Plan

Vegetation Health Monitoring and Management Plan

Christmas Creek – Water Management Scheme

3 February 2012

CC-PL-EN-0004 Rev 2

Fortescue
The New Force in Iron Ore

	Christmas Creek Water Management Scheme Vegetation Health Monitoring and Management Plan		**CC-PL-EN-0004**
Revision Number	**2**		**3/02/2012**
Status	**IFU - ISSUED FOR USE**		
Author	M Garkaklis (Astron)	Signature	27/09/2011
Checked	L Egerton	Signature	3/02/2012
Approved	S McGunnigle	Signature	3/02/2012
Confidentiality	**FORTESCUE STAFF & CONTRACTORS**	**Publish on Extranet**	☒ Yes ☐ No
Review Date	**30/11/2012**		

Revision History *(to be completed for each version retained by Document Control)*

Author	**Checker**	**Approver**	**Rev No.**	**Status**	**Issued Date**
M Garkaklis	L Egerton	S McGunnigle	0	**IFR**	2/09/2011
M Garkaklis	L Egerton	S McGunnigle	1	**IFU**	27/09/2011
M Garkaklis	L Egerton	S McGunnigle	2	**IFU**	**3/02/2012**

This document was prepared on behalf of Fortescue Metals Group Limited by:

astron
environmental services

Approved by Fortescue:	S McGunnigle	Signature	3/02/2012

TABLE OF CONTENTS

List of Tables

LIST OF FIGURES

LIST OF APPENDICES

1. INTRODUCTION

Fortescue Metals Group (Fortescue) is an integrated business comprised of mine, rail and port operations based in the Pilbara region of Western Australia, with its head office located in Perth.

Fortescue has commenced operation of the Pilbara Iron Ore and Infrastructure Project at its Cloudbreak and Christmas Creek mine sites (Chichester Operations). The Chichester Operations consist of several iron ore mines and associated rail and port infrastructure in the Pilbara region of Western Australia (Figure 1).

Continued mining at Christmas Creek requires dewatering to access ore below the watertable. As a result, the Christmas Creek Water Management Scheme Project (the Project) has been developed to increase the mine dewatering rate at the Christmas Creek mine to 50 Gigalitres per annum and to inject the surplus water into groundwater aquifers.

The Project received State approval under the *Environmental Protection Act 1986* (Ministerial Statement 871) and Commonwealth approval under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Approval 2010/5706).

1.1 Requirement for Management Plan

This Vegetation Health Monitoring and Management Plan (VHMMP) is required by the Minister as part of the development approval of the Project approved under Ministerial Statement 871 (MS871) and EPBC approval 2010/5706.

1.2 Objectives and Scope

The objective of the VHMMP is to address the scientific rationale, vegetation health and community monitoring and monitoring schedules required to satisfy Condition 8 of MS871 and Condition 13 of EPBC Act approval 2010/5706. The sections of this Plan which address these requirements are identified in Appendix A.

This VHMMP covers the following relevant groundwater dewatering and injection management areas (see Figure 2):

- **Dewatering impact area** – EPA (2011) indicates that the vegetation of interest in this zone is phreatophytic riparian vegetation. A 5m decline in groundwater to a maximum depth of 20 m has the potential to affect phreatophytic vegetation. The EPA considers that any potential impacts in the area are manageable, but advises that vegetation monitoring should occur to comply with Condition 8-1.
- **Mounding impact areas 1 and 2** – EPA (2011) indicates that the vegetation of interest in these two mounding impact areas is Mulga dominated communities. Injection of brackish water has the potential to impact 173 ha of Mulga vegetation that may

experience a groundwater rise to within 2m of the surface for 5% of the year. The EPA considers that any potential impacts in the areas are manageable, but advises vegetation monitoring should occur to comply with Condition 8-1 of MS871.

1.3 Definition of Keystone Plant Species

Keystone plant species identified in this VHMMP are those species occurring in vegetation communities that provide high ecosystem service value to the community, or are species within communities of high conservation value of which little precise knowledge regarding ecosystem function is known. For this VHMMP, the following keystone plant species are identified:

- Mulga (*Acacia aneura*) – Low open forest to woodland;
- River Red-gum (*Eucalyptus camaldulensis*) – Riparian woodland to open woodland;
- Coolibah (*Eucalyptus victrix*) – Riparian woodland to open woodland; and
- Samphire communities (*Tecticornia* species and other major shrubs such as *Muellerolimon salicorniaceum)*.

1.4 Legislation and Regulatory Framework

Fortescue employees and contractors are obliged to comply with all relevant environmental Commonwealth and State legislation. There is a range of legislation that relates to VHMMP in Western Australia (Table 1).

Table 1: Commonwealth and State Legislation Relating to the VHMMP

Legislation	Application
Conservation and Land Management Act (WA)	Provides for the vesting or reservation of land for conservation purposes, and the ability to enter into agreements with private landholders and pastoral lessees. It establishes a number of statutory bodies including the Conservation Commission of Western Australia.
Environment Protection and Biodiversity Conservation Act 1999 (Cth)	Protection on environmental matters of national significance.
Environmental Protection Act 1986 (WA)	Prevention, control and abatement or pollution and conservation protection and enhancement of environment.
Environmental Protection (Clearing of Native Vegetation) Regulations 2004 (WA)	Regulates the clearing of native vegetation.
Rights in Water and Irrigation Act 1914 (WA)	Relates to rights in water resources, to make provision for the regulation, management, use and protection of water resources, to provide for irrigation schemes, and for related purposes.
Wildlife Conservation Act 1950 (WA)	Provides for the conservation and protection of wildlife (flora and fauna). Special provisions and schedules cover protection and management of gazetted rare flora and fauna.

The following Fortescue documents are also of relevance to this VHMMP:

- *Christmas Creek Groundwater Operating Strategy* (CC-PH-HY-0002);
- *Mulga Monitoring Guidelines* (45-GU-EN-0001).

2. ROLES AND RESPONSIBILITIES

All Fortescue employees and contractors are required to comply with the requirements of this Plan.

Accountability for fulfilling the requirements of this VHMMP is dependent on the stage of project development (construction, operations, decommissioning) and the project type (port, rail, mine).

Whether construction activities are undertaken by an external service provider, or internal Fortescue personnel, the Project Director will be accountable for ensuring the requirements of this VHMMP are met.

During operational stages, the General Manager will be accountable for ensuring the requirements of this VHMMP are met.

Where responsibilities are delegated, this must be clearly recorded and communicated.

In Section 8, specific Management Actions have been attributed to the appropriate personnel.

3. STAKEHOLDER CONSULTATION

This plan was submitted to the Department of Environment and Conservation for its feedback, and to the Office of the Environmental Protection Authority (OEPA) and the Department of Sustainability, Environment, Water, Population and Communities (SEWPaC) for their approval, in accordance with MS871 and EPBC Approval 2010/5706.

4. MONITORING AND EVALUATION FRAMEWORK

This plan uses the Monitoring and Evaluation framework developed by the International Union for Conservation of Nature (IUCN). Monitoring and evaluation for environmental management effectiveness is a cyclical, rather than linear framework that uses the principles of active adaptive management as the core project planning, design and evaluation procedure (Hockings *et al.* 2006). This is a 'learning by doing' approach, but in a systematic and purposeful way (Stem *et al.* 2005).

Active adaptive management is recognised as the most effective contemporary approach for the conservation of natural areas (Hockings *et al*. 2006) and is adopted by numerous environmental management agencies worldwide, including the Western Australian DEC. Adaptive management is usefully applied in environmental management since it assumes that it is impossible to know all knowledge regarding the management unit or ecosystem. However, it allows modification to management actions on the basis of learning new information regarding the management unit or ecosystem.

The Monitoring and Evaluation framework includes the following elements:

- Understand the current state of vegetation potentially effected by modified groundwater levels resulting from mine dewatering and injection activities (State).
- Determine the pressures or threats to the vegetation (Pressure).
- Evaluate and select adaptive management responses available to Fortescue to achieve a target vegetation state (i.e. avoiding unacceptable change to the vegetation) (Response).

These elements collectively comprise the Pressure-State-Response model used when applying an adaptive management approach for protecting environmental values in natural areas. This provides a framework for planning and implementing environmental management actions.

5. EXISTING ENVIRONMENT

Information regarding the existing environment associated with the Project, including the current state of vegetation and threats to vegetation within the Project area is in Appendix B.

6. KEY ENVIRONMENTAL ACTIVITIES

Many of the activities[1] associated with Fortescue's exploration, construction, operation and decommissioning activities have the potential to impact on the environment.

The key activities associated with the Project which have the potential to impact on vegetation health include:

- Groundwater abstraction and distribution;
- Groundwater injection.

[1] Fortescue uses the term 'activities' to refer to 'Environmental Aspects' as defined by ISO14001.

7. POTENTIAL ENVIRONMENTAL IMPACTS

The potential impacts to vegetation health arising from Project activities are presented in Table 2.

Table 2: Potential environmental impacts to vegetation health arising from Project activities

Aspect of Project	Potential environmental impact
Dewatering	Adverse impact (significant alteration beyond natural variation) to the vegetation community. Death of keystone phreatophytic species.
Brackish water injection	Adverse impact (significant alteration beyond natural variation) to the vegetation community. Death of keystone plant species.

8. ENVIRONMENTAL MANAGEMENT

A series of environmental management objectives with respect to mitigating potential environmental impacts have been developed. These are:

Prevent adverse impact[2] on native vegetation communities attributable to the Project outside the predicted impact areas.

Prevent mortality of keystone plant species or significant changes in habitat characteristics attributable to the Project within the dewatering and mounding impact areas.

For each objective, management actions have been developed to ensure the impacts from Fortescues operations are managed, and that appropriate monitoring, reporting and corrective action functions are implemented to support the successful implementation of the management actions.

The key elements of the environmental management process associated with each objective are described in Table 3.

Table 3: Description of elements of environmental management process to achieve identified objectives

Element	Definition / Description
Objective	What is intended to be achieved.
Management Action	Tasks undertaken to enable the objective to be met.
Performance Indicators	Metrics for evaluating the outcomes achieved by the Management Action.
Reporting/Evidence	Demonstrates that the Management Action has been applied and the outcome evaluated.
Responsibility	Accountability for ensuring Management Action is completed.

[2] Adverse impacts are defined as statistically significant (either positive or negative) differences in monitoring criteria within impact sites in comparison to reference sites (allowing for natural variation between seasons and between years).

Table 4: Key Management Actions for Vegetation Health Monitoring and Management in the Project Area

Reference	Management Action	Objective	Performance Indicators	Reporting / Evidence	Timing	Responsibility
1.	Conduct a baseline vegetation assessment for dewatering impact areas and mounding impact areas identified in Figure 2 of this Plan.	1,2	• Baseline assessment conducted • No change greater than natural variation that is attributable to the Project measured by spatially distributed replicate monitoring sites • No change greater than natural variation that is attributable to the Project measured by monitoring sites within impact areas in comparison to reference (no impact) areas.	• Report • Baseline assessment	Design	Project Manager
2.	Implement the Vegetation Health Monitoring Program in Section 9 of this Plan to monitor any change in vegetation health at dewatering impact areas and mounding impact areas and where necessary implement corrective actions.	1,2	• No change greater than natural variation that is attributable to the Project measured by spatially distributed replicate monitoring sites. • No change greater than natural variation that is attributable to the Project measured by monitoring sites within impact areas in comparison to reference (no impact) areas. • Incident reports of vegetation stress potentially attributable to the Project. • Monitoring requirements are included in the *Christmas Creek Operating Strategy.*	• Vegetation Health Monitoring Program • Monitoring reports • Incident reports • Annual Environmental Report	Design/ Construction/ Operation	Project Manager/ Manager Mining/ HSES Manager

Reference	Management Action	Objective	Performance Indicators	Reporting / Evidence	Timing	Responsibility
3.	Where vegetation health monitoring detects vegetation stress potentially attributable to the Project, implement management measures outlined in the *Christmas Creek Groundwater Operating Strategy* (CC-PH-HY-0002).	1,2	• No change greater than natural variation that is attributable to the Project measured by spatially distributed replicate monitoring sites. • No change greater than natural variation that is attributable to the Project measured by monitoring sites within impact areas in comparison to reference (no impact) areas. • Adherence to the Christmas Creek Groundwater Operating Strategy. • Incident reports of vegetation stress potentially attributable to the Project. • Monitoring requirements are included in the Christmas Creek Groundwater Operating Strategy.	• Monitoring report • Annual Environmental Report • Groundwater Operating Strategy	Construction/ Operation	Project Manager/ Manager Mining
4.	Where trigger levels have been exceeded as a result of the implementation of the Project, comply with Condition 8-5 of MS871 and Condition 13 of EPBC Approval 2010/5706.	1,2	• Compliance with MS871 • Compliance with EPBC Approval 2010/5706.	• Monitoring report • Correspondence with the OEPA/SEWPaC • Monitoring Report	Construction/ Operation	Project Manager/ HSES Manager

9. MONITORING PROGRAM

This monitoring program has been prepared as part of the VHMMP to incorporate best practice methods to address the goals and objectives addressed in this Plan. This program will address the monitoring conditions outlined in MS871 and EPBC Approval 2010/5706.

9.1 Monitoring Site Selection

The rational used for site selection for this monitoring program involved:

- Stratification between impact and references areas;
- Identification of phreatophytic communities in dewatering impact and reference areas;
- Identification of Mulga communities in re-injection impact and reference areas;
- Selection of ecophysiological sampling locations close to existing monitoring bores; and
- Selection of reference quadrats previously surveyed by ENV to provide a repeat measure.

In addition, site selection was guided by road access and took into account heritage issues.

The location of impact and reference monitoring sites are shown in Figures 3-5.

With regard to the monitoring of groundwater levels and groundwater quality in proximity to the vegetation monitoring sites, the groundwater data collected in Fortescue's quarterly aquifer reviews provides appropriate baseline groundwater monitoring data for the Project and the VHMMP. The most recent of these reviews (Fortescue 2011d; Appendix C), identifies the bores currently being monitored. In addition, five recently-constructed near-marsh monitoring bores will also provide more marsh-focussed baseline data. Data for these near-marsh monitoring bores will be incorporated into subsequent monitoring reviews.

Fortescue considers that this groundwater level and EC data , which is collected monthly, and reported quarterly to stakeholders, is also the most appropriate data to satisfy the 2nd part of Condition 8-3(3) in MS871, and the 2nd part of Condition 13(d) in EPBC approval 2010/5706, as it's collected most near to the vegetation monitoring points.

9.2 Frequency and Duration

Baseline monitoring for the Project was conducted in August 2011. Biannual monitoring will nominally be conducted in:

- May 2012; and
- November 2012.

The exact timing of monitoring may be subject to prevailing weather conditions, which may affect site accessibility and the utility of some monitoring methods. Any changes to the frequency of monitoring in 2013 will be evaluated following the analysis of the repeat measures of data from August 2011 to November 2012.

9.3 Baseline Monitoring

Baseline monitoring was conducted prior to the reinjection of surplus water in accordance with Condition 8-4 of MS 871 and Condition 13 of EPBC2010/5706.

The baseline monitoring included:

- Qualitative phreatophytic tree health assessments following an adapted method of Souter *et al.* (2010);
- Digital canopy photography cover measurements of phreatophytic trees (Eucalypts) in dewatering and reference areas;
- Qualitative Mulga community health assessments in accordance with the Fortescue Mulga Monitoring Guidelines (Fortescue 2011c). A summary description of the methodology is provided in Appendix D;
- Quantitative phreatophytic (Eucalyptus) water status assessments using pre-dawn and midday leaf water potential measurements in dewatering versus reference areas (this data is linked to borefield measurements collected as part of the Project). An example of the data record template used is provided in Appendix E;
- Quantitative Mulga water status assessments using pre-dawn and midday leaf water potential measurements in reinjection versus reference areas (this data is linked to borefield measurements collected as part of the Project);
- Measurement of gravimetric soil moisture at 1 m depths in Mulga reinjection impact areas versus reference areas. This data augmented the groundwater level monitoring in nearby Fortescue bores, and provided the basis for indentifying correlations between groundwater level changes, increases in soil moisture in the root zone and the detection of physiological responses in Mulga trees.
- Sampling to 1 m depth is practical using hand equipment, but may not capture soil moisture changes through the bulk extent of plant rooting depth. Options for increasing the sampling depth (to up to 6 m) using vehicular mounted drilling equipment at selected sites are being investigated by Fortescue, to further inform relationships between groundwater level changes and soil moisture response in the unsaturated profile;
- Samphire cover estimates (type labels only until reproductive material available) of Samphire communities in line intercept transects within impact and control areas; and
- Samphire height and tip die-off measurements for each individual plant intersected in Samphire line intercept transects.

For the first year of injection operations of the Project, biannual monitoring of keystone species health and water status of phreatophytic trees and Mulga will be conducted. Biannual botanical survey of transects will be conducted. Appendix F contains the initial baseline vegetation monitoring report (Astron 2011).

A summary of monitoring conducted for this monitoring program is provided in Table 5.

Table 5: Summary of monitoring to be conducted for the VHMMP

Potential impact	Monitoring criteria	Data analysis
Groundwater decline due to dewatering.	Qualitative Phreatophytic tree health assessments	Non-parametric ANOVA (Zar 2009).
	Quantitative Digital Canopy Photography	Univariate Control Chart – Level 1 management response required in exceedance of 1 Standard Deviation in percentage canopy cover. ANOVA – Level 1 management response required if significant differences (normalised data and $p<0.05$) detected.
	Quantitative health assessments	Multivariate Control Charts of multiple ecophysiological variables – Level 1 management response required in exceedance of 90% Confidence Interval in Control Chart trend (Anderson and Thompson 2004). ANOVA – Level 1 management response required if significant differences (normalised data, $p<0.05$) detected.
Groundwater rise due to reinjection	Qualitative Mulga health assessments	Non-parametric ANOVA (Zar 2009).
	Quantitative Mulga water status health assessments	Multivariate Control Charts of multiple ecophysiological variables – Level 1 management response required in exceedance of 90% Confidence Interval in Control Chart trend. ANOVA – Level 1 management response required if significant differences (normalised data, $p<0.05$) detected. Tests of association between soil moisture measurements and water status.
	Samphire community analysis	Multivariate control charts of species presence and cover. Control limit set to 90% Confidence Interval. Per-MANOVA. Identification of significant species changes. Between year shifts in Samphire community represented in pairwise Analysis of Similarity Ordination Plots (Clarke and Warwick 2001).
	Samphire health	Univariate Control Chart – Level 1 management response required in exceedance of 1 Standard Deviation in tip die off and height. MANOVA – Level 1 management response required if significant differences ($p<0.05$) detected.

9.4 Monitoring methodology

Monitoring will be a combination of quantitative and qualitative vegetation measurements, ecophysiological measurements and health assessments using qualitative criteria and digital canopy photography. The detailed methodology for each vegetation community defined by its keystone species is described below.

Phreatophytic Vegetation Communities

Management Targets and Monitoring Hypotheses

Table 6 outlines the management targets and monitoring hypotheses for phreatophytic vegetation communities.

Table 6: Management targets and monitoring hypotheses for phreatophytic vegetation communities

Management targets	Details
Vegetation management target	No adverse impact, beyond natural variability, to phreatophytic trees or recruitment due to dewatering.
Groundwater management trigger	Management of groundwater decline to ensure actual groundwater levels do not fall to below 20 m beneath the ground surface in dewatering areas in accordance with the *Christmas Creek Groundwater Operating Strategy* CC-PH-HY-0002.
Vegetation monitoring management triggers	Pre-dawn leaf water potentials significantly greater in dewatering zones in comparison to reference.
	Percentage canopy cover significantly greater than reference ($p<0.05$) and/or greater than 1 Standard Deviation from the Control Chart mean.
	Deaths of keystone tree species significantly greater than reference ($p<0.05$) and/or greater than 1 Standard Deviation from the Control Chart centerline.
Management hypothesis	The water status, health and recruitment of phreatophytic trees within areas of dewatering and lowing of the water table will not alter significantly in comparison to phreatophytic vegetation in area not affected by lowering of groundwater though dewatering.

Methodology

Each monitoring site will include an area of approximately 2 ha in which permanent sample trees will be selected and quadrats will be established. At each site thirty mature phreatophytic trees (*E. camaldulensis* and *E. victrix*) will be randomly selected for repeated measurements using qualitative visual health assessment scores (see Appendix E). An approximate 1:1 mix of both species will be sought where they co-occur. Each measurement tree will be permanently labeled with a metal tag, measured for diameter over bark at breast height (DBHOB; at 130 cm above ground level) and identified to species level (where possible[3]). Of the 30 permanent sample trees, a subsample of ten trees will be selected for quantitative monitoring. The quantitative measurements performed on the ten subsample trees will include predawn leaf water potentials and projected foliar cover (PFC). A permanent photo point to measure PFC will be installed under the canopy of the 10 subsample trees with a short star picket and protective cap.

Sites will be selected to provide a good spatial representation of the potential impact area, where significant stands of phreatophytic vegetation exist, and in areas easily accessible for future monitoring.

[3] Fortescue recognises that *E. victrix*, as currently described, could potentially consist of several cryptic taxa within an overall species complex.

During a four day period predawn leaf water potential measurements will be taken. Three excised shoots (two to ten leaves) will be sampled from the mid-canopy of each of the ten permanent subsample trees one to two hours before dawn. Shoots will be immediately sealed in an airtight plastic bag and kept chilled in an esky until their water potentials will be measured with a pressure chamber (Model 1000, PMS Instrument Company, Oregon, USA). The leaf water potential measurements are a scientifically robust technique that can provide an in situ indication of plant water status (Turner 1988) and soil water availability (O'Grady *et al*. 2002); however careful interpretation of results is necessary due to the potential for disequilibrium to occur between predawn leaf and soil water potentials in some situations.

