

National Environmental Monitoring Standards

Rainfall Recording

Measurement, Processing and Archiving of Rainfall Intensity Data

Version: 1.0

Date of Issue: June 2013



NEMS

NEMS Standards Documents

The following standards can be found at www.landandwater.co.nz.

- National Quality Coding Schema
- Safe Acquisition of Field Data In and Around Fresh Water
Code of Practice
- Dissolved Oxygen Recording
Measurement, Processing and Archiving of Dissolved Oxygen Data
- Open Channel Flow Measurement
Measurement, Processing and Archiving of Open Channel Flow Data
- Rainfall Recording
Measurement, Processing and Archiving of Rainfall Intensity Data
- Soil Water Measurement
Measurement, Processing and Archiving of Soil Water Content Data
- Turbidity Recording
Measurement, Processing and Archiving of Turbidity Data.
- Water Level Recording
Measurement, Processing and Archiving of Water Level Data
- Water Meter Data
Acquisition of Electronic Data from Water Meters for Water Resource Management
- Water Temperature Recording
Measurement, Processing and Archiving of Water Temperature Data

Limitations

It is assumed that as a minimum the reader of these documents has undertaken industry based training and has a basic understanding of environmental monitoring techniques. 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.

The documents do not relieve the user (or a person on whose behalf it is used) of any obligation or duty that might arise under any legislation, and any regulations and rules under those acts, covering the activities to which this document has been or is to be applied.

The information in this document is provided voluntarily and for information purposes only. Neither NEMS nor any organisation involved in the compilation of this document guarantee that the information is complete, current or correct and accepts no responsibility for unsuitable or inaccurate material that may be encountered.

Neither NEMS, nor any employee or agent of the Crown, nor any author of or contributor to this document shall be responsible or liable for any loss, damage, personal injury or death howsoever caused.

When implementing these standards, the following act, regulations and code of practice shall be complied with:

- Health and Safety in Employment Act 1992
- Health and Safety in Employment Regulations 1995
- NEMS Safe Acquisition of Field Data In and Around Fresh Water, Code of Practice 2012

National Environmental Monitoring Standards (NEMS)

The National Environmental Monitoring Standards steering group (NEMS) has prepared a series of environmental monitoring standards on authority from the Regional Chief Executive Officers (RCEO) and the Ministry for the Environment (MFE). The strategy that led to the development of these standards was established by Jeff Watson (Chairman) and Rob Christie (Project Director). The implementation of the strategy has been overseen by a steering group consisting of Jeff Watson, Rob Christie, Jochen Schmidt, Martin Doyle, Phil White, Mike Ede, Glenn Ellery, Lian Potter, Lucy Baker, Eddie Stead and David Payne.

The development of these standards involved consultation with regional and unitary councils across New Zealand, electricity generation industry representatives and the National Institute for Water and Atmospheric Research Ltd (NIWA). These agencies are responsible for the majority of hydrological and continuous environmental related measurements within New Zealand. It is recommended that these standards are adopted throughout New Zealand and all data collected be processed and quality coded appropriately.

The writers of this document were Jeff Watson, Brent Watson, Nathan Penny and Gareth Gray, of Horizons Regional Council. The input of NEMS members into the development of this document is gratefully acknowledged; in particular the review undertaken by the NEMS Steering Group and non-technical editing by writer Chris Heath of Heath Research Services.

Funding

The project was funded by the following organisations:

- Auckland Council
- Bay of Plenty Regional Council
- Contact Energy
- Environment Canterbury Regional Council
- Environment Southland
- Genesis Energy
- Greater Wellington Regional Council
- Hawke's Bay Regional Council
- Horizons Regional Council
- Marlborough District Council
- Meridian Energy
- Mighty River Power
- Ministry for the Environment
- Ministry of Business, Innovation & Employment – Science & Innovation Group
- National Institute of Water and Atmospheric Research Ltd (NIWA)
- Northland Regional Council
- Otago Regional Council
- Taranaki Regional Council
- Tasman District Council
- West Coast Regional Council
- Waikato Regional Council

Review

This document will be reviewed by the NEMS steering group in February 2014, and thereafter once every two years.

Signatories

NEMS Project Director	NEMS Chairman	MFE	NIWA	Workgroup Leader
-----------------------	---------------	-----	------	------------------

TABLE OF CONTENTS

Definitions	iii
About this Standard	v
The Standard – Rainfall Recording	vii
Quality Codes – Rainfall Recording	x
1 Section 1– Site Selection	1
1.2 Practical Controls	2
1.3 Exposure	3
2 Deployment	7
2.2 General	9
2.3 Primary Reference Gauges	11
2.4 Intensity Gauges	15
2.5 Existing Deployments	16
2.6 Resolution	17
3 Data Acquisition	19
3.2 Measurement	20
3.3 Instrument Validation and Calibration	22
4 Data Processing & Preservation	25
4.2 Missing / Synthesised Records	26
4.3 Quality Coding and Metadata	28
4.4 Preservation of Record	30
4.5 Quality Assurance	32
Annex A – List of Referenced Documents	35
Annex B – Site Inspections	36
Preparing for a Site Inspection & Gauge Reading	37
Inspecting a Standpipe Reference Gauge	39
Reading the Primary Reference Gauge	40
Comparing Primary Data with Intensity Gauge Data	41
Validation	43

Validating an OTA or TB3 Rain Gauge (Field Calibrator Method)	46
Validating an OTA's Tipping Buckets (Pipette Method)	47
Validating TB3 Tipping Buckets (Pipette Method)	48
Maintaining Site Integrity.....	51
 Annex C – Data Processing.....	 52
Setting up a Working File.....	53
Removing Gaps from the Data	54
Deleting Manual Tips.....	55
Reconciling Rainfall Data	56
Synthesis Methods	57
Plotting Primary Reference Gauge Data & Check Data Records	60
Checking for Unintended Time Adjustments	62

Definitions

adjusted intensity gauge data The intensity gauge data that has been corrected to the primary reference gauge total.

calibration The process of determining, checking, or rectifying the quantitative measurements of any instrument by comparison with a traceable standard.

check data (primary reference gauge data) The rainfall total recorded by the Primary Reference Gauge over a given time period. Check data is the term that is generally used when processing data.

comments file A metadata file associated with the data file. The metadata provides relevant information about the site and data.

daily manual gauge A type of a primary reference gauge; usually read the same time each day.

exposure The degree to which wind alters the trajectory of precipitation as it falls to the ground also splash from raindrops hitting the surrounding ground or drops from higher objects.

intensity gauge A tipping bucket or fixed rainfall volume mechanical or electronic measuring device, from which an electronic signal or record can be produced. It is used to record the onset, intensity and cessation of rainfall.

Note: In New Zealand the predominant intensity gauge is currently the tipping bucket type. Other gauges that may be in use, or have preceded tipping bucket types, are weighing gauges and float types.

Kainga primary reference gauge A type of a primary reference gauge.

metadata Data about the data that may describe the content, quality, condition and/or other characteristics of the data.

octapent A type of a primary reference gauge.

primary reference gauge data (check data) The rainfall total as recorded by the Primary Reference Gauge for a given time period. 'Check gauge data' is the term that is generally used in the field.

primary reference gauge A storage gauge deployed for long-term measurement of rainfall volumes over time.

QC Abbreviation for quality code. For example, a quality code of 600 may be referred to as QC 600

quality codes An overlying set of associated information that provide the end user with information about the quality of the data.

raw intensity gauge data Data sourced directly from a data logger.

receiver canister A canister that holds rainfall in a storage gauge.

resolution The interval that is measurable by a scientific instrument.

standpipe gauge A type of a primary reference gauge; generally used without a receiver canister.

site The geographical location of the rain gauge site. A site is generally identified by its site name and/or site number.

stationarity of record The quality of a process in which the statistical parameters of the process do not change with time. Stationarity of record is maintained when variability, of the parameter being measured, is only caused by the natural processes associated with the parameter. Stationarity of record ceases when variability is caused or affected by other processes, e.g., moving a gauge, adjusting the height of a gauge's orifice or changes to the exposure of the gauge.

transform A process within time-series software that enables data to be modified.

validation A field check to determine if the device conforms to specifications.

working file A file containing a copy of a site's data. The file's data is processed prior to updating to an archive.

About this Standard

Introduction

This document provides requirements, information and methodologies to enable the consistent collection, processing and archiving of rainfall data. Key to planning, maintaining and recording flow measurement is the understanding of and catering for stationarity.

Historically, within New Zealand, the 'standard rain gauge' was the daily manual rain gauge or primary reference gauge, which was fitted with a 127 mm orifice (5 inch) installed 305 mm (one foot) above ground level.

The variety of rain gauges pictured below highlights the need for standardisation.



Figure 1 – Rain Gauges

A selection of primary reference and intensity gauges currently and historically used in New Zealand. These gauges demonstrate the large variance in orifice height and diameter.

Photograph: NIWA Instrument Systems

Prior to the 1950's few automatic rainfall gauges existed within New Zealand and in particular outside of the urban areas.

Changes in instrumentation types over the years have generally resulted in improvements in the resolution of time and rainfall depth over the recording history of many sites. Improvements in resolution have however come at a cost to maintaining stationarity. The time interval over which data has been collected has also changed significantly over time.

Over the last 60 years rainfall intensity has been recorded as a total over various time intervals. These time intervals have typically been 1 hour, 15 minutes, 7.5 minutes, 6 minutes or 5 minute time intervals. Current data loggers however, now permit a greater range of options and very short time resolutions can now be achieved.

Significant growth in hydrological research and growing operational needs for hydrological information in New Zealand during the 1960's, coupled with the International Hydrological

Decade that commenced in 1965 saw many of what are now the nations long term rainfall intensity recording sites being established.

Objective

The objective of this standard is to ensure rainfall intensity data, is gathered, processed and archived over time and across New Zealand in a consistent manner and is suitable for 'at site' and comparative analysis.

Scope

The scope of the standard covers all processes associated with:

- site deployment
- the acquisition of rainfall data from automatic recording sites
- data processing, and
- quality assurance (QA) that is undertaken prior to archiving the data.

This standard focuses on liquid precipitation.

The Standard – Rainfall Recording

For data to meet the standard the following shall be achieved:

Resolution	Rainfall Intensity Gauge	<ul style="list-style-type: none"> • 0.5 mm generally, or • 0.1 or 0.2mm in catchments < 25 km², or • 1.0 mm in high rainfall, mountainous areas
Stationarity	Stationarity of record shall be maintained.	

As a means of achieving the standard (QC 600), the following requirements apply to both intensity gauges and primary reference gauges:

Units of Measurement	Intensity and Primary Reference Gauges	Express units of rainfall depth in: <ul style="list-style-type: none"> • millimetres, or • micrometres.
Timing of measurements	Frequency (where practicable)	1 s
	Frequency (where not practicable) Note: The instrumentation may not permit 1 second recording intervals.	≤ 60 s
	Accuracy	± 90 s / month
	Time Zone	Express time as New Zealand standard time (NZST) <i>Do not use New Zealand daylight time (NZDT)</i>
Metadata	Scope	Metadata shall be recorded for all measurements.
Processing of Data		All changes shall be documented. All data shall be quality coded as per Quality Flowchart.

