1	Type ‘E’ Cylinder
6/721/6/7603/604/R1	Type ‘D’ Cylinder
6/721/6/7603/605	Type ‘C’ Cylinder
6/721/6/7603/606	Type ‘B’ Cylinder
6/721/6/7603/607	Type ‘A’ Cylinder
6/721/6/7603/608/R1	Door Latch Type 1
6/721/7/7603/601	Platform

Note: The MWD design drawings do not cover foundation details or bracing requirements for the stilling well.

2.2.2. Approval

Prior to any site work or construction, the stilling well design (including foundation and bracing details) should be approved by a chartered professional engineer who has competency in structural design.

2.2.3. Compliance

All new building work should comply with the most recent New Zealand Building Code.

Note: Use of the MWD design alone does not guarantee compliance.

2.3 General Design Considerations

The stilling well should:

- be firmly founded so that subsidence will not occur;
- have sufficient height and depth to allow the float to freely travel up and down the full range of expected water levels;
- be vertical and not allow the float and counter-weight system to come in contact with the walls, or each other;
- be watertight, so that water in bulk can only enter and leave through the intake pipe(s);
- be sited to reduce the chances of impact from flood debris.

Note: Stilling well design includes an assessment of maximum expected flood level using whatever local information is available, or regional flood estimation methods in the absence of other information. The determination of the maximum expected flood level will require the survey of one or more x-sections through which the design flow can be routed to derive a height. See NEMS Water Level (Version 3.0), Annex H.

2.4. Strength and Stability

2.4.1 General strength considerations

The stilling well must be designed to resist live and snow loads (via a catwalk), dead loads, wind and hydrodynamic loads, and combinations of these in accordance with AS/NZS 1170.0 (2002). Wind loads are determined from AS/NZS 1170.2. Hydrodynamic loads should be derived from the hydrological record, with due regard to the extent of the record.

Special attention should be given to the base of the stilling well. Stilling well sections that include an access hatch are particularly susceptible to local buckling which is very direction-dependent. For the design of bracing, it may be necessary to include analysis using a hinge at the base. Also the portion of the stilling well that comes out of the substrate or concrete may require special measures to reduce corrosion which tends to be more severe at that level.

2.4.2 Foundations

The foundation should be of a type, size and depth that is determined by specific design. Foundations often involve either a concrete footing or a number of buried stilling-well sections, but may involve both or neither of these features. Piles may also be used. The design will be dependent on the substrate available.

Note: The MWD steel stilling well design drawings do not give any guidelines on foundation design.

Ultimate strength, potential deformations that affect the usefulness of the structure, and durability (including corrosion of the steel stilling well) should be considered. The foundations must fulfil the following functions, at times simultaneously:

- Resistance to vertical loads. The purpose of a stilling well is related to fixed vertical datums, so vertical settling is inconvenient;
- Resistance to scouring. If the channel is likely to degrade, the bottom of a block foundation should be at least 0.5 metres below the maximum predicted scour depth;
- Resistance to shear;
- Resistance to overturning. If the stilling well deviates from vertical it may be become unusable. Foundation details and bracing requirements for the structure should be considered together to ensure the stability of the structure;
- Resistance to impact (of flood debris).

2.4.3. Bracing

Stilling wells are often supported from the bank by wire ropes or struts of various types. In its simplest (and least effective) form, bracing is a wire rope attached to the stilling well and tied into the bank on the upstream side, used to resist the downstream force of flood water. This arrangement can be enhanced by solid struts (including catwalks) and additional wire ropes in the downstream direction. Particularly at steep walled sites, it may be possible to support the stilling well using solid braces that are bolted to rock on the sides. But more typically, stilling wells are built without such direct support and use tension (rope) bracing that tightens onto a compression element. The ability to provide bracing (of any sort) is dependent on there being suitable anchorage points on the channel bank.

Bracing requirements are site specific. They are determined by the loading on the stilling well, by the ability of the foundations to resist overturning, and by the strength of the stilling well, particularly at the base where there is likely to be an access hatch (a point of weakness).

Note: The MWD steel stilling well design drawings do not give any guidelines on requirements for bracing elements.

The bracing requirements should be determined by specific design which should consider:

- The presence and health of trees that may drop timber onto the bracing;
- The height of the design maximum flood level. If bracing can become inundated, a debris raft may form which must be accounted for in the design loading;
- The direction of the load applied to the stilling well. The most adverse load may not be in the downstream direction. Stability is required in all directions;
- Whether bracing is required at more than one height (not common);
- Any catwalk-anchoring requirements. If used as a bracing element, ensure the catwalk is adequately anchored to the stilling well at one end, and to an adequate abutment that is keyed into ground at the other end. The abutment and end connections must be designed such that the catwalk main members are capable

of transmitting a design longitudinal force from the stilling well through the abutment to ground. The catwalk will require specific design to resist buckling under this compressive force.

2.4.4. Catwalk

The presence of a catwalk does not necessarily improve the stability of the stilling well. Three important factors regarding the catwalk are:

- Worker and public safety. See section 3 "Access Platforms and Catwalks".
- For stability purposes the catwalk can act as a compression strut between the stilling well and the bank, with the provision of lateral tension bracing (typically guy wires that are anchored to ground). However, this requires specific design of the catwalk as described above.
- If a catwalk is below the level of the design maximum flood, the design lateral load must include load from a debris raft which will form on the catwalk and its handrails. This can be significant.

2.5 Construction of Concrete Foundations

There a number of factors to consider in the design of the concrete mix when a new foundation is to be made. These include:

- Strength. In general it will not be cost-effective to use low strength (<30MPa) concrete unless the application is purely for ballast.
- Abrasion resistance. Where the stilling well is situated in an area of significant scour, or bed-load transport, an abrasion resisting mix should be considered.
- Chemical resistance. Especially in geothermal, coastal or estuarine locations, the concrete, and the reinforcing, can be susceptible to chemical action. In these cases a mix can be designed for increased durability.

Dry construction methods should be used where practicable, but if necessary, a wet construction method can be used, in which case the concrete should be placed into still water, and an accelerant added to the concrete mix to reduce setting time. Concrete construction should be supervised by an experienced person.

Depending on the design, the following steps may be applicable:

1. Set up the bottom stilling well section.
2. Box up the foundation space.

   This creates a form into which the concrete will be poured/pumped. Ensure *adequate concrete cover over the reinforcing.*

3. De-water the site (unless using a wet construction method).

   A submersible pump can be used for this.

4. Pour a 100-mm minimum thickness layer of blinding concrete.

   Allow 24 hours for the concrete to set before continuing with Step 5.

5. Pour/pump concrete into the form and vibrate it to remove any air.

   When pumping, ensure the exit end of the hose is kept within the concrete body. Allow 24 hours for the concrete to set before continuing with Step 6.

   Important: Poured concrete used for foundations must:

   - be well mixed, and
   - not be dropped from a height.

6. Remove the form.

   Extreme caution; - the concrete may still be quite weak at this time. Allow 7 days for the concrete to cure.

2.6. Hydraulic Design

2.6.1. Intake Pipe Sizing

The stilling well should be connected to the lake or river by means of a suitably sized intake pipe fitted with a static tube.

River Sites

For river sites, a relatively large intake pipe can be used to allow the recorder float to respond quickly to water level changes. The general guideline is to use a ratio of 12:1 between stilling well and intake pipe diameter. This means that for the MWD steel stilling well with its 600-mm diameter section, a 50-mm intake tube should be used.

Lake and Sea-Level Sites

For lake and sea-level sites, a smaller pipe may be required to:

- dampen out short-term fluctuations, and

  Short-term fluctuations can result from, for example, surging water and wind waves.

- preserve long-term fluctuations.

  Long-term fluctuations can result from, for example, tide and seiche.

For sizing intake pipes that are to be deployed at lake and sea-level sites, see Section 2.7: 'Linear Stilling Well Design'.

2.6.2. Aggradation and Degradation

In rivers, alternative intake pipes may be required at a range of levels to allow for possible bed aggradation or degradation.

The lowest intake pipe should be set at least:

- 150 mm below the lowest anticipated water level (but considerably further if degradation of the bed is possible)

  Note: This is a very important decision that may impact considerably on the usefulness of the structure over time.

- 300 mm and preferably 1 metre above the bottom of the stilling well, to avoid blockage by sediment.

2.6.3. Intake Pipe – Flow Control

Active Intake Pipe

- The active intake pipe, which is the intake pipe that is connected to the static tube, is recommended to have a simple on/off valve fitted.

  Note: A simple on/off valve is needed so that flow into and out of the stilling well can be shut off to allow filling of the well and then opened to flush sediment during de-silting operations.

Inactive Intake Pipes

- Inactive intake pipes need to be closed under normal operations to prevent excessive siltation of the stilling well. This can be achieved by, for example, stop-ending/capping the pipe or using a simple on/off valve (e.g. a gate valve).

2.6.4. Static Tube

It is recommended that static tubes be fitted to all stilling well intake pipes.

The reasons for this are:

- Where velocity past the river end of the intake is at times high (i.e. above 1.5 m/s) this will create drawdown of the water level in the stilling well. To reduce this, a capped and perforated static tube should be attached, oriented parallel to the direction of flow (± 10°).

- The fitting of a static tube will minimise the egress of sediments into the intake pipe and stilling well.

For more information on static tubes and intake pipes, see NEMS *Water Level* and/or the NEMS *Glossary* of terms.

2.7. Linear Stilling Well Design

A problem in measuring water levels in coastal sites or on lakes or harbours is that the long-period waves of interest are of much smaller magnitude than the short-period wind waves, which act as noise. For example, in lakes, seiching is typically in the order of 0.1 to 0.2 metres, whereas wind waves may be 0.5 metres or higher.

Seelig (1977) provides a methodology (called linear stilling well design) for designing a stilling well that accurately measures water level fluctuations of interest and damps out undesirable short-term fluctuations.

The linear stilling well design consists of a well and orifice pipe. A unique characteristic of the design is that no nonlinear water level amplifications occur; that is, water levels inside the well respond linearly to fluctuations outside the well.

A key requirement is that the orifice pipe be free from fouling since the response characteristics of the well are sensitive to even small pieces of debris in the orifice. Because of this, the method is recommended for short-term operation in clear water areas only.

Under the linear stilling well design, the theoretical length of the orifice pipe, L_p, is given as:

$$L_p = 48790 * [(\beta_2 Dp^4 \mathrm{T})/D\omega^2]$$

where: L_p is the length of the orifice pipe in metres

Dp is the inside diameter of the orifice pipe in metres

T is the wave period in seconds

$D\omega$ is the inside diameter of the stilling well in metres, and

β_2 is a dimensionless frequency parameter.