<u>Visual Assessment</u>

All sample trees (30 per site) will be visually assessed using an adapted method originally developed by Souter *et al.,* (2009) to monitor the health of phreatophytic eucalypts. The assessment method is based on a conceptual model of the symptoms of decline due to water stress and indicators of recovery as conditions improve. The method incorporates the following aspects of tree health:

- Crown growth;
- Crown density;
- Epicormic growth;
- Epicormic state;
- Reproduction;
- Crown tip growth;
- Leaf die off;
- Leaf damage;
- Mistletoe; and
- Bark form.

Crown condition ratings are based on a scale from 0 to 9 which will be assigned to the stages of tree decline and recovery as displayed as combinations of crown extent and density classes in Souter *et al.* (2010). A rating of 0 corresponds to a tree with no leaves and 9 corresponding to a tree where the canopy is completely foliated and the foliage is at maximum density. A score of 5 represents a tree with moderate canopy foliation and moderate foliage density.

Determination of crown condition trajectory will be based on the system of Souter *et al*. (2009; 2010). Scores for recovery attributes (epicormic growth, reproduction and crown growth) and decline attributes (leaf die off and leaf damage) will be totaled, with scores ranging from 0 (effect absent) to 3 (effect dominates appearance of tree) given for each attribute (Souter *et al*. 2009). In addition, one point will be added to the decline attributes total when the tree has cracked bark and one point will be deducted from the recovery attributes total when epicormic growth (if present) is inactive. A declining trajectory will be assigned to trees where the decline total exceeded the recovery total by more than one point, and vice versa for a recovery trajectory. Where the difference is one point or less, the trajectory will be considered to be stable.

Projected Foliar Cover

Projected foliar cover (PFC) will be determined for individual trees and across transects. PFC is related to canopy density which is often related to plant stress, as the shedding of leaf canopy is one of the first physiological responses to water stress (Souter *et al.* 2009).

For assessing the PFC within the canopy of individual trees, permanent sampling points will be installed underneath the ten subsample trees at each site with a 60 cm star picket. A 12.0 Megapixel Digital Camera will be locked onto a tripod with the camera looking skywards. A surface level (or bubble level) will be used to ensure the camera was kept level. By placing the tripod at the same permanent location and through the use of the surface level the PFC images can be replicated on a temporal scale to give an indication of changes into canopy density. Images will be analysed to estimate a PFC in accordance with MacFarlane *et al.* (2007a; 2007b). Data obtained from these images can only be used to interpret changes in foliar cover on a temporal scale. Therefore, this data will not be presented until a second monitoring trip is completed.

Quadrat canopy cover estimates using a leaf area index (LAI) meter (e.g. LAI-2200 Plant Canopy Analyser or equivalent) will be investigated, particularly with respect to their application in demonstrating consistent estimates of the LAI in spare canopy of Coolibahs.

Mulga Vegetation Communities

Management Targets and Monitoring Hypotheses

Table 7 outlines the management targets and monitoring hypotheses for Mulga vegetation communities.

Table 7: Management targets and monitoring hypotheses for Mulga vegetation communities

Management targets	Detail
Vegetation management target	No adverse impact to vegetation community or Mulga and associated *Acacia* species trees due to groundwater mounding
Groundwater management trigger	Management of groundwater to remain 2m below ground level in accordance with the *Christmas Creek Groundwater Operating Strategy* CC-PH-HY-0002.
Vegetation monitoring management triggers	Midday leaf water potentials significantly greater in mounding impact areas in comparison to reference.
	Percentage canopy cover of Mulga trees significantly greater than or less than reference in reinjection zones.
	Deaths of keystone Mulga trees significantly greater than or less than reference.
Management hypothesis	The water status and health of Mulga vegetation within areas of reinjection and rising of the water table will not alter significantly in comparison to Mulga vegetation in areas not affected by rising groundwater through reinjection.

Methodology

Vegetation monitoring will follow guidelines provided in the *Mulga Monitoring Guidelines* (45-GU-EN-0001). Additions and deviations to the guidelines are based on the following monitoring:

- Pre-dawn and leaf water potentials measured on Mulga trees and Mulga vegetation community survey following procedures outlined under the methodology for Phreatophytic vegetation communities.

- Soil moisture measurements in monitoring sites and tests of association between soil moisture and Mulga water status.

Samphire Vegetation Communities

Management Targets and Monitoring Hypotheses

Table 8 outlines the management targets and monitoring hypotheses for Samphire vegetation communities.

Table 8: Management targets and monitoring hypotheses for Samphire vegetation communities

Management targets	Detail
Vegetation management target	No adverse impact to Samphire vegetation community due to groundwater mounding.
Groundwater management trigger	Management of groundwater to remain 2m below ground level, or otherwise at a depth that is not significantly different to reference areas in accordance with the *Christmas Creek Groundwater Operating Strategy* CC-PH-HY-0002.
Vegetation monitoring management triggers	Plant species composition within communities within mounding areas does not alter significantly as measured by non-parametric multivariate analyses from vegetation transects in reference areas (identification with reliable reproductive material from surveyed plants)
	Tip die off or tip growth of Samphire plants is not significantly greater in mounding impact areas in comparison to reference areas.

Methodology

Change in the maximum and mean height of Samphire plants is not significantly lower or greater in mounding impact areas in comparison with references areas.

Monitoring will be based on several replicate line-intercept sampling transects in reference and mounding impact areas. Additional analyses of soil parameters, which may be used as supplemental triggers or surrogates for plant health, will be determined over the repeat measurements in this sampling program.

9.5 Data Analysis

Two methods will be applied to determine if differences or trends in monitoring data are occurring. These are:

- Application of single variable (univariate) or multiple variable (multivariate) Control Charts, to identify trends in data that may indicate changes taking place within impact sites in comparison to reference sites (Anderson and Thompson 2004, Morrison 2008). Control Charts incorporate a centerline value (for stochastic parameters) and 'control limits' within which these parameters are expected to be maintained in the absence of significant impacts;

- Tests of significant differences between impact sites and reference sites in single variables (Analysis of Variance - ANOVA) or multiple variables (Permutation Multiple Analysis of Variance; PERMANOVA) (Anderson 2001, Zar 2009).

Parametric statistics are commonly used to detect changes in impact and reference areas using the Before-After-Controlled-Impact monitoring. The application of Control Charts is a relatively new approach to assist environmental managers to interpret trends in monitoring data. In Western Australia, Control Charts are used in the analysis of monitoring data for the Marine Turtle Monitoring Program in the Gorgon Gas Development.

9.6 Adaptive Management

Analysis of the effectiveness of vegetation management identified in the monitoring program will be compiled within the VHMMP annual report for 2012. The OEPA and DEC will be consulted if any changes to the monitoring methodologies are proposed.

Results, discussion and new information obtained from the monitoring program will be included in the annual report. Opportunities for adaptive management that may arise from these analyses will be explored.

10. AUDIT

Internal auditing of activities associated with the VHMMP will be carried out in accordance with Fortescue's internal audit schedule.

Audit criteria may include, but is not limited to:

- Management actions within this document;
- Implementation of monitoring program; and
- Applicable conditions and commitments within Ministerial Statements.

Where non-conformance issues or opportunities for improvement are identified these will be documented and tracked via the Business Management System (BMS).

11. CORRECTIVE ACTIONS

The management trigger-response framework adopted in the VHMMP includes two levels. At the outset of the program a Level 1 response will be triggered if Control Charts indicate change greater than 1 Standard Deviation in a univariate measure(s), or beyond the 90% Confidence Interval for multivariate Control Charts (Anderson and Thompson 2004). Level 2 Management Response Triggers will be implemented when significant adverse differences attributable to the project are determined or predicted to occur without management intervention (See Section 6.2).

Level 1 Vegetation Management Response Trigger

This is considered the first level of vegetation monitoring response. Monitoring will identify if changes occur in a range of metrics related to vegetation condition. The magnitude of change in dewatering and Injection zones, in comparison with reference areas, provides the basis for detecting potential adverse impacts. A Level 1 Management Response Trigger represents the amount of change in a measured parameter, or group of parameters, in excess of a defined statistical threshold necessary to enact a management response.

On the identification of a Level 1 management trigger, the management response will be:

- Re-examination of groundwater levels to validate that groundwater is within water management trigger levels;
- Increase in vegetation monitoring frequency;
- Compilation of rainfall, soils, and groundwater monitoring information for detailed statistical analyses using Generalized Liner Modelling/Multiple regression approach. The outcome of these analyses is to partition the degree of variance towards predictors of the vegetation impact.

Note that the detection of change in a repeated measurement dataset does not enable cause and effect to be determined without additional statistical analysis. As such the exceedance of a Level 1 trigger value does not imply that an adverse impact has occurred, but rather indicates that additional analysis is required to determine this.

Level 2 Vegetation Management Response Trigger

This is considered the second level of vegetation monitoring response. On the identification of a Level 2 management trigger, the management response will be:

- Increase in vegetation monitoring frequency (as per Trigger Level 1);
- Adaptive water management response (modified dewatering and injection regime) following management guidance within the Christmas Creek Groundwater Operating Strategy CC-PH-HY-0002 ; and

- In accordance with Condition 8-5 of MS 871:
  - The trigger exceedance will be reported to the CEO of the OEPA within 7 days of the exceedance being identified
  - Evidence allowing the determination of the cause of the exceedance will be provided to the CEO of the OEPA within 21 days of the exceedance being identified; and a response action plan will also be provided where deemed necessary by the CEO of the OEPA.
  - Actions to address the exceedance will be implemented where the need is identified to the satisfaction of the CEO of the OEPA.
- In accordance with Conditions 13h-j of EPBC2010/5706, in the event that the monitoring indicates that the triggers defined in this VHMMP have been exceeded, Fortescue shall:
  - Report such findings to the Department of Sustainability, Environment, Water, Population and Communities (SEWPaC) within 7 days of the exceedance being identified
  - Provided written advice to SEWPaC, within 21 days of the exceedance being identified, stating:
    - the direct cause of the exceedance; and
    - actions and associated timelines proposed to remediate the groundwater levels.
  - If actions cannot be undertaken to address the exceedance or there is a loss of EPBC Act listed threatened species habitat, then an offset, for approval by the Minister responsible for administration of the EBC Act, will be provided within 3 months of the identification of the exceedance. The offset will be for the long term protection of habitat that maximises the potential for the conservation of EPBC Act listed threatened fauna species, including the Greater Bilby (*Macrotis lagotis*), Night Parrot (*Pezoporus occidentalis*), and Mulgara (*Dasycercus cristicaudata*), at a ratio of 7 ha for every 1 ha impacted by the exceedance. The approved offset will be implemented. The operation of the project cannot continue beyond 4 months of an exceedance being identified, unless the offset has been approved.

With regards to adaptive water management, Fortescue has developed a system for assigning and managing an appropriate distribution of monitoring points (bores), associated trigger levels (Class 1 and Class 2) and management responses for groundwater embodied in the Christmas Creek Groundwater Operating Strategy CC-PH-HY-0002.

The full description of the groundwater monitoring triggers is provided in the Christmas Creek Groundwater Operating Strategy CC-PH-HY-0002. These management responses are to occur with the exceedance of a Class 2 Groundwater trigger. This involves implementation of modifications to operational activities including:

- Reducing volumes of water piped to the affected area by redirecting water to other injection areas;
- Redirection of disposal water to transfer and/or infiltration ponds; and
- Redirection of disposal water to void mine pits.

12. REPORTING

Following each monitoring survey, a brief letter report will be prepared summarising the work completed and any problems encountered. A report will be prepared annually, which will provide a detailed summary of monitoring, analysis of results and contingency actions undertaken. The annual report will assist in evaluating the effectiveness of the management and monitoring program and will provide information on the current status of the vegetation in relation to the Project.

13. REVIEW

It is important that Management Plans are frequently reviewed and revised as Fortescue's operations change and opportunities for improved management practices are identified.

The VHMMP will be reviewed following analysis of monitoring results obtained during the first 15 months of monitoring commencing in August 2011. Depending on the outcome of this review, the VHMMP may be expanded, continued unchanged or reduced in scope. If necessary, new management targets will be set using an adaptive management approach (Stem *et al.* 2005).

Upon review, the document will be revised where appropriate and the revision status will be updated in accordance with Fortescue's document control procedures.

14. REFERENCES

Anderson, M.J. 2001. A new method for non-parametric multivariate analysis of variance. *Austral Ecology* 26: 32-46.

Anderson, M.J. & Thompson, A.A. 2004. Multivariate control charts for ecological and environmental monitoring. *Ecological Applications* 14: 1921-1935.

Astron (2011). Christmas Creek Vegetation Health Monitoring and Management Program Baseline Report. October 2011. Unpublished report prepared for Fortescue, October 2011.

Beard, J.S. (1975). The vegetation survey of Western Australia. *Plant Ecology* 30:179-187.

BOM 2010, The Bureau of Meteorology, Melbourne, website viewed March 2010, http://www.bom.gov.au

Clarke, K.R. & Warwick, R.M. 2001. *Change in marine communities: an approach to statistical analysis and interpretation*. 2nd Edition. PRIMER-E: Plymouth, UK.

Environment Australia (2001) A Directory of Important Wetlands in Australia. Canberra. (www.deh.gov.au/water/wetlands/database/directory/index.html)

EPA (2011). Christmas Creek Water Management Scheme. Report and Recommendations of the EPA, Report 1402. EPA, Perth WA, June 2011.

Fortescue (2011a). Christmas Creek Water Management Scheme Environmental Review. April 2011. CC-RP-EN-0011_Rev 1.

Fortescue (2011b). Christmas Creek Groundwater Operating Strategy. April 2011. CC-PH-HY-0002.

Fortescue (2011c). Mulga Monitoring Guidelines, July 2011. 45-GU-EN-0001.

Fortescue (2011d). Christmas Creek Groundwater Monitoring Review, 1 August 2010 - 31 July 2011. Unpublished report prepared by Fortescue, September 2011.

Grigg, A. M., E. J. Veneklaas, and H. Lambers 2008. Water relations and mineral nutrition of closely related woody plant species on desert dunes and interdunes. Australian Journal of Botany 56:27-43.

Hockings, M., Stolton, S., Leverington, F., Dudley, N. and Courrau, J. (2006) *Evaluating Effectiveness. A framework for assessing management effectiveness of protected areas*. 2nd edition. IUCN (The World Conservation Union), Gland, Switzerland and Cambridge U.K.

Kew G. (2011), *Fortescue Marsh – preliminary soil investigation*, Client report for Fortescue Metals Group Limited, March 2011.

Loomes, R. 2010. Determining water level ranges of Pilbara riparian species. Pages 21. Environmental water report. Department of Water, Perth.

McKenzie N.L, van Leeuwen S. & Pinder A.M. (2009), *Introduction to the Pilbara Biodiversity Survey, 2002–2007*, Records of the Western Australian Museum, Supplement No. 78, Western Australian Museum Perth.

Morrison, L.W. 2008. The use of control charts to interpret environmental monitoring data. *Natural Areas Journal* 28: 66-73.

O'Grady A.P., Eamus, D., Cook, P., Lamontagne, S., Kelly, G., Hutley L., (2002). *Tree water use and sources of transpired water in riparian Vegetation along the Daly River*, Northern Territory. Report to Environment Australia as part of the Healthy Rivers Program.

Stem, C., Margoulis, R. Salafsky, N. And Brown, M. (2005). Monitoring and evaluation in conservation: a review of trends and approaches. *Conservation Biology* 19: 295-309.

Souter N.J., Cunningham S., Little S., Wallace T, McCarthy B and Mark Henderson (2010), 'Evaluation of a visual assessment method for tree condition of eucalypt floodplain forests', *Ecological Management & Restoration*, Vol 11 No 3 December 2010.

Souter N. J., Watts R. A., White M. G., George A. K. and McNicol K. J. (2009). *Method Manual for the Visual Assessment of Lower River Murray Floodplain Trees. River Red Gum* (Eucalyptus camaldulensis). DWLBC Report 2009 ⁄ 15, Government of South Australia through Department of Water, Land and Biodiversity Conservation, Adelaide.

Van Vreeswyk, A.M.E, Payne, A.L., Leighton, K.A. and Hennig, P. (2004) *An inventory and condition survey of the Pilbara region, Western Australia*. Technical Bulletin 92, Western Australian department of Agriculture.

Zar J.H. (2009 – 5th Edition*). Biostatistical Analysis*. Prentice Hall.

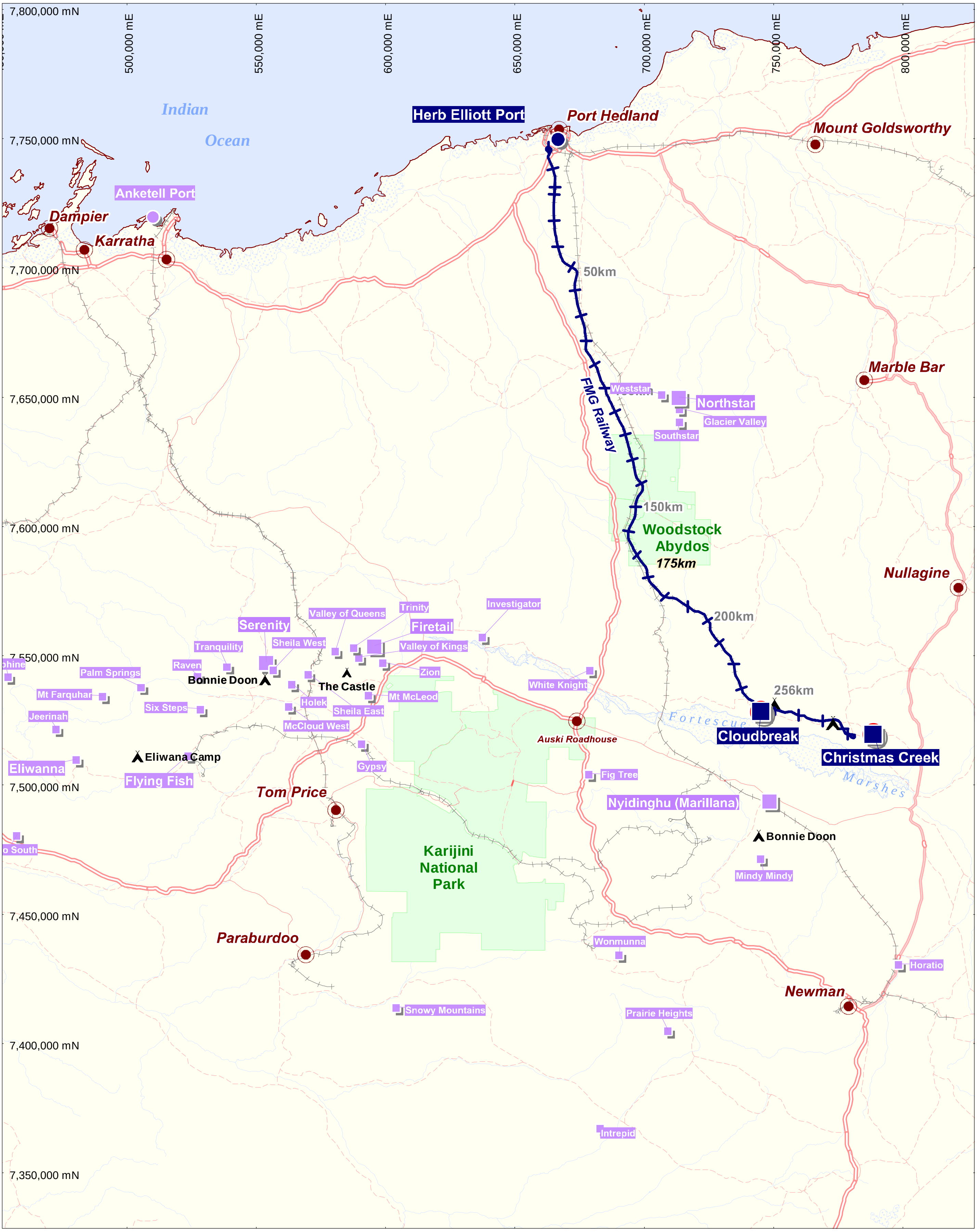
Figures

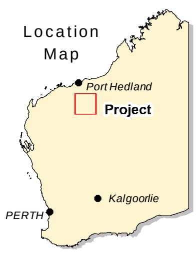
This page has been left blank intentionally

Figure 1

Regional Project Location

This page has been left blank intentionally





Legend

- Towns
- Major Roads/Tracks
- Creeks
- FMG Railway
- Other Railways
- FMG Projects
- FMG Mines

N

0 20 40 80

kilometres

Fortescue Metals Group Ltd

Figure 1

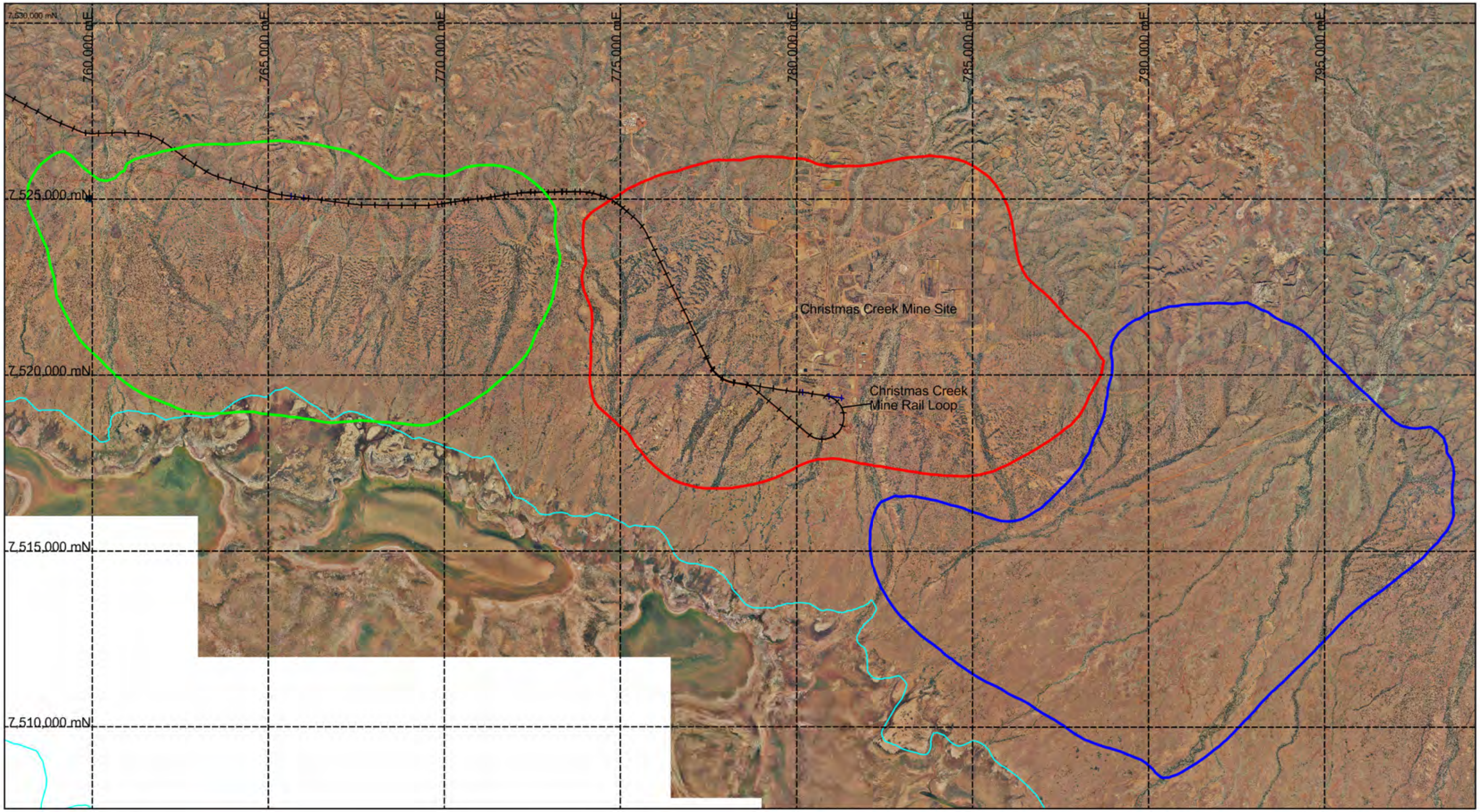
Regional Project Location

Author: MYC	Date: 21/07/2011
Drawn By: JB	Revision: 7
Doc No: 100_MP_EN_0003	Confidentiality: 1
Projection: MGA Zone 50 (GDA 94)	Scale: 1:2million

Figure 2

Predicted Impact Areas

This page has been left blank intentionally



Mounding Impact Area 1

Drawdown Impact Area

Mounding Impact Area 2

Fortescue Marsh

Railway

N

0 1.25 2.5 5
kilometres

Note: The mounding and drawdown impact areas are in accordance with Schedule 2 of MS 871.