As a means of achieving the standard (QC 600), these requirements apply only to intensity gauges:

Minimum Resolution	General	0.5 mm
	Catchments < 25 km ²	0.2 mm
	Areas of high rainfall, and mountainous areas	1.0 mm
Orifice Height	Above ground	450 mm to 600 mm
Validation Method	Preferred	653 ml Field Calibrator
	Acceptable	Pipette

Continued on next page...

Validation	Frequency	Validate at least once per annum <i>Note: Also validate when a site inspection indicates that the instrument is not performing. For more information, see '3.3 Instrument Validation and Calibration'.</i>
Calibration	Frequency	As recommended by the manufacturer or when validation fails.
	Method	As recommended by the manufacturer or as advised for New Zealand conditions by a recognised calibration agency.

As a means of achieving the standard (QC 600), these requirements apply only to primary reference gauges:

Resolution	Daily Manual Gauge (\leq 1.0 mm of rainfall depth)	0.2 mm increments
	Daily Manual Gauge ($>$ 1.0 mm rainfall depth)	1.0 mm increments
	Storage Gauge	1.0 mm increments
Diameter	Standard Primary Reference Gauge	127 mm <i>Note: There is no diameter standard for standpipe primary reference gauges.</i>
Orifice Height	With anti-splash grid	Ground-level \pm 20 mm
	Without anti-splash grid	305 mm \pm 20 mm above ground
	Altitude $>$ 200 m and subject to significant snowfall	1000 mm \pm 20 mm above ground 500 mm \pm 20 mm above maximum expected snow depth
Validation Method		Check for leaks
Inspection	Frequency	At least once per annum
Calibration	Frequency	Not Applicable

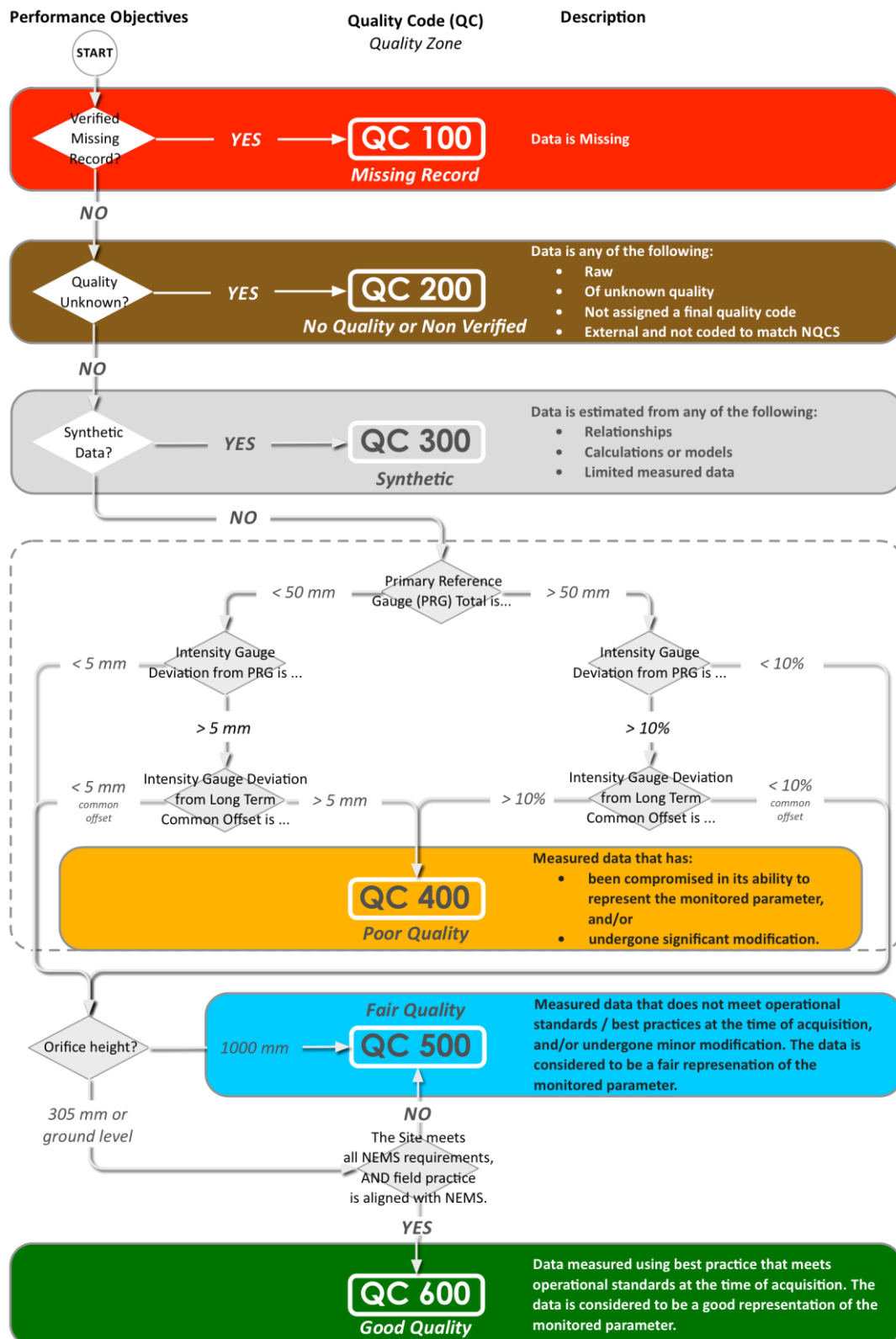
Continued on next page...

The following table summarises best practice and is not required for QC 600:

Site Validation Methods	Inspection of Recording Installations	Sufficient inspections to ensure collected data are free from error and bias; both in depth and time
Archiving	Original and Final Records	File, archive indefinitely, and back up regularly: <ul style="list-style-type: none"> • Raw and processed records • Primary reference data • Supplementary measurements • Validation checks • Calibration results • Metadata
Auditing	Data shall be audited aligned with each organisations current standards	<i>Quality assurance requirements are under development.</i>

Quality Codes – Rainfall Recording

All data shall be quality coded in accordance with the National Quality Coding Schema. The schema permits valid comparisons within and across multiple data series. Use the following flowchart to assign quality codes to all rainfall intensity data.



1 Section 1– Site Selection

1.1.1 In this Section

This section contains information the site related variables that need to be considered when selecting a deployment site.

1.1.2 Stationarity

Consideration shall be given to the longevity of the recording location when selecting a site.

1.1.3 Exposure

The primary site related variable to consider is exposure.

1.1.4 Sites to Avoid

Unless specifically stated in this standard, where practicable, rain gauges shall not be deployed on:

- a slope, or
- the roof of a building.

1.2 Practical Controls

1.2.1 Site Access

Site access shall be secure and safe for the complete period of deployment.

A long term access agreement with any landowners whose land must be crossed to gain access to the site is recommended.

1.2.2 Safety

Hazards (for observers, the public, livestock, and wildlife) related to the location and the measurement activity shall be identified and mitigated.

1.2.3 Hazard Review

On selection of a final site, a hazard review shall be carried out in accordance with relevant guidelines or best practise.

The potential for human activity affecting the measurement, e.g., vandalism, shall be minimised.

1.3 Exposure

1.3.1 Considerations

When deploying rain gauges, carefully consider how to mitigate the exposure of the gauges to the effects of the wind.

Selecting a rain gauge site involves consideration of the airflow of the prevailing rain-bearing winds, and their effect in the vicinity of the gauge.

1.3.2 Overexposure

Overexposure generally results from gauge siting that allows additional water to enter the catch. This usually occurs as a result of the gauge being located where droplets can be blown off nearby objects or vegetation into the rain gauge.

Rain gauges that are over exposed will under represent the rainfall. The relationship between the primary reference gauge and the intensity gauge(s) will be improved at sites where the wind effects are minimised.

With the upward convergence in the streamlines having the tendency to lift and deflect raindrops over a gauge (Figure 2), some precipitation that should be captured, may not even reach the orifice. This is termed over exposure, and can reduce catch by more than 80% in certain circumstances.

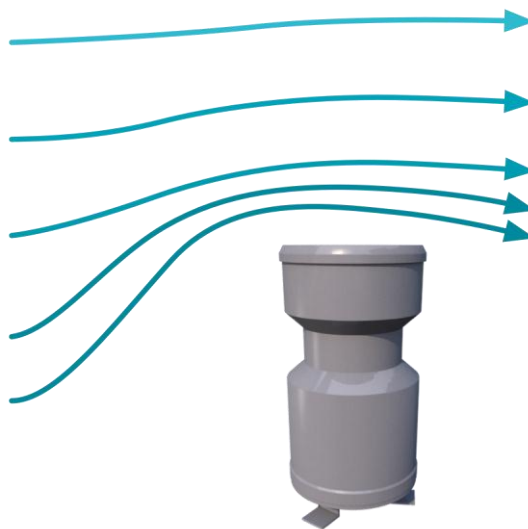


Figure 2 – Overexposure: Deflection of Wind Above a Rain Gauge.

Illustrator: Chris Heath

(based on an image from Applied Hydrology, 1963; C Toebes)

When choosing a site for primary reference gauges and intensity gauges, exposure to strong winds shall be minimised by considering:

- topography, and
- nearby shelter.

Where practicable, a site shall be chosen where the wind speed is likely to be low.

1.3.2.1 Shelter Belts and Walls

Nearby shelter (e.g. vegetation), if any, may be taken advantage of if it can reduce wind speed. Shelter-belts and clearances within forests, where practicable, shall be used to:

- minimise the effects of overexposure caused by wind, and
- maximise unimpeded rainfall

Note: Shelter belts are preferable to solid walls because they are permeable and can slow the wind causing less turbulence than solid walls. Solid walls produce turbulence in their lee and may significantly affect rainfall catch.

1.3.2.2 Wind Shields

If installed, a windshield will help:

- ensure a parallel flow of air over the orifice of the gauge
- avoid local acceleration above the orifice, and
- reduce the velocity of the wind striking the sides of the gauge.

1.3.3 Underexposure

Nearby objects or shelter that cause underexposure, shall be avoided.

Care shall be taken to ensure that the enclosure fence is not adversely affecting the exposure of the gauges.

Note: Underexposure is caused by objects or shelter:

- that intercept the rain before it can reach the orifice
- that obstruct prevailing rain bearing winds

1.3.3.1 Vegetation in Close Proximity

Low-lying vegetation that is in close proximity to the gauge shall be trimmed to the height of the orifice or less. This height shall be maintained.

1.3.3.2 Proximity to Larger Objects

A minimum distance shall be maintained between an obstacle, e.g., tree, and the gauge. Where practicable, the minimum distance shall be equal to twice the height of the obstacle above the orifice.

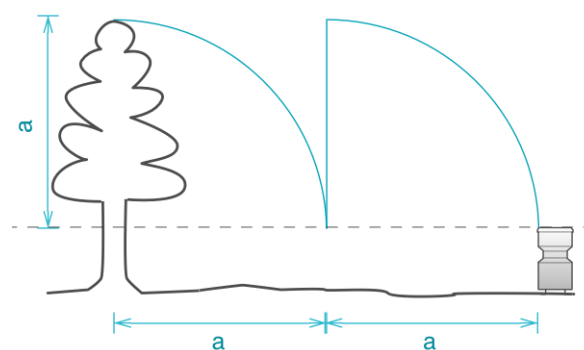


Figure 3 – Distance Between the Rain Gauge and an Obstacle
Distance 'a' = the difference in height between the gauge and the obstacle.