Figure 2 plots the amplitude response curve for the linear stilling well design as a function of the dimensionless frequency parameter, β_2.

Generally, it is desirable to have β_2 less than or equal to 0.45 for the long-period waves to be measured. At the same time, β_2 should be taken as 10 or greater when considering the short-period wind waves.

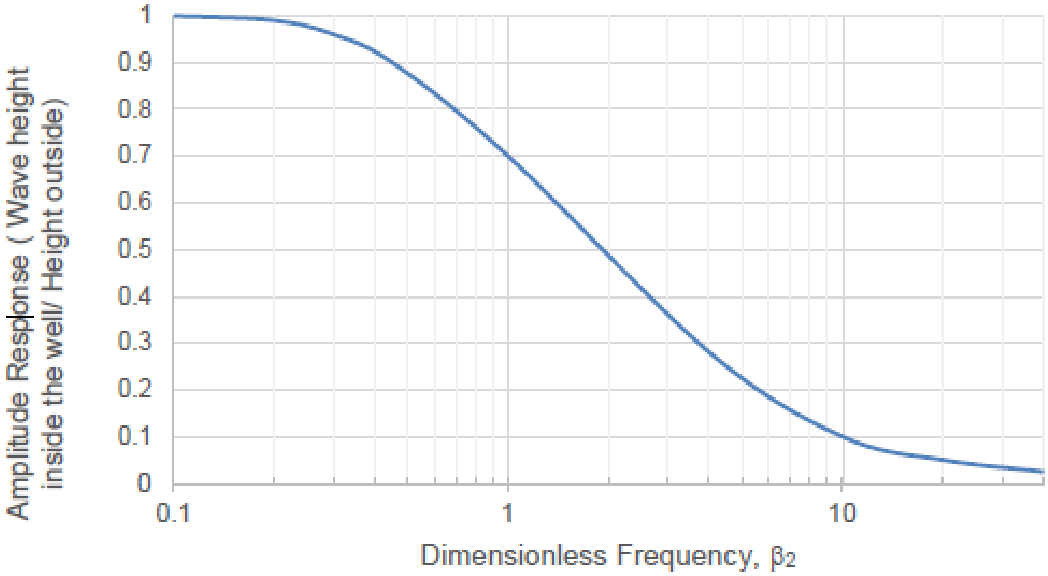

Figure 2 - Amplitude response curve for a linear stilling well

Source: Seelig, 1977.

Note:

- $\beta_2 = 0.45$ *corresponds to an amplitude response factor of 0.9, meaning that 90% of the amplitude of the long-period wave to be measured will be retained.*
- $\beta_2 = 10$ *corresponds to an amplitude response factor of 0.1, meaning that 10% of the amplitude of the short-period wind wave will be retained; or alternatively, that 90% of the amplitude of the short-period wave will be damped.*
- $\beta_2 = 20$ *corresponds to an amplitude response factor of 0.05, meaning that 5% of the amplitude of the short-period wind wave will be retained; or alternatively, that 95% of the amplitude of the short-period wave will be damped.*

Example

A 600-mm stilling well is required to damp out 95 % of the amplitude of wind waves with a period of 10 seconds. The period of the long waves is unknown, so design is based on damping the short-period wind waves. Assume a 20-mm diameter orifice pipe is to be used.

Applying equation (1), the length of the orifice pipe required is given as:

$L_p = 48790 * [(\beta_2 Dp^4 T)/Dw^2] = 48790 * [(20*0.020^4 * 10)/0.6^2]$

$= 4.34m$

3. Access Platforms, Catwalks, and Ladders

3.1. Background

Platforms may be required at water level recorder sites for access to a recorder housing or for water sampling. Catwalks are simple bridged walkways that generally run as a single span from the river-bank to a recorder housing. The beams may have intermediate supports if the topography allows, and multi-span catwalks may be required at some sites. Broadly speaking, timber or steel construction are the two main options with many different combinations possible. There are many and varied factors that will influence the design of access ways: structural, safety, environmental, and social to name a few.

3.2 Inspection and maintenance

The design of a structure should ensure that it will withstand specified loading conditions. However, on-going inspection and maintenance is required to ensure that this continues to be the case over the life of the structure. Inspections should be regular, documented, and cover known points of weakness. Changes in public accessibility to the site should also be noted and addressed.

3.3 Upgrade of existing structures

Existing structures, or parts of them, may not meet current standards. Where the issue involves fall barriers, the structure should be upgraded to the current standards. Where the issue involves live loading, and upgrading the structure is not practicable, a load limit should be signposted on the entrance to the structure. This should give the maximum working load of the structure in terms of number of persons. Where the structure is in a built-up or populated area, this should be supplemented by locked gates or similar means of preventing access.

3.4. Design Considerations

3.4.1. General

The rationale for these design considerations is that hydrometric access-ways are industrial fixtures and subject at a minimum, to loadings described in AS/NZS 1657:1992. However, these structures are often in locations that are, or appear to be public domain, and it is a reasonable public expectation that they would be designed as if on conservation land. Therefore, if public access can't be prevented by physical barriers, the design should at least have equivalence with SNZ HB 8630:2004.

This standard does not apply to unlocked access-ways that are attached to buildings or in built-up areas. In those situations, design loading and barrier design should be guided by standards relating to the specific location which would likely include AS/NZS 1170:1:2002 and the Building Code (B1 guidance on barrier design).

A new platform or catwalk, to comply with the New Zealand Building Act (2004), will typically need a building consent.

Note: A building consent is not required where it is not possible for a person to fall more than 1.5 metres (under Exemption (g) of Schedule 1 of the New Zealand Building Act 2004).

All structural components should be determined by specific design. Prior to site work or construction, the design should be approved by a chartered professional engineer with competence in structural engineering.

3.4.2 Fall prevention

The provision of effective barriers (handrails) is an essential component of the design of access platforms and catwalks. The type of barrier should be appropriate for the location. In particular, barriers that are difficult to climb over or through should be provided in locations that are likely to be frequented by children. This means all openings should be less than 100mm across and there should be no toe-holds between 150mm and 760mm high above the floor. Solid infill may also be used. If a site is not likely to be frequented by children, a 3-rail barrier is appropriate. This consists of a top handrail, a middle rail, and a bottom rail/kickboard. If the nature of public access changes (for example, due to residential or recreational developments) then rail type barriers can be upgraded by removing the middle rail and fastening galvanised pool fencing to the top and bottom rails (provided that all components of the barrier have been checked for strength).

3.4.3. Loading

In designing catwalks and access platforms, the design live load should be taken as:

- 3.0 kPa at locked sites or on rural private property.
- 4.0 kPa at sites close to populated areas or rural sites with easy public access.
- 1.8kN concentrated load at any point on the floor or step.

Note: It is recommended that all catwalks are designed for a live load of at least 4.0kPa.

Barriers design should consider a design live load acting on the top edge, acting as either:

- a 0.35 kN/m uniformly distributed load, acting horizontally or vertically, or
- a 0.75 kN/m uniformly distributed load, acting horizontally or vertically, at sites close to populated areas.
- a concentrated load of 0.6 kN acting down, inwards or outwards at any point of the top rail.

3.5. Existing Catwalks including MWD design

Many existing catwalks are built to a Ministry of Works and Development (MWD) design.

The MWD design, as documented in the Ministry's *Standard specifications for automatic water level recorder installations and current meter gauging stations* (Hanson & Turner, 1958), should not be used for new catwalks.

Catwalks that do not meet current design requirements should be upgraded to current design specifications and display “load limit” signage until this upgrade work is completed.

Note: The MWD design, although commonly used, does not comply with current Building Code requirements:

- *The design live load adopted was 45 lb/ft2 which equates to 2.1 kPa. This is less than the current design live load requirements for a new catwalk (see sub*section 3.4.3: ‘*Design Loading*’*).*
- *The barrier handrail does not meet current requirements, in that it doesn’t have a centre rail or kick plate.*

Figure 3– Catwalk (MWD design)

Note: Figure 3 shows a typical example of this design, although it differs in having an expanded mesh floor (the floor in the MWD design is made of timber planks).

Photo: Courtesy of Jeremy Walsh, NIWA.

3.6. New Catwalk Designs and Upgrades

Figure 4 shows a steel design fitted to an existing water level recorder site with concrete stilling well. Note the handrail design which is harder for small children to climb. Figure 5 shows a timber design with steel handrails.

Figure 4 – Steel Catwalk

Photo: Courtesy of Jon Marks, GWRC.

Figure 5 – Timber Catwalk with Steel Handrails

Note: Due to a lack of suitable anchorage positions and a high incidence of falling timber, lateral bracing struts or ropes were not employed at this site. Lateral stability is achieved by a modified concrete design at the base.

Photo: Courtesy of Ralph Dickson, NIWA.

The strength of handrail stanchions is a common issue where older catwalks do not meet current standards. New handrails can be retro-fitted to existing steel beams where the beams and posts are serviceable and adequate in strength. This can be done using underslung u-shaped steel components to form the handrail stanchions. These are diagonally braced to provide longitudinal stiffness, and support horizontal pipes at top, middle and bottom, to form the handrail on each side. An underside view of an upgrade in progress, showing the u-shape component connection details is shown in Figure 6.

Another common issue for existing sites, where a catwalk is fitted to a 600-mm steel stilling well, is the support provided at the stilling well end. Figure 7 shows a steel bracket design that extends to the flange below the catwalk, so that vertical loading from the catwalk is transmitted to the flange in bearing.

Note: The MWD design uses an angle seat that is bolted through the stilling well cylinder. Improper packing of the angle seat has resulted in bending of the cylinder walls and the angle seat at some sites, with consequent loss of strength. The design modification illustrated in Figure 7 eliminates this problem.

Figure 6 – Underside view of NIWA-design handrail upgrade.

Photo: Courtesy of Colin Grace, NIWA.

Figure 7 – Attachment to 600-mm stilling well with the new seat design (NIWA)

Photo: Courtesy of Colin Grace, NIWA.

3.7. Stairways, Ramps and Ladders

Stairways, ramps, and ladders shall comply with SNZ HB 8630:2004 (which references the New Zealand Building Code, D1 access routes), or, if not easily accessible by the public, may be designed to NZS/AS 1657:1992.