Fortescue Metals Group Ltd

Figure 2

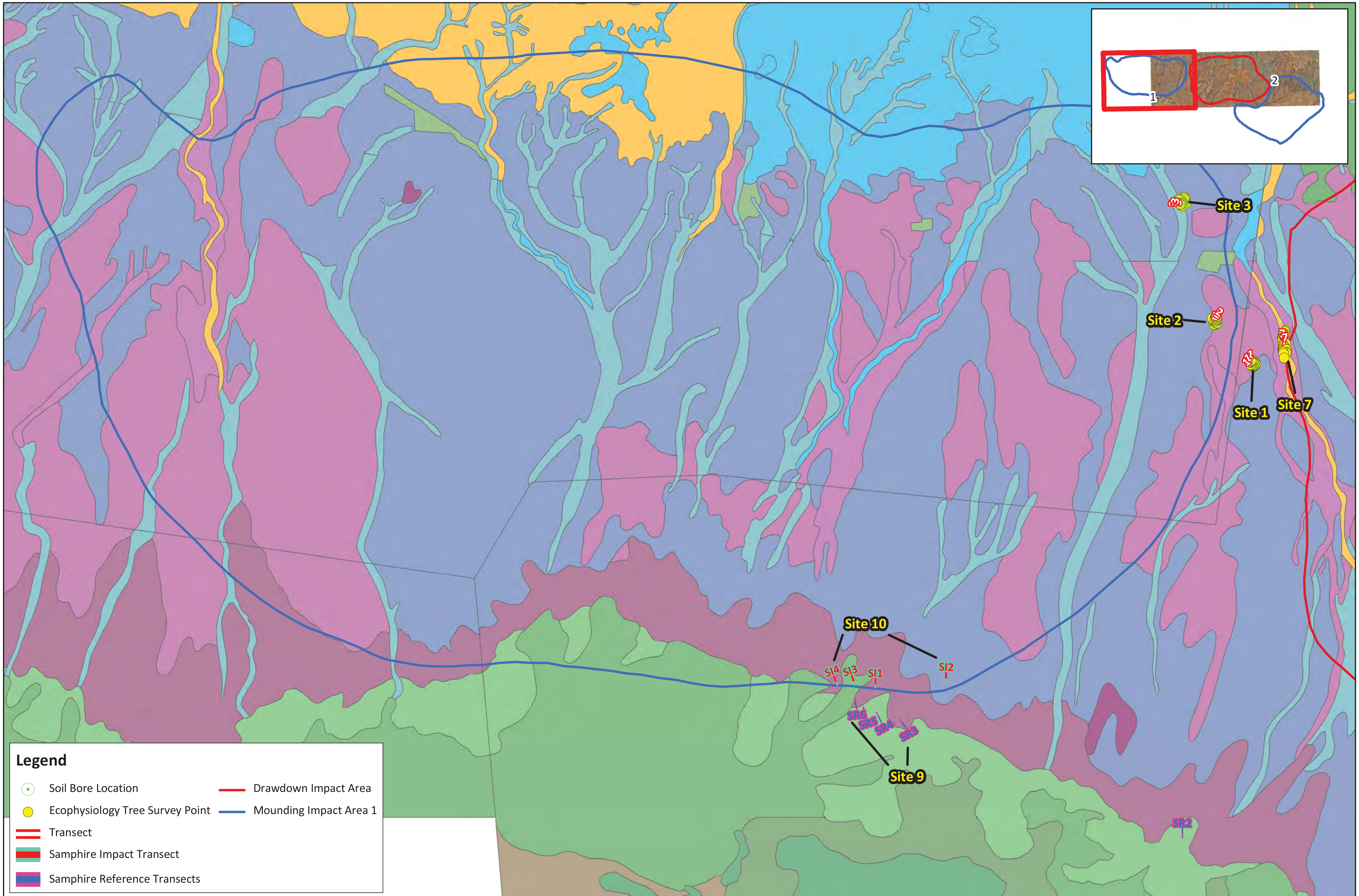
Christmas Creek Water Management Scheme
Predicted Impact Areas

Author: B. Von Perger	Date: 25/8/2011
Drawn By: DN	Revision:
Dwg No: CC_MP_EN_0134.2	Report No:
Projection: MGA Zone 50 (GDA 94)	Scale: 1:150000

Figure 3

Survey Point Locations in Mounding Impact Area 1

This page has been left blank intentionally



Fortescue Metals Group

Christmas Creek Vegetation Health Monitoring

Figure 3: **Survey Point Locations in Mounding Impact Area 1**

Datum: GDA 1994

Projection: MGA Zone 50

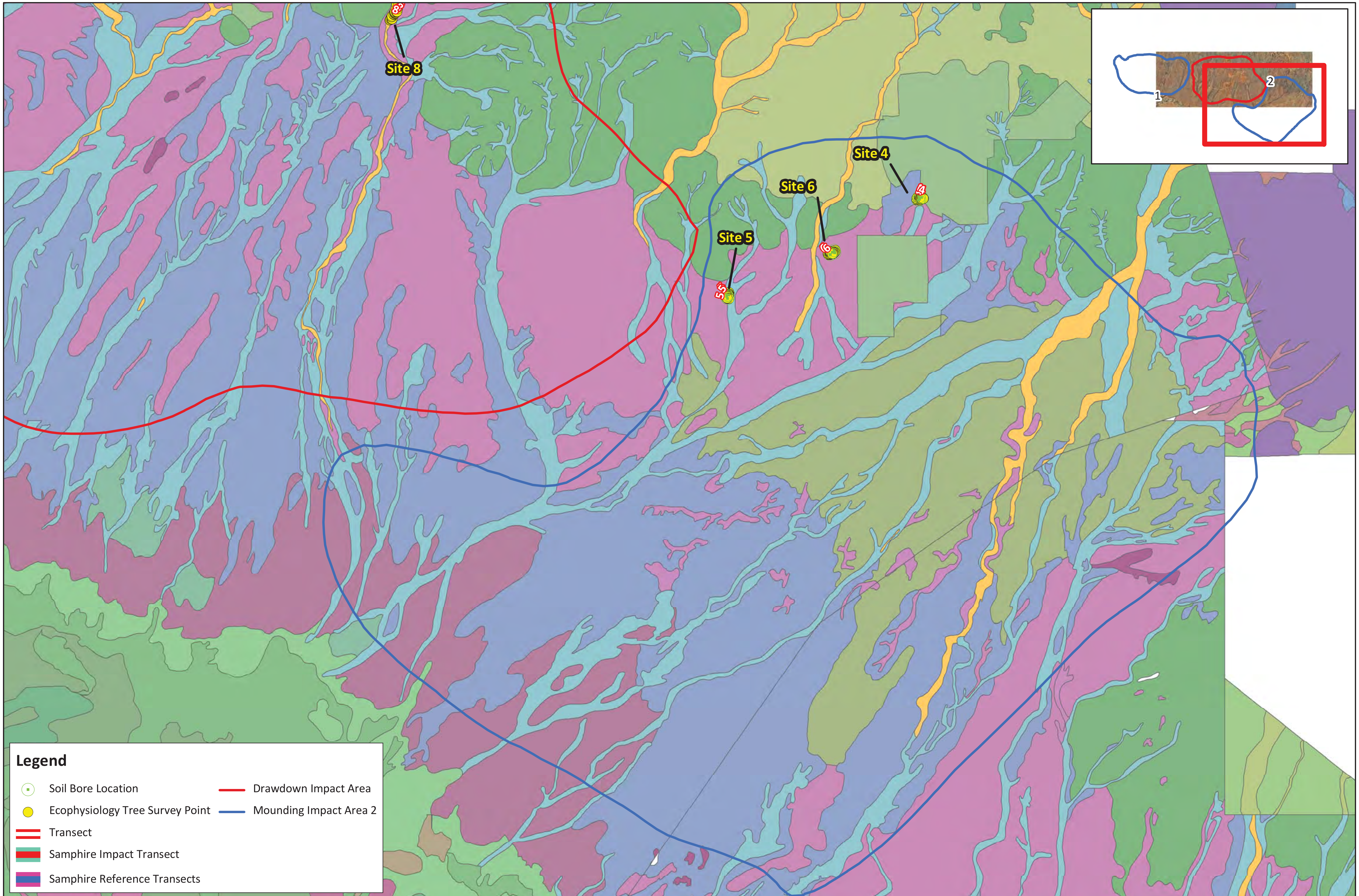
astron environmental services

Author: Mark Garkaklis | Drawn: R. Wathugala / S. Fielden | Date: 27-09-2011 | 12306-11FMVXRevA_110927_Figure_5a

Figure 4

Survey Point Locations in Mounding Impact Area 2

This page has been left blank intentionally



Fortescue Metals Group

Christmas Creek Vegetation Health Monitoring

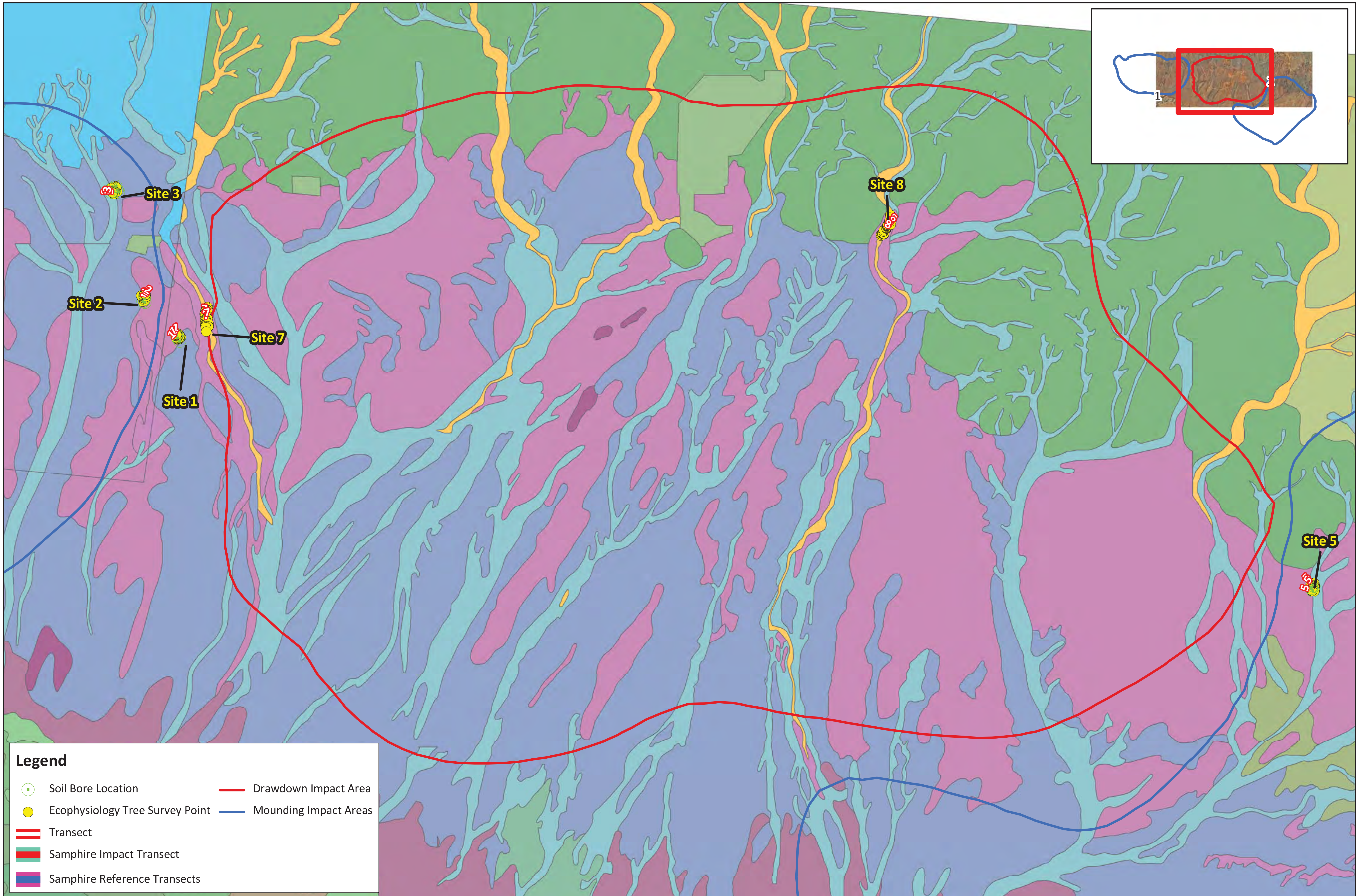
Figure 4: **Survey Point Locations in Mounding Impact Area 2**

Author: Mark Garkaklis | Drawn: R. Wathugala / S. Fielden | Date: 27-09-2011 | 12306-11FMVXRevA_110927_Figure_5b

Figure 5

Survey Point Locations in Drawdown Area

This page has been left blank intentionally



Fortescue Metals Group

Christmas Creek Vegetation Health Monitoring

Figure 5: **Survey Point Locations in Drawdown Area**

Author: Mark Garkaklis | Drawn: R. Wathugala / S. Fielden | Date: 27-09-2011 | 12306-11FMVXRevA_110927_Figure_5c

Appendices

This page has been left blank intentionally

Appendix A.

Cross reference to State and Federal Statutory Requirements

This page has been left blank intentionally

Appendix A: Cross reference to State and Federal Statutory Requirements

Ministerial Statement and Condition	Requirement or Issue	Location in this Plan
EPBC 2010/5706: 13	The Plan must be developed by an appropriately qualified expert and in consultation with the WA DEC to the satisfaction of the Minister.	Page 2 Section 3
EPBC 2010/5706: 13a	Measures to ensure there is no adverse impact on native vegetation communities attributable to the project outside the predicted impact areas.	Sections 8 & 9
MS871: 8-3(1) EPBC 2010/5706: 13b	Identification of keystone plant species and habitat characteristics and limits of acceptable change in health and/or condition of these to be used as the basis for monitoring.	Appendix B
MS871:8-3(2) EPBC 2010/5706: 13c	Locations for predicted impact and reference monitoring sites (outside the predicted impact areas) for baseline and ongoing monitoring, with sites selected based on scientific rationale and to the satisfaction of the Department of Environment and Conservation.	Figures 3-5 Section 9
EPBC 2010/5706: 13d	Define the collection and timeframes of baseline monitoring for vegetation health, species composition and habitat characteristics at both predicted impact and reference monitoring sites and groundwater levels and ground water quality at agreed sites in proximity to the vegetation monitoring sites.	Section 9
MS871: 8-3(3)	Results of baseline monitoring for vegetation health, species composition and habitat characteristics at both predicted impact and reference monitoring sites, and groundwater levels and groundwater quality at agreed sites in proximity to the vegetation monitoring sites.	Section 9 Appendices C and F
MS871: 8-3(4) EPBC 2010/5706: 13e	Specifications for the monitoring program for vegetation health, species composition and habitat characteristics, including trigger levels for additional management actions to prevent further impacts and ensure compliance with condition 8-1.	Section 9
MS871: 8-3(5)	Specific management and contingency actions beyond reporting or initiating assessment.	Section 8 & 11
MS871: 8-4	The monitoring is to be carried out according to a method and schedule determined prior to the injection of surplus water to the satisfaction of the CEO OEPA, and is to be carried out until such a time as the CEO OEPA determines on advice from the DEC that monitoring may cease.	Sections 8 & 9
EPBC 2010/5706: 13f	Reporting on milestones and compliance with this plan	Section 12
EPBC 2010/5706: 13g	Results of the monitoring program and compliance with the plan must be published on the company's website.	Section 12
MS871: 5(1) MS871: 5(2) MS871: 5(3) MS871: 5(4)	In the event that monitoring required by condition 8-3 indicates an exceedance of trigger levels determined as a result of the implementation of the groundwater abstraction and disposal (dewatering and injection): 1. The proponent shall report such findings to the CEO of the OEPA within 7 days of the exceedance being identified; 2. The proponent shall provide evidence which allows determination of the cause of the exceedance within 21 days of the exceedance being identified; 3. If determined by the CEO of the OEPA to be a result of activities undertaken implementing the proposal, the proponent shall submit actions to be taken to address the exceedance within 21 days of the determination being made to the CEO of the OEPA; and	Sections 8 and 11

Ministerial Statement and Condition	Requirement or Issue	Location in this Plan
	4. The proponent shall implement actions to address the exceedance upon approval of the CEO of the OEPA and shall continue until such a time the CEO of the OEPA determines the remedial actions may cease.	
EPBC 2010/5706: 13h EPBC 2010/5706: 13i EPBC 2010/5706: 13j	In the event that the monitoring indicates that the triggers defined as part of condition 13b have been exceeded, the person taking the action shall: • Report such findings to the department within 7 days of the exceedance being identified; • Provide written advice to the department, within 21 days of the exceedance being identified, stating: - The direct cause of the exceedance. - Actions and associated timelines proposed to remediate the groundwater levels. • If actions cannot be undertaken to address the exceedance or there is a loss of EPBC Act listed threatened species habitat, then an offset, for approval by the Minister, must be provided within 3-months of the identification of the exceedance.	Sections 8 & 11

Appendix B.

Existing Environment

This page has been left blank intentionally

1. EXISTING ENVIRONMENT

1.1 Climate

The climate of the Pilbara region of Western Australia is classified as arid tropical with two distinct seasons: a hot wet summer (October – April) and a mild dry winter (May – September). The region is characterised by highly variable, but generally low rainfall, and high year-round temperatures.

The passage of high pressure systems to the south during winter, produce easterly winds and some precipitation over the inland Pilbara (Van Vreeswyk *et al*. 2004). During the summer, heat-generated low pressure systems dominate the inland Pilbara region generating intermittent thunder storms. Tropical cyclones develop over warm tropical waters between December and March. These often track south west along the Pilbara coast, or turn inland across the Pilbara bringing destructive winds, widespread rain and flooding (Payne and Tille 1992).

Bureau of Meteorology (BOM) weather stations with long term rainfall records in the vicinity of the Project area include Marillana (Station No. 5009) and Roy Hill (Station No. 5023). Long term median and mean annual rainfall at Marillana is 258 mm and 315 mm respectively, and at Roy Hill, 242 mm and 260 mm respectively. Most of the rain falls in January to March (BOM 2010). Annual pan evaporation is approximately 3700 mm; peaking at 1100 mm over the summer months and 550 mm over the winter months.

The mean maximum temperatures are above 30˚C for much of the year and exceed 40˚C during the months of December and January. Mean maximum temperatures can fall below 30˚C during the months of June, July and August.

1.2 Geology

The main continental blocks that make up the Australian continent are the Yilgarn Craton, the Pilbara Craton, the Gawler Craton and Wilyama Block (Lane 2004). The Christmas Creek mine is in the Hamersley Basin of the Pilbara Craton, which formed more than 3000 million years ago.