1.3.3.3 Mountainous Areas

Correct exposure is often difficult to obtain, particularly in mountainous areas.

Driving rain in mountainous areas can be at or near horizontal, mounting a gauge at an angle normal to the slope may be required to fully catch the rainfall.

Where practicable, a forest clearing where the wind is slowed down from all directions shall be used.

Rain gauges should not be placed on the lee of a hill where the slope is down and away from the prevailing wind.

Note: Placing a gauge on the lee of a hill where the slope is down and away from the prevailing wind will result in under-catch and will create invalid data that cannot be rectified.

2 Deployment

2.1.1 In this Section

This section contains information on deployment. It primarily covers the site related variables that determine the positioning of equipment on the selected site.

2.1.2 Functional Requirement

All equipment used to measure rainfall intensity must be deployed and maintained to ensure:

- stationarity of record
- consistent exposure, and
- appropriate resolution of time and recorded rainfall depth.

2.1.3 Stationarity

The usefulness of a rainfall record is dependent upon it having been collected at the same location (x,y,z), with similar exposure, and using similar recording standards over the entire period of record.

Over time, a range of instrumentation has been utilised at most rainfall intensity recording sites and changes in instrument types will continue into the future. The instruments that have historically been deployed have had a range of orifice heights.

A sample of orifice heights for several common types of sensors deployed in New Zealand over the last few decades is shown in the table below. Where the record from these gauges has not been adjusted to a primary reference gauge, anomalies in recorded catch will have occurred due to the height of the various intensity gauges that have been deployed over time.

Table 1 – Orifice Heights

Gauge Type	Orifice Height
30 day Lambrecht	1020 mm
7 day Casella	305 mm
Hydrological Services TB3	342 mm
OTA	473 mm
Hydrological Services TB2	332 mm

Note: Existing TB2; TB3 and OTA installations have additional variability in orifice height due to the differing instrument mounting arrangements used across organisations.

As provided in the definition at the start of this document, stationarity of record is maintained when variability of the parameter being measured is only caused by the natural processes associated with the parameter. Stationarity of record ceases when variability is caused or affected by other processes, e.g., moving the station, or changes to the height of a rain gauge's orifice.

Without stationarity, a data record cannot be meaningfully analysed for changes over time (such as climate change). While the accuracy of collection processes may change, it is critical that the methods and instruments used to collect rainfall record remain without bias over the lifetime of the record. For example, if the data from a rainfall intensity gauge is not adjusted to a primary reference gauge that is maintained at a constant level over time the record will experience a change in stationarity whenever an intensity gauge with a different orifice height is installed.

Because the methods of collecting continuous environmental data do change over time, a reference gauge should always be used, against which the continuous data can be checked against and adjusted to. In the case of rainfall data, this is a primary reference gauge that is maintained over time to ensure that its orifice remains at a constant height above ground level.

It is notable that many of the early rainfall records can be directly compared to records collected today despite changes in the agencies responsible for collecting the data and changes in instrumentation that have occurred. Unfortunately there are also many long-term rainfall records that are of limited value, primarily due to loss of stationarity resulting from different orifice heights associated with various instruments that have been used and the failure to maintain and utilise a primary reference gauge effectively. That many long-term records can be utilised meaningfully is a direct result of well thought out practices carried out by the pioneers of rainfall measurement in New Zealand. The basic principles applied by these pioneers can still be used today, along with refinements and new practises developed along the way.

2.2 General

2.2.1 Stationarity

Once deployed, rain gauges shall remain in the same location, with the orifice at the same x, y and z co-ordinates, for the life of the data series. If this cannot be achieved due to changes in instrument types than the primary reference gauge shall, as a minimum, remain at a constant x,y,z location.

2.2.2 Required Gauges

Each intensity gauge shall have an adjacent primary reference gauge to which the catch of the intensity gauge can be apportioned.

Note: Tipping bucket gauges that have a siphon arrangement have a tendency to both under and over represent (depending on the circumstances) the amount of rainfall that has fallen at any given time.

2.2.3 Proximity to Other Gauges

Gauges should be located far enough apart to ensure that no splash occurs from one gauge on to the other.

2.2.4 Ground

The ground surface surrounding the rain gauge shall be short grass or washed gravel.

Note: Short grass or small washed aggregate minimises splashes, dust and dirt from getting into the gauge.

Hard, flat surfaces such as concrete shall be avoided.

Note: With hard surfaces, the increased number of water splashes entering the orifice can be significant, particularly during intense rainfall events.

2.2.5 Levelling

The orifice of any gauge shall be horizontal unless otherwise stated in this standard.

Note: If gauges do not have an incorporated bubble-level then a spirit level across the rim of the gauge at opposing 90 degree angles can be used to level the gauge.

Note: Some incorporated bubble-levels may not be accurately set or may have moved in their mounting. The spirit level method provides greater reliability.

2.2.6 Evaporation

A few millimetres of oil shall be added to standpipe gauges to prevent, or minimise evaporation.

2.2.7 Freezing

To minimise the effects of freezing:

- anti-freeze or saturated salt solution should be added to primary reference gauges, and
- heating should be provided for tipping bucket intensity gauges.

Note: Freezing may cause a primary reference gauge to rupture.

Note: Frozen water in a bucket of a tipping bucket rain gauge will cause the gauge to misread at the onset of rainfall.

2.2.8 Site Records

Detailed records of each site shall be maintained. These records shall include a record of exposure that includes diagrams drawn, and/or photos taken over the life of the gauge. A record of changes in gauge type shall also be kept and maintained. These records may be hard copy or electronic. An annual photograph provides a good long-term visual record of exposure.

2.3 Primary Reference Gauges

A primary reference gauge shall have a 127 mm (5 inch) diameter orifice, for example:

- Octapent
- Kainga storage gauge
- Daily manual gauge

2.3.1 Resolution

Rainfall data obtained from manual storage gauges shall be collected to a resolution of at least ± 1.0 mm and time to a time resolution of one minute.

Generally a measuring flask with a resolution of 0.2 mm should be used to measure rainfall from a daily manual gauge.

2.3.2 Height of Orifice Above Ground

The orifice height of a primary reference gauge shall be 305 mm above ground level.

Primary reference gauges may be deployed at ground level if an anti-splash grid is used.

If neither of these orifice heights can be achieved, then a height of 1000 mm shall be used.

Note: In areas with high snowfall or other genuine considerations, an alternative height may be necessary. This height must remain constant over the life of the site.

If a height of 1000 mm is used, the maximum quality code that can be assigned to the data shall be QC 500.



Figure 4 – Primary Reference Gauge

Photograph: Horizons Regional Council Archives

2.3.2.1 Where Significant Snowfall Occurs / Above 200 Metres

The following exceptions to orifice height above ground, shall apply where the primary reference gauge is deployed above 200 metres or where significant snowfalls occur:

- A standpipe gauge may be used as the primary reference gauge. This type of gauge is appropriate where significant snowfall occurs
- If an orifice height of 305 mm or orifice at ground level is impracticable, the orifice height above ground shall be:
 - 1000 mm, or
 - in more extreme cases, 500 mm above the maximum expected level of the snow.



Figure 5 – Primary Reference Gauge 1000 mm above Ground

Photograph: Environment Canterbury Archives

If a height of 1000 mm is used, the maximum quality code that can be assigned to the data shall be QC 500.

Note: This increased orifice height ensures that the gauge is not buried under accumulated snow, and all precipitation is captured.

Note: Un-shielded gauges are unreliable in strong winds. The gauge will tend to underestimate the precipitation.

Note: Drifting snow can be caught in a gauge and cause large errors. Gauge heights of 3000 mm to 6000 mm may be required for measuring precipitation in areas of high snowfall.

2.3.3 Orifice Specifications

The size of the primary reference gauge's orifice is not as critical as the shape of the orifice.

The orifice shall:

- have a sharp edge designed to minimise splash out of and in to
- be vertical on the inside and have a steeply bevelled outside edge
- Have a vertical inner wall sloping steeply down to the receptor

- have an area known to the nearest 0.5% and made of material that remains a constant size with temperature, and
- have a narrow neck and be protected from solar radiation to minimise evaporation.

Note: Octapent and Kainga Primary Reference Gauges meet these orifice standards.

2.3.3.1 Octapent Gauges

The orifice of an octapent gauge shall be positioned 305 mm (± 20 mm) above ground level.

Note: Octapent primary reference gauges have a 127 mm (5 inch) diameter.

2.3.3.2 Kainga Primary Reference Gauge (Or Similar)

Where practicable, the orifice shall be positioned 305 mm (± 20 mm) above ground level.

If the orifice cannot be set to 305 mm (± 20 mm) above ground level, it shall be set to 1000 mm above ground level.

Note: Kainga primary reference gauges have a 127 mm (5 inch) diameter.

Note: In some cases it may be undesirable or impractical to excavate to sufficient depth to meet the specified orifice height above ground level.

2.3.3.3 Daily Manual Gauges

Where used, 'Daily Manual' gauges shall have an orifice that is:

- 127mm (5 inch) in diameter, and
- located 305mm (± 20 mm) above ground level.

2.3.4 Anti-Splash Grids

Anti-splash grids for primary reference gauges are recommended because they:

- reduce exposure to the wind, and
- reduced the risk of splash around the orifice.

Anti-splash grids shall be installed in accordance with British Standard BS EN 13798:2002.



Figure 6 – Anti-Splash Grid

Photographer: Matthew Putt, Horizons Regional Council

2.3.5 Freezing

It is recommended that antifreeze or saturated salt solution is placed in primary reference gauges to minimise the likelihood of gauges fracturing during freezing conditions. Allow for this solution at the next site inspection to ensure that this fluid is not counted as rainfall.

2.3.6 Evaporation

Where evaporation is an issue, oil shall be placed inside the primary reference gauge to reduce evaporation. The amount of oil added shall be measured and subtracted from the total rainfall measured at the next site inspection.

Note: Significant losses due to evaporation can occur from standpipe primary reference gauges.

2.3.7 Paint

The receiving surface (orifice) of the primary reference gauge must be smooth and not painted. This is to minimise raindrops sticking to the orifice and subsequently evaporating.

2.4 Intensity Gauges

2.4.1 Intensity Gauge

The purpose of an intensity gauge is to record the onset, intensity and cessation of rainfall.

Each intensity gauge shall have an adjacent primary reference gauge to which the catch of the intensity gauge can be apportioned.

2.4.2 Height of Orifice Above Ground

The orifice shall be between 450 mm and 600 mm above ground level unless site characteristics such as snow depth require a higher setting. Where this can't be achieved a comment shall be filed and data shall be quality coded accordingly.

Intensity gauges may be deployed at ground level if an anti-splash grid is utilised.

2.4.3 Backup Tipping Bucket Rain Gauges

Consideration shall be given to installing a backup tipping bucket rain gauge to provide a record if the primary sensor should fail. Where deployed, these gauges shall have their orifice height above ground level, equivalent to that of the primary tipping bucket intensity gauge ± 50 mm.

2.4.4 Resolution

The intensity gauge shall have a resolution of 0.5 mm or better.

Note: Less resolution may be necessary in areas of extremely intense rainfall to ensure that the tips of the buckets are not too fast for the datalogger (where one is deployed) to record. For small (less than 25 km²) and urban catchments a 0.1mm or 0.2mm tipping buckets shall be used.