3.7.1. General Requirements

When choosing a fixed ladder design, the following factors should be considered:

- the reason for access, the intended frequency of use, and the need to carry tools or materials by hand;

  Note: Rung-type ladders should not be used where frequent access and the carriage of tools, equipment or materials are required.

- protection from falling

  Note: People should be protected from falling from all fixed ladders that rise more than:

  - *6.0 metres above the ground level or rise from a landing or platform.*

        - *See the most recent NZ Building Code for acceptable solutions for safety hoops and longitudinal straps.*
    - the landing width and length; and
    - rung or tread spacing uniformity.

3.7.2. Fixed Ladders types

The building code and NZS/AS 1657 give requirements for different ladder types including:

- Step-Type Ladders (slope between 60 and 70 degrees to horizontal)
    - tread width and spacing
    - width between stiles
    - height between landings
    - toe and hand clearances
    - horizontal openings at landings, and
    - handrails
- Rung-Type Ladders (slope between 70 and 90 degrees to horizontal)
    - width between stiles
    - height between landings
    - toe, hand, side and back clearances, and
    - access to landings
- Individual Rung-Type Ladders (for example, a ladder with individual climbing rungs cast into a vertical concrete surface)
    - rung size and spacing
    - tread width limitations , and
    - height and clearance limitations.

4. Slack-Line Cableways

4.1. Background

Slack-line cableways are commonly used for carrying out flow gaugings on small rivers and streams.

The components of a slack-line cableway comprise: a static ropeway, suspended between anchor ends; a traveller; a horizontal positioning mechanism; and a lifting mechanism. In operation, the traveller runs on the ropeway and functions as an unmanned ‘cable car’.

All operations are carried out from the bank.

4.2. Manual Winch Slack-Line Cableway

In the manual winch slack-line cableway, the horizontal positioning and lifting mechanisms are non-motorised.

4.2.1. Horizontal Positioning Mechanism

The horizontal position of the traveller is controlled by means of a manual winch that feeds a line across the span and over a pulley mounted on the far side and back to the traveller.

4.2.2. Lifting Mechanism

A separate line from a gauging reel feeds out to the traveller, runs over a pulley mounted on the traveller, and connects to a current meter and counterweight, thereby suspending these from the traveller.

The gauging reel controls the vertical position of the current meter.

Figure 8 shows a flow gauging being carried out on a manual winch slack-line cableway.

Figure 8 – Flow gauging from a manual winch slack-line cableway

Photo: Courtesy of John Fenwick, NIWA.

4.2.3. Span

The span of a conventional manual winch slack-line cableway is limited by the length of the gauging reel.

'A'-type gauging reels are 30 metres in length, but extended range reels, of 60 metres, are available and these are typically used when doing a slack-line gauging. Assuming an extended range reel and allowing for 4 metres vertical travel (which is typically what is required), this means that the maximum span is limited to around 54 metres.

Note: This span refers to the distance between the near-side 'A' reel mounting point to the far side of the active channel, not the active channel width or the cable span.

4.2.4. Maximum Load

A maximum load of 45 kilograms (100 lb) applies, as it is difficult to manhandle a direct drive gauging reel with a higher load than this.

4.3. Ott Slack-Line Cableway

The Ott slack-line cableway is a variant of the conventional manual winch slack-line design. Its main point of difference is that it incorporates a double drum winch, with one drum for traversing and the other drum for raising and lowering the gauging line. Both drums are operated manually.

The main advantage of the Ott design is an increase in span. Use of a dedicated winch drum for the gauging line, instead of an extended range reel, allows the span to be increased to around 100 metres.

Note: There are other commercially available unpowered slack-line designs that have similar capabilities.

4.4. Motorised Slack-Line Systems

Several proprietary motorised slack-line cableway systems are now available.

These systems provide motorised control of the traveller and incorporate a remote controlled winch, powered by batteries incorporated in the traveller.

Motorised slack-line systems are not restricted in span by the length of the gauging cable because the gauging winch and drum is on the traveller. Typically, these systems can be used with spans up to 250 to 400 metres.

Furthermore, since they can be fitted to run on a larger static cable, they can be retrofitted to manned cableways, thereby converting these to an unmanned slack-line system.

Figure 9 shows an example of such a system.

Figure 9 – Flow gauging using a 'Hornet' motorised slack-line system retrofitted to a manned cableway

Photo: Courtesy of Neil Blair, NIWA.

Retrofitting a motorised slack-line to a manned cableway eliminates the need to have one or more field staff suspended over a river during a flood to gauge the flow. It provides a safer environment for field staff during gauging operations. There are also cost savings in reduced certification and maintenance requirements. However, there are some compromises involved.

Feedback from field staff who have used these systems indicates that:

- water depth is difficult to determine

Note: This is because it is difficult to sense when the Columbus weight hits the bottom.

Note: Some systems, e.g. Hornet Plus, incorporate a ground feeler device that alerts the operator when contact is made with the bed, which eliminates this problem.

- angular flow may be difficult to assess

Note: Because flow is oblique to the cross-section, the angle of the flow is not measured directly.

- visibility, when operating close to the bank, may be an issue

  For example, where the site is in a gorge, or the line of sight is obstructed by trees or other obstacles.

- undertaking depth-integrated sediment gaugings may be problematic because of:

  - the time required to traverse back to the bank after each sample to change the sampling bottle, or
  - inadequate control of the vertical traversing rate in some systems, and

- maintenance of the cable, far bank backstay, anchor block and traveller pulley may be expensive, or have to cease.

  Note: This can occur where the cableway was the only access to the far bank.

There are some advantages, therefore, in retaining manned cableways, particularly for sites with very long spans and where visibility to the water is an issue.

4.5. Design Considerations

All components of a slack-line system should be determined by specific design and approved by a chartered professional engineer with competency in structural engineering.

The design should be based on the design loads specified below.

4.5.1 Cable

The static cable should be designed for a 3.5 kN snag load acting at minimum operating temperature.

Note: The 3.5 kN snag load can be regarded as the maximum possible load that can be applied to the instrument cable. It assumes a load-limiting device rated at 3.5 kN has been installed at the connection between the instrument cable socket and the gauging equipment hanger bar.

Note: Minimum operating temperature is generally taken as –10°C, but could be higher. Each site must be considered on its own merits.

The cable tension under load at minimum operating temperature (maximum cable tension) should not exceed the allowable working load of the cable, T, given as:

$$T = U/F_s$$

where: T is the allowable working load of the cable in kilonewtons (kN)

U is the ultimate tensile strength of the cable in kilonewtons (kN), and

F_s is the factor of safety, which is taken as 4.5

4.5.2 Anchor Ends

For a conventional slack-line, the static cable is generally anchored to a steel cross- beam that is mounted on timber posts and tied back to suitable anchors via wire ropes attached to each end of the cross-beam.

The cross-beams should be:

1. Mounted on posts placed securely into firm ground.

   This is to ensure the foundations are stable.

2. At about 1.5 metres height above ground.

   This is governed by the need to provide a comfortable height for manual operation of the winch and gauging reel.

3. Mounted at the same or near-same elevation on each side of the span. *This is particularly important for long spans, in which case a vertical height difference between the supports may make operation of the manual winch against the gradient very difficult.*

The design of the cross-beams, timber posts, tie-backs and suitable anchors should be of sufficient strength as determined by detailed design.

Likewise, forces acting on the suitable anchors should be considered. If these are conventional gravity anchor systems, then stability against sliding and overturning should also be considered.

4.5.3 Navigational Clearance

The cable should have a safe working clearance of at least 3 metres from design maximum flood level to the bottom of the traveller at maximum working temperature, when under load.

The safe working clearance is to allow small trees and floating debris to pass under the cable. The 3-m clearance may be insufficient if the river in full flood usually carries large floating debris.

Note: Design maximum flood level is generally taken as the 0.05 annual exceedance probability level (i.e. 1:200-year flood level).

Note: Maximum working temperature is generally taken as 50 degrees above minimum operating temperature.

Where the cable is a potential hazard to large craft using the reach, higher clearance from high flood level to the cable may be required. In this case, details of the site and clearances should be forwarded to the appropriate authorities for approval prior to commencement of construction. The Regional or District council should be contacted in the first instance. However, they may manage navigational issues on a day-to-day basis through a local harbour master.

5. Meteorological Masts

5.1 Background

Meteorological masts come in many different types, and there are many different variations of the same type. Even on flat lowland areas, constraints on the building footprint and differences in meteorological equipment can lead to many variations on the same type. The basic function of a mast is to allow equipment to be mounted in a specific way, and usually at a specified height.

5.2 Disclaimer

The masts described in this section are given as examples of commonly used types and are not intended to be a complete list. Their representation in this document is not intended as a recommendation for use, nor of compliance with the New Zealand Building Code.

5.3. Common Types of Mast

The common types of meteorological masts described in this section are:

- 10-m tilting mast (NIWA)
- 6-m tilting mast (NIWA)
- 3-m, 6-m and 10-m lattice masts (NIWA)

Lattice masts are typically used for high loads or adverse conditions. An important advantage of the tilting masts is the ability to tilt the mast to ground using the tilting arm, which avoids the need to climb the mast. A disadvantage of the 10m tilting mast is its large footprint: a 6.5-m radius is required for the guys and, in addition, 10 metres of working space is required to lower the mast. The 6m mast is less conspicuous.

5.4 Inspection and maintenance.

The design of a mast should ensure that it will withstand specified loading conditions. However, on-going inspection and maintenance is required to ensure that this continues to be the case over the life of the mast. Inspections should be regular and documented. Particular notice should be taken of corrosion at structurally important parts. These will include, but certainly not be limited to threaded tube joints, fastenings, wire fittings, moving parts where galvanising wears off, and steel at foundation level.

5.5. Design Considerations

5.5.1 General

Wind load is the main (and in most cases the only) load that needs to be accounted for in the design of meteorological masts for strength. AS/NZS 1170.2 (2011) is the appropriate standard for determining the wind load.

Lattice masts are commonly used in areas of high wind-speed or other adverse conditions, and load-bearing components should be determined by specific design in those cases. The rationale behind the design of the tilting mast types described here is that in normal circumstances they will withstand the wind load associated with a stated annual exceedance probability. Factors that then require specific consideration are, but are not limited to:

- Consequence of failure, location, and accessibility. This includes issues such as public danger, public nuisance, and the importance of the data being collected.
- Suitability of the local soil/substrate for the standard footings/anchors.
- Unusually large sized equipment mounted on the mast, which will increase the wind load. If the equipment mounted on the mast is changed such that a significant difference in wind-loading is likely to occur, the mast design should be revisited.
- Position in topography. For instance, a mast on a ridge-line will be exposed to higher wind speeds.
- Position in relation to alpine lee zones or Cook Strait, where higher design wind speeds are applicable.