The Christmas Creek deposit lies within the Hamersley Basin, where granatoid rocks of the Archaean Pilbara Craton are overlain by sedimentary groups (Fortescue 2011b). Granatoid rocks of the Pilbara Craton are overlain by the Archaean-Proterozoic Hamersley Group. The Jeerinah formation is the youngest formation within the Fortescue Group, and marks the base of the main ore body. The Jeerinah is sub-divided into a number of members, with Roy Hill Shale the uppermost. Mineralisation at Christmas Creek is confined to the Nammuldi member of the Mara Mamba Formation (MMF), the lowest formation of the Hamersley Group (Fortescue 2011b). The MMF outcrops in areas towards the Chichester Ranges, but is generally overlain by tertiary detritals and alluvium in current and proposed mining areas, which deepen closer to the Fortescue Marsh.

The tertiary alluvium and detritals are derived from weathering products of the Chichester ranges, include multiple facies (proximal and distal), and display varying degrees of cementation. These show significant lateral variability, with not all sub-stratigraphies present at different locations.

1.3 Landforms

The Pilbara region has been surveyed by the Western Australian Department of Agriculture and Food (DAFWA), for the purposes of land classification, mapping and resource evaluation. The region consists of 102 land systems; distinguished on the basis of topography, geology, soils and vegetation (Van Vreeswyk *et al.* 2004). The Project area coincides with the Jamindie, Turee, Cowra and Marsh land systems (see Table 1).

Table 1: Land systems in the Project area

Land system name	Location in Project area	Description	Geomorphology
Jamindie	Extensive (north and central)	Stony hardpan plains and rises supporting groved Mulga shrublands, occasionally with Spinifex understorey.	Depositional surfaces, characterised by stony surfaced soils with abundant shallow hardpans. Low relief is associated with Mulga grove formations.
Turee	Central	Stony alluvial plains with gilgaied and non-gilgaied surfaces supporting tussock grasslands and grassy shrublands.	Depositional surfaces characterised by loam and clay soil types, often with stony surface mantles. Generally level relief with Mulga grove formations on the non-gilgaied surfaces.
Cowra	South	Plains fringing the Marsh land system and supporting snakewood and Mulga shrublands with some halophytic undershrubs.	Depositional surfaces, characterised by almost level and level alluvial plains with gravelly soils. Shallow hardpans are likely to be common.
Marsh	South	Lake beds and flood plains subject to regular inundation supporting Samphire shrublands, salt water couch grasslands and halophytic shrublands.	Depositional surfaces, typified by level floodplains subject to periodic inundation and saline floodplains subject to regular inundation. Clay soils with frequent hardpans.

1.4 Surface Water

The Project area is located within the Upper Fortescue River catchment, which drains from the Chichester Ranges in a southerly direction towards the Fortescue Marsh (Fortescue 2011b). Rainfall runoff from the Chichester Ranges flows south, through the Project area in defined water courses and drains into the Fortescue Marsh. Surface water flows in the vicinity of the Project take the following main forms:

- Hillslope runoff – Located in the portion of the local catchment where the majority of the runoff is contained within small creeks and gullies;
- Channel flow – Large creek channels and adjacent floodplains that drain steeper areas rather than those that are closer to the Fortescue Marsh;
- Diverging flow – Located where channel flow disperses and channel form is lost; and
- Sheet flow – Forms in areas where overland flow moves downslope while maintaining a broad shallow front (Fortescue 2011b).

1.5 Vegetation and Flora

Regional Biogeography

The Interim Biogeographic Regionalisation for Australia (IBRA) divides Australia into 85 bioregions based on major biological, geological and geographical attributes (Thackway and Cresswell 1995). These bioregions are subdivided into 44 sub-regions.

The Project area spans the Chichester and Fortescue sub-regions of the Pilbara bioregion. The Chichester sub-region is characterised by plains with a shrub steppe of *Acacia inaequilatera* over *Triodia wiseana* hummock grasslands and *Eucalyptus leucophloia* tree steppes on rangelands (Kendrick and McKenzie 2001). The Fortescue sub-region is characterised by alluvial plains with *Acacia aneura* (Mulga) over grass communities and *E. camaldulensis* woodlands fringing drainage lines (Kendrick 2001).

Beard (1975) mapped vegetation across the Pilbara region at a scale of 1:1,000,000. The Project area is located in the Fortescue Valley & Chichester Plateau in the Eremaean Botanical Province of Western Australia as per Beard (1975). The vegetation in the Project area was mapped by Beard (1975) as:

- Sparse Low Mulga Woodland, discontinuous in scattered groups;
- Hummock grasslands, shrubb steppe; *Acacia inaequilatera* over soft spinifex over *Triodia wiseana* on basalt;
- Mosaic of Mulga woodlands in valleys, and low open *Eucalyptus leucophloia* tree steppe and *Triodia wiseana* hummock grasslands ; and
- Succulent steppe, Samphire (*Tecticornia* species).

The Fortescue Marsh is a dominant feature south of the Project area, and is recognised as a unique and extensive inland floodplain system within the Pilbara region (McKenzie *et al.* 2009).The marsh is listed on the Australian Heritage Commission Register of the National Estate as an “indicative place” and on the Directory of Important Wetlands in Australia (Environment Australia 2001).

Vegetation and Flora

A total of 17 vegetation types have been described and mapped in the Christmas Creek mine area (ENV Australia 2010). Thirteen of these occur within the dewatering and mounding impact areas subject to this VHMMP. None of the vegetation communities resembled any of the known Threatened Ecological Communities (TECs) or Priority Ecological Communities (PECs) classified by the DEC. However the Project area is located on the northern edge of the Fortescue Marsh, which contains the Fortescue Marsh Priority 1 PEC.

Three vegetation types in the Project area are associated with locally significant Mulga communities (*Acacia aneura* and close relatives). One vegetation type is associated with the presumed groundwater dependent species River Red Gum (*Eucalyptus camaldulensis*), and potentially groundwater dependent Coolibah (*Eucalyptus victrix)*.

Mulga vegetation communities occur on the foot slopes of the Chichester Ranges and to the northern and southern flanks of the Fortescue Marsh. The Chichester Ranges define the northern limit of Mulga vegetation in Western Australia. Mulga is highly morphologically variable and appears to play an important role in water and nutrient capture, and is thus important to ecosystem function (ENV Australia 2010). Mulga displays xeromorphic adaptations and typically has a relatively shallow root system, with maximum root depths in the order of 2 to 5 m. Water sources important for Mulga include incipient rainfall, streamflow and in some instances sheet flow.

River Red Gums are commonly associated with shallow watertables in the Pilbara region, and are considered to be groundwater dependent in most situations. Coolibahs are considered to be facultative phreatophytes, which are species that can utilize groundwater opportunistically at times when water availability is limited. In the Christmas Creek locality both species are restricted to drainage lines entering the Fortescue Marsh from the Chichester Range (ENV Australia 2010).

The samphire vegetation communities associated with the Fortescue Marsh are unique in the Pilbara region. Multiple community types have been identified in vegetation surveys of the northern fringes of the marsh and surrounds (ENV Australia 2010). Species assemblages are putatively correlated with factors such as elevation, evaporation, rainfall, surface run-off, groundwater levels, soil types, and surrounding land use. Generally *Tecticornia* species are dominant in these communities; however other low shrubs such as *Muehlenbeckia florulenta* and *Muellerolimon salicorniaceum* are prominent or sometimes dominant components.

The samphire vegetation communities fringing and within the Fortescue Marsh could potentially have varying degrees of reliance on groundwater as a source of moisture. Very little is understood of samphire root systems and water uptake physiology in the marsh vegetation communities (or elsewhere). Research undertaken by the University of Western Australia (UWA) has shown that samphire water use is maintained throughout the year, and is strongly correlated with evaporative demand (D Huxtable, pers. comm.). This suggests that samphire is always able to access sufficient moisture reserves from the soil. Potential water sources include storage in the surface profile derived from rainfall and run-on, and groundwater accessed directly or via capillary rise.

The findings to date suggest that groundwater dependence may vary between samphire species based on changes in elevation (and therefore depth to groundwater) and the presence of shallow hardpan layers in the unsaturated soil profile. Groundwater salinity may also be a significant factor. The hardpan is likely to impeded root penetration and has been found to be extensive at depths of 50 to 100 cm below the surface in areas south and west of the Fortescue Cloudbreak mine (Kew 2011). Species in areas of relatively low elevation (towards the center of the Marsh) are considered likely to be groundwater dependent. Towards the centre of the Marsh it is considered that groundwater is closer to the surface. Species in areas of relatively high elevation (near the fringe of the marsh) are considered to be possibly dependent on groundwater (ENV Australia 2010).

Fortescue has developed a conceptual model of the eco-hydrology of the marsh vegetation communities dominated by *Tecticornia*, based on current knowledge (Figure 1). This provides a guiding framework for future research, monitoring and management activities. The key components of the conceptual model include:

- The marsh fringe is predominantly a surface driven system, with plant available water supplied from episodic recharge, soil water storage and slow discharge (via evapo-transpiration and impeded deep drainage). The unsaturated profile includes a shallow hardpan, the topography and thickness of which varies spatially. This creates a disconnection between the surface and the underlying groundwater (at about 3 m depth). The surficial soils above the hardpan have high water storage capacity, and surface crusting contributes to impeded soil evaporation rates. As soil water is depleted, salinity increases and transpiration rates decline. Samphire vegetation in the fringe zone (e.g. *Tecticornia indica* and *T. auriculata*) uses physiological adaptations to conserve moisture and protect against salinity until the next rainfall/flood event.

- The watertable becomes progressively shallower towards the interior of the marsh, where it is maintained at a shallow extinction depth by evaporation. Samphire vegetation in the interior of the marsh (e.g. *T. medusa*) is likely to interface with the shallow, hypersaline groundwater and have some level of groundwater dependence.
- Samphire species zonation reflects the variable edaphic conditions and tolerance to the stressors of drought, salinity and waterlogging.

Fortescue is progressing additional research activities in 2011/12, to further validate the conceptual model and better elucidate water sources used by marsh samphire communities in collaboration with UWA and the CSIRO. Future work is anticipated to include other dominant marsh species (e.g. *Muellerolimon salicorniaceum*).

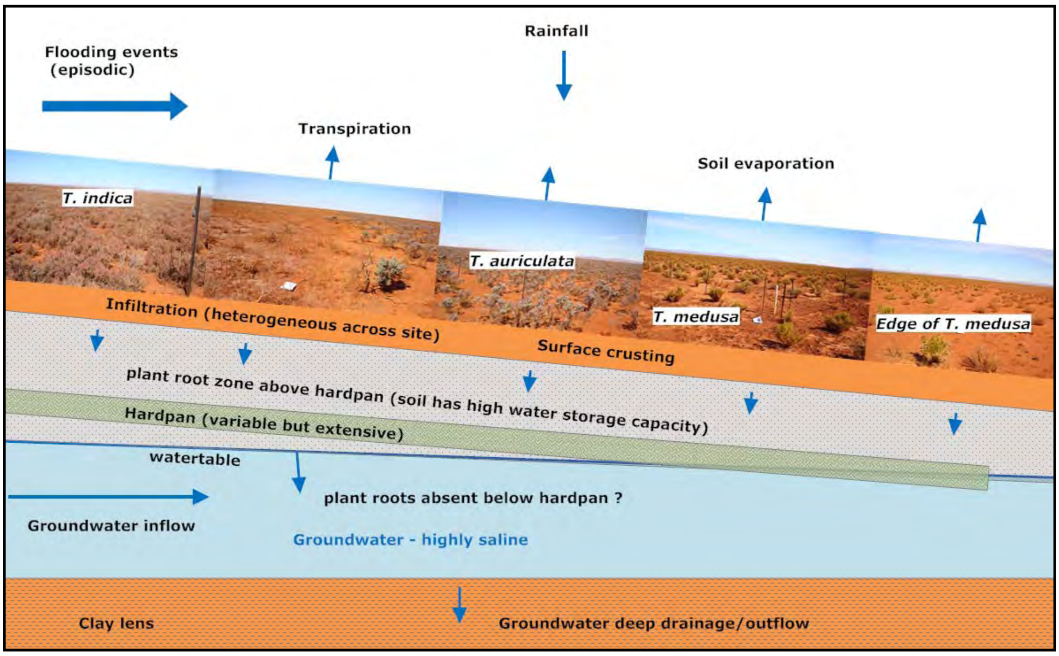


Figure 1: The Fortescue Marsh ecohydrology conceptual model (not to scale)

The key vegetation types that are locally distributed but outside the dewatering and mounding impact areas include:

- *E. camaldulensis* and 'yintas' that typically occur within a few kilometers of the marsh shoreline
- *Melaleuca* woodlands that are often associated with creekline outwash areas
- low shrublands dominated by *Muehlenbeckia florulenta* that often occur in a mosaic with Samphire communities, and
- chenopod and *Acacia* communities, which occur in upslope locations.

Due to their absence from predicted impact areas, it is not appropriate to locate reference sites in these vegetation types for the purposes of this VHMMP.

2. CURRENT STATE OF VEGETATION, AND THREATS TO VEGETATION WITHIN THE PROJECT AREA

2.1 Overview

The condition of the vegetation within the survey area ranges from 'Excellent' to 'Good'. The majority of vegetation in the fringe of Samphire Flats, Creek and Drainage Line and Ranges, Hills and Hill slope vegetation types was categorised as 'Excellent', whilst the majority of vegetation on Broad Flats and Plains was categorised as 'Good' due to grazing pressures (ENV Australia 2010). Specific vegetation communities within the drawdown and mounding impact areas of the Project are discussed below.

2.2 Vegetation within Groundwater Dewatering and Mounding Areas

Seven vegetation types occur within the drawdown impact area. Ten vegetation types occur within mounding impact area 1, and 11 vegetation types occur in mounding impact area 2. Mulga community types (mapping codes 2, 3 and 4) are the most prevalent within each of the impact areas. There is considerable overlap of common vegetation communities between all three zones and in the surrounding vegetation. The current state of these vegetation types (vegetation communities) and their area extent within each management area are summarised in Table 2.

Table 2: Vegetation communities occurring within the dewatering and mounding areas (ENV Australia 2010)

Vegetation mapping code	Vegetation community description	Landscape position	Area (hectares)*		
			Drawdown impact area	Mounding impact area 1	Mounding impact area 2
1	Open woodland of *Eucalyptus victrix*, *E. camaldulensis* with pockets of *Acacia coriacea* subsp. *pendens* over *Grevillea wickhamii*, *Petalostylis labicheoides*, *Acacia tumida* over *Triodia longiceps*, *Chrysopogon fallax*, *Themeda triandra* and *Aristida* species	Drainage lines	193	325	242
2	Low woodland to low open forest of *Acacia aneura* var. *aneura*, *A. citrinoviridis*. *A. pruinocarpa* over *A. tetragonophylla* and *Psydrax latifolia* over *Chrysopogon fallax*, *Stemodia viscosa*, *Blumea tenella*, *Themeda triandra* and species of *Triodia* and *Aristida*	Drainage lines	1941	1003	1948
3	Low woodland to low open forest of *Acacia aneura* var. *aneura*, *A. pruinocarpa*, *A. tetragonophylla*, *A. tenuissima*, *Grevillea wickhamii* subsp. *aprica*, *Psydrax latifolia* over *Dodonaea petiolaris* and species of *Triodia* and *Aristida*	Broad to flat drainage	3305	4726	4102
4	Low woodland to low open forest of *Acacia aneura* var. *aneura*, *A. pruinocarpa*, *A. xiphophylla*, *A, victoriae*, *A. tetragonophylla*, *Psydrax latifolia* and *Psydrax suaveolens*, over *Ptilotus obovatus*, and mixed species of *Maireana* and *Sclerolaena*	Broad flats	3702	2264	1409
8	Closed scrub to tall shrubland of *Acacia pruinocarpa*, *A. tumida*, *A. maitlandii*, *A. kempeana*, *A. tetragonophylla* with occasional *Eucalyptus gamophylla* and *Corymbia deserticola* over *Triodia epactia*, *Themeda triandra* and species of *Aristida*	Drainage lines	145	282	204

Vegetation	Vegetation community description	Landscape	Area (hectares)*		
10	Low woodland of *Acacia xiphophylla*, *A, victoriae*, *A. aneura* var. *aneura* over *A. tetragonophylla*, *Ptilotus obovatus*, *Senna* species and mixed species of *Maireana* and *Sclerolaena*	Upslope or saddle between broad drainage	17	4	27
13	Low Halophytic shrubland of *Tecticornia auriculata*, *T. indica* subsp. *leiostachya*, *T. halocnemoides* subsp. *tenuis* with patches of *Frankenia* species	Fringing outer marsh	0	470	942
16	Hummock Grassland of *Triodia basedowii* with pockets of *Triodia epactia* and *Triodia lanigera* with emergent patches of *Eucalyptus leucophloia*, *Corymbia deserticola* over *Acacia ancistrocarpa*, *Acacia hilliana*, *Acacia acradenia*, *Acacia pyrifolia*, *Hakea lorea*	Upslope from broad flats or sheetwash areas	0	364	0
17	Hummock grassland of *Triodia basedowii* with pockets of *T. epactia*, *T. lanigera* with emergent patches of *Eucalyptus leucophloia*, *Corymbia deserticola* over *Acacia ancistrocarpa*, *A. pyrifolia*, *Hakea lorea*, subsp. *lorea* over *Goodenia stobbsiana* and mixed *Senna* and *Ptilotus* species	Very broad flats	1634	0	374
22	Low shrubland of *Tecticornia indica* subsp. *bidens* and *Nicotiana occidentalis* over grasses with the occasional stands of *Sesbania cannabina* and *Cullen cinereum*	Outer marsh	0	45	4
26	Low Shrubland of *Muellerolimon salicorniaceum* and *Tecticornia indica* subsp. *bidens*.	Fringing marsh	0	144	0
30	High open Shrubland of *Acacia synchronicia* with *Senna glaucifolia* over *Aristida* sp.	Upslope from broad drainage	0	0	2493
33	Low shrubland of *Tecticornia indica* subsp. *bidens* and *Scaevola spinescens* with *Acacia synchronicia*	Outer marsh	0	0	8
222	BURNT		0	0	209

* Vegetation communities occupying greater than 5% of the impact areas respectively are shaded.

2.3 Keystone Species and Habitat Characteristics within Vegetation Communities of the Project Area

Condition 8-3 of MS 871 requires the identification of 'keystone plant species' in the Project area. A review of the flora and vegetation survey information, coupled with the assessment by the OEPA, has informed the identification of the following keystone plant species that have been identified within the Project area. This assessment is made with respect to species roles in ecosystem function and knowledge of sensitivity of some species within the Project area to alterations in groundwater regime.

Mulga Vegetation Communities

The Mulga communities in the Project area range from low woodland, low open forests to mixed *Acacia* scrub. These are generally dominated by members of the Mulga species complex, however other prominent species include *Acacia xiphophylla, A. pruinocarpa* and *A. tetragonophylla* (Table 2). Groundwater monitoring associated with the Fortescue bore network indicates that the baseline depth to watertable ranges from about 3 to >15 m where these communities occur (Fortescue 2011b).

Habitat and plant / community health characteristics targeted for vegetation monitoring include:

- Density (cover) of dominant *Acacia* species;

- Life histories of dominant *Acacia* species (fruiting, seed-set and recruitment);
- Cover of species in the perennial understorey measured between sites; and
- Indicative health of dominant *Acacia* species measured by water status and soil moisture measurements between sites.

The potential for incorporating additional parameters into the monitoring program, such as ant community structure, is being further investigated by Fortescue.

Facultative (Partially) Phreatophytic Vegetation

Within the Project area, River Red Gums (*Eucalyptus camaldulensis*) and Coolibahs (*E. victrix*) are restricted to major drainage lines, where they grow in open woodland formations (Table 2). Groundwater monitoring associated with the Fortescue bore network indicates that the baseline depth to watertable ranges from about 3 to >15 m where these species occur (Fortescue 2011b).

The major riparian species in the Christmas Creek locality is *E. victrix*, with some patchy occurrences of *E. camaldulensis*. A brief outline of the characteristics these two species is presented below.

- *E. camaldulensis* – tree height of approximately 20 m that is found along watercourses throughout much of Australia. In the Pilbara region it is generally considered to be an obligate phreatophyte. It has a biomorphic root system of numerous surface lateral roots and a major tap root. In a Department of Water study spanning multiple sites on the Robe, Yule and De Grey Rivers and the Fortescue River at Millstream, the 5-year absolute water level range tolerated by *E. camaldulensis* was between 1.6 m (inundation) and -9.2 m (depth to groundwater) (Loomes 2010), although length of time experienced at these levels was not discussed.
- *E. victrix* – spreading tree to 12 m and is also considered a facultative phreatophyte as it occurs low in the landscape, most commonly on the floodplains along watercourses. It has a spreading, heavily lateralised root system with major laterals appearing to act as tap roots in some cases, with small secondary laterals and secondary sinker roots also common (Grigg et al. 2008). In a Department of Water study spanning two sites on the De Grey Rivers and Fortescue River at Millstream respectively, the 5-year absolute water level range tolerated by *E. victrix* was between 1.6 m (inundation) and -7.5 m (depth to groundwater) (Loomes 2010), although length of time experienced at these levels was not discussed.

The vegetation habitat characteristics for (potentially) phreatophytic communities that are targeted for vegetation monitoring and management are riparian systems that maintain the density of trees, canopy health (in comparison to controls) and recruitment (in comparison to controls) for *E camaldulensis* and *E. victrix* riparian woodlands.

Samphire Vegetation Communities

The Samphire communities in the project area are largely comprised of Low Halophytic shrubland of *Tecticornia auriculata*, *T. indica* subsp. *leiostachya*, *T. halocnemoides* subsp. *tenuis* with patches of *Frankenia* species (Vegetation Type 17). Areas of *Muellerolimon salicorniaceum* and *T. indica* subsp. *bidens*. shrubland (Vegetation Type 26) also occur in Mounding impact area 1 to a lesser extent.