2.4.5 Freezing

Consideration should be given to utilising an intensity gauge equipped with a heating element, controlled by a temperature sensor within the gauge, where snow and ice conditions occur. In particular, this type of gauge should be considered for lower altitude gauges (< 200 m) that experience relative frequent snow but not snow to a great depth. The utilisation of this type of gauge at high altitudes, while desirable, may not be practicable due to excessive power requirements

Note: Care must be taken to ensure that the heating element is not left on continuously and as a consequence allow the gauge to get too hot or else evaporation of precipitation may occur.

2.5 Existing Deployments

2.5.1 Relocation and Adjustment of Gauges

Once in use:

- primary reference gauges shall not be relocated solely for the purpose of complying with this standard, and
- a primary reference gauge's orifice height above ground level shall not be changed.

Note: Loss of record stationarity will occur if a rain gauge is relocated or if the height of its orifice above ground is changed, thereby compromising the long-term record.

2.5.1.1 Existing Gauges

Existing gauges deployed at ground level and equipped with an anti-splash grid shall remain at ground level.

2.5.2 Where Relocation or Adjustment is Desirable or Unavoidable

It may be possible to acquire higher quality data from a more suitable location nearby, e.g., because the primary reference gauge has poor exposure.

If relocation of the primary reference gauge or adjustment of the gauge's orifice height is unavoidable or desirable, the equipment shall only be relocated after robust correlation data has been obtained. To do this:

- a new gauge shall be set up at the new location and/or new height (of orifice)
- data shall be acquired, for the overlapping period, from:
 - the existing location, elevation and orifice height, and
 - the new location, elevation and orifice height.

2.5.2.1 Duration of Overlapping Record

The duration of an overlapping period of record shall be 24 months or longer.

Note: Once the data has been acquired from both locations for the overlapping period, and a strong correlation developed, the original gauge can be removed.

2.6 Resolution

2.6.1 Intensity Gauges

Intensity gauges that provide a resolution of at least 0.5 mm shall be deployed for the measurement of rainfall intensity.

2.6.2 Calibration

Intensity gauges shall be calibrated. .

2.6.3 Event Recording

Rainfall intensity shall be recorded on an event basis with time recorded to a resolution of one second.

If this cannot be achieved then rainfall intensities shall be recorded at a maximum of 60-second intervals.

Note: Changes in recording intervals shall be recorded in the site comments files.

2.6.4 Small Catchments

For small catchments (< 25 km²) and urban runoff studies, a 0.1 mm or 0.2 mm resolution instrument shall be used.

3 Data Acquisition

3.1.1 In this Section

This section focuses on mitigating errors associated with data acquisition, in particular, errors associated with:

- methods of measurement, and
- instrument validation and calibration.

3.2 Measurement

Dipsticks and flasks shall be used to measure the water volume of a primary reference gauge.

The dipstick shall be used first, then the flask.

3.2.1 Dipsticks

Dipsticks shall be made of a material that does not absorb water; wooden dipsticks are generally unsuitable if oil has been used to suppress evaporation inside the gauge. Dipsticks should be graduated to the relative areas of the cross section of the gauge and the orifice of the receiving canister whilst making allowance for the displacement of the dipstick itself.

Graduations of every 10 mm should be shown and a maximum error should be $\pm 0.5\%$ (or ± 1.0 mm between 0 and 20 mm) at any one point.

3.2.2 Flasks

Flasks shall be:

- made of glass or plastic that has a low coefficient of expansion, and
- marked with the orifice diameter of the gauge that it should be used with.

Flasks shall be marked every 0.2 mm up to 1 mm and every 1 mm after that, including the 10 mm marks.

3.2.2.1 Measuring the Volume of Water in a Flask

The bottom of the meniscus is to be used as the defining line when measuring the volume of water in the flask; keep the flask vertical to avoid errors.

3.2.2.2 Inspections

During the inspection every flask reading shall be recorded and counted.

Where the flask reading is considered inaccurate for whatever reason, the dipstick reading shall be used as the primary reference for that period.

3.2.3 Snowfall at Sites not Equipped with a Standpipe Gauge

If a significant snowfall event occurs at a site that is not equipped with a standpipe reference gauge, the surrounding snowfall shall be measured by depth and the water equivalent calculated. This will provide some useful guidance to processing this record.

If calculating the water equivalent from snowfall depth, the maximum quality code that can be assigned to the data shall be QC 400.

3.2.4 Primary Reference Gauge

3.2.4.1 Kainga and Octapent Gauges

Flasks shall be read to the nearest 1 mm.

3.2.4.2 Daily Manual Gauges

Flasks shall be read to the nearest 0.2 mm.

Where available, more accurate flasks shall be used.

3.2.4.3 Mitigating Errors

Efforts shall be made to mitigate the risk of error caused by:

- inaccurate dipstick and flask readings
- spilling water when transferring to the measurement flask
- not transferring all the water into the flask, and
- leaking gauges.

3.2.4.4 Ice Formation

Antifreeze or saturated salt solution shall be used to stop the gauge cracking due to ice formation but allow for this so the next inspection does not include this extra volume.

3.2.4.5 Leaks

Primary reference gauges should be checked periodically for leaks.

3.2.4.6 Overflow

If the primary reference gauge has overflowed or leaked into the outer housing then the outer housing can be removed and the water within the container shall be measured.

Note: This may require the use of a sponge to remove the last of the water from the container for measurement.

3.2.4.7 Gauge Removal

If the gauge is removed to enable it to be emptied, it shall be replaced at the same height and location, and levelled when re-installed.

3.2.5 Intensity Gauges – Causes of Error

3.2.5.1 Intensity Gauges Equipped with a Siphon

Steps shall be taken to mitigate the under and over representation of rainfall that has fallen at any given time.

Note: Tipping bucket gauges that have a siphon arrangement have a tendency to under and over represent the amount of rainfall (depending on the circumstances) that has fallen at any given time.

3.3 Instrument Validation and Calibration

3.3.1 Performance

Rain gauges shall be regularly validated and calibrated to ensure measurements, taken over the life of the data series, are accurate.

3.3.2 Validation

The purpose of the instrument validation is to provide a field check on the performance of the intensity gauge.

3.3.2.1 Validation Methods

Where practicable, intensity gauges shall be validated using the field calibrator method.

The pipette method used for the following rain gauges, may also be used to meet this standard:

- OTAs
- TB3 tipping buckets

For information on how to validate intensity gauges using the field calibrator and pipette methodologies, see: 'Annex B – Site Inspections'.

3.3.2.2 When to Validate

Intensity gauges shall be validated at least once per annum.

Intensity gauges shall also be validated whenever any of the following circumstances arise:

- A site inspection reveals that the instrument requires checking.
- The intensity gauge is found to vary by more than $\pm 10\%$ from the primary reference gauge.
- There is:
 - less than 50 mm of rainfall has been recorded by the primary reference gauge between two consecutive site inspections, and
 - the difference between the primary reference gauge and the intensity gauge is greater than 5 mm or 10%.

Note: If the difference between the primary reference gauge and the intensity gauge exceeds the tolerances identified above, the primary reference gauge should be checked for leaks prior to the commencement of the intensity gauge validation.

3.3.3 Calibration of Intensity Gauges

The purpose of calibration is to provide traceability of measurement and therefore standardisation of data sets. A calibration may involve the physical adjustment of the device.

3.3.3.1 Calibration

Intensity gauges shall be calibrated at the intensity(s) recommended by the manufacturer or as advised, for New Zealand conditions, by an accredited calibration agency. Gauges shall maintain their performance up to this measurement intensity.

3.3.3.2 How and When to Calibrate

Intensity gauges shall be calibrated in accordance with the methodology recommended by the manufacturer or calibration agency:

- when the instrument validation check has failed to conform with the specifications, and
- at the frequency recommended by the manufacturer.

3.3.3.3 Where to Calibrate

Intensity gauges shall be calibrated:

- preferably, in a controlled laboratory environment, or
- in a suitably equipped office or workshop.

Pre and post calibration results shall be requested and obtained from the service agent.

Note: Pre-calibration data can be used to help reconstruct the rainfall intensity record.

3.3.3.4 Who Shall Calibrate

Calibration shall be undertaken by an accredited service provider who is able to comply with the manufacturers' specifications.

4 Data Processing & Preservation

4.1.1 In this Section

This section defines the standards relating to the:

- synthesis of records where records are missing
- quality coding of data
- preservation of record, and
- quality assurance.

4.1.2 Performance

The methodology used to process and preserve data shall be documented.

Note: The methodologies applied by each agency vary because of the software utilised for hydrological data processing and archiving.

4.2 Missing / Synthesised Records

Even with the best of equipment and field practices it is inevitable that some missing records will occur.

Future analyses of the record become difficult and the data is of limited value if the gaps in the record are not filled.

4.2.1 Who Synthesises Records

The agency and staff that collects the data shall fill any gaps (missing record) that occur in the data.

4.2.2 Missing Record

Any gaps that occur in a rainfall record shall be filled to the best time resolution practical. The maximum time resolution shall be daily.

4.2.2.1 Acceptable Percentage of Missing Record

Note: Robust filed procedures and good quality instrumentation should result in no more than two percent missing record occurring in any one site-year of record across an organisations network. If more than two percent missing record occurs at a site over any rolling 12-month period, the underlying cause should be addressed.

4.2.3 Comments

Any synthetic record created and any gaps that are filled shall be identified in the Comments file.

4.2.4 Synthetic Rainfall Series

In most cases the derivation of statistics from hydrological data is significantly impaired by gaps in the record.

Note: The "Handbook of Hydrological Procedures: Procedure No. 27, Rainfall Correlation" contains useful information on how to correlate rainfall in situations when missing record arises.

4.2.4.1 When To Synthesise

The decision on the method to be used to construct synthetic data shall be based on the:

- duration of the synthetic data required
- availability of supporting data from other sites
- availability of primary reference readings from the problem site
- length and quality of the existing record, and
- expected reliability of the synthesised data.

Note: Synthesising missing data is best done when record from the site is available, both before and after the missing period.