5.5.2 Guys

Guy wires are typically of galvanised steel wire or Parafil.

Note: Parafil is a synthetic rope consisting of a core of closely packed, high-strength aramid, PBO or high-tenacity polyester fibres, encased in a protective polymeric sheath. Properties of Parafil include high tensile strength, high strength-to-weight ratio, good tension fatigue resistance, and good resistance to degradation under UV light.

The use of Parafil is becoming more widespread and is preferable at sites where high rates of corrosion are likely. Parafil has lower stiffness than galvanised steel wire so is less likely to snap because of over-tightening. However, Parafil is more expensive than galvanised steel wire, mainly because of the high cost of fittings required. Because of this, galvanised steel wire is still often used.

5.5.3. Footing

All masts require a concrete footing. If the mast is not guyed, over-turning moments applied to the mast must be resolved by the footing, which will require detailed design for that purpose. AS/NZS 4676 (2000) may be consulted for concrete pile-type foundations that are round or near-round. (NB; Even where the mast is guyed, some resistance to overturning in the footing is still generally utilised for lattice masts, and considered for specific loading scenarios in other cases).

5.5.4. Anchors

Anchors for guys are generally concrete gravity blocks that are embedded 600 mm into earth.

Anchors should be adequately sized to prevent uplift and horizontal forces. For alpine sites, rock anchors are generally used.

5.6. 10-metre Tilting Mast

The 10-m tilting mast is a NIWA design. Figure 10 shows an example of this type of mast.

Figure 10 – Example of a 10-m tilting mast

Photo: Courtesy of Andrew Harper, NIWA.

This type of mast comprises a vertical mast, a horizontally mounted tilting arm, guy wires, a concrete foundation pad, and concrete anchor pads or ground anchors.

The lower third of the mast and tilting arm are made up of 80-mm nominal bore (NB) steel tube. Smaller 50-mm NB tube is used for the upper part of the mast. The point of attachment of the three guy wires is about 6m high. More recently, 80 NB tube has been used for the whole mast, with two sets of guy wires, attached at the top and at about 4m high.

5.7. 6-metre Tilting Mast

A 6-m tilting mast is sometimes used for sites where:

- Wind data is needed, but not necessarily at 10 metres, or
- The footprint available at the site is less than that required for a 10-m tilting mast.

The mast is un-guyed, and the wind load on the mast cannot be as high as some of the guyed masts; that is, it cannot carry bulky equipment near the top. Often the mast-top only has a wind sensor.

Figure 11 shows an example of this type of mast.

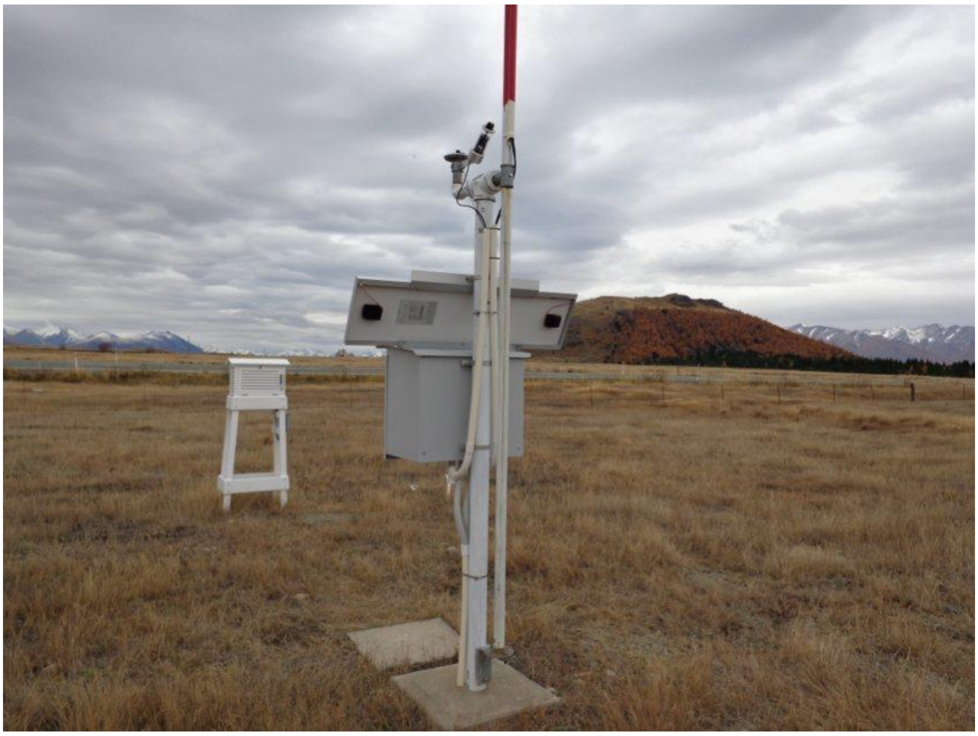

Figure 11 – Example of a 6-m tilting mast

Photo: Courtesy of Andrew Harper, NIWA.

The mast is essentially a 3.25-m long, 80-mm nominal bore galvanised pipe that is concreted into the ground to a depth of 750 mm with standard off-the-shelf pipe fittings to pivot a 6.5-m length of 40-mm pipe, to allow work on instrumentation at ground level.

5.8. 3-metre, 6-metre and 10-metre Lattice Masts (NIWA)

The lattice mast is a fixed mast; it cannot be pivoted.

This type of mast must be climbed to service instruments, and this introduces a working-at-heights hazards both for the person climbing the mast, and for other people in the vicinity. There must be provision for the management of this hazard in the design of a lattice mast site.

Lattice masts have applications at alpine sites, where strength and a minimal footprint is usually necessary because of:

- high wind speeds
- snow and ice loading
- consenting issues, and
- the amount of equipment needed to be installed on the mast.

Figures 12 and 13 show examples of this type of mast.

Figure 12– Example of a 3-m lattice mast

Photo: Courtesy of Andrew Harper, NIWA.

Figure 13 – Example of a 6-m lattice mast

Photo: Courtesy of Andrew Harper, NIWA.

Typically, 3-m lattice masts are guyed at the top, and 6-m lattice masts are guyed either only at the top or at both top and mid-level. The base is either a 1-m section concreted into the ground or the mast is bolted to threaded studs that are epoxied into rock.

Annex A – List of Referenced Documents

Building Act 2004. Available from http://www.legislation.govt.nz/act/public/2004/0072/latest/DLM306036.html?search=qs_act%40bill%40regulation%40deemedreg_New+Zealand+Building+Act+2004_res el_25_h&p=1&sr=1

Building Regulations 1992, Schedule 1 (The Building Code). Available from http://www.legislation.govt.nz/regulation/public/1992/0150/latest/whole.html#DL M162576

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Health and Safety at Work Act 2015. Available from http://www.legislation.govt.nz/act/public/2015/0070/latest/whole.html

National Environmental Monitoring Standards (NEMS). (2013). *Glossary* (A National Environmental Monitoring Standard). Wellington, New Zealand: Available from https://www.nems.org.nz/nems - Glossary.pdf

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Resource Management Act 1991. Available from http://www.legislation.govt.nz/act/public/1991/0069/latest/DLM230265.html?search=qs_act%40bill%40regulation%40deemedreg_Resource+Management+Act_resel_25_h&p=1&sr=1

Seelig, W. N. (1977). *Stilling well design for accurate water level measurement* (Technical Paper No. 77-2). Fort Belvoir, VA: Coastal Engineering Research Center (US).

6. Annex B – Relevant Statutes and Codes of Practice

The most recent New Zealand statutes:

- Building Act

  Available from
  http://www.legislation.govt.nz/act/public/2004/0072/latest/DLM306036.html

- Building Regulations

  Available from
  http://www.legislation.govt.nz/regulation/public/1992/0150/latest/DLM162570.html

- Health and Safety in Employment Act, and

  Available from
  http://www.legislation.govt.nz/act/public/1992/0096/latest/DLM278829.html

- Resource Management Act

  Available from
  http://www.legislation.govt.nz/act/public/1991/0069/latest/DLM230265.html

The most recent New Zealand Building Codes for:

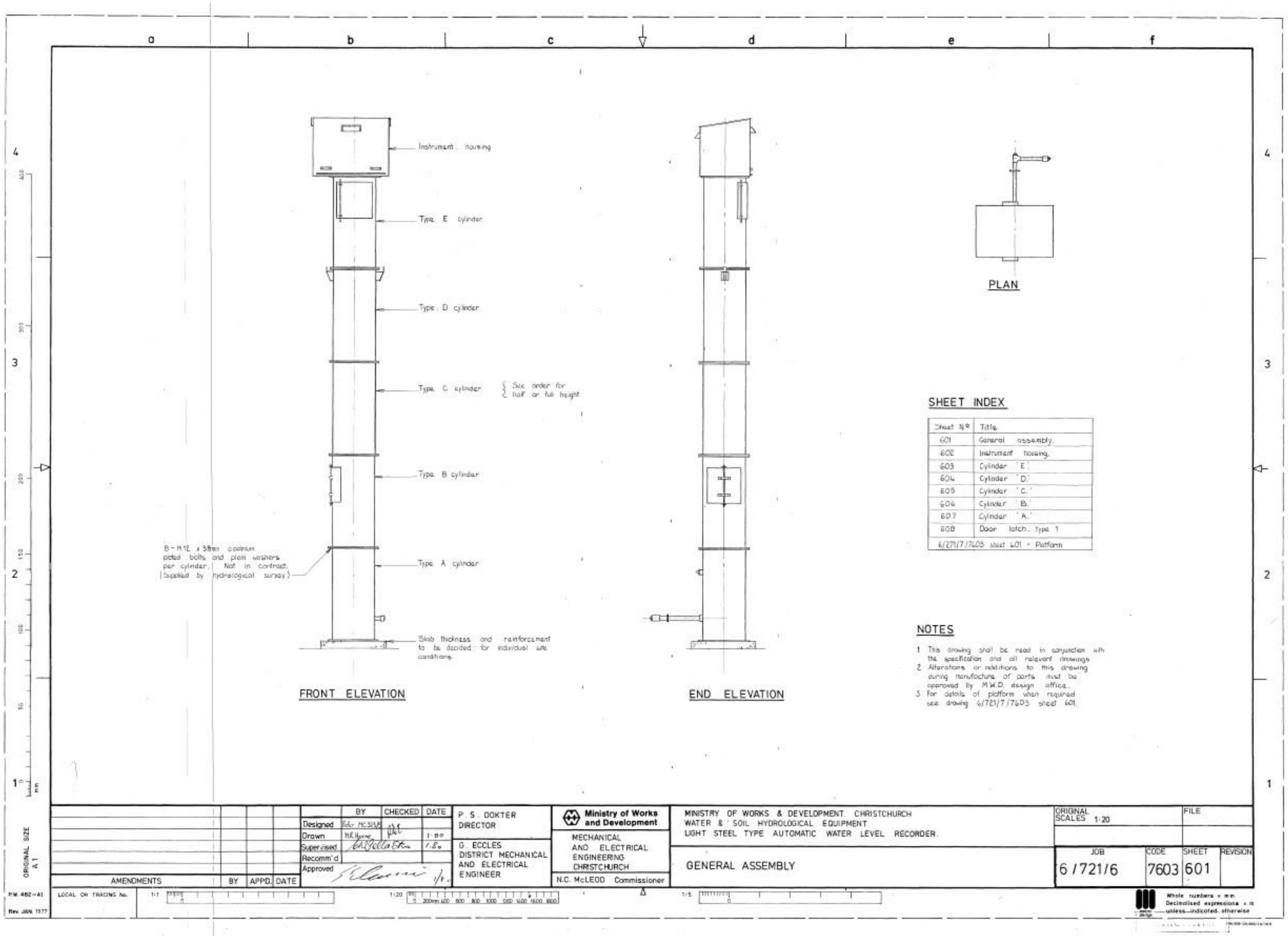
- concrete construction
- steel structures
- timber structures, and
- design loading.