Typically the watertable is several (2 to 5) meters deep near the marsh fringe and shallower towards the centre of the marsh. Samphire species zonation in the project area is considered to reflect the variable edaphic and water quality conditions; and varying tolerance to the stressors of drought, salinity and waterlogging between the dominant species. These communities may have varying levels of groundwater dependence.

The habitat characteristics that are targeted for vegetation monitoring and management are the distribution of species and plant health, comparable to control or reference transects. The taxonomic identification of Samphire species is problematic. Therefore, plants surveyed in the VHMMP will be assigned reference labels in the interim to taxonomic identification becoming possible.

Keystone Plant Species and Habitat Characteristics – Summary

Keystone plant species identified in this VHMMP are those species occurring in vegetation communities that provide high ecosystem service value to the community, or are species within communities of high conservation value of which little precise knowledge regarding ecosystem function is known. For this VHMMP, the following keystone plant species are identified:

- Mulga (*Acacia aneura*) – Low open forest to woodland;
- River Red-gum (*Eucalyptus camaldulensis*) – Riparian woodland to open woodland;
- Coolibah (*Eucalyptus victrix*) – Riparian woodland to open woodland; and
- Samphire communities (*Tecticornia* species and other major shrubs such as *Muellerolimon salicorniaceum)*.

Other vegetation communities considered regionally important, e.g. low woodland dominated by Snakewood (*Acacia xiphophylla*), are not significantly represented within the Project area. Hummock grassland dominated by *Triodia basedowii* is extensive in the northern portions of the drawdown impact area (Table 2), but is considered unlikely to be susceptible to drawdown impacts. The baseline depth to watertable where this vegetation type occurs is >20 m (see Fortescue 2011a).

2.4 Primary and Secondary Threats (Pressures) to Vegetation (Keystone species) within Dewatering and Injection zones

Primary and secondary threats (referred to as 'Pressures' within the Pressure-State-Response framework) must be considered within the Project area to allow appropriate replication of impact monitoring sites and reference (control) monitoring sites.

Primary pressure – Altered Groundwater Regime

The Project will result in altered groundwater regimes due to:

- lowering of the water table in the groundwater dewatering area; and
- rises in the water table in areas where brackish water is injected (EPA 2011).

The EPA notes that the predicted changes to groundwater levels are unlikely to have a significant impact on vegetation in the Project area (EPA 2011). The changes in groundwater level due to mining activities in areas of the Fortescue Marsh or Samphire vegetation is predicted to be 1 to 1.5 m (mounding and dewatering), which is within the natural variation of groundwater levels (Fortescue 2011b). Approximately 173 ha of Mulga vegetation may be affected by groundwater rise to within 2 m of the surface. A drawdown of 5 m in dewatering zones may see an impact in 82 ha of vegetation communities dominated by Coolibah and River Red Gum. However, potential losses are unlikely to be significant (EPA 2011), consistent with experience from mining projects elsewhere in the Pilbara region.

The Project is not expected to impact the surface water regime or groundwater quality in the Project area (EPA 2011).

Secondary pressures

A number of secondary pressures that could affect vegetation at a regional scale may be occurring within the Project area. These include:

- Inappropriate fire regimes;
- Grazing by introduced species;
- Weed infestation; and
- Climatic variability and regional climate change effects.

These secondary pressures have been accounted for in this VHMMP when selecting monitoring sites, assessing replication between altered groundwater impact sites (groundwater drawdown and mounding) and reference sites, and in the proposed analyses of repeated-measures (time series) data. Measurements or assessments of secondary pressures related to this VHMMP are:

- Weed pressure measurements – each sampling location was assessed for the occurrence of weed species using a weed record point assessment. This uses an assessment of the abundance and cover of weed species within repeated 5 m quadrats measured across each sampling site. Data are input to a Geographical Information System (GIS) to provide a spatial distribution of weed species richness and density across the sampling site.
- Gazing pressure index – At each weed record point the occurrence grazing cattle is assessed by counts of hoof prints and droppings.
- Fire regimes – in the event of fire, impacts to vegetation in affected sampling sites will be assessed as a component of on-ground monitoring activities. The extent of fire impacts will also be evaluated annually through interpretation of *Landsat* (Thematic Mapper or similar) remote sensed imagery. This technique is commonly applied to fire impact assessments in Western Australia.
- Climatic variability – significant shifts in the perennial plant community matched between reference and impact sites, coupled with an assessment of climatic information, will be used to indicate if seasonal factors are affecting vegetation response.

The potential for incorporating additional parameters into the monitoring program to detect secondary pressures, such as ant community structure, is also being investigated by Fortescue.

Appendix C.

Baseline Hydrological Data Report

This page has been left blank intentionally

Christmas Creek

Groundwater Monitoring Review

1 August 2010 – 31 July 2011

29 September 2011

CC-RP-HY-0018

Document title	**Christmas Creek Groundwater Monitoring Review 1 August 2010 – 31 July 2011**
Document no.	**CC-RP-HY-0018**
Document type	**Report**
First issue date	**30 September 2011**

Rev	**Issue date**	**Description of revisions made**	**Signatures**		
			Originator	**Checked**	**Approved**
0	**30 September 2011**		**Neil Buchanan/ Timothy Wilkinson**	**Timothy Wilkinson**	**Ian Brandes de Roos**
			T.Wilk	T.Wilk	Ian Brandes

[This page has been left blank intentionally]

Table of contents

List of tables

1. Introduction

This review outlines groundwater data recorded across the Christmas Creek mine site (Christmas Creek) for the period defined in Table 1 and includes an analysis of the data to assess the impact of groundwater abstraction from the local aquifers. It has been written in accordance with *Operating Policy no. 5.12 - Hydrogeological reporting associated with a groundwater well licence* (Department of Water, 2009).

The review period comprises four quarters as defined in Table 1. Groundwater monitoring summaries were submitted to the Department of Water (DoW) for the first, second and third quarters. This review serves as both the annual groundwater monitoring review and the quarterly groundwater monitoring summary for the fourth quarter.

Table 1 – Definitions of the four quarters and the review period

	From	To
First quarter	1 August 2010	31 October 2010
Second quarter	1 November 2010	31 January 2011
Third quarter	1 February 2011	30 April 2011
Fourth quarter	1 May 2011	31 July 2011
Review period	1 August 2010	31 July 2011

Christmas Creek is an iron ore mine site operated by Fortescue Metals Group and productive since April 2009. It is located in The Pilbara region of Western Australia, approximately 270 km south-east of Port Hedland and approximately 30 km east of Cloudbreak mine site (Cloudbreak), another iron ore mine site operated by Fortescue and productive since May 2008. The location of Christmas Creek is presented in Figure 1.

Groundwater abstracted from Christmas Creek is used for dust suppression, construction, camp supply and ore processing. Christmas Creek water demand is supplemented with groundwater abstracted and conveyed from Cloudbreak. It is expected that from September 2011 this demand will be met solely by groundwater abstracted from Christmas Creek.

Groundwater is abstracted in accordance with the 5C licence issued by the DoW. A copy of the licence is in Appendix A. The licence has an expiry date of 31 July 2011, although groundwater abstraction has continued beyond this date while an application for renewal of the licence (submitted on 21 July 2010) is pending. This is in accordance with the *Rights in water and irrigation act 1914* (Government of Western Australia, 2010). A copy of the application for renewal is also in Appendix A. Details of the 5C licence are presented in Table 2.

Table 2 – Details of the 5C licence

Description of water resource	Pilbara, Hamersley – fractured rock
Annual water entitlement	1150000 kL
Duration of licence	1 August 2010 – 31 July 2011

2. Climate

The climate of the Pilbara can be separated into two distinct seasons: a hot summer from November to March and a warm, dry winter from April to October. The summer season is influenced by cyclonic events that can bring heavy, spatially variable rainfall. Christmas Creek does not have its own temperature gauge and does not have a rain gauge with sufficient historical data. The nearest temperature gauge is at Newman, approximately 100 km to the south and operated by the Bureau of Meteorology, and the nearest rain gauge with sufficient historical data is at Cloudbreak. The records for these gauges from January 2010 to July 2011 are presented in Figure 2. There was a total of 153.5 mm rainfall in the calendar year January to December 2010, with a peak of 41 mm in January 2010. There was a total of 432.2 mm rainfall in the review period, with a peak of 178 mm in February 2011, and a total of 11.0 mm in the fourth quarter, with the only rainfall being in May 2011.

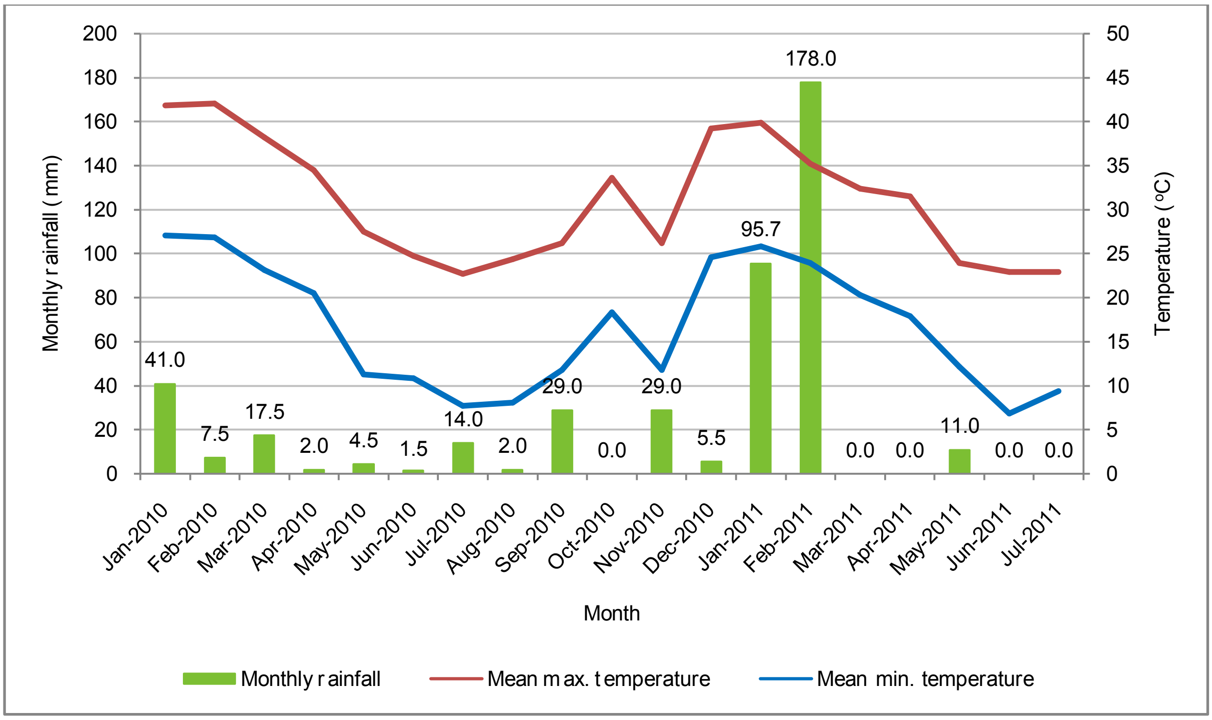


Figure 2 – Temperature records of Newman and rainfall records of Cloudbreak

3. Hydrogeology

Christmas Creek is located on the mid to lower slopes of the Chichester Range, along the northern edge of the Fortescue Marsh.

The stratigraphy of Christmas Creek is presented in Figure 3. There are four regionally grouped aquifers: Gravel Aquifer; Calcrete Aquifer; Dolomite Aquifer; and Banded Iron Formation (BIF) Aquifer (Johnson & Wright, 2001). These aquifers can be grouped into three types: unconsolidated sedimentary; chemically deposited; and fractured-rock (Johnson & Wright, 2001).

The local aquifers are recharged via rainfall throughflow in outcrop regions of the Marra Mamba Iron Formation, with lesser recharge from the Tertiary Detritals, and via throughflow from the Roy Hill Shale Formation. Direct rainfall recharge to the Tertiary Detritals and Marra Mamba Iron Formation is low in Christmas Creek, reflecting the generally low rainfall of the region.

Groundwater throughflow and storage are enhanced in mineralised zones of the Marra Mamba Iron Formation units and the Oakover Formation. The permeability of lower unmineralised (chert and BIF) zones is enhanced along faults, while areas of lower permeability are associated with increasing proportions of shale units. Marra Mamba Iron Formation aquifers are partially confined to unconfined towards the Chichester Range and are confined towards the south where they are overlain by clayey Tertiary deposits. The Tertiary Detritals have variable hydraulic characteristics and Channel Iron Deposits form laterally-constrained but linear areas of moderate to high permeability and storage.

Groundwater discharge from topographically-driven flow (in both the Tertiary and Marra Mamba Iron Formation systems) is low due to the poor hydraulic connection between topographic discharge areas (the surface of the Fortescue Marsh) and underlying aquifers. The presence of hypersaline water in the discharge zone, beneath the Fortescue Valley, also impedes groundwater discharge, as the saline groundwater creates an opposing density-driven flow potential. Topographic-driven groundwater flow in the shallow Tertiary aquifer system is likely to discharge towards the Fortescue valley floor via generally low-permeability sediments and be removed from the system by evaporation and evapotranspiration processes. The body of saline water that occupies the down-dip extension of the aquifer and the Fortescue valley inhibits discharge.

Formation						Aquifer			
Age	**Supergroup**	**Group**	**Name**	**Thickness**	**Lithology**	**Name**	**Type**	**Groundwater quality**	**Bore yield**
Cenozoic	n/a	Tertiary Detritals	Alluvium	10-40 m	Poorly-sorted, angular to subangular, polymictic gravel of chert, goethite and hematite in a silt or clay matrix; predominantly brown.	Gravel	Unconsolidated sedimentary	Fresh[1] to brackish[2] (although saline[3] to hypersaline[4] near the Fortescue Marsh)	Up to 900 kL/day
			Detritals	Up to 15 m	Goethite and maghemite pisoids and ooids in a clay matrix; predominantly brown.				
			Clay	Up to 30 m	Clay stained brown, red, white or yellow.	n/a	n/a	n/a	n/a
			Oakover Formation	Up to 40 m	Calcrete; predominantly grey or white; characterised by secondary porosity developed through partial dissolution of calcrete via percolating surface water and moving groundwater.	Calcrete	Chemically deposited	Saline to hypersaline	Up to 5000 kL/day
UNCONFORMITY									
Early Proterozoic	Mount Bruce Supergroup	Hamersley Group	Wittenoom Formation	Up to 10 m has been observed but it may be thicker	Dolomite with goethite and hematite alteration and chert inclusions; predominantly grey.	Dolomite	Fractured-rock	Fresh to hypersaline (salinity increasing with proximity to Fortescue Marsh)	Up to 2500 kL/day
			Marra Mamba Iron Formation	Up to 50 m	Only the lowermost member (Nammuldi Member) has been observed. Interbedded goethite, hematite and chert with minor magnetite, maghemite and jaspilite; predominantly grey, mustard yellow, and dark purple.	Banded Iron Formation (BIF)	Fractured-rock*	Fresh to hypersaline (salinity increasing with proximity to Fortescue Marsh)	Up to 2500 kL/day
		Fortescue Group	Jeerinah Formation	Up to 40 m has been observed but it may be thicker	Only the uppermost member (Roy Hill Shale Member) has been observed. Soft, carbonaceous shale; dark grey to black.	n/a	Inferred to be fractured-rock	Fresh to hypersaline (salinity increasing with proximity to Fortescue Marsh)	n/a

[1]Fresh ≤ 800 µS/cm; [2]brackish = 800 – 50000 µS/cm; [3]saline = 50000 – 80000 µS/cm; [4]hypersaline ≥ 80000 µS/cm

*With further secondary porosity due to alteration processes

Figure 3 – Stratigraphy of Christmas Creek (based on Hickman, 1983, and Johnson & Wright, 2001)

4. Site Borefields

Site borefields consists of monitoring, production and injection bores. The numbers of each are presented in Table 3. Not all of the production and injection bores are in use. A summary of the details of all bores in Christmas Creek is presented in Appendix B. Full details including screened intervals are in bore completion reports submitted to the DoW (for 2010 these documents have the prefix CC-RP-HY; for 2011 these documents have the prefix CC-RP-UT).

A map of the locations of the monitoring bores is presented in Figure 4; a map of the locations of the production and injection bores is presented in Figure 5.

A series of five monitoring bores less than 1 km from the northern edge of the Fortescue Marsh is under construction; four were constructed in the review period (FMMB04, FMMB04, FMMB05 and FMMB05).

Table 3 – Numbers of each bore constructed

	Number of bores constructed		
	Monitoring	Production	Injection
Prior to first quarter	23	36	0
First quarter	0	0	0
Second quarter	0	12	0
Third quarter	9	9	0
Fourth quarter	17	8	4
Review period	26	29	4
Total	49	65	4

5. Abstraction

The volumes of groundwater abstracted from the producing bores are presented in Table 4.

Table 4 – Volumes of groundwater abstracted

		Abstraction for each bore (kL)											Abstraction total (kL)
		CCCP01	CCCP02	CCE19T	CCP22	CCE41T	CCE13	Charlton Bore	Francos Bore	WS20P1	WS21P1	WS21P3	
First quarter	Aug-2010	9849	0	12887	13411	11215	12	16337	17650	33011	10493	19696	144561
	Sep-2010	346	9018	13155	13171	12919	3641	17900	16950	22285	9242	28040	146667
	Oct-2010	3263	10172	15643	21669	17944	6560	24240	26249	4005	4184	28399	162328
	Total	**13458**	**19189**	**41685**	**48252**	**42078**	**10213**	**58477**	**60849**	**59301**	**23920**	**76136**	**453556**
Second quarter	Nov-2010	1512	13359	14772	18554	17920	2	0	19821	0	0	3694	89634
	Dec-2010	0	12633	10752	30498	16032	4	0	7967	0	0	0	77886
	Jan-2011	1004	12170	8551	13471	11638	1	0	0	0	0	0	46836
	Total	**2517**	**38162**	**34075**	**62523**	**45590**	**7**	**0**	**27788**	**0**	**0**	**3694**	**214355**
Third quarter	Feb-2011	2145	8593	1345	13799	8952	8	0	0	0	0	0	34842
	Mar-2011	3908	12322	182	20500	2100	7	0	0	0	0	0	39019
	Apr-2011	5660	12840	112	22421	11791	214	0	0	0	0	0	53037
	Total	**11713**	**33755**	**1639**	**56719**	**22843**	**229**	**0**	**0**	**0**	**0**	**0**	**126898**
Fourth quarter	May-2011	6654	12022	11	18604	13853	1	0	0	0	0	0	51145
	Jun-2011	5163	3600	1	14514	12385	4	0	0	0	0	0	35667
	Jul-2011	6515	8239	37	10780	17674	1	0	0	0	0	0	43247
	Total	**18332**	**23861**	**49**	**43898**	**43913**	**6**	**0**	**0**	**0**	**0**	**0**	**130058**
Review period		46019	114968	77448	211391	154423	10454	58477	88637	59301	23920	79830	**924868**

6. Monitoring

Monthly measurements of water levels and EC have been conducted in monitoring bores throughout the Christmas Creek mine site. The water levels do not change significantly in a majority of the monitoring bores due to only a small volume of groundwater being abstracted. Several monitoring bores have significant changes to either the water level or EC. Explanations are provided below.

CCE01
EC values in CCE01 decreased significantly in the quarter with values ranging from 113 143 µS/cm to 2,553 µS/cm. The reason for this is due to the sampling depth being changed from 75 mTOC to 54 mTOC. This demonstrates the vertical change in EC that is evident throughout the site and the need for consistency in measurement depths.

CCF01A_D
The monitoring bore was destroyed in March 2011. Upon inspection of the site the 50mm PVC was laying on the ground. It appeared to have been pulled out of the borehole. The cause of this is unknown.

CCF01B_S
The 5 m increase in water level from January to March is most likely a recharge response from large amounts of rainfall over the wet 2010-11 summer period.

CCF02T
The significant rise in EC values in January 2011 is most likely due to the incorrect monitoring equipment being used in the earlier monitoring period. The monitoring equipment that was being used was not suitable for the high EC concentrations typically present in monitoring bores to the south of the mine site. The error was picked up after reviewing the data in December 2010 and has since been monitored with suitable equipment.

Groundwater levels, abstraction and electrical conductivity for active production bores are presented in Appendix C. Groundwater levels and electrical conductivity for the monitored bores are presented in Appendix D. Contour plots of groundwater levels and electrical conductivity are presented in Figures 6 – 11 and commented upon in Table 5.

Table 5 – Contour plot figure listing and comments

Figure	Description	Comments
6	BIF Aquifer groundwater level at end of review period	The contour plot was created by averaging the groundwater levels for July 2011. Groundwater levels generally follow topography.
7	BIF Aquifer change in groundwater level over review period	The contour plot was created by calculating the difference between the average groundwater level in August 2010 and the average groundwater level in July 2011. The figure shows no significant changes to groundwater level. From September 2011, when groundwater demands are to be met solely through abstraction in Christmas Creek, greater drawdown is expected.
8	BIF Aquifer electrical conductivity at end of review period	The contour plot was created by averaging the electrical conductivity for July 2011. The figure shows electrical conductivity increases from north to south in line with the salinity gradient towards the Fortescue Marsh.
9	Gravel Aquifer groundwater level at end of review period	The contour plot was created by averaging the groundwater levels for July 2011. Groundwater levels generally follow topography.
10	Gravel Aquifer change in groundwater level over review period	The contour plot was created by calculating the difference between the average groundwater level in August 2010 and the average groundwater level in July 2011. There appear to have been no significant changes to groundwater level. From September 2011, when groundwater demands are to be met solely through abstraction in Christmas Creek, greater drawdown is expected.
11	Gravel Aquifer electrical conductivity at end of review period	The contour plot was created by averaging the electrical conductivity for July 2011. The figure shows electrical conductivity increases from north to south in line with the salinity gradient towards the Fortescue Marsh.