4.2.4.2 Identifying the Synthetic Data In The Archived Dataset

If a dataset contains synthetic data:

- it will be quality coded according to the Quality Code Schema described elsewhere in this document, and
- a filed comment shall be made outlining the:
 - methods of construction
 - supporting data used, and where practicable:
 - an indication of the expected accuracy of the synthetic data

Note: For example, supply a:

- *coefficient of determination*
- *correlation coefficient, and*
- *sample size or an error margin.*

All periods of synthesised data shall be:

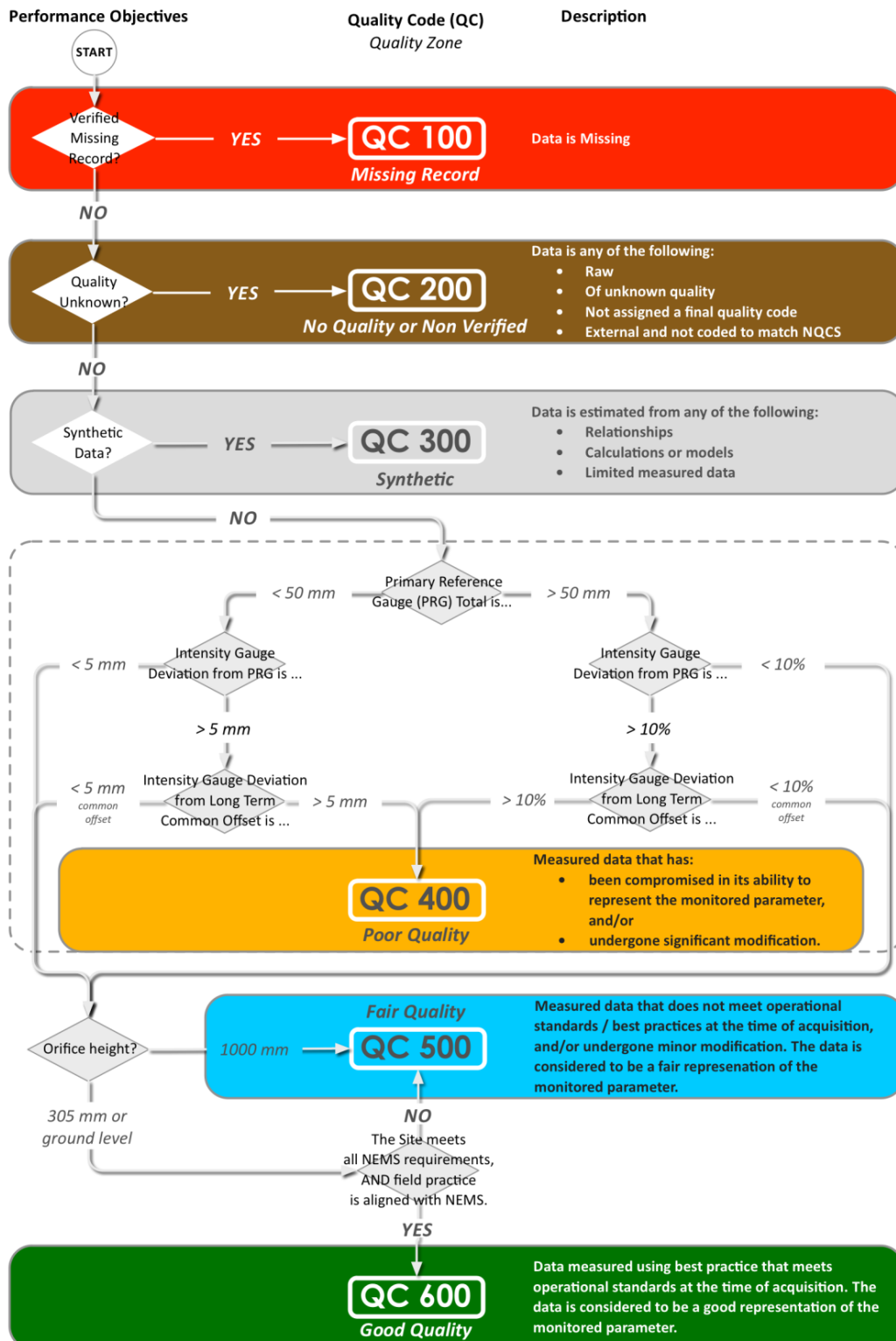
- individually flagged with an associated filed comment, and
- quality coded appropriately so that the synthesised data can be removed from the record if desired by a client.

4.3 Quality Coding and Metadata

4.3.1 Performance

All data shall be quality coded in accordance with the National Quality Coding Schema.

Note: The National Quality Coding Schema permits valid comparisons within a data series and across multiple data series.



4.3.2 Considerations

The following points shall be considered when quality coding data:

- Whether the recording deployment as a whole meets one or both of the following:
 - Operational standards.
 - Best practice at the time of data acquisition.
- The resolution of the instrumentation at the time of data acquisition.
- The instrument calibration status at the time of data acquisition.
- The occurrence and quality of synthetic record.
- The processing standards at the time of archiving.

4.3.2.1 Data that Does Not Meet the Standard

Any data that is collected from equipment that does not meet this best practice standard shall be assigned a quality value from QC 100 to QC 500.

Important: *A quality value of QC 600 shall only be applied where this standard and associated best practice is achieved.*

4.3.2.2 Comments File

Any adjustment to the recorded data shall be commented.

4.4 Preservation of Record

4.4.1 Performance

The following data shall be archived and retained indefinitely:

- Raw intensity gauge data (the original data as recorded)
- Primary reference data (check data)
- Edited intensity gauge data
- Edited intensity gauge data that has been adjusted to the primary reference gauge data

Important: *For the purpose of comparing data sets across regions or nationally, edited intensity gauge data that has been adjusted to the primary reference gauge data, shall be used.*

All original records shall be retained indefinitely by the recording agency.

Note: The raw data may be required at a later date, for example, when the archive data:

- *is found to be in error*
- *becomes corrupted or*
- *is lost.*

4.4.2 Data Archiving

The archiving procedures, policies, and systems of the archiving body shall consider:

- future data format changes
- off-site duplication of records, and
- disaster recovery.

4.4.3 Metadata – Site Details

Adequate mechanisms shall be put in place to store all relevant site related metadata with the actual data records including, but not limited to:

- site purpose
- recording agency
- site location
Standard and defined coordinate system (preferably WGS 84) shall be used.
- site name and past and present aliases
- names and/or indices of relevant environmental features
- start and end date of site and record
- related sites and records, and
- reference to the standard used

4.4.3.1 Metadata – Other Details

Adequate mechanisms shall be put in place to store all non-site related metadata with the actual data records including, but not limited to:

- sensor details
Preferably through an agency instrument management system.
- original format details

For example: chart or digitised format details.

- logger and telemetry details
- calibration records
Preferably through an agency instrument / asset management system.
- any relevant comments in document vocabularies that future users will understand, and
For example: Terms shall be defined and instrument types referred to; not brands.
- information about:
 - legal requirements
 - confidentiality agreements
 - intellectual property, and
 - any other restrictions related to data access.

4.5 Quality Assurance

The information on quality assurance below is considered to be best practice. All agencies should implement a standard methodology for data audit and review.

Note: This is to ensure standardisation of data sets that enable meaningful analyses and comparison of rainfall intensity data within regions, across regions and nationally.

4.5.1 Audit Cycle

Quality Assurance processes shall include an audit of the data:

- at a frequency appropriate to the organisation's and users' needs, or
- as defined by the organisation's quality management systems documentation or documented procedures.

This work shall be undertaken by a suitably qualified and experienced practitioner.

Unaudited data that is released for use shall be identified as being unaudited.

Gauges other than those under review may be included in the audit, and it may also include data from daily manual rain gauges. Where available, reliable records from gauges operated by other agencies may be used. When using data from other agencies steps should be taken to determine:

- the standard to which the data has been collected to
- if it has been quality coded
- some knowledge of the observer
- what the measuring device is, and
- its precise location and exposure.

4.5.2 Minimum Audit Report Requirements

As a minimum, analyses and information required for an audit report for rainfall sites shall cover:

- catchment and site details
- comments and quality coding
- data tabulations, and
- data plots

4.5.2.1 Catchment and Site Details

The following shall be included in the audit report:

- Catchment Details Summary
- A location map, with gauge locations identified.

The catchment details summary shall:

- identify the catchment or region
- identify other rain gauges utilised in the audit report for comparison purposes or for generating missing record
- include associated flow or water-level sites if available, and
- for each rain gauge, identify:
 - the period of record covered
 - the site name and number
 - map reference
 - altitude, and
 - gauge type.

4.5.2.2 Comments and Quality Coding

The following shall be included in the audit report:

- For each gauge being reviewed, a copy of the filed comments for the total record periods.
- A copy of the quality codes of all of the data being audited.

4.5.2.3 Data Tabulations

For each intensity, primary reference and daily manual gauge, the following shall be included in the audit report:

- Tabulated monthly rainfall totals covering the reporting period, and
Note: Care needs to be taken to ensure that the daily rainfall covers the same 24-hour period (i.e. 0900 hrs-0900 hrs or 2400 hrs-2400 hrs NZST).
- A summary tabulation of all daily totals exceeding 50 mm.
Note: These events will generally require individual verification.

For all automatic gauges, tabulated annual extreme values for a range of durations shall be included in the audit report.

For the whole period of common record, the following shall be included in the audit report:

- Tabulation of rainfall deviations between intensity gauges and primary reference/ daily manual gauges.
- Tabulation of deviation between pairs of storage and intensity gauges (or daily manual gauges if no intensities are available), over each accumulation interval in the storage gauge data.

4.5.2.4 Data Plots

The following shall be included in the audit report:

- Double mass plots with at least two, and preferably several nearby rain gauges with good quality record.
- Comparative plots of rainfall and flow for the reporting periods.
Note: Rainfall may be plotted as daily histograms or accumulated into 6 hour events. Flow may be plotted to a logarithmic scale.
- Annual accumulated rainfall plots for all gauges included in the report.
- Plots of short duration (6 minutes, 1 hour and 3 hour) rainfall totals.

4.5.3 Other Requirements

4.5.3.1 Outputs

Recommended report outputs include:

- a hard copy report
- an electronic report, or
- at a minimum, an electronic document that only identifies which periods of record have passed audit.

4.5.3.2 Audit Certification

The completed audit shall contain the name and signature of the auditor and the date that the audit was completed.

Annex A – List of Referenced Documents

- Fenwick J. K., (2008). NIWA Hydrometric Field Manual.
- Handbook of Hydrological Procedures: Procedure No. 27, Rainfall Correlation. Water and Soil Division, Ministry of Works, New Zealand
- NEMS (2012) National Quality Coding Schema, National Environmental Monitoring Standards, New Zealand
- World Meteorological Organisation; Guide to Hydrological Practices; Volume 1; Hydrology –From Measurement to Hydrological Information. WMO-No. 168; Sixth Edition 2008
- World Meteorological Organisation, Guide to Meteorological Instruments and Methods of Observation. WMO-No 8; 7th Edition.

Annex B – Site Inspections

About this Annex

The information in this annex has been approved by NEMS as:

- meeting the objectives of the National Environmental Standard – Rainfall Intensity Recording, and
- a guide for how the requirements of the standard may be met.

Preparing for a Site Inspection & Gauge Reading

A periodic Hazard Review should be carried out in accordance with your organisations Health and Safety policies

Site inspections should be completed on a regular basis; this will ensure that the site is kept tidy and that the instruments are clean and operating effectively.

Prior to any work being done on site, a visual inspection of the site and rain gauges shall be carried out. The visual inspection should include a general assessment of the state of:

- wiring
- power supplies
- communications equipment
- the presence of vermin and birds nests
- changes in exposure, and
- the overall site condition and any maintenance required.

If the time between inspections is too infrequent, problems are not picked up early enough and the corresponding quality of the rainfall record is jeopardised.

A general rule of thumb is to inspect a rain gauge with at least 100 mm in the gauge so that the percentage difference between the primary reference gauge and the intensity gauge can be minimised. If the gauges are working correctly the percentage difference should become smaller over time.

Irrespective of the rainfall totals recorded the time between site inspections should not exceed three months.

Any data that is generated through the process of inspection and/or validation shall be noted so that it can be removed from the final archive data. Where data is displayed on web pages in near real time this artificial data shall be removed from the displayed record as soon as possible. Where data is transferred to a third party in near real time the third party should be notified as soon as possible to enable them to remove this artificial data.

Continued on next page ...