User should ensure that they are consulting the most recent versions of these documents.

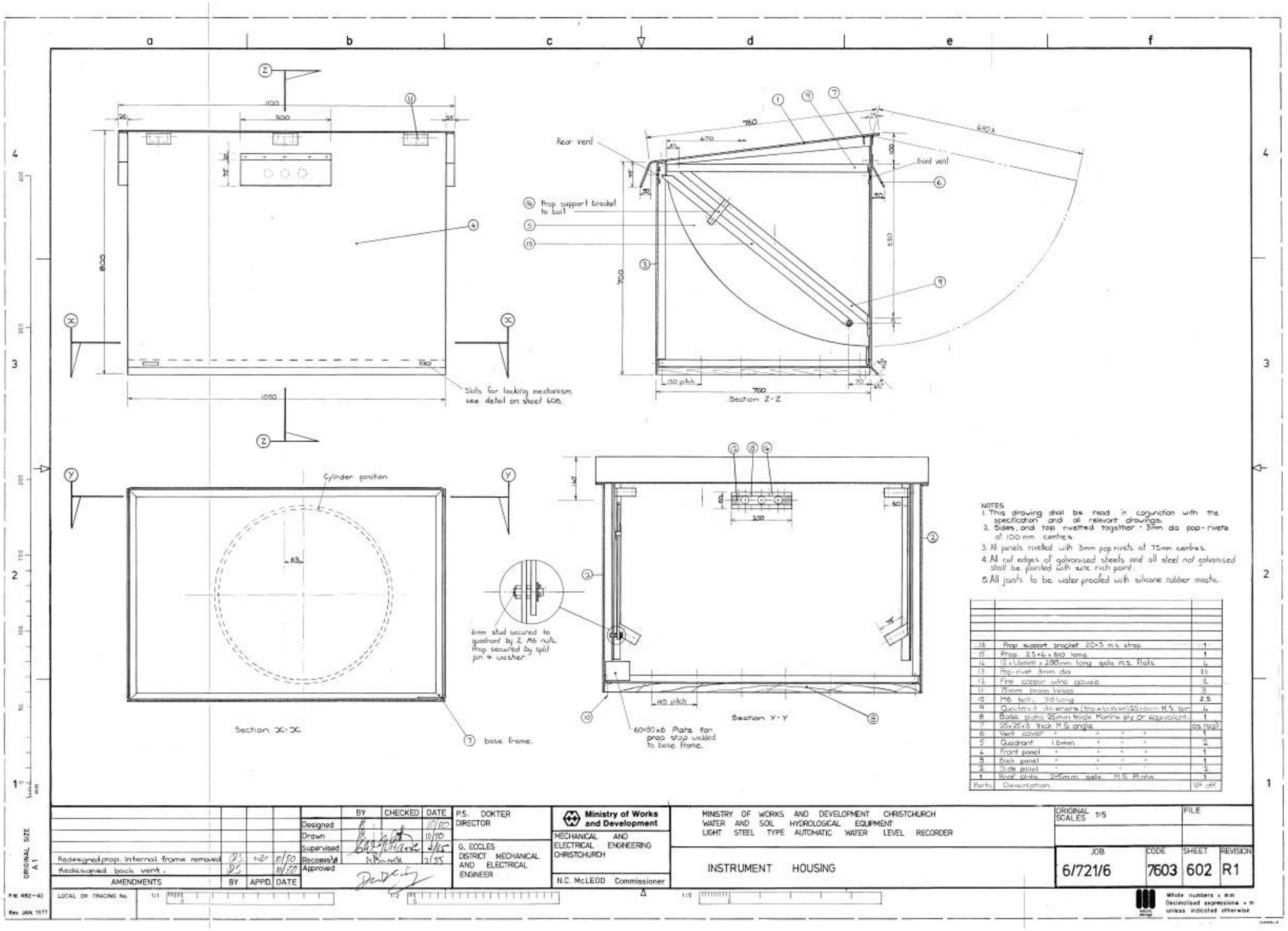
7. Annex C – Steel Stilling Well Design Drawings

This Annex contains the following Ministry of Works and Development design drawings, and static tube intake design:

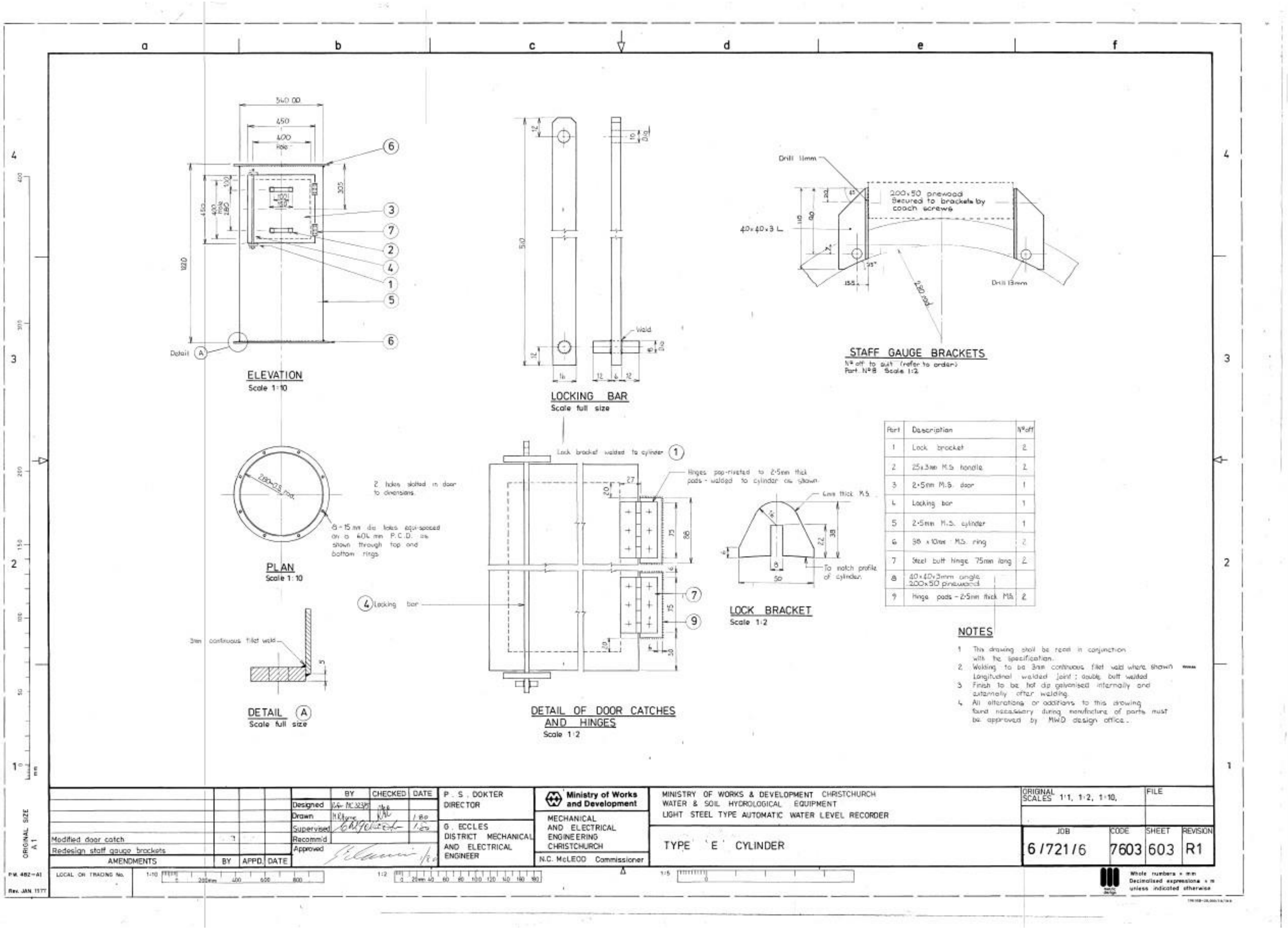
• General Assembly	MWD Drawing 6/721/6/7603/601
• Instrument Housing	MWD Drawing 6/721/6/7603/602/R1
• Type 'E' Cylinder	MWD Drawing 6/721/6/7603/603/R1
• Type 'D' Cylinder	MWD Drawing 6/721/6/7603/604/R1
• Type 'C' Cylinder	MWD Drawing 6/721/6/7603/605
• Type 'B' Cylinder	MWD Drawing 6/721/6/7603/606
• Type 'A' Cylinder	MWD Drawing 6/721/6/7603/607
• Door Latch Type 1	MWD Drawing 6/721/6/7603/608/R1
• Platform	MWD Drawing 6/721/7/7603/601
• Static tubes for intake pipes	NEMS Water Level Recording, July 2016