7. Compliance

Licence compliance is presented in Table 6; monitoring compliance is presented in Table 7; trigger level status is presented in Table 8. These tables are based on the *Christmas Creek groundwater operating strategy* (Fortescue Metals Group, 2011). Groundwater levels and electrical conductivity for bores associated with trigger level compliance are presented in Appendix E.

The electrical conductivity in CCF01B_S has been increasing steadily since April 2011. The electrical conductivity hasn't exceeded the level 1 trigger level of and will continue to be monitored closely.

Table 6 – Licence compliance

Licence type	Instrument number	Duration of licence		Entitlement (kL)	Cumulative abstraction as percentage of entitlement (%)				Compliance	Comments
		From	To		First quarter	Second quarter	Third quarter	Fourth quarter		
5C	GWL167593(1)	1 August 2010	31 July 2011	1150000	39.4	58.1	69.1	80.4	Compliant	None

Table 7 – Monitoring compliance

Item		Monitoring frequency	Compliance	Comments
Producing bores	Abstraction	Monthly	Compliant	None
	Field electrical conductivity	Monthly	Compliant	Electrical conductivity data are not available for all of the third quarter as high rainfall rates made some of the bores inaccessible.
	Biofouling	Six monthly	Compliant	None
Monitored bores	Groundwater level	Monthly	Compliant	None
	Field electrical conductivity	Monthly	Compliant	Electrical conductivity data are not available for all of the third quarter as high rainfall rates made some of the bores inaccessible.
	Hydrogeochemistry	Six monthly (February and August)	Compliant	None
Site use	Meter readings	Monthly	Compliant	None
	Comparison of meter readings with associated groundwater demands	Monthly	Compliant	None

Table 8 – Trigger level status

Aspect	Status	Comments
Groundwater level	No exceedances	None
Electrical conductivity	Previously-suspected Level 1 exceedance	A single, isolated trigger level exceedance was reported for CCF07B_S during the third quarter summary, with electrical conductivity recorded as being 8000 µS/cm compared to the trigger level of 7440 µS/cm. However, the reported exceedance does not fit with the longer-term EC trend, and hydrogeochemical analysis of a groundwater sample taken during the same week as the recording revealed the electrical conductivity to be 6000 µS/cm. It is therefore concluded that the recording was an error (likely to have been due to roots, which, after a visual inspection, appear to have penetrated the bore casing and created a blockage). The blockage appears to have stopped the monitoring equipment from reaching the designated depth in a bore that is known to have significant electrical conductivity variability over depth. It is recommended that the bore be airlifted to remove the roots.

8. Impact

An assessment of the impact of groundwater abstraction on the aquifers is presented in Table 9.

Table 9 – Assessment of the impact of groundwater abstraction on the aquifers

Aspect	Assessment
Capacity to sustain demands	The aquifers have the capacity to sustain the site water demand to date.
Past and likely future effects of groundwater abstraction on other users and the Fortescue Marsh	Past effects have been insignificant. The likely future effects are unknown, although when the construction of the series of five monitoring bores less than 1 km from the northern edge of the Fortescue Marsh is completed and there are more producing bores, an assessment should be possible.
Significant changes to groundwater quantity or quality	There have been no significant changes.

9. Recommendations

It is recommended that CCF07B_S be airlifted to remove roots that appear to have penetrated the bore casing and created a blockage.

10. References

- Department of Water, 2009, *Operational policy no. 5.12 – Hydrogeological reporting associated with a groundwater well licence*, Department of water, Perth, Western Australia. Series no. DWPF 5.12.

- Fortescue Metals Group, 2011, *Christmas Creek groundwater operating strategy*, document CC-PH-HY-0002, Fortescue Metals Group, Perth, Western Australia.

- Government of Western Australia, December 2010, *Rights in water and irrigation act 1914* (*Schedule 1*, *Division 5*, *Clause 22*, *Subclause 5*), Version 08-g0-00, State Law Publisher, Perth, Western Australia.

- Hickman, A. H., 1983, *Geology of the Pilbara Block and its environs*, Bulletin 127, Geological Survey of Western Australia.

- Johnson, S. L. & Wright, A. H., 2001, *Central Pilbara groundwater study*, Water and Rivers Commission, Hydrogeological Record Series, Report HG 8, 102 pages.

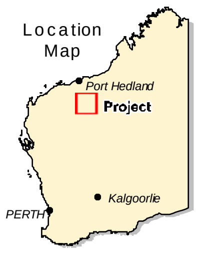
Figures

[This page has been left blank intentionally]

Figure 1

Location map

[This page has been left blank intentionally]



Doc No: Y:\GIS Plans\05 Water Resources \01 02 Cloudbreak Area \Stage4 rev4 operating strategy \Figure 1 - Chichester Operations Area

N

0 10 20 40
kilometres

Fortescue Metals Group Ltd

FIGURE 1

Location map

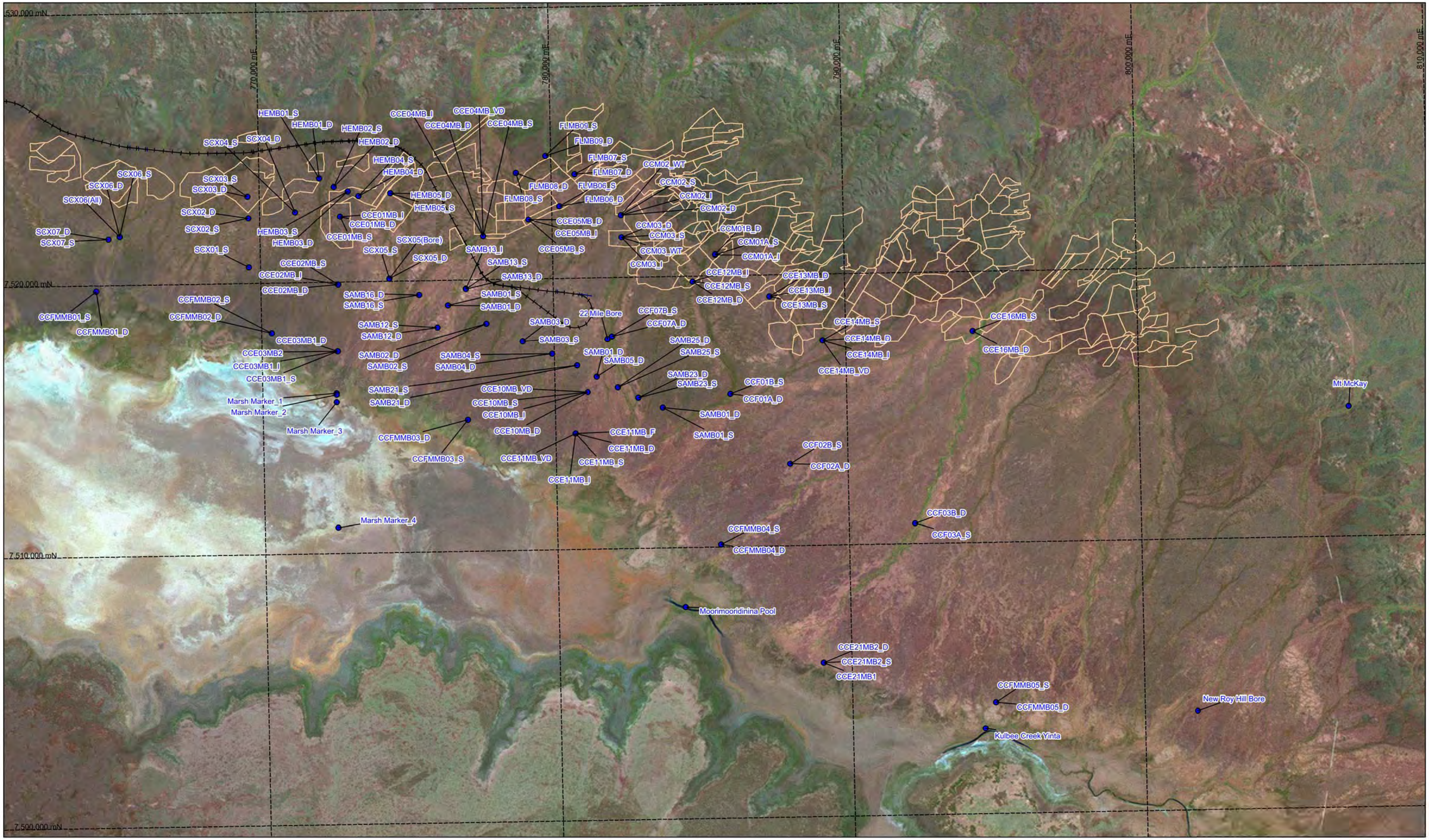
Author: BWJ	Date: 11/05/2009
Drawn By: UB	Revision: 1
Doc No. Figure 1	Confidentiality: 1
Projection: MGA GDA 94	Scale: 1:1000000

[This page has been left blank intentionally]

Figure 4

Locations of the monitoring bores

[This page has been left blank intentionally]



Location Map

Port Hedland
Project
Kalgoorlie
PERTH

Monitoring Bore

Future Mine Pit

Kennedy Railway

N

0 1 2 3

Kilometres

Fortescue Metals Group Ltd

Christmas Creek
Monitor Bores

Author: C. Byrne	Date: 23/09/2011
Drawn By: DN	Revision: 0
Dwg No: CC-MP-HY-0056	Report No: 1
Proj: MGA Zone 50 (GDA 94)	Scale: 1:120000

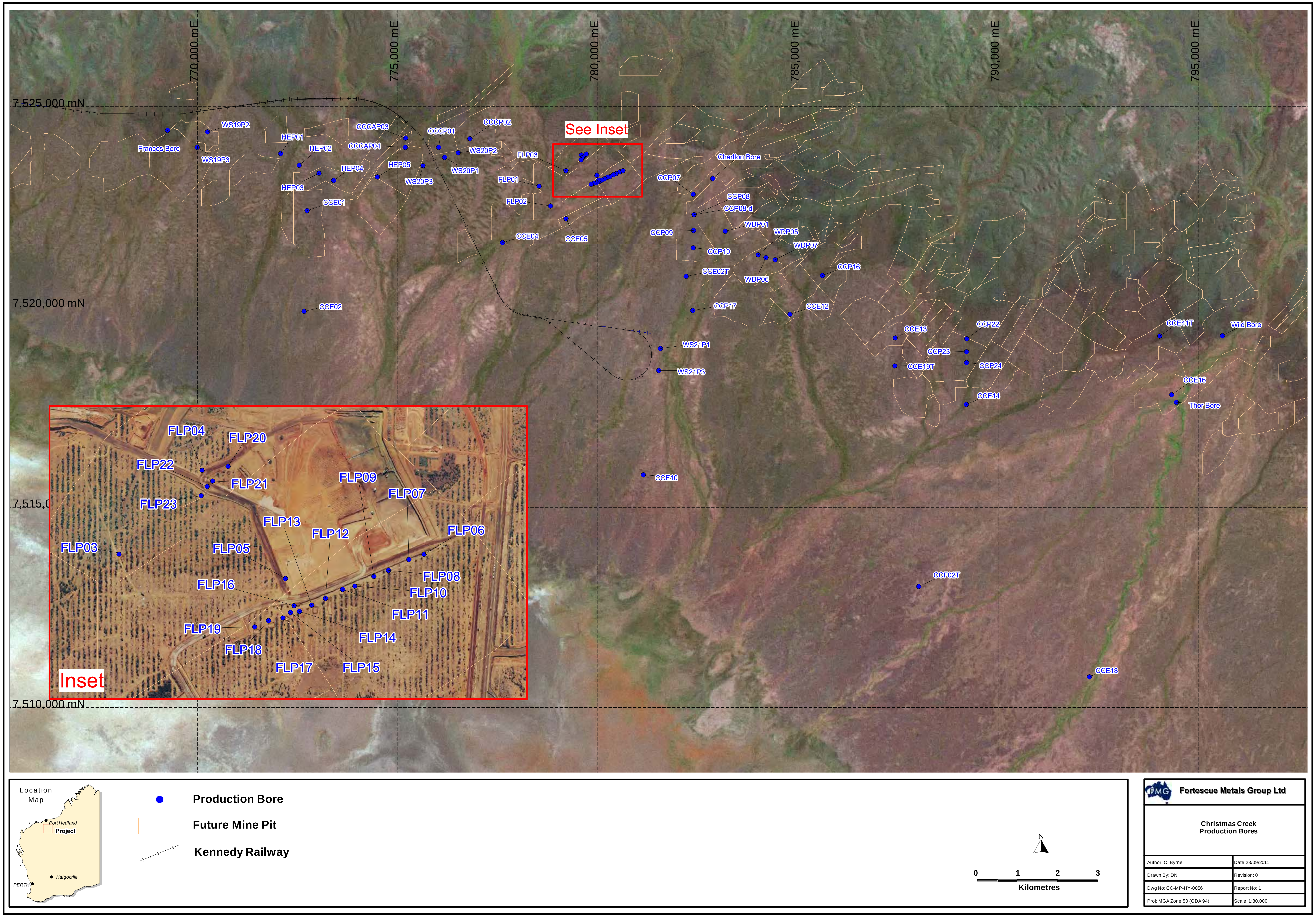
Y:\GIS Plans\01 GIS Dept\2011 Plans\CC_MP_HY_0056 Aquifer Review\September 2011 Bore Maps PDFs and Workspace\CC_MP_HY_0056_September_2011_BoreMaps.wor

This page has been left blank intentionally

Figure 5

Locations of the production and injection bores

[This page has been left blank intentionally]



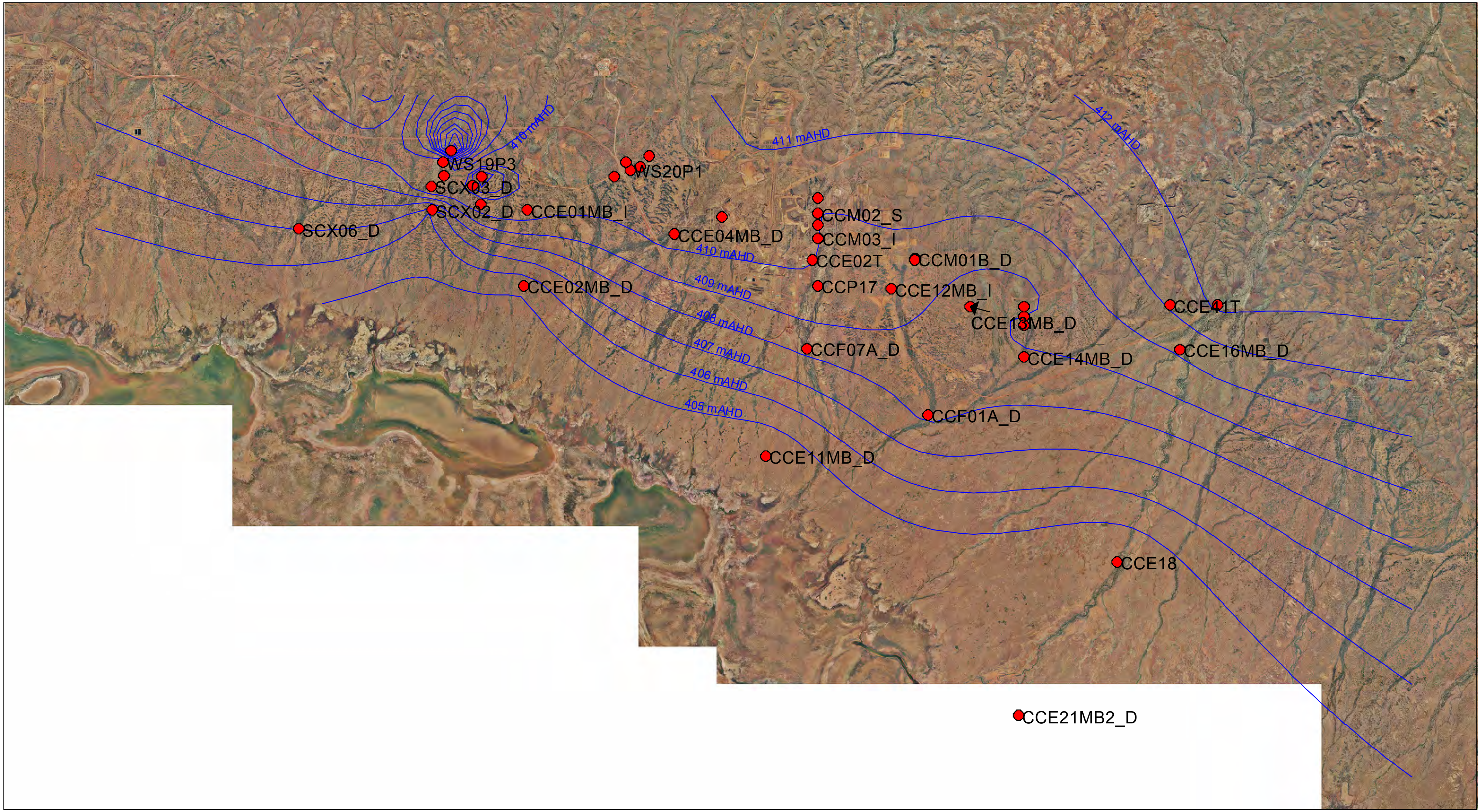
Y:\GIS Plans\01 GIS Dept\2011 Plans\CC_MP_HY_0056 Aquifer Review\September 2011 Bore Maps PDFs and Workspace\CC_MP_HY_0056_September_2011_BoreMaps.wor

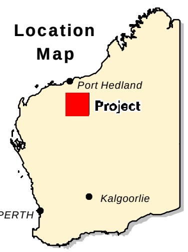
This page has been left blank intentionally

Figure 6

BIF Aquifer groundwater level at end of review period

[This page has been left blank intentionally]





N

Fortescue Metals Group

Date:28/9/2011

Author: TW

Office: CC

Drawing: 1

Scale: 1:60000

Figure 6:
Christmas Creek Banded
Iron Formation Aquifer
groundw ater level contours
July 2011

Projection: GDA94 (Zone 50)

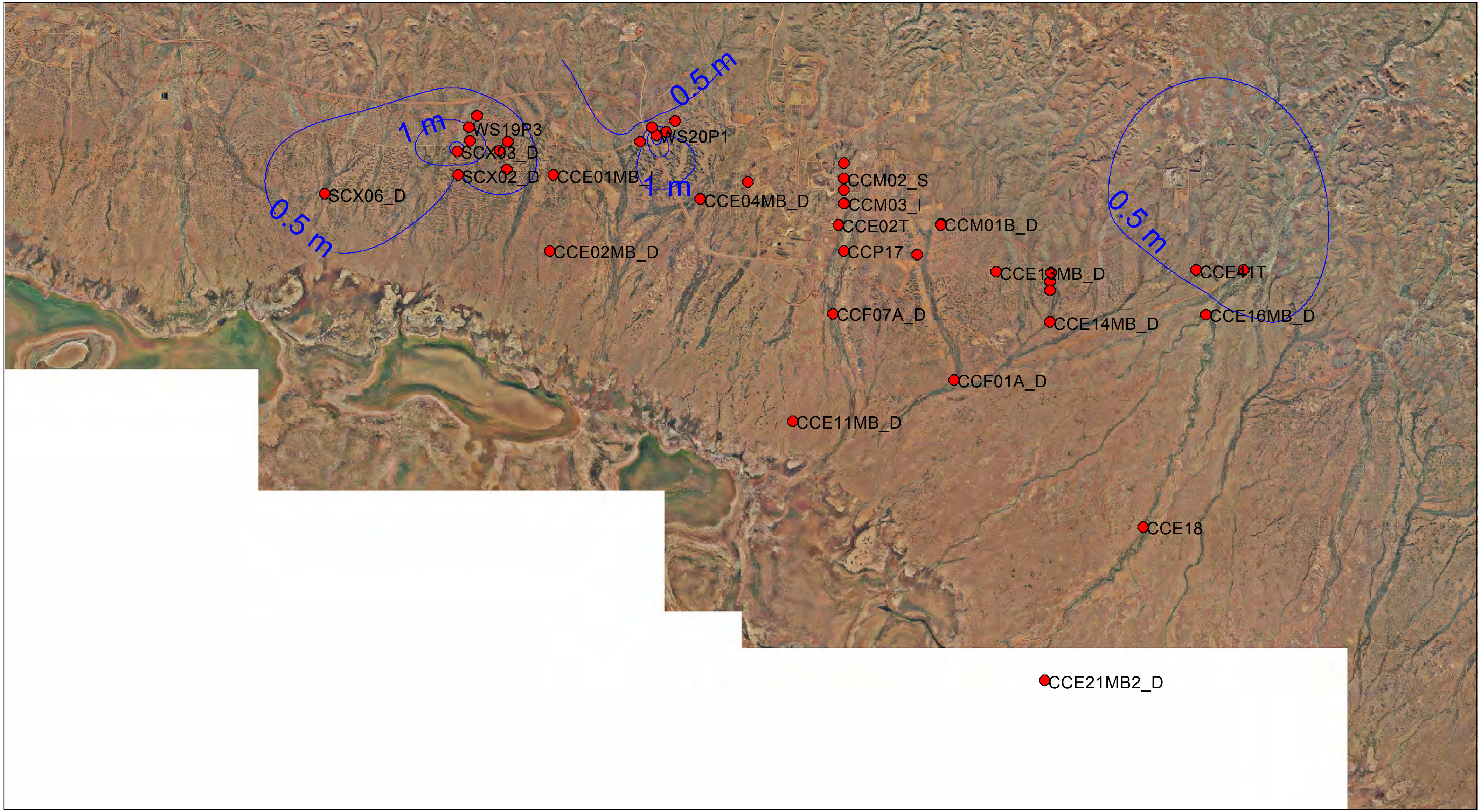
0 0.5 1 2

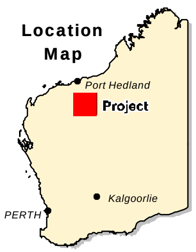
kilometres

Figure 7

BIF Aquifer change in groundwater level over review period

[This page has been left blank intentionally]





Note:

- Positive conotour values represent an increase in water level
- Negative contour values represent a decline in the water level.