To prepare for a site inspection & reading of gauges:

As part of your preparation, ensure that:

- where practicable, you choose a time when it is not raining.
Note: When processing the data, trying to decipher manual tips from actual rainfall when it is raining will potentially compromise the data.
- you can enter the site safely and that permission has been obtained to enter the property.
- you have the following items on hand:
 - dipstick
 - measuring flask
 - spirit level
 - site logbook
 - calibrated steel measuring tape
 - electrical test meter
 - spare tipping bucket
 - spare intensity gauge
 - spare datalogger, and
 - site maintenance tools.

Inspecting a Standpipe Reference Gauge

Where a standpipe gauge is deployed, it should be the first gauge to be inspected.

Before You Begin

Before inspecting a standpipe gauge, ensure that you have a calibrated steel measuring tape.

To inspect a Standpipe Gauge:

1. Measure from the reference mark to the bottom of the gauge and read the depth of the wetted surface.

Note: Use a calibrated steel measuring tape or a dipstick specifically calibrated for the gauge.

Note: If there is no point, marked, make a mark that can be used for this and subsequent inspections.

2. Write the reading down to the nearest 1 mm.

Note: If the standpipe is not likely to be completely full by the next inspection leave the water inside it. This will be more accurate and the gauge does not require oil, antifreeze or saturated salt solution to be added.

3. If the standpipe has been emptied:

- add the equivalent rainfall of approximately 8-10 mm of oil to the gauge
- add antifreeze or saturated salt solution to the gauge to prevent freezing, and
- measure down from the common point on the orifice to determine the depth from the bottom of the gauge to the wetted surface. Write the reading obtained down to the nearest 1 mm.

Note: Write down the value so that this depth of liquid does not get added at the next inspection. The depth of liquid added needs to be subtracted from the total depth at the next inspection to determine the total rainfall over that period. All measurements should be made to the top of the oil surface whilst trying to avoid meniscus interfering with the readings.

Note: Every time the inspection is carried out, ensure that the measurements are made from the common point.

Reading the Primary Reference Gauge

When checking gauges on site, the primary reference gauge should be read first.

Before setting off to read the primary reference gauge:

- try to choose a time when it is not raining to do the inspection.
Note: Trying to decipher manual tips from actual rainfall when it is raining will potentially compromise the data.
- ensure that you can enter the site safely and that permission has been obtained to enter the property.
- ensure that you have the following items on hand:
 - Dipstick
 - Measuring flask
 - Spirit level
 - Site logbook
 - Calibrated steel measuring tape

Dipsticks

To minimise the causes of primary reference gauge misreading's, first use the dipstick with the storage canister in place.

The dipstick should be marked with the type and size of gauge that it should be used with, for example, Kainga or Octapent.

Dipstick readings of an Octapent primary reference gauges shall be undertaken with the frost plug removed.

Flasks

Once a reading has been taken using the dipstick, use the flask to measure the amount of rainfall in the primary reference gauge.

To read the primary reference gauge:

1. Pour the primary reference gauge contents into the flask

Note: Ensure all individual readings are noted.

2. Using the bottom of the meniscus as the reference, note down the exact amount of water to the nearest 1 mm.

3. Add the total of the flask measurements.

Note: This should be approximately the same as the dipstick reading

4. If the primary reference gauge is spilled, note down that this has happened.

Note: Use either the dipstick reading or the tipping bucket record (if you are confident that it is working correctly) as the primary reference for this particular inspection when processing the data. The data for the period shall be quality coded and commented accordingly.

Comparing Primary Data with Intensity Gauge Data

The primary reference gauge should be reconciled against the intensity gauges while you are at the site. This will enable you to determine if there are problems with the gauge(s).

If the difference between the primary reference gauge and the intensity gauge is greater than 5 mm or 10%, where less than 50 mm of rainfall has been recorded by the primary reference gauge between site inspections, then the intensity gauge shall require validation.

Note: Where the difference between the two gauges is greater than 10%, and more than 50 mm of rainfall has been recorded by the primary reference gauge, the rainfall intensity gauge shall be validated.

Note: At some sites a consistent variability that is greater than 10% may occur due to site peculiarities. A run chart of the percentage difference between the primary reference gauge and the intensity gauge should be maintained electronically, or as hard copy, on site. Where it can be demonstrated that the difference (over a minimum period of two years) between the gauges is a consistent bias that is greater or less than 10%, the extent of that bias and its derivation shall be fully documented in that sites comments file. Where the variation deviates from the bias that has been documented by a further 10% a validation then needs to be carried out

Reconciling the Primary Reference Gauge

To reconcile the primary reference gauge against the intensity gauges:

- read the primary reference gauge
For more information, see 'Reading the Primary Reference Gauge' (previous page).
- download the data from the intensity gauge data logger and determine the total amount of rainfall recorded since the last site inspection.
Any manual tips must be subtracted from the apparent intensity gauge total.

Note: When removing the gauge lid, ensure that the buckets don't tip.

Important: *If tips do occur note down how many tips have transferred through to the logger as accidental readings.*

To compare data:

Follow these steps to compare primary reference gauge data with the Intensity gauge data:

- 1. Compare the total of the flask measurements (primary reference gauge) to the total of the main intensity gauge.**

Note: If the difference between the primary reference gauge and the intensity gauge is greater than 5mm or 10%, where less than 50 mm of rainfall has been recorded by the primary reference gauge between site inspections the intensity gauge requires validation. For more information, see 'Validation' later in this document.

If the difference is within 10% leave the gauge and carry on with the inspection.

- 2. Check previous field sheets for continuity of data or make an on site plot of the data.**

Note: Maintaining a plot (run chart) on site of the percentage variation in the gauges will show any trends that may be occurring with that particular gauge over time. This can be carried out by the utilisation of a run chart that shows the percentage difference between the primary reference gauge and the tipping bucket intensity gauge.

*Note: The equation is (Intensity gauge (mm) / Primary reference gauge (mm))*100. The run chart may be a hard copy or it may be maintained electronically.*

3. Put five manual tips through the primary intensity gauge.

Note: This tests both sides of the tipping bucket arrangement twice. Put three manual tips on any 1 mm resolution or single bucket gauges. This is best done by gently tipping the buckets over by hand. It can also be done by pouring water through the gauge but, some residual water may be left in the buckets.

4. Check that the tips have registered on the datalogger or where direct data transmission is deployed that the tips have been received and logged at the receiving location.

5. If the counter was zeroed write this down on the site inspection sheet.

Difference is Greater than Ten Percent

If the difference between the primary reference gauge and the intensity gauge is greater than 5 mm or 10%, where less than 50 mm of rainfall has been recorded by the primary reference gauge between site inspections and the gauges do not have a consistent verifiable bias plus or minus, validate the intensity gauge.

If the intensity gauge requires validation, see the relevant topic:

- Validating an OTA or TB3 Rain Gauge (Field Calibrator Method)
- Validating an OTA's Tipping Buckets (Pipette Method)
- Validating TB3 Tipping Buckets (Pipette Method)

Note: Of the methods (listed above) the preferred method is the Field Calibrator Method.

Validation

Objective

The validation process is intended to check the calibration of a rain gauge in the field, to the extent that it can be accomplished in the field. The methods described here are less accurate than can normally be accomplished by an instrument service facility, and are intended to serve as a validation of the calibration, not a re-calibration. If a gauge does not meet the limits of a validation process as described here (normally within a 3% range), then it should be serviced and re-calibrated in a facility that can provide a calibration certificate stating that it is within 1.5% or better.

One of the following methods shall be used for validating intensity gauges:

- Field Calibrator Method
- Pipette Method

Note: Of the two methods, the preferred method is the field calibrator method. The information below shall be used in conjunction with the validation methods outlined in this annex.

Field Calibrator Method

The following table shows the number of resultant tips for a Hydrological Services, 653 ml Field Calibration Device (FCD) at a nominal rainfall rate of 100 mm/hr.

Table 2 – Field Calibration Device – Number of Tips

Gauge	Theoretical Bucket Capacity (ml)	Nominal Bucket Size (mm of rainfall)	Validation Range (Tips $\pm 5\%$)	Note: For Calibration (Tips $\pm 3\%$)
TB3 with siphon	15.70	0.5	40 to 44	40.3 to 42.8
TB 3 without siphon	15.70	0.5	40 to 44	40.3 to 42.8
TB3 with siphon	6.28	0.2	99 to 109	100.8 to 107.0
TB3 without siphon	6.28	0.2	99 to 109	100.8 to 107.0
OTA	15.70	0.5	40 to 44	40.3 to 42.8
OTA	6.28	0.2	99 to 109	100.8 to 107.0

Note 1. Where high rainfall intensities are likely to be experienced, consideration should be given to calibration at higher rates such as 200 mm/hr or 300 mm/hr.

Note 2. If a siphon device is removed from a TB3 it needs to be re-calibrated back to a practical bucket size of 15.7ml.

Gauge is Out of Range

If the gauge is outside the range specified in the above table, replace the gauge and send the faulty unit away to be calibrated in a suitably equipped calibration facility.

Pipette Method

Table 3 – OTA Tipping Bucket Rain Gauges

Gauge Type	Siphon	ml/bucket	Validation Range
OTA			
1.0 mm / bucket	n/a	31.4 ± 5%	29.8 ml to 33.0 ml
0.5 mm / bucket	n/a	15.7 ± 5%	14.9 ml to 16.5 ml
0.2 mm / bucket	n/a	6.28 ± 5%	6.0 ml to 6.6 ml

Table 4 –Hydrological Services Tipping Bucket Rain Gauges

Gauge Type	Siphon	ml / Bucket	Validation Range
1.0 mm / bucket	N	29.5 ± 5%	27.4 ml to 30.2 ml
0.5 mm / bucket	Y	14.4 ± 5%	13.7 ml to 15.1 ml
0.5 mm / bucket	N	15.7 ± 5%	14.9 ml to 16.5 ml
0.2 mm / bucket	Y	5.2 ± 5%	4.9 ml to 5.5 ml
0.2mm / bucket	N	6.1 ± 5%	6.0 ml to 6.6 ml

Validating an OTA or TB3 Rain Gauge (Field Calibrator Method)

Use the field calibrator method (below) to perform a field validation on the following rain gauges:

- OTA tipping bucket rain gauge
- TB3 tipping bucket

Note: The field calibrator method is the preferred field method for validating tipping bucket rain gauges. It is not a full laboratory calibration.

For each rain gauge, carry out the validation:

- at least once per year, and
- whenever a specific threshold is broken at the time of inspection.
For example, when there is a greater than ten per cent difference from the primary reference gauge.

To validate an OTA or TB3 rain gauge:

1. Check the rim is level.

Note: To do this, place a spirit level on the rim of the gauge, this should be done at 90 degree angles, that is, level the gauge in both directions.

2. Fill the field calibration device (FCD) to the very top with water.

3. Record the quantity of tips.

4. Compare the quantity of tips.

Note: For a 200 mm orifice and 0.5 mm buckets (without siphon), the expected threshold for:

- OTA gauges is 653 ml for 41.6 tips ($\pm 5\%$)
- TB3 gauges is 653 ml for 41.6 tips ($\pm 5\%$)

Note: If you remove the siphon from a TB3 gauge, the gauge will require re-calibration at an appropriate service facility.

What's Next?