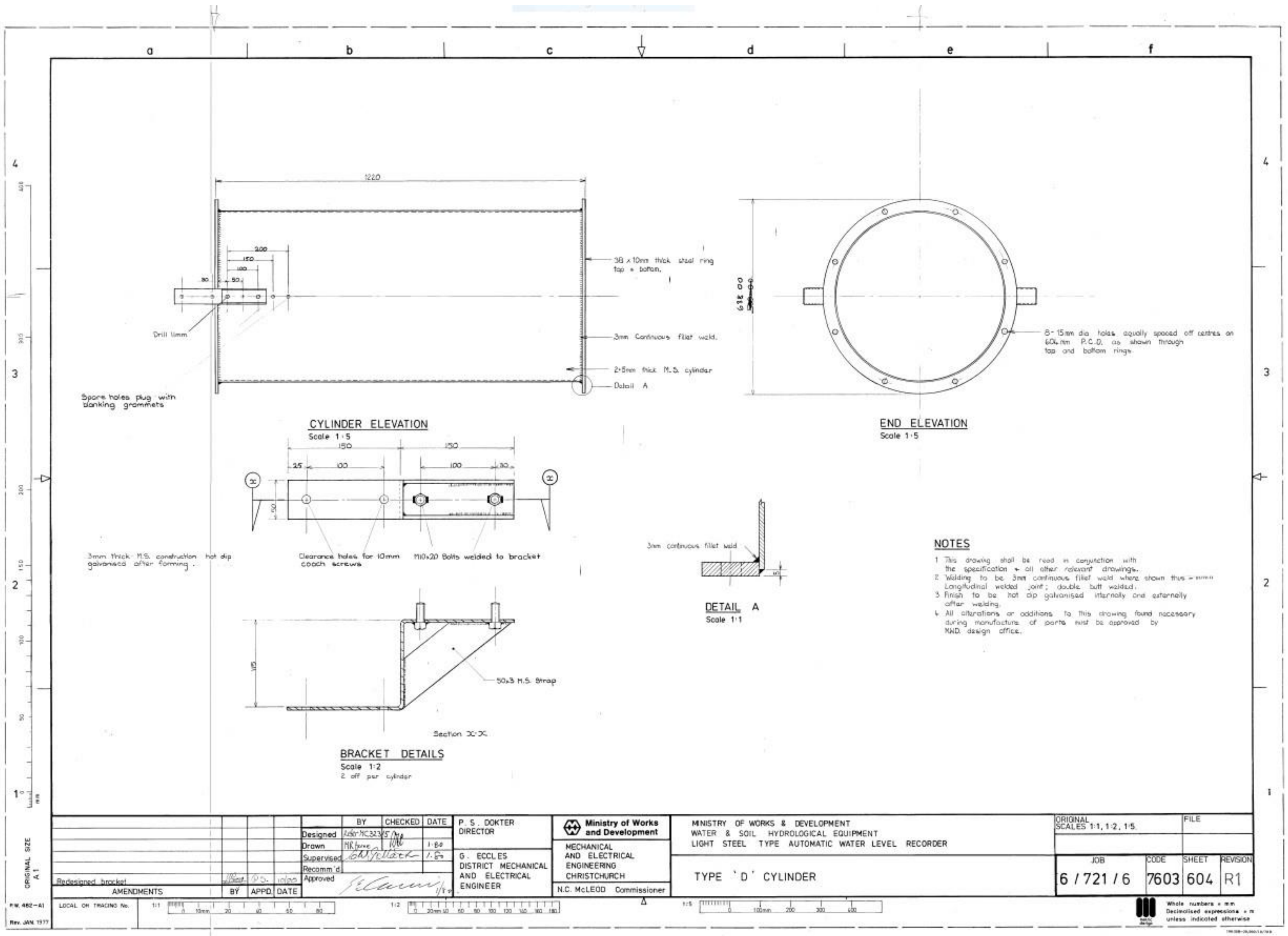
General assembly
(MWD Drawing 6/721/6/7603/601)



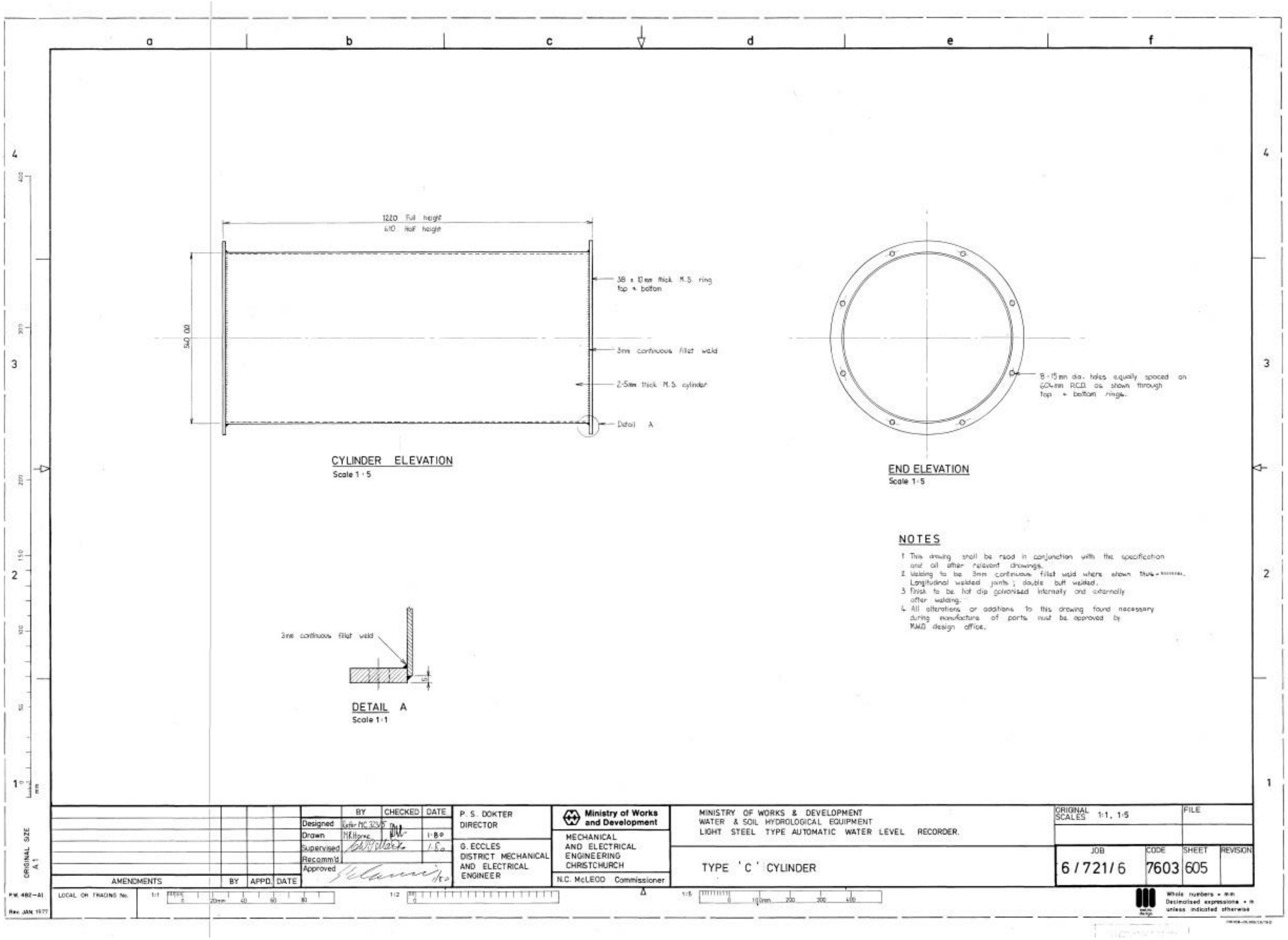
Instrument housing
(MWD Drawing 6/721/6/7603/602/R1)



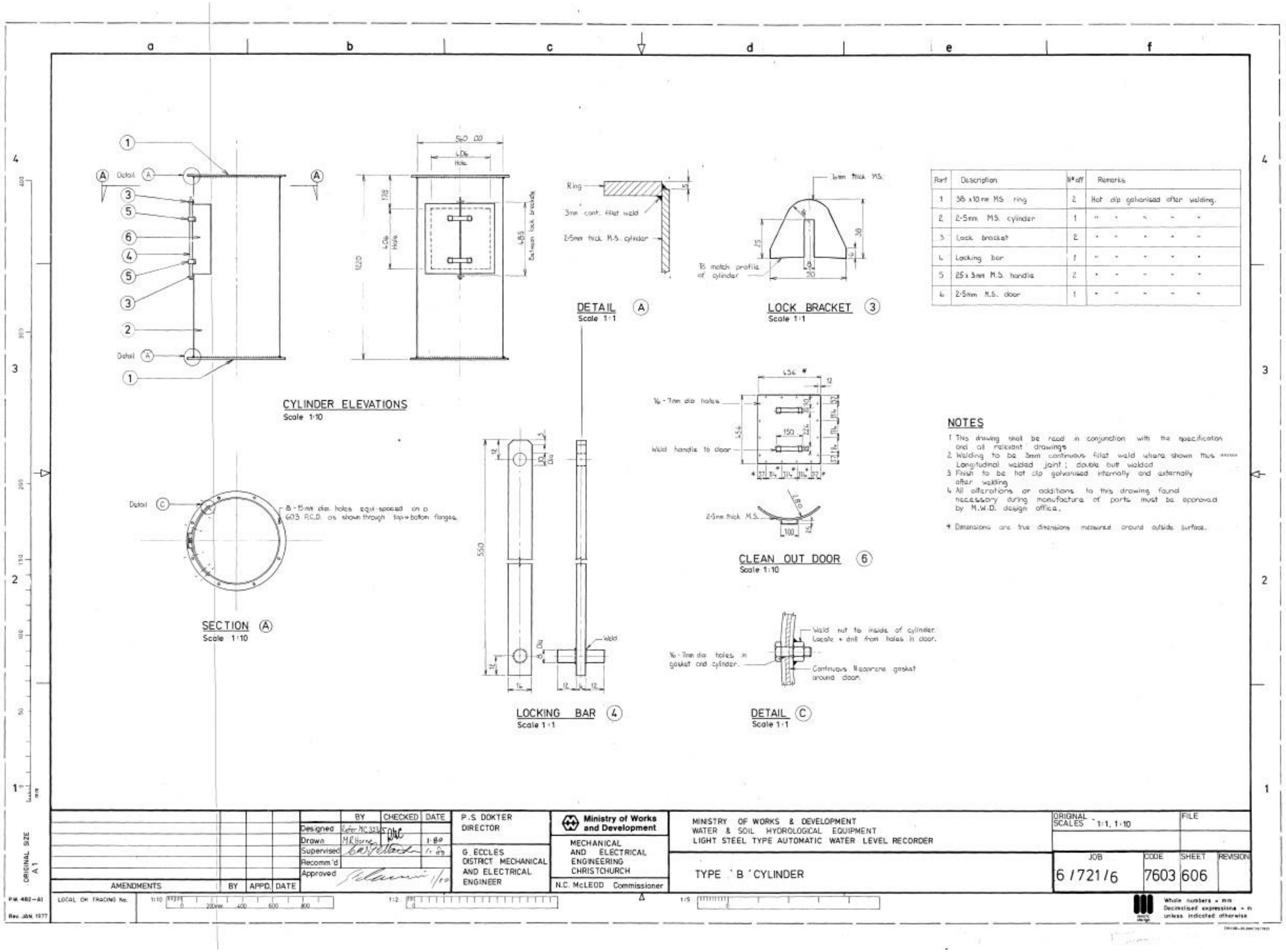
Type 'E' cylinder
(MWD Drawing 6/721/6/7603/603/R1)