N

Fortescue Metals Group

Date:28/9/2011
Author: TW
Office: CC
Drawing: 1
Scale: 1:60000

Figure 7:
Christmas Creek Banded Iron Formation Aquifer change in groundwater level for review period August 2010 - July 2011

Projection: GDA94 (Zone 50)

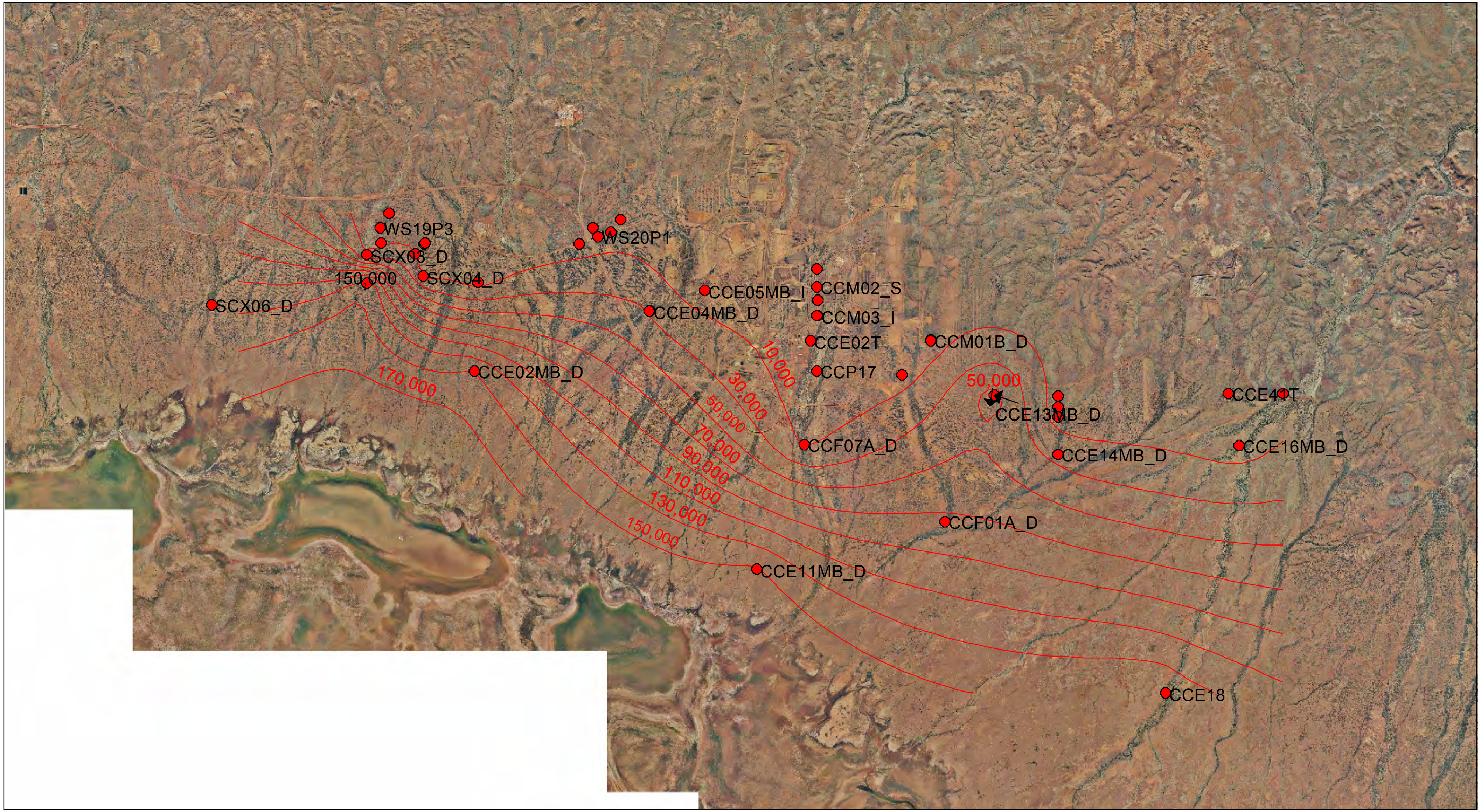
0 0.5 1 2
kilometres

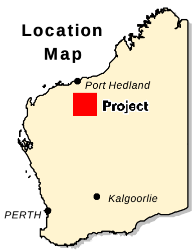
This page has been left blank intentionally

Figure 8

BIF Aquifer electrical conductivity at end of review period

[This page has been left blank intentionally]





N

Fortescue Metals Group

Date:28/9/2011	Figure 8: Christmas Creek Banded Iron Formation Aquifer electrical conductivity (µS/cm) contours July 2011
Author: TW	
Office: CC	
Drawing: 1	
Scale: 1:60000	Projection: GDA94 (Zone 50)

0 0.5 1 2

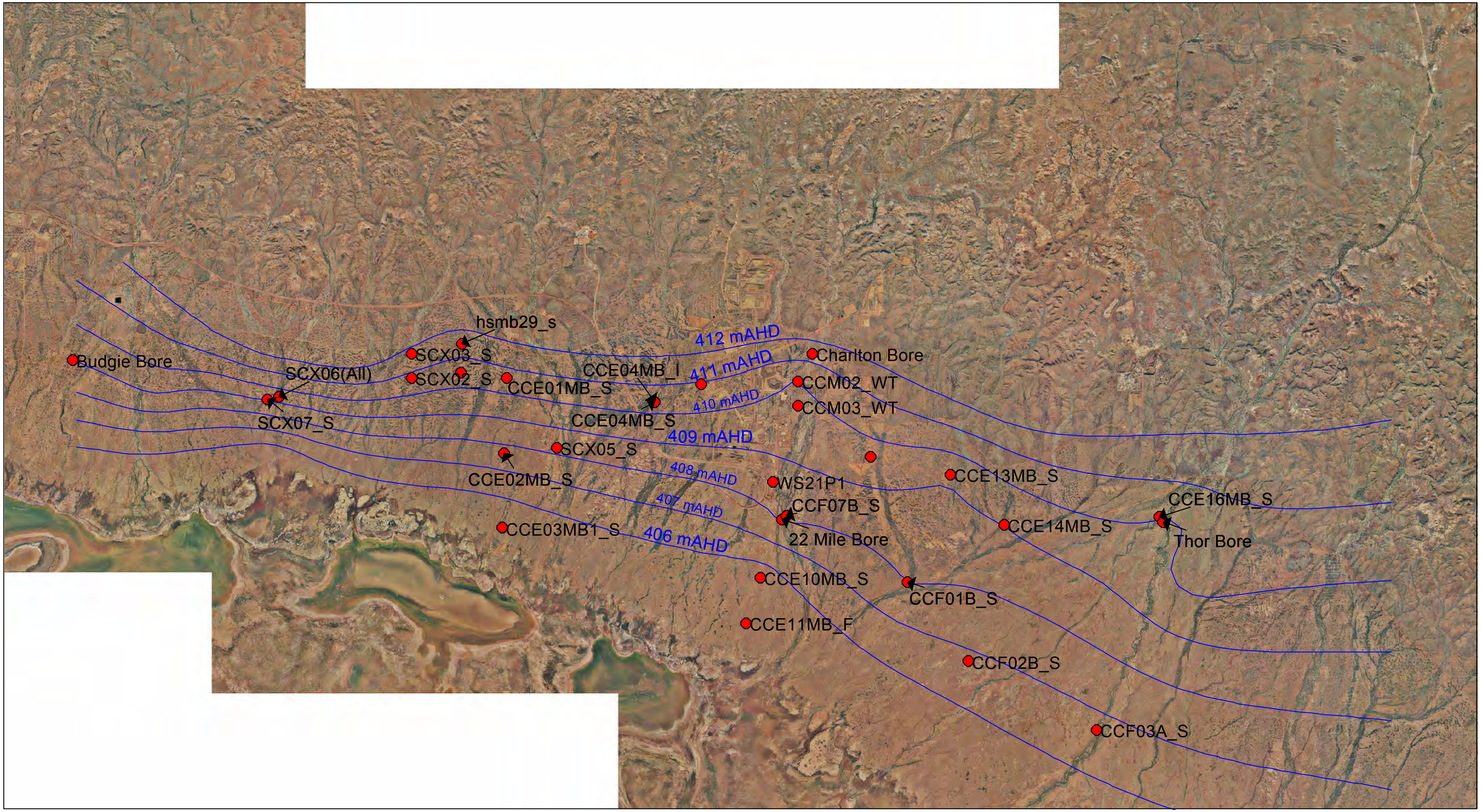
kilometres

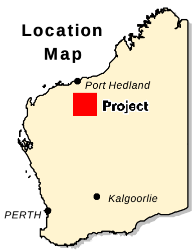
This page has been left blank intentionally

Figure 9

Gravel Aquifer groundwater level at end of review period

[This page has been left blank intentionally]





N

Fortescue Metals Group

Date:28/9/2011
Author: TW
Office: CC
Drawing: 1
Scale: 1:60000

Figure 9:
Christmas Creek Gravel
Aquifer groundwater level
contours July 2011

Projection: GDA94 (Zone 50)

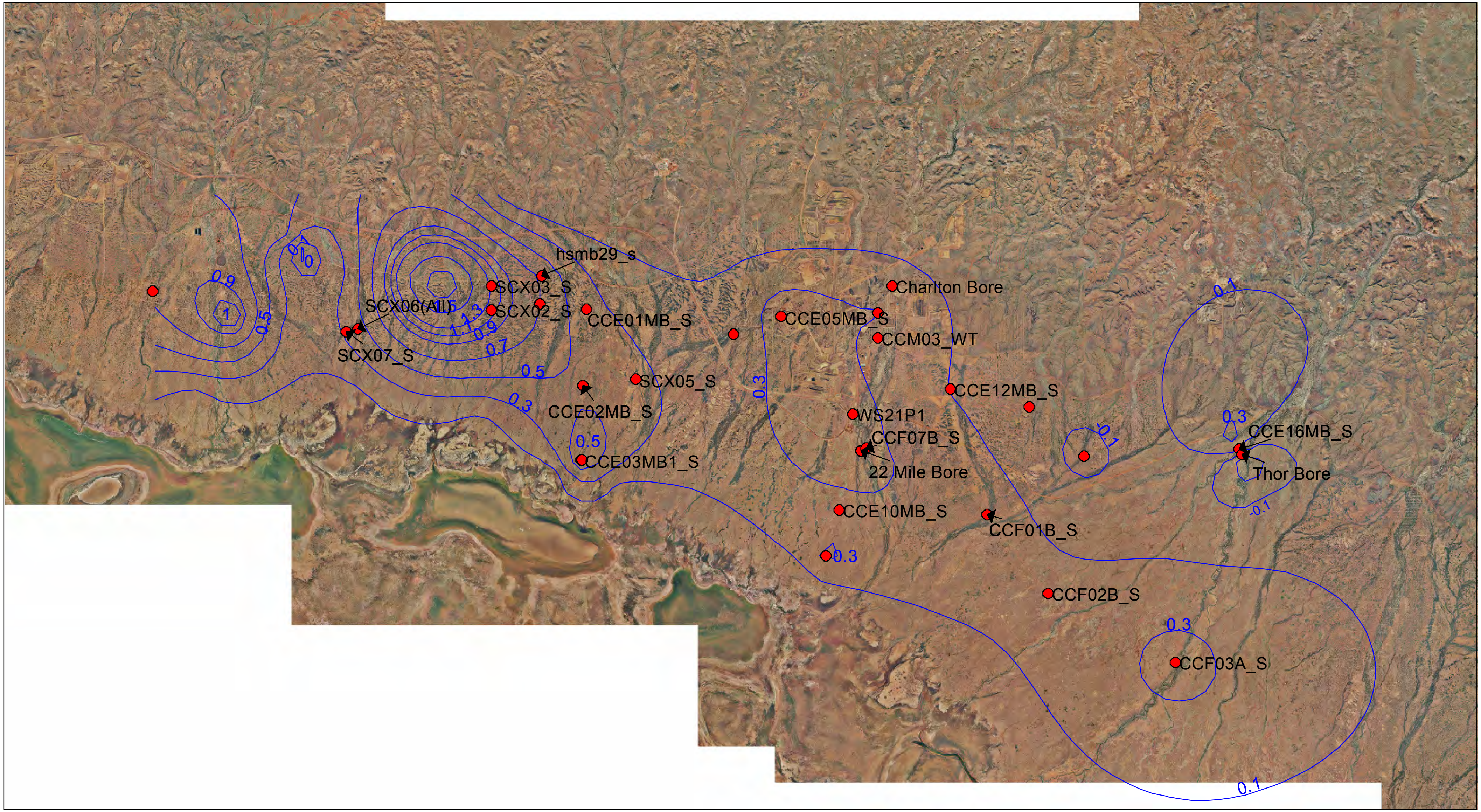
0 0.5 1 2
kilometres

This page has been left blank intentionally

Figure 10

Gravel Aquifer change in groundwater level over review period

[This page has been left blank intentionally]



Location Map

Port Hedland

Project

Kalgoorlie

PERTH

Note:

- **Positive conotour values represent an increase in water level**
- **Negative contour values represent a decline in the water level.**

N

Fortescue Metals Group

Date:28/9/2011

Author: TW

Office: CC

Drawing: 1

Figure 10:
Christmas Creek Gravel
Aquifer change in
groundw ater level
for review period
August 2010 - July 2011

Scale: 1:60000 Projection: GDA94 (Zone 50)

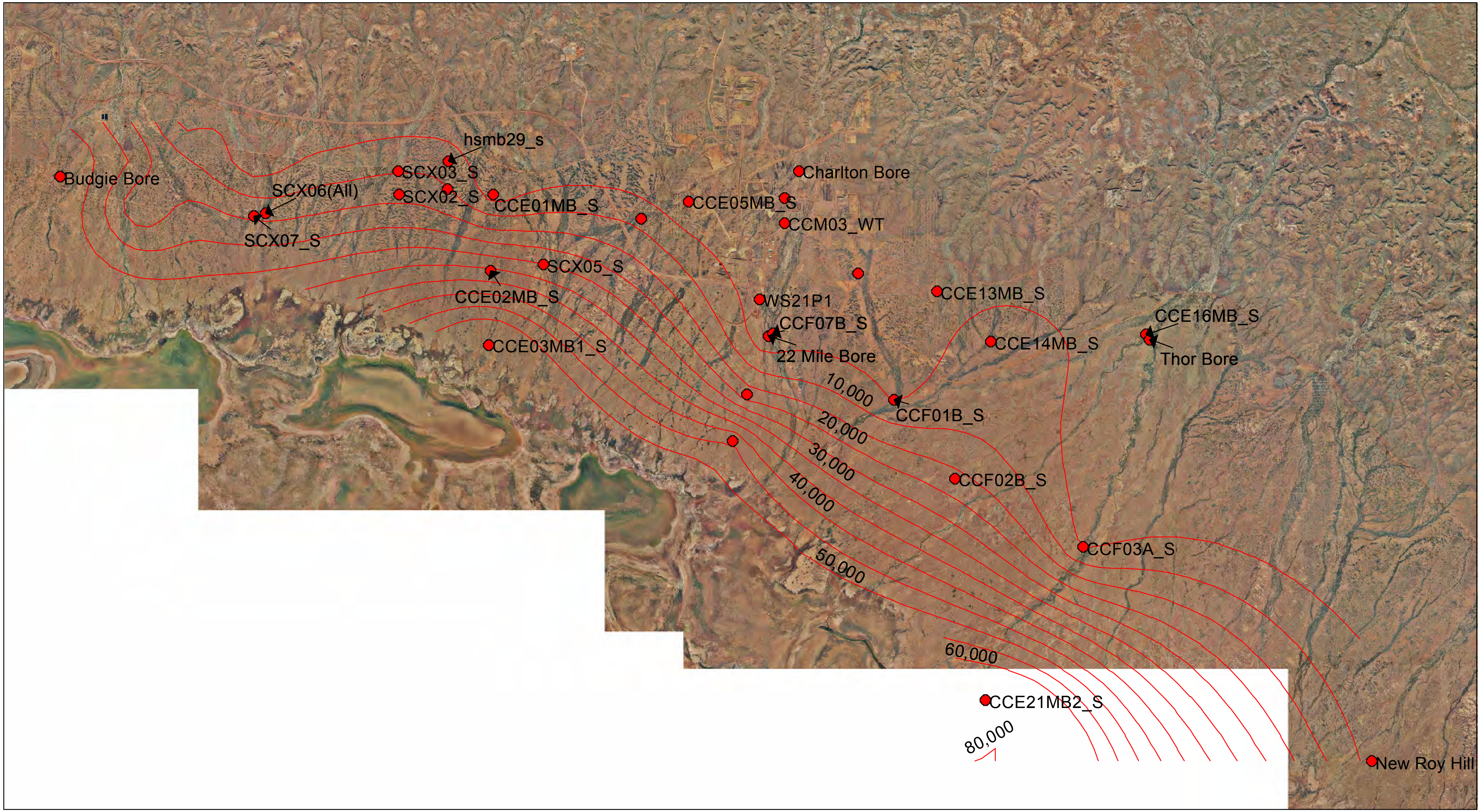
0 0.5 1 2
kilometres

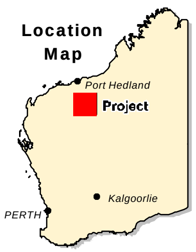
This page has been left blank intentionally

Figure 11

Gravel Aquifer electrical conductivity at end of review period

[This page has been left blank intentionally]





Fortescue Metals Group

Figure 11:
Christmas Creek Gravel
Aquifer electrical conductivity
(μS/cm) contours July 2011

Date:28/9/2011
Author: TW
Office: CC
Drawing: 1
Scale: 1:60000
Projection: GDA94 (Zone 50)

N

0 0.5 1 2
kilometres

This page has been left blank intentionally

Appendices

[This page has been left blank intentionally]

Appendix A

Groundwater abstraction licence

[This page has been left blank intentionally]

Fortescue
The New Force in Iron Ore

Your Ref:
Our Ref: LS-100-E-1087

21 July 2010

Kevin Hopkinson
Senior Natural Resource Management Officer
Department of Water
PO Box 836
KARRATHA WA 6714

Dear Kevin

RE: REQUEST FOR THE RENEWAL OF SECTION 5C LICENCE GWL167593(1)

Fortescue Metals Group Limited (Fortescue) requests the renewal of Section 5C licence GWL167593(1). This licence approves an annual water entitlement of 1,150,000 kilolitres at Fortescue's Christmas Creek mine site and is due to expire on 31 July 2010.

The annual water entitlement approved under this licence is used to support mining operations and construction activities at the Christmas Creek mine site. To allow these activities at the Christmas Creek mine site to continue, Fortescue requests a licence renewal for GWL167593(1). A completed Form 3G: *Application for a 5C Licence to Take Groundwater* requesting the renewal of this licence has been attached to this application (Appendix A). Fortescue will be shortly submitting an Operating Strategy to the Department of Water outlining the management and mitigation measures which will be applied to groundwater abstraction activities at the Christmas Creek mine site.

Should you require further information, please contact Amy Barker on 6218 8748 or at abarker@fmgl.com.au.

Yours sincerely
FORTESCUE METALS GROUP LIMITED

SEAN MCGUNNIGLE
Manager, Environmental Approvals

Enc.

Appendix A: A completed Form 3G: *Application for a 5C Licence to Take Groundwater* requesting the renewal of section 5C licence GWL167593(1).

Government of **Western Australia**
Department of **Water**

OFFICE USE ONLY

Form 3G

Application for a 5C licence to take groundwater

Application for a licence under Section 5C of the *Rights in Water and Irrigation Act 1914*

- All fields applicable to your application type must be completed and are to be written clearly in block letters.
- If there is insufficient room please use a separate piece of paper.
- Submission of this form is an **application only** and is subject to assessment by a licensing officer.
- Incomplete applications will be returned.
- Refer to the checklist located at the rear of the form when completing the application.

Part 1: Application

Renewals
A renewal of an existing licence is where there are no changes to allocation, usage, properties or conditions.

Amendment
If changes are required to the existing usage, allocation, properties or conditions select the amend an existing licence option.

Application to take groundwater under Section 5C

- ☐ **New licence to take groundwater**
- ☐ **Amend an existing licence to take groundwater**
- ☑ **Renew an existing licence to take groundwater**

Existing licence number: GWL 167593(1)

Part 2: Applicant(s) details

The applicant's full name is the name that will appear on the licence. Do not use initials unless they form part of the legal entity's name.

Applicant(s) full name: Fortescue Metals Group Ltd

Contact name (if different from above): Mr Sean McGunnigle

ABN / ACN (if applicable): 5 7 0 0 2 5 9 4 8 7 2

Are you a water service provider: ☒ No ☐ Yes

If yes, provide the licence number:

Provide the legal name registered under the ABN or ACN.

Water service provider name:

Postal address (PO Box if applicable): Level 2, 87 Adelaide Terrace, East Perth WA 6004.

Property address (if different from above):

Provide at a minimum your primary contact number.

Telephone: 6218 8415 **Facsimile:** 6218 8999

Mobile:

Email: smcgunnigle@fmgl.com.au

Part 3: Application details

Which of the following categories match your application:

Draw water from a: ☑ Well ☐ Soak ☐ Excavation

☐ Other (please specify)..

For new applications only fill out details below:

Is the well, soak, excavation or other: ☐ Existing (please attach bore log) ☐ New (Form 1 is required)

If new, please provide Form 1 or 26D licence number (if known): CAW

If new, has a form 2 bore log been submitted? ☐ Yes ☐ No

Part 4: Property from which water is to be taken

Applicants amending an existing Section 5C licence are required to complete this section only if the property details have changed.