When the quantity of tips matches the specifications in Step 4 (above), the gauge can be assumed to be functioning satisfactorily.

If the quantity of tips does not match the manufacturer's specifications, replace the gauge as soon as possible. Return faulty gauges to a service agent for the documentation of any servicing and calibration details.

Validating an OTA's Tipping Buckets (Pipette Method)

The steps below describe how to validate an OTA's intensity gauge's two tipping buckets using the Burette/Pipette method. This method can be used as a secondary reference to the field calibrator method if further investigation into a failed calibration is required.

Note: The field calibrator method is the preferred method for validating tipping bucket rain gauges. For more information, see 'Validating an OTA or TB3 Rain Gauge (Field Calibrator Method)' earlier in this document.

For each rain gauge, carry out a validation:

- at least once per year, and
- whenever a specific threshold is broken at the time of inspection.
For example, when there is more than a ten per cent difference between the primary reference gauge and the rainfall intensity gauge.

To validate a OTA tipping bucket using the pipette method:

1. Check the rim is level.

Note: Observe the built in bubble or if one is not fitted place a spirit level on the rim of the gauge, this should be done at 90 degree angles, that is, level the gauge in both directions.

2. Pour water to fill the reservoir

Note: Ensure both buckets and the funnel are wet.

3. Ensure the uppermost bucket is empty.

Important: If the uppermost bucket is not empty, tip again and replace the funnel.

4. Fill the pipette (or burette to) 20 ml.

5. Release the water slowly into the funnel.

Note: The first 10 ml can be released quite quickly and then the flow rate should be reduced for the remaining water.

6. Observe how many ml remain in the burette when the bucket tips.

7. Subtract the remaining amount from the 20 ml you started with.

Result: This leaves you with the amount required to make the bucket tip.

Note: The amount to make the bucket tip should be 15.7 ml + 5% (i.e. between 14.9 and 16.5 ml).

8. Repeat steps 3-7 above for the other bucket.

9. Check the total for both buckets.

The total should be $\pm 5\%$ of 31.4 ml, i.e., between 29.8 ml and 33.0 ml.

Continued on next page...

10. If the rain gauge is outside the required tolerance replace the gauge.

Note: Re-calibration may be done in the field by adjusting the bucket rests; however to get accurate results this is very time consuming without the proper equipment, and is not recommended. Servicing of the pivots must be done by the appropriate servicing agents.

11. Fully document the validation using the appropriate form.

Validating TB3 Tipping Buckets (Pipette Method)

The steps below describe how to validate a TB3's intensity gauge's two tipping buckets using the Pipette method (a Burette may also be used). This method can be used as a secondary reference to the Field Calibrator method if further investigation into a failed validation is required.

Note: The Field Calibrator method is the preferred method for validating tipping bucket rain gauges. For more information, see 'Validating an OTA or TB3 Rain Gauge (Field Calibrator Method)' earlier in this document.

For each rain gauge, carry out a validation:

- at least once per year, and
- whenever a specific threshold is broken at the time of inspection.
For example, when there is more than a ten per cent difference between the primary reference gauge and the rainfall intensity gauge.

Some gauges with the same orifice size and resolution could have differing results depending on whether the gauge is fitted with a siphon or not. Siphons are supposed to create an even flow of water into the buckets. This flow can be at a very high rate.

When the flow rate through the siphon is high, the buckets do not account for all of the water during the tipping action. The bucket that is full and ready to tip continues to be filled, at this time some water is tipped out without being measured.

Also, in windy conditions siphons have been known to empty their contents into the bucket before the full amount is in the siphon chamber. This can result in insufficient water entering the bucket and it not tipping until the next siphon occurs. This can cause gauges with siphons to under-register rainfall.

Siphon style gauges should be used with these cautions in mind, especially when they pour at such a high rate. The user should have an understanding of the gauge behaviour and the range of intensities that it is calibrated for. Some manufacturers will supply a siphon type and a non-siphon type of gauge.

The same can occur on non-siphon gauges with high rainfall rates but the rate of outflow to the buckets is negligible compared to the consistent pouring action of siphon gauges. For example, Hydrological Services gauges with 200 mm orifice, 0.5 mm buckets and no siphon should tip with 15.70 ml in each bucket. Hydrological Services gauges with 0.5 mm buckets equipped with a siphon, will tip with 14.4 ml. This smaller quantity accounts for the amount of water lost during the tipping action.

Note: It is recommended that any gauge that has its siphon removed is re-calibrated at a suitably equipped service facility.

The procedures on the following pages describe how to validate a TB3 tipping bucket rain gauge that is:

- equipped with a siphon, and
- not equipped with a siphon.

To validate a TB3 tipping bucket rain gauge (0.5mm) that is equipped with a siphon:

Note: The HS tipping bucket rainfall intensity gauge incorporates a siphon, the siphon holds water in the siphon body and then releases it into the bucket.

1. Check the rim is level.

Note: Observe the built in bubble, or if one is not fitted place a spirit level on the rim of the gauge, this should be done at 90 degree angles, that is, level the gauge in both directions. Be aware that some in-built bubbles may not be set accurately or that it may have moved in its mounting. The spirit level method is more reliable.

2. Ensure that the gauge is level according to the built-in bubble.

Note: This is used to level the gauge for calibration.

3. Pour enough water into the funnel to fill the siphon and make the buckets tip twice to wet the buckets.

IMPORTANT: *When putting the second wetting tip through the instrument, ensure the pipette (or burette) is shut off as soon as the bucket tips so that you have an empty siphon body for the calibration check.*

4. Ensure the uppermost bucket is empty (tip again if not) and replace the funnel.

5. Fill the pipette (or burette) to 20 ml and release the water slowly into the funnel.

Note: To save time the first 10 ml can be released quite quickly and then the flow rate can be reduced for the remaining water. Observe how many ml remain in the pipette (or burette) when the bucket tips. The amount remaining should be subtracted from the 20 ml you started with to give the amount required to make the bucket tip.

6. The amount to make the bucket tip should be 14.4 ml + 5% (i.e. between 13.68 ml and 15.12 ml).

7. Check the total of both buckets, which should be within +/- 5% of 28.8 ml (i.e. between 27.4 ml and 30.2 ml). Replace the gauge if it is outside this required tolerance.

Note: Re-calibration may be done in the field by adjusting the bucket rests; however to get accurate results this is very time consuming without the proper equipment, and is not recommended. It is best done at your local service agent.

What's Next?

Fully document the validation using the appropriate form.

To validate a TB3 tipping bucket rain gauge (0.5mm) that is not equipped with a siphon:

1. Check the rim is level.

Note: Observe the built in bubble, or if one is not fitted place a spirit level on the rim of the gauge, this should be done at 90 degree angles, that is, level the gauge in both directions. Be aware that some in-built bubbles may not be set accurately or that it may have moved in its mounting. The spirit level method is more reliable.

2. Ensure that the gauge is level according to the built-in bubble.

Note: This is used to level the gauge for calibration.

3. Pour enough water into the funnel to fill the siphon and make the buckets tip twice to wet the buckets.

IMPORTANT: *When putting the second wetting tip through, ensure the pipette (or burette) is shut off as soon as the bucket tips so that you have an empty siphon body for the calibration check.*

Note: The HS tipping bucket incorporates a siphon, the siphon holds water in the siphon body and then releases it into the bucket.

4. Ensure the uppermost bucket is empty (tip again if not) and replace the funnel.

5. Fill the pipette (or burette) to 20 ml and release the water slowly into the funnel.

Note: To save time the first 10 ml can be released quite quickly and then the flow rate can be reduced for the remaining water. Observe how many ml remain in the pipette (or burette) when the bucket tips. The amount remaining should be subtracted from the 20 ml you started with to give the amount required to make the bucket tip.

6. The amount to make the bucket tip should be 15.7 ml \pm 5% (i.e. between 14.9 ml and 16.5 ml).

7. Check the total of both buckets.

Result: The total should be within \pm 5% of 31.4 ml (i.e. between 29.8 ml and 33.0 ml).

Note: Replace the gauge if it is outside this required tolerance.

Note: Re-calibration may be done in the field by adjusting the bucket rests; however to get accurate results this is very time consuming without the proper equipment, and is not recommended. It is best done at your local service agent.

What's Next?

Fully document the validation using the appropriate form.

Maintaining Site Integrity

To maintain site integrity:

1. Check all on site wiring.

Note: Ensure it is all tidy and well protected from the elements and animals.

2. If the site is telemetered, where practicable, perform a communications test with the base site.

3. Maintain on-site vegetation.

Note: If required, spray any unwanted vegetation. Concentrate on spraying near the gauges and make sure the spray doesn't enter them.

4. Note all observations and any site changes.

Note: Record observations and site changes in the site log book. Where site changes have occurred a photographic record should be obtained and this should be stored with other site metadata.

What's Next?

On returning to the office, check the rainfall totals.

Note: The rainfall totals must match the telemetry record. Ensure they match the field totals for the inspected period and the recorded total calculated in the field.

Annex C – Data Processing

About this Annex

The information in this annex has been approved by NEMS as:

- meeting the objectives of NEMS Rainfall Recording, and
- a guide for how the requirements of the standard may be met.

This annex does not form an integral part of the standard.

Setting up a Working File

Clear workflow is critical for traceability of data processing.

Each period of data that is processed shall have:

- an individual working file, and
- where software allows, set up an audit trail or alternatively an electronic system for tracking data modifications

To set up a working file:

1. Locate the end date of the previous processing run.

2. Register the processing period.

Note: Allocate an individual sequential ID, or other unique identifier, to the period of record being worked on.

3. Find and photocopy all relevant log sheets for the registered processing period.

4. Populate the site inspection recording system/catalogue with the details from the Site Inspection.

5. Create a new “working” dataset

6. For the period, copy the time series data into your working file.

Note: The finish date and time for your copy should be the date and time of the last log sheet inspection.

7. Update your working file.

Note: Ensure that you have copied any rainfall backup data (covering the same period) and nearby rainfall sites and flow data into your working file.

Note: This assists with processing of the data and the filling of any missing record.

Removing Gaps from the Data

Checking the data for gaps in the record can be undertaken by over plotting backup rainfall or nearby sites. It is recommended that rainfall data is also checked against nearby flow sites to assist with highlighting any potential errors in the data.

To remove gaps from the data

1. Check for any gaps in the record.

Note: Check any gaps against the raw data files.

Note: Raw data files may be either telemetry files or manual field downloaded files.

2. Delete any gap markers that are not real.

3. Resolve Gaps and verify the validity of each gap.

Note: There may be missing data that you have yet to locate, there may be no rain, or there may be no data and it may need to be synthesised.

What's Next?

Once the gaps (if any) have been resolved:

- print or copy the output from this process for final documentation, then
- reconcile the rainfall data.

For more information, see 'Reconciling Rainfall Data' later in this document.

Deleting Manual Tips

The method of deleting manual tips depends on whether the rainfall data is:

- of a set period, or
- event rainfall.

Rainfall Data is of a Set Period

For rainfall data that is of a set period, manual tips should be replaced with a zero.

Note: Periods may, for example, be 5 minutes, 6 minutes, 15 minutes or 1 hour.

Rainfall Data is Event Rainfall

If the rainfall data is event rainfall (SCADA type rainfall) then the manual tips should be deleted. If manual tips are surrounded by actual rainfall tips (i.e. it was raining at the time of inspection, then replacing the tips with zeros may affect intensity calculations

If it is raining at the time of inspection, file the inspection information at the time of the last actual tip.