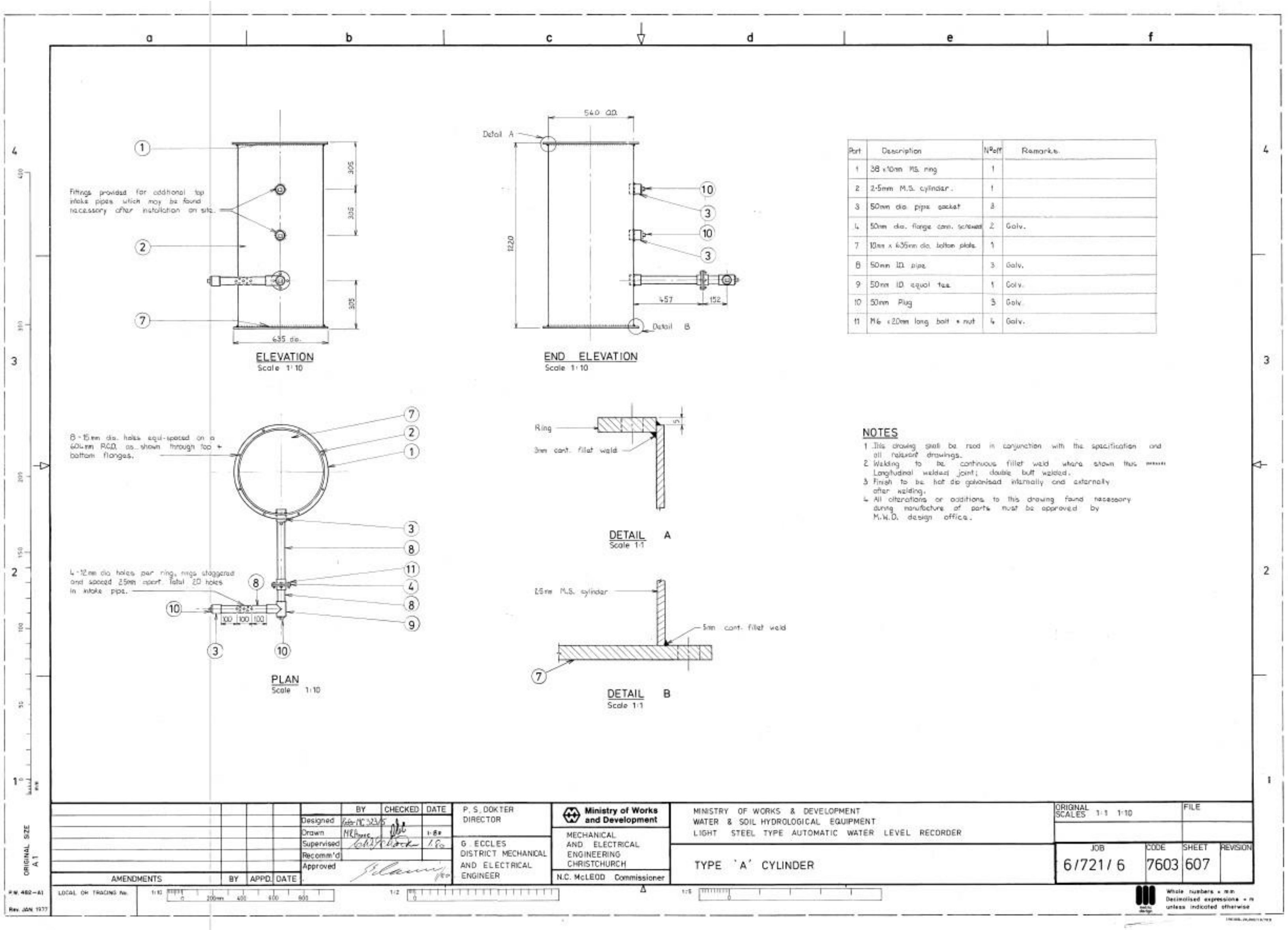
Type 'D' cylinder
(MWD Drawing 6/721/6/7603/604/R1)



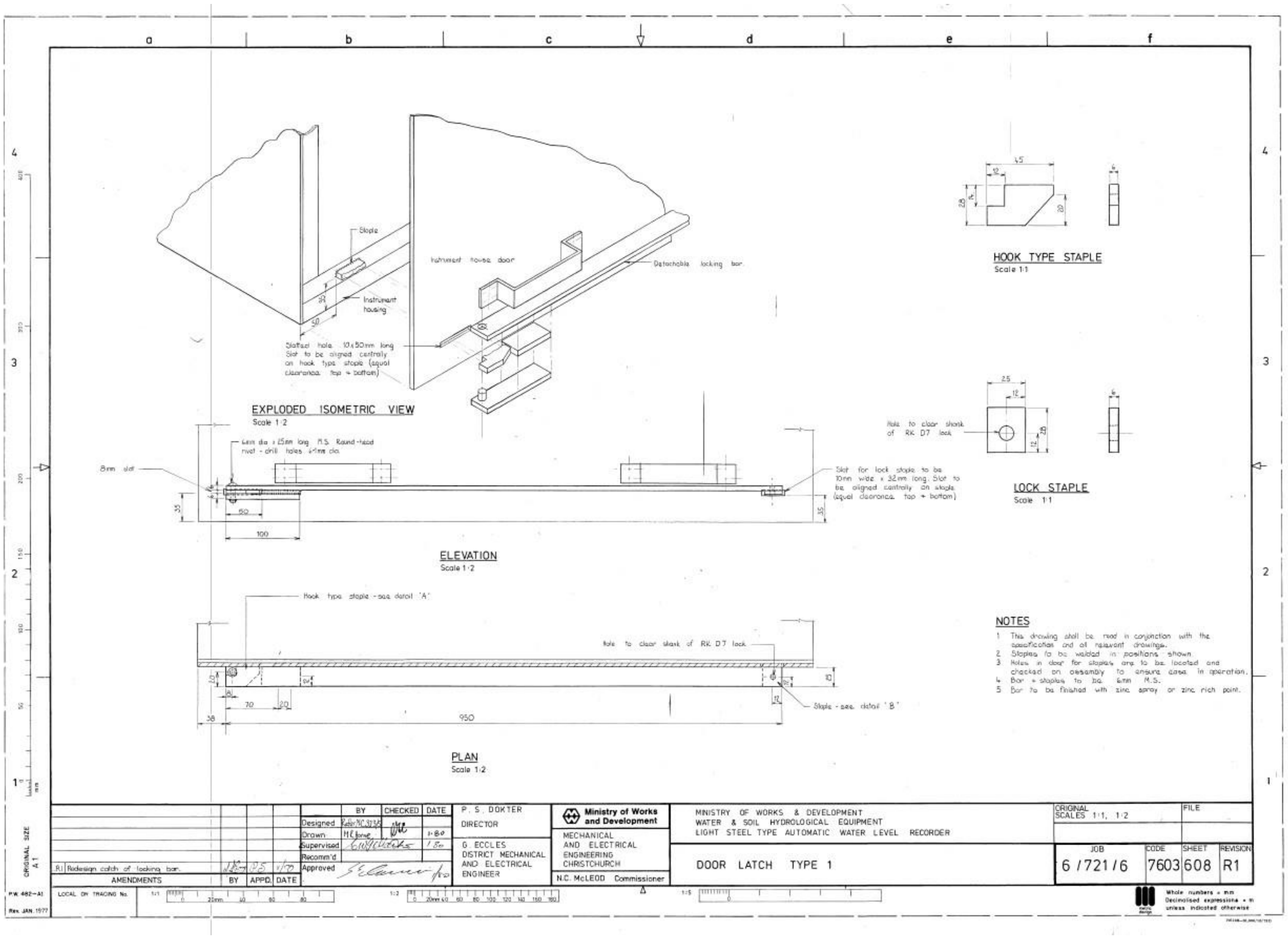
Type 'C' cylinder
(MWD Drawing 6/721/6/7603/605)