If it is not raining, file the inspection information at the inspection time; the rainfall values can be a zero.

Before You Begin

Before deleting any manual tips, list each period of inspection and copy all periods into the processing documentation.

To delete manual tips:

1. Remove the manual tips from the record

2. Where relevant, replace manual tips with a zero.

If the rainfall data is of a set period, replace the manual tip with a zero.

If the rainfall data is event rainfall (SCADA type rainfall), and it is raining at the time of the inspection, then delete the manual tips. Do not replace them with a zero.

If the rainfall data is event rainfall (SCADA type rainfall), and it is not raining at the time of the inspection, replace the manual tips with a zero.

3. List out and copy the periods around the inspection,

Note: Including these periods in the processing documentation will show the successful removal of the manual tips.

What's Next?

Reconcile the Total Rec. and the Recorder Totals

Graph the data between inspections to note the recorder totals (with manual tips removed).

Note: The difference for each batch should equal the number of manual tips you've removed in that batch converted to mm.

Reconciling Rainfall Data

Reconciling the recorded rainfall data that you are working on against observed long term rainfall data provides a useful reality check on rainfall intensities and rainfall totals.

Before You Begin

Before reconciling rainfall data:

- check sensor validations and calibrations to ensure that they are current
- delete manual tips and where relevant, replace them with a zero, and
- for the period being processed, check the deviations between the intensity gauge and primary reference gauge against the deviations over the long term.

To reconcile rainfall data:

- 1. Graph the data between inspections.**
- 2. Note down the recorder totals.**
- 3. Identify any high or unrealistic short duration intensities.**
Note: Manual inspection tips should have been removed before this.
- 4. Review daily totals, hour totals and recording interval totals for errors in data.**
Note: The graph total must include part days belonging to the day of the batch end inspection.
- 5. Compare unusually high intensity values to a HIRD's output.**
- 6. Note down the rainfall total shown under the graph's x-axis**
- 7. Extract the computed rainfall totals between inspections**
- 8. Verify totals against inspection values.**

Synthesis Methods

The methods for constructing synthetic rainfall series shall be based on:

- apportioning the primary reference gauge totals (for the site) to the distribution of rainfall recorded at an adjacent site, or
- from regression analysis between adjacent sites.

Where the primary reference gauge total is not available or is suspected to be in error, then prior to apportioning, consideration shall be given to utilising an assessed primary reference gauge total that is derived by a suitable method.

Apportioning the Primary Reference Gauge Total

Apportioning a primary reference gauge total shall be based on deriving daily values for the period of missing record.

Note: In some situations only weekly or monthly values may be possible.

Judgement shall be exercised in determining whether to apportion or only file the primary reference gauge total.

Apportioning to periods less than a day, using data from a nearby intensity gauge shall be avoided unless a strong correlation can be shown to exist between sites.

Where long-term analysis of rainfall variation indicates an excellent relationship between intensity gauges, apportioning to intervals down to 6 hours is acceptable.

Note: Significant spatial variation of rainfall intensity and duration is often experienced; particularly at higher altitudes.

Deriving Daily Totals

Daily totals from an adjacent site shall be extracted to cover the period of missing intensity data.

Care needs to be taken to ensure that the period over which rainfalls are totalled are the same (generally 0900 hrs-0900 hrs or 2400 hrs-2400 hrs). Data should be filed accordingly.

Note: Data from daily manual rainfall sites is generally recorded at 0900 hrs NZST, although some voluntary observers may read the gauge at 0900 hrs NZ summer time.

A ratio shall be calculated between the total rainfall from the adjacent gauge and the problem site, for complete days for the maximum period or common record available, and that ratio shall be applied as a multiplier using a transformation process, to the daily gauge data.

The rainfalls recorded at the problem site, for the part days either side of the missing period, shall be subtracted from the daily totals obtained from the transformation for those days, to preserve the actual record. These adjusted daily totals and those in between shall be filed as the synthetic record.

The synthetic record shall be totalled and compared with the observed primary reference gauge total to ensure that the totals match and the method has been correctly applied.

Regression Analysis

Use shall be made of regression analysis when:

- reliable primary reference gauge totals are not available to apportion, and
- the recorder has failed to function correctly.

Daily rainfalls from adjacent sites and the problem site are analysed using the maximum period of record available. Correlating durations of less than a day, using data from a nearby intensity gauge is not desirable unless analysis of long-term records indicates a close relationship.

The sample size, correlation coefficient and estimated prediction error are calculated and noted for inclusion in the filed comment as before. If the relationship is reliable, the predictor equation is applied to the daily rainfall totals from the adjacent sites for the period over which the synthetic data is required, to obtain a synthetic record of daily rainfalls for the problem site.

The rainfalls recorded at the problem site for the part days either side of the missing period (time defined by the period of the daily totals available e.g. 0900 hrs to 0900 hrs) are totalled and subtracted from the synthetic daily totals for those days.

The remaining synthetic rainfall for those days is filed so that the totals for the days at the beginning and end of the missing period match the synthesised daily totals.

If the recorded rainfalls for the part days exceed the synthetic daily totals for those days the regression analysis should be checked. If the analysis is acceptable the recorded rainfalls remain in the data as the only rainfall on those days.

Consideration needs to be given to the impact of applying the regression analyses to days when rainfall obviously did not occur. Any residual rainfall applied to non-rainfall days needs to be removed and apportioned across the rain days to retain zero values where these are appropriate.

Deriving a Primary Reference Gauge Total

Where the primary reference gauge total is not available or is suspected to be in error, then prior to apportioning, the primary reference gauge total may be assessed:

- by double mass curve
- by linear or multiple regressions, or
- where periods are consistent with the missing period, by application of the ratio of observed intensity gauge to primary reference gauge totals.

Double Mass Curve

A double mass curve is derived by accumulating the rainfall for the adjacent and problem sites over a suitable common period. This shall be done using data prior to or following the missing period, and by plotting the accumulations against each other.

A line of mean slope is estimated from the double mass curve.

The primary reference gauge total, from the adjacent site for the period that requires assessing may then be entered onto the line of mean slope, and a value for the problem site derived.

If several adjacent sites are available the double mass curve method may be repeated with each adjacent site and the assessments averaged.

Linear or Multiple Regressions

Linear or multiple regressions may be used to analyse a suitably sized sample of corresponding rainfall readings from adjacent sites and the problem site.

For the period over which the assessment is required, an assessed primary reference gauge total shall be obtained. To do this, the prediction equation shall be applied to the gauge total from the adjacent sites.

Note: This method is only applicable where the recorded rainfall intensity data is valid.

The expected accuracy of the resultant primary reference gauge assessment shall be entered in to the site's comment file. The comment should also identify the sample size and correlation coefficient.

If the intensity record is also faulty, the prediction equation shall be used to obtain the synthetic daily rainfalls.

Note: This is preferable to obtaining an assessed primary reference gauge total that must then be apportioned.

Recorder to Primary Reference Gauge Ratio

Where inspections have been relatively frequent and instrumentation has not changed, a primary reference gauge reading may be assessed from an average of the ratios between the:

- primary reference gauge, and
- recorder totals at previous inspections.

The calculated average ratio, used to assess the primary reference gauge totals, shall be noted in the filed comment.

Review

As additional data is acquired from recording sites the relationships between gauges and sites can be refined.

Over the first 20 years of record, any data filed for missing record, shall be reviewed every five years and revised as necessary.

Plotting Primary Reference Gauge Data & Check Data Records

Plot the primary reference gauge inspection data against the recorded rainfall. The factors for any one tipping bucket gauge should be consistent over time and not be too far away from 1.0.

When plotting primary reference data, look for trends, anomalies, sudden changes and cycles in the factors that may indicate gauge leakage, incorrect readings, bucket pulse failure or any one of a number of issues that must be resolved if discovered.

Corrections greater than ± 0.1 (10%) should be reviewed carefully as this would indicate that there is a significant technical issue with the dataset or the inspections.

Any of the above issues must be addressed.

Before You Begin

Before plotting the primary reference data, decide what you will use as your primary reference gauge reading for each batch. Normally this will be the measuring flask reading, but there may be instances where the dipstick reading is preferable. This is likely to occur if there is doubt about the true measurement flask total or if the primary reference gauge reading requires adjustment to account for missing data or leakage. If the dipstick reading is also considered to be inaccurate use the intensity gauge total.

Note: If a value for the primary reference gauge cannot be confidently determined the unadjusted data may need to be filed or alternatively a primary reference gauge value determined by correlation with another site may need to be used and the data be quality coded as synthetic.

To plot primary reference gauge data:

- 1. Divide the primary reference gauge's final reading by the recorder total.**
- 2. Load the 'check data' to the correct site (and Datasource).**

*Note: Include any comments that may provide future insight from the inspection sheets (log sheets). If your organization files rainfall in micro millimetres, ensure data is in micro millimetres (*1000: 0.5 mm will be loaded as 500).*

- 3. Plot (cumulative) the primary reference data with the check data records.**

Over-plot the backup rainfall data or nearby sites rainfall data.

What's Next?

Analyse the graph for:

- strange patterns
- high or unrealistic intensities
- divergence, and
- differences between the primary rainfall record and backup.

Any of the above should initiate further analyses to validate the record.

Continued on next page...

Adjust the record to the primary reference data by:

- transforming the data by a correction value, or
- linearly adjust the intensity data to the primary reference gauge total(s).

Checking for Unintended Time Adjustments

Unintended time adjustments can be made inadvertently while processing the data. It is important that checks are undertaken to ensure that the times associated with the data are correct.

To check for unintended time adjustments:

1. Quickly check the data for seconds in the file times.

Note: This is only an issue for fixed interval rainfall data.

2. Correct the dataset for any incorrect dates and times.

Note: If corrections have been made, re-run the ramp correction.

Note: Any seconds in the file times indicates that a time correction has been made.

Unless you intended one to be made (and you have a good reason to do so) there is probably a check date and/or time entered incorrectly.

3. Graph the data between checks again and note the recorder totals.

Note: These totals should match the primary reference gauge final readings ($\pm 0.06\%$).

What's Next?

At the completion of the data processing, collate the following data:

- Update Request Form including:
 - site name
 - datasource, and
 - processing period
- Staff member and processing date
- Final file location
- Rainfall Data Processing Form
 - Note: This should be fully documented with inspection details and correction notes.*
- A list of the following:
 - Comments
 - Quality Codes
 - Data Gaps
 - Manual Tip Deletions
- Summary of any synthetic data
- Three monthly rainfall (1 or 3 hour totals) plot with nearby flow site:
- One hour plots – full range:
 - Short duration intensity plot (10 minutes) for full period
 - Plots of one day rainfall
 - Cumulative corrected rainfall (with check data)
- Cumulative over-plot with either backup rainfall or rainfall from a nearby site:
 - Daily rainfall totals
 - Long term deviation plots

When collated, pass the data and processing record on to another staff member for verification prior to archiving. The processing tracking system should be populated as well.

Chart Records

Throughout New Zealand charts from older types of rainfall intensity gauges still remain unprocessed. When processing this record, data from chart records should be extracted at the finest resolution possible while recognising the inherent time and rainfall depth resolution of the recording mechanism.



NEMS