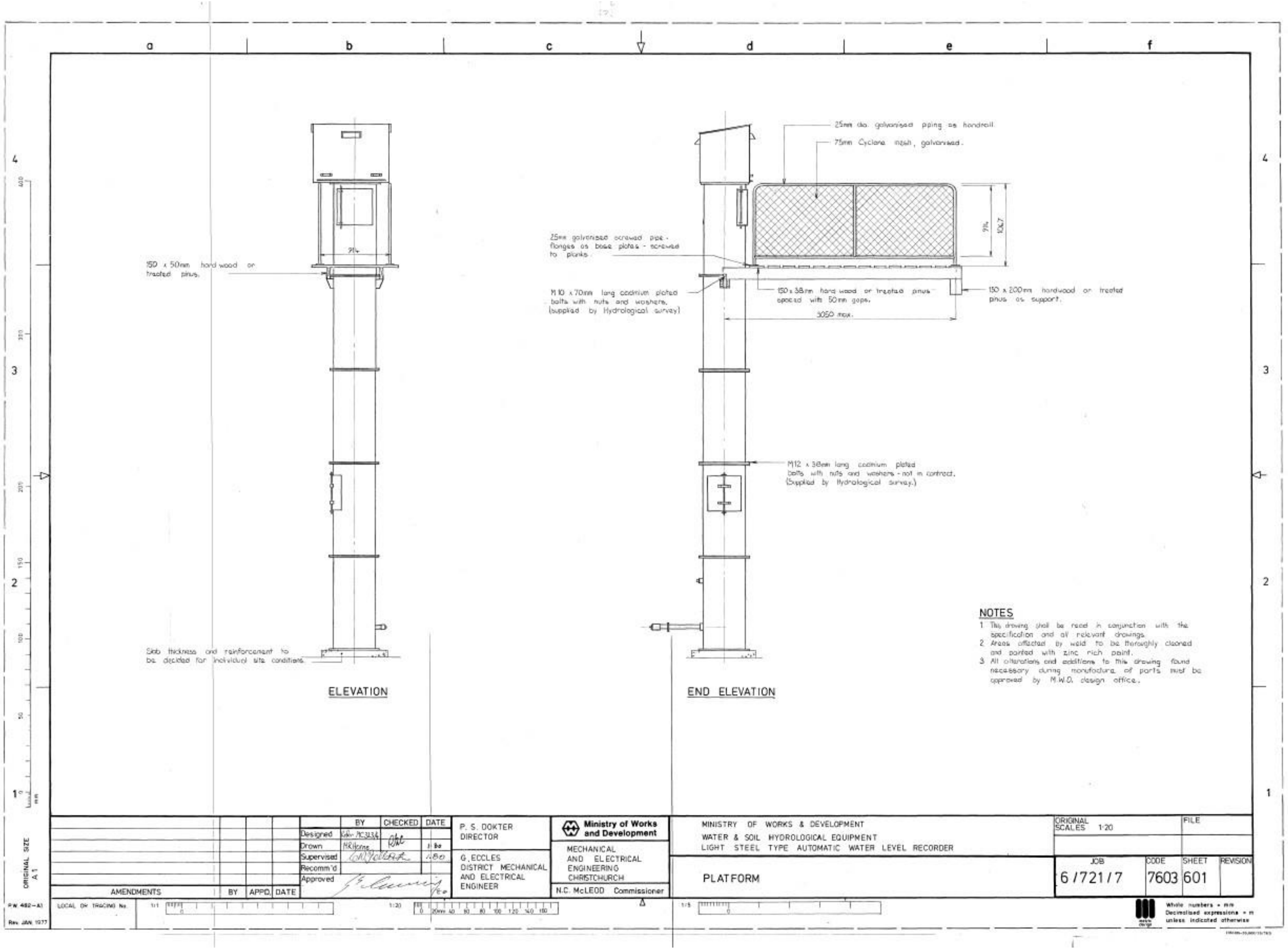
Type 'B' cylinder
(MWD Drawing 6/721/6/7603/606)



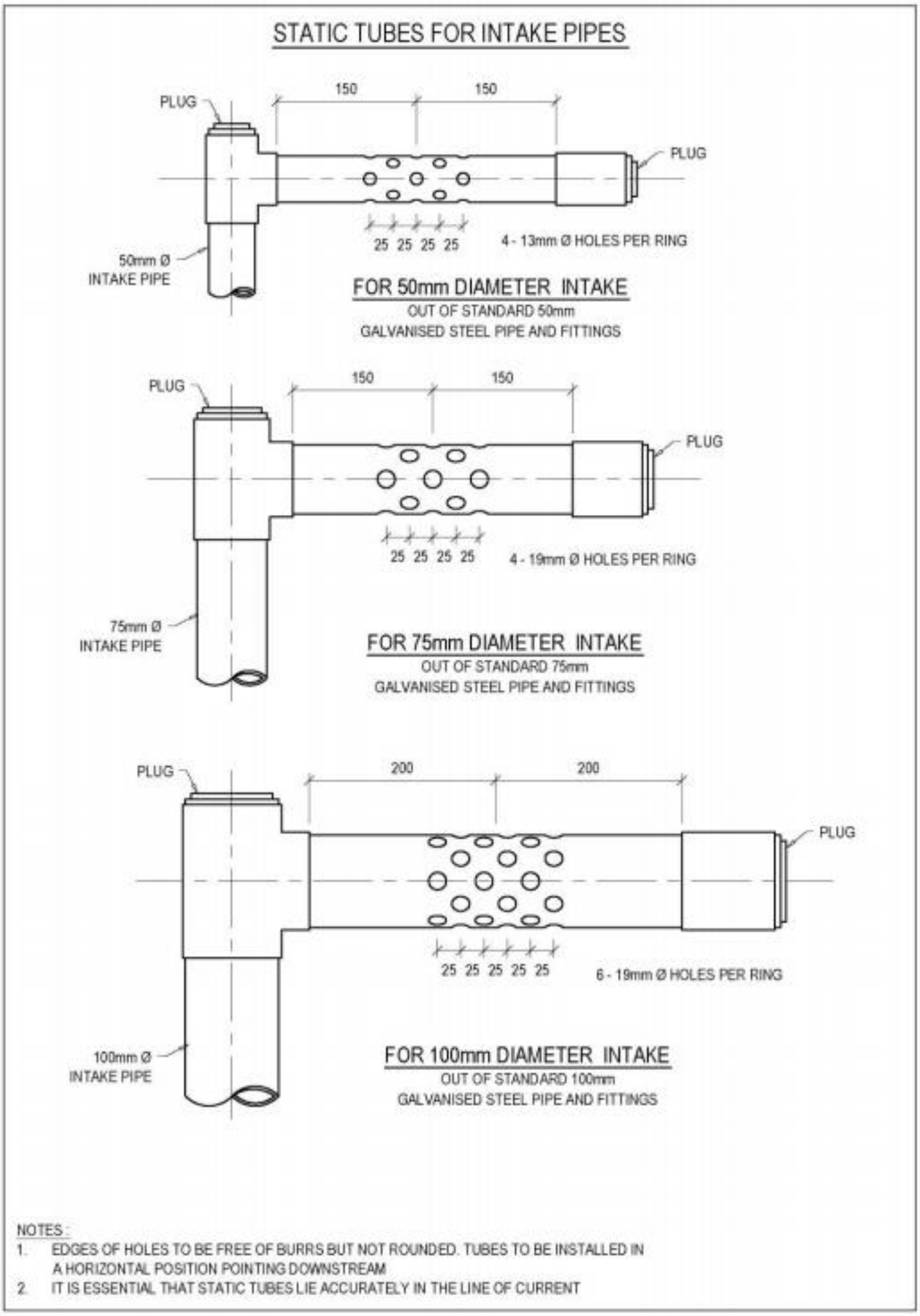
Type 'A' cylinder
(MWD Drawing 6/721/6/7603/607)



Door latch Type 1
(MWD Drawing 6/721/6/7603/608/R1)

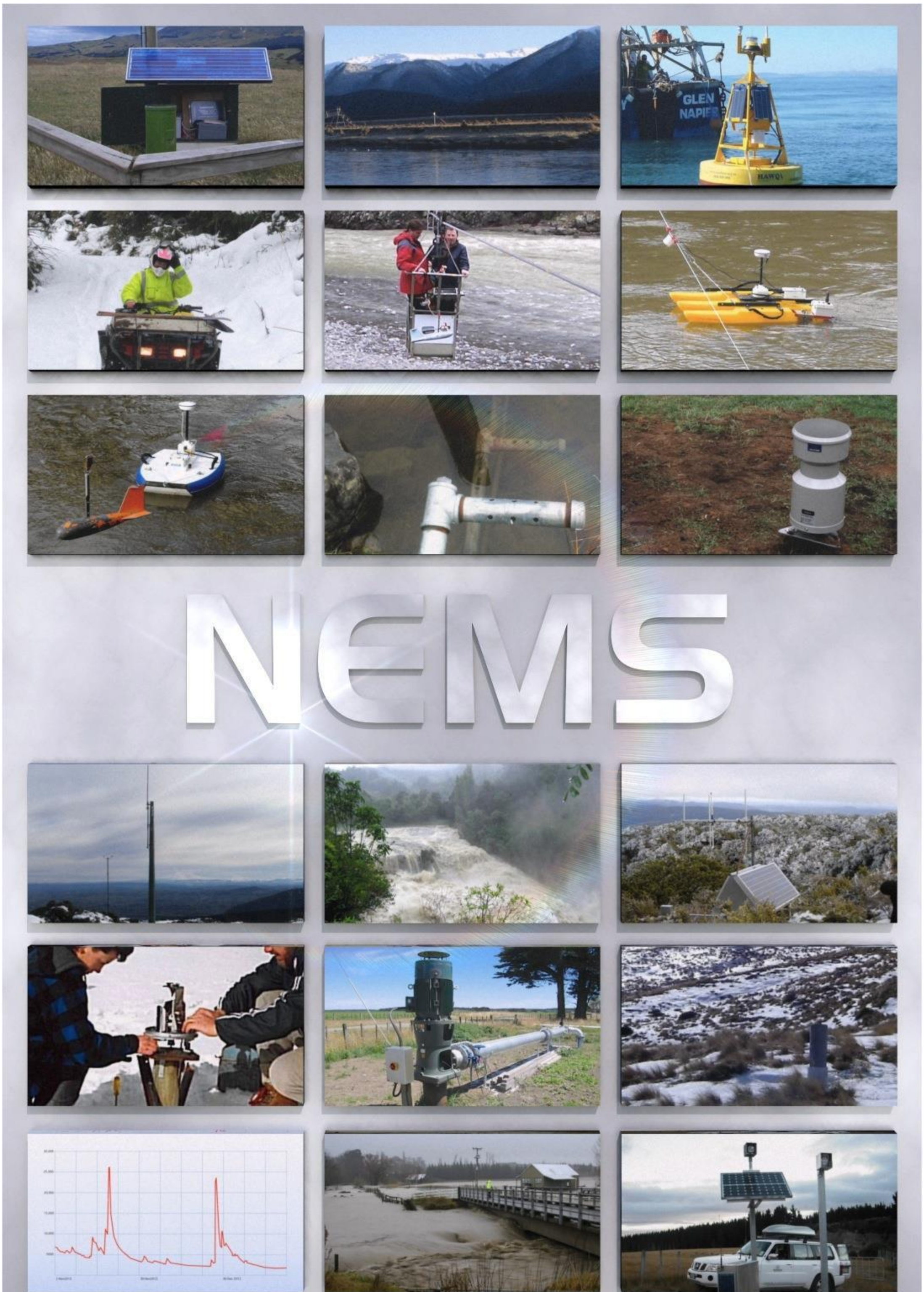


Platform
(MWD Drawing 6/721/7/7603/601)



Static tubes for intake pipes

(NEMS water Level recording, July 2016)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