Legal land description(s) for properties should be provided as they appear on the Certificate of Title (e.g. Lot 75 on plan 14797).

Legal land descriptions for mining tenements should be provided as they appear on TENGRAPH.

Property description (lot number, street and suburb/locality) ______

Total area of property (if known) ______ **ha**

GPS Coordinates Easting ______ **Northing** ______ **Zone** ______

OR

Mine name ______

Mining tenement number(s) ______

Mining field ______

If the property where the water is to be used is different from above please provide detail below;

Property description (lot number, street and suburb/locality) ______

Total area of property (if known) ______ **ha**

GPS Coordinates Easting ______ **Northing** ______ **Zone** ______

OR

Mine name ______

Mining tenement number(s) ______

Mining field ______

Part 5: Legal access

Applications to amend an existing Section 5C licence are only required to complete this section if the property details have changed.

What is the nature of your access to the land on which the water is located?

☐ Own the land ☐ Mining tenement ☐ Lease the land from the Crown

☐ Approval of landholder to use land (attach copy landholder's written approval and the term of lease)

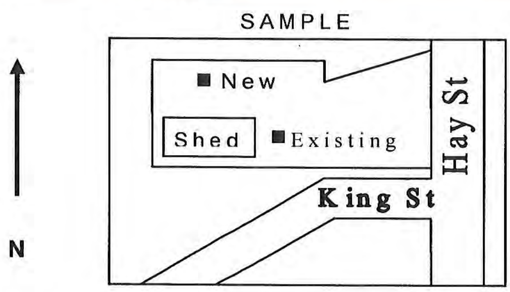
OR

☐ Negotiating to purchase or lease the land (provide copy of contract of sale / lease or owner's name and anticipated date of completion of sale / lease)

Name ______ **Date** ______

☐ Other (please specify)

Part 6: Location plan



In the box to the right, please sketch a plan showing:
- location of all wetlands / watercourses / wells / soaks (existing and proposed)
- major improvements (house, large sheds etc.)
- shaded sections to indicate areas under development

For mining leases attach a tenement map showing the location within Western Australia and the MGA coordinates

Part 7: Details of water use

Please note: Complete only those sections relevant to your application. Applications for a 5C renewal are not required to complete this section. Applicants applying to amend a Section 5C licence are only required to complete this section where the usage details on the existing licence have changed.

Where is the water to be used?
(tick all that apply)

☐ House ☐ Garden / lawn ☐ Fire fighting
☐ Industrial ☐ Horticultural ☐ Stock watering
☐ Mining ☐ Aquaculture
☐ Other……………………………………………………………

1 acre is equal to 0.4 ha

1 kL = 1000 litres

Area (for garden / lawn or other use) ______ ha

Irrigation use:
Planting density (number of plants per hectare e.g. for orchards, tree farms etc.)

Irrigation method (e.g. sprinkler, trickle, butterfly sprinkler).

Irrigation use – specify each crop type (i.e. carrots, apples)	Planting density (per ha) if applicable	Irrigation method	Usage area (ha)	Estimated annual quantity (kL) if known
		Total		

Stock use:
Stock type (e.g. sheep, horses) Describe operation (e.g. meat production, breeders, agistment).

Intensive means conditions in which the cattle or stock are confined to an area smaller than that required for grazing under normal conditions and are usually fed by hand or by mechanical means.

Specify each stock type & description of operation (e.g. sheep, cattle, feedlot meat production)	Average No of stock (Yr)	Intensive operation (Y/N)	Estimated annual quantity (kL) if known
		Total	

Aquaculture use:
Aquaculture type (e.g. yabbies, marron, fish etc).

Details of pond dimensions, holding facilities, evaporation, seepage and discharge must be supplied.

Aquaculture use – specify each type of operation	Plan of operation details attached (Y/N)	No of times ponds emptied per year	Estimated annual quantity (kL) if known
		Total	

Other water use:
Other water usages include firefighting, road verge watering, bottling, public water supply, road construction, ablutions, public open spaces, recreations

Water usage – specify individual usage	Usage area (ha)	Estimated annual quantity (kL) if known

Mining or industrial use:
Specify each water usage e.g. processing, dewatering, dust suppression, camp purposes, rehabilitation, care and maintenance.

Mining or industrial use - water usage	Estimated annual quantity (kL) if known	Salinity per use (TDS)

If dewatering, will water be discharged to the environment? ☐ Yes ☐ No

Part 8: Resources

Do you have the resources (including financial) to undertake the proposed activities to which the licence relates? ☒ Yes ☐ No

If no, what steps are in train to address this?

Please indicate time frame:

Part 9: Signature or seal of applicant

All persons eligible for the licence must provide their signature.

By signing this form you are declaring that the statements on this form are true and correct.

Date: 21 July 2010 *(dd/mm/yyyy)*

I Sean McGunnigle (name of applicant/s in bold letters)

apply for a licence under the *Rights in Water and Irrigation Act 1914.*

[signature]
Signature of applicant or person duly authorised to sign on behalf of the applicant

OR

Common seal or company seal

was hereby affixed in the presence of ______________ (Authority to sign)

Signature of applicant or person duly authorised to sign on behalf of the applicant

Position Title

PLEASE NOTE: IF YOU ARE SIGNING ON BEHALF OF ANOTHER PERSON PROOF OF YOUR AUTHORITY IN WRITING MUST BE PROVIDED.

Important information

- An application for a licence will not be accepted by the Department of Water unless all applicable information in this form has been completed. Please use the attached checklists to ensure you meet this requirement.
- Applications which are returned may result in water not being available when the completed application is re-submitted to the Department of Water.

Please retain a copy of this form for your records

[This page has been left blank intentionally]

Appendix B

Summary of details of all bores

[This page has been left blank intentionally]

2nd quarter	3rd quarter	4th quarter

Bore	Location		Elevation (mAHD)	Date of construction	Screened aquifer	Purpose	Status
	Easting	Northing					
22 Mile Bore	781846.67	7517728.51	n/a	n/a	Gravel	Production	Monitored
CCCAP03	775199.9	7524214.4	429.526	24-Jan-2011	BIF	Production	Non-active
CCCAP04	775194	7523986	428.85	26-Jan-2011	BIF	Production	Non-active
CCCP01	776024.853	7523984.077	432.356	30-Aug-2008	BIF	Production	Producing
CCCP02	776803.279	7524201.801	435.775	1-Sep-2008	BIF	Production	Producing
CCE01	772734.06	7522409.53	425.01	3-Aug-2009	BIF	Production	Non-active
CCE01MB_D	772752.31	7522418.06	425.22	3-Aug-2009	BIF	Monitoring	Monitored
CCE01MB_I	772752.31	7522418.06	425.22	3-Aug-2009	BIF	Monitoring	Monitored
CCE01MB_S	772752.31	7522418.06	425.22	3-Aug-2009	Gravel	Monitoring	Monitored
CCE02MB_D	772649.15	7519911.98	416.86	2-Aug-2009	BIF	Monitoring	Monitored
CCE02MB_I	772649.15	7519911.98	416.86	2-Aug-2009	Calcrete	Monitoring	Monitored
CCE02MB_S	772649.15	7519911.98	416.86	2-Aug-2009	Gravel	Monitoring	Monitored
CCE02T	782203.693	7520769.111	432.435	22-Mar-2005	BIF	Production	Non-active
CCE03MB1_D	772586.66	7517443.55	409.43	29-Jul-2009	Dolomite	Monitoring	Monitored
CCE03MB1_I	772586.66	7517443.55	409.43	29-Jul-2009	Calcrete	Monitoring	Monitored
CCE03MB1_S	772586.66	7517443.55	409.43	29-Jul-2009	Calcrete	Monitoring	Monitored
CCE03MB2	772593.02	7517442.19	409.21	30-Jul-2009	Calcrete	Monitoring	Monitored
CCE04	777617.33	7521608.48	427.34	24-Jul-2009	BIF	Production	Non-active
CCE04MB_D	777634.16	7521608.83	427.25	21-Jul-2009	BIF	Monitoring	Monitored
CCE04MB_I	777634.16	7521608.83	427.25	21-Jul-2009	Calcrete	Monitoring	Monitored
CCE04MB_S	777634.16	7521608.83	427.25	21-Jul-2009	Gravel	Monitoring	Monitored
CCE04MB_VD	777634.16	7521608.83	427.25	21-Jul-2009	BIF	Monitoring	Monitored
CCE05	779206.51	7522202.47	432.52	31-Jul-2009	Gravel & BIF	Production	Non-active
CCE05MB_D	779194.67	7522190.89	432.37	26-Jul-2009	BIF	Monitoring	Monitored
CCE05MB_I	779194.67	7522190.89	432.37	26-Jul-2009	BIF	Monitoring	Monitored
CCE05MB_S	779194.67	7522190.89	432.37	26-Jul-2009	Gravel	Monitoring	Monitored
CCE10	781133.56	7515812.41	416.06	21-Jul-2009	Calcrete	Production	Non-active
CCE10MB_D	781132.05	7515791.09	416.05	21-Aug-2009	Calcrete	Monitoring	Monitored
CCE10MB_I	781132.05	7515791.09	416.05	21-Aug-2009	Gravel	Monitoring	Monitored
CCE10MB_S	781132.05	7515791.09	416.05	21-Aug-2009	Gravel	Monitoring	Monitored
CCE10MB_VD	781132.05	7515791.09	416.05	21-Aug-2009	Dolomite	Monitoring	Monitored
CCE11MB_D	780670.56	7514277.5	410.36	19-Aug-2009	BIF	Monitoring	Monitored
CCE11MB_F	780670.56	7514277.5	410.36	19-Aug-2009	Gravel	Monitoring	Monitored
CCE11MB_I	780670.56	7514277.5	410.36	19-Aug-2009	Calcrete	Monitoring	Monitored
CCE11MB_S	780670.56	7514277.5	410.36	19-Aug-2009	Gravel	Monitoring	Monitored
CCE11MB_VD	780670.56	7514277.5	410.36	19-Aug-2009	BIF	Monitoring	Monitored
CCE12	784799.74	7519818.98	429.62	19-Aug-2009	BIF	Production	Non-active

Bore	Location		Elevation (mAHD)	Date of construction	Screened aquifer	Purpose	Status
	Easting	Northing					
CCE12MB_D	784800.83	7519797.85	429.56	21-Aug-2009	BIF	Monitoring	Monitored
CCE12MB_I	784800.83	7519797.85	429.56	21-Aug-2009	BIF	Monitoring	Monitored
CCE12MB_S	784800.83	7519797.85	429.56	21-Aug-2009	Gravel	Monitoring	Monitored
CCE13	787423.62	7519228.84	435.28	14-Aug-2009	Gravel & BIF	Production	Producing
CCE13MB_D	787418.38	7519209.54	435.34	10-Aug-2009	BIF	Monitoring	Monitored
CCE13MB_I	787418.38	7519209.54	435.34	10-Aug-2009	BIF	Monitoring	Monitored
CCE13MB_S	787418.38	7519209.54	435.34	10-Aug-2009	Gravel	Monitoring	Monitored
CCE14	789203.9	7517564.17	425.71	18-Aug-2009	Gravel & BIF	Production	Non-active
CCE14MB_D	789214.78	7517550.24	425.89	14-Aug-2009	BIF	Monitoring	Monitored
CCE14MB_I	789214.78	7517550.24	425.89	14-Aug-2009	Calcrete	Monitoring	Monitored
CCE14MB_S	789214.78	7517550.24	425.89	14-Aug-2009	Gravel	Monitoring	Monitored
CCE14MB_VD	789214.78	7517550.24	425.89	14-Aug-2009	BIF	Monitoring	Monitored
CCE16	794335.56	7517807.36	437.54	4-Sep-2009	BIF	Production	Non-active
CCE16MB_D	794352.04	7517803.36	437.54	3-Sep-2009	BIF	Monitoring	Monitored
CCE16MB_S	794352.04	7517803.36	437.54	3-Sep-2009	Gravel	Monitoring	Monitored
CCE18	792278.12	7510765.73	420.56	1-Sep-2009	BIF	Production	Non-active
CCE19T	787418	7518530	437.6	29-Mar-2005	BIF	Production	Producing
CCE21MB1	789032.5	7505675.32	n/a	n/a	Gravel	Monitoring	Monitored
CCE21MB2_D	789032.5	7505675.32	407.44	1-Sep-2009	BIF	Monitoring	Monitored
CCE21MB2_S	789032.5	7505675.32	407.44	1-Sep-2009	Gravel	Monitoring	Monitored
CCE41T	794036.94	7519273.34	439.37	24-Mar-2005	BIF	Production	Producing
CCF01A_D	786015.995	7515638.343	416.873	n/a	BIF	Monitoring	Monitored
CCF01B_S	786015.995	7515638.343	416.793	10-Sep-2004	Gravel	Monitoring	Monitored
CCF02A_D	788019.232	7513023.787	418.709	12-Oct-2004	Dolomite	Monitoring	Monitored
CCF02B_S	788019.232	7513023.787	418.649	12-Oct-2004	Calcrete	Monitoring	Monitored
CCF02T	788019.232	7513023.787	418.192	8-Mar-2005	Dolomite	Monitoring	Monitored
CCF03A_S	792255.047	7510749.238	421.261	n/a	Gravel	Monitoring	Monitored
CCF03B_D	792255.047	7510749.238	421.291	n/a	BIF	Monitoring	Monitored
CCF07A_D	782007.728	7517828.372	423.014	n/a	BIF	Monitoring	Monitored
CCF07B_S	782007.728	7517828.372	423.004	n/a	Gravel	Monitoring	Monitored
CCM01A_I	785592.616	7520772.473	433.818	6-Sep-2008	BIF	Monitoring	Monitored
CCM01A_S	785592.629	7520772.441	433.818	6-Sep-2008	BIF	Monitoring	Monitored
CCM01B_D	785592.715	7520797.343	433.555	6-Sep-2008	BIF	Monitoring	Monitored
CCM02_D	782386.45	7522299.2	438.04	10-Sep-2008	BIF	Monitoring	Monitored
CCM02_I	782386.45	7522299.2	438.04	10-Sep-2008	BIF	Monitoring	Monitored
CCM02_S	782386.45	7522299.2	438.04	10-Sep-2008	BIF	Monitoring	Monitored
CCM02_WT	782386.45	7522299.2	438.04	10-Sep-2008	Gravel	Monitoring	Monitored

Bore	Location		Elevation (mAHD)	Date of construction	Screened aquifer	Purpose	Status
	Easting	Northing					
CCM03_D	782396.82	7521482.41	435.02	22-Sep-2008	BIF	Monitoring	Monitored
CCM03_I	782396.82	7521482.41	435.02	22-Sep-2008	BIF	Monitoring	Monitored
CCM03_S	782396.82	7521482.41	435.02	22-Sep-2008	Gravel	Monitoring	Monitored
CCM03_WT	782396.82	7521482.41	435.02	22-Sep-2008	Gravel	Monitoring	Monitored
CCP07	782380.446	7522811.839	439.239	26-Aug-2008	BIF	Production	Non-active
CCP08	782404.59	7522301.66	438.73	6-Sep-2008	BIF	Production	Non-active
CCP09	782388.917	7521908.434	436.98	9-Sep-2008	BIF	Production	Non-active
CCP10	782380.46	7521479.94	435.05	13-Sep-2008	BIF	Production	Non-active
CCP16	785608.71	7520782.87	433.08	4-Sep-2008	BIF	Production	Non-active
CCP17	782367.472	7519909.003	429.704	17-Sep-2008	BIF	Production	Non-active
CCP22	789214.928	7519204.289	432.761	13-Sep-2008	BIF	Production	Producing
CCP23	789210.093	7518879.849	431.766	22-Sep-2008	BIF	Production	Non-active
CCP24	789208.03	7518610.09	429.93	18-Feb-2009	BIF	Production	Non-active
Charlton Bore	782868.08	7523206.81	441.25	8-Dec-2006	Gravel	Production	Producing in first quarter; monitored
DT Bore	781443.806	7516363.924	418.574	7/08/2011	Gravel	Monitoring	None
FLMB01	780640	7523420	439.963	26-Feb-2011	BIF	Monitoring	None
FLMB02	780474	7523342	439.518	28-Feb-2011	BIF	Monitoring	None
FLMB03	780319	7523270	438.521	2-Mar-2011	BIF	Monitoring	None
FLMB04	780179	7523213	437.715	6-Mar-2011	BIF	Monitoring	None
FLMB05	780061	7523158	437.259	9-Mar-2011	BIF	Monitoring	None
FLMB06_D	780267.359	7522670.558	437.235	4/05/2011	BIF	Monitoring	None
FLMB06_S	780267.359	7522670.558	437.235	4/05/2011	BIF	Monitoring	None
FLMB07_D	780805.654	7523846.79	441.072	2/05/2011	BIF	Monitoring	None
FLMB07_S	780805.654	7523846.79	441.072	2/05/2011	n/a (screened below BIF Aquifer)	Monitoring	None
FLP01	778530.4	7523014	432.521	13-Dec-2010	BIF	Production	Monitored
FLP02	778815.1	7522523	432.233	15-Dec-2010	BIF	Production	Monitored
FLP03	779200.8	7523404.44	434.252	23-Jan-2011	BIF	Production	Monitored
FLP04	779590	7523796	436.789	17-Dec-2011	BIF	Production	Monitored
FLP05	779978	7523290	437.75	15-Jan-2011	BIF	Production	Monitored
FLP06	780627.237	7523402.962	439.912	19-Jan-2011	BIF	Production	Monitored
FLP07	780555.524	7523378.918	439.473	27-Mar-2011	BIF	Production	None
FLP08	780460.896	7523328.04	439.456	23-Mar-2011	BIF	Production	None
FLP09	780392.758	7523300.001	438.785	30-Mar-2011	BIF	Production	None
FLP10	780303.342	7523254.27	438.498	2-Apr-2011	BIF	Production	None
FLP11	780246.763	7523238.537	438.242	8-Apr-2011	BIF	Production	None
FLP12	780166.959	7523197.707	437.538	13-Apr-2011	BIF	Production	None
FLP13	780101.791	7523165.531	437.37	18-Apr-2011	BIF	Production	None

Bore	Location		Elevation (mAHD)	Date of construction	Screened aquifer	Purpose	Status
	Easting	Northing					
FLP14	780044.388	7523135.68	437.115	12-Mar-2011	BIF	Production	None
FLP15	780003.487	7523130.929	436.876	16-Mar-2011	BIF	Production	None
FLP16	780020.08	7523162.733	437.169	19-May-2011	BIF	Production	None
FLP17	779967.075	7523106.01	436.922	15-May-2011	BIF	Production	None
FLP18	779900.305	7523092.529	436.651	12-May-2011	BIF	Production	None
FLP19	779835.19	7523063.948	436.702	22-May-2011	BIF	Production	None
FLP20	779710.658	7523813.805	436.848	27-May-2011	BIF	Production	None
FLP21	779638.665	7523745.366	436.384	30-May-2011	BIF	Production	None
FLP22	779613.495	7523720.106	436.224	25-May-2011	BIF	Production	None
FLP23	779585.805	7523676.562	435.998	8-May-2011	BIF	Production	None
FMMB04_D	n/a	n/a	n/a	24-Jul-2011	n/a (screened below BIF Aquifer)	Monitoring	None
FMMB04_S	n/a	n/a	n/a	24-Jul-2011	Gravel	Monitoring	None
FMMB05_D	n/a	n/a	n/a	31-Jul-2011	BIF	Monitoring	None
FMMB05_S	n/a	n/a	n/a	31-Jul-2011	Gravel	Monitoring	None
Franco's Bore	769252.712	7524412.92	432.64	16-Dec-2005	BIF	Production	Producing in first and second quarter; monitored
HEM01_D	772064	7523844	427.203	6-Feb-2011	BIF	Monitoring	None
HEM01_S	772064	7523844	427.203	6-Feb-2011	BIF	Monitoring	None
HEM02_D	772556	7523517	427.179	23-Apr-2011	BIF	Monitoring	None
HEM02_S	772556	7523517	427.179	23-Apr-2011	Gravel	Monitoring	None
HEM04_D	773398	7523159	427.751	1-Feb-2011	BIF	Monitoring	None
HEM04_S	773398	7523159	427.751	1-Feb-2011	Gravel	Monitoring	None
HEM05_D	774490	7523249	426.866	3-Feb-2011	BIF	Monitoring	None
HEM05_S	774490	7523249	426.866	3-Feb-2011	Gravel	Monitoring	None
Mt McKay	807180.146	7514792.468	n/a	n/a	n/a (screened below BIF Aquifer)	Production	Monitored
New Roy Hill Bore	801804.892	7503658.453	413.283	n/a	Gravel	Monitoring	Monitored
SAI01	776040.611	7518261.548	415.522	19-Aug-2011	Calcrete	Injection	None
SAI02	780795.13	7516787.896	419.492	13-Aug-2011	Calcrete	Injection	None
SAI04	782195.719	7515946.516	417.454	1-Aug-2011	Calcrete	Injection	None
SAI05	783665.664	7515127.881	414.959	26-Jul-2011	Calcrete	Injection	None
SAMB01_D	776396.244	7519077.641	418.503	10-Jun-2011	BIF & Calcrete	Monitoring	None
SAMB01_S	776396.244	7519077.641	418.503	10-Jun-2011	Gravel	Monitoring	None
SAMB02_D	777695.388	7518375.423	418.373	16-Jun-2011	BIF	Monitoring	None
SAMB02_S	777695.388	7518375.423	418.373	16-Jun-2011	Gravel	Monitoring	None
SAMB03_D	778926.646	7517701.325	419.45	25-Jun-2011	Calcrete	Monitoring	None
SAMB03_S	778926.646	7517701.325	419.45	25-Jun-2011	Gravel	Monitoring	None
SAMB04_D	779920.135	7517232.462	419.918	29-Jun-2011	Calcrete	Monitoring	None
SAMB04_S	779920.135	7517232.462	419.918	29-Jun-2011	Gravel	Monitoring	None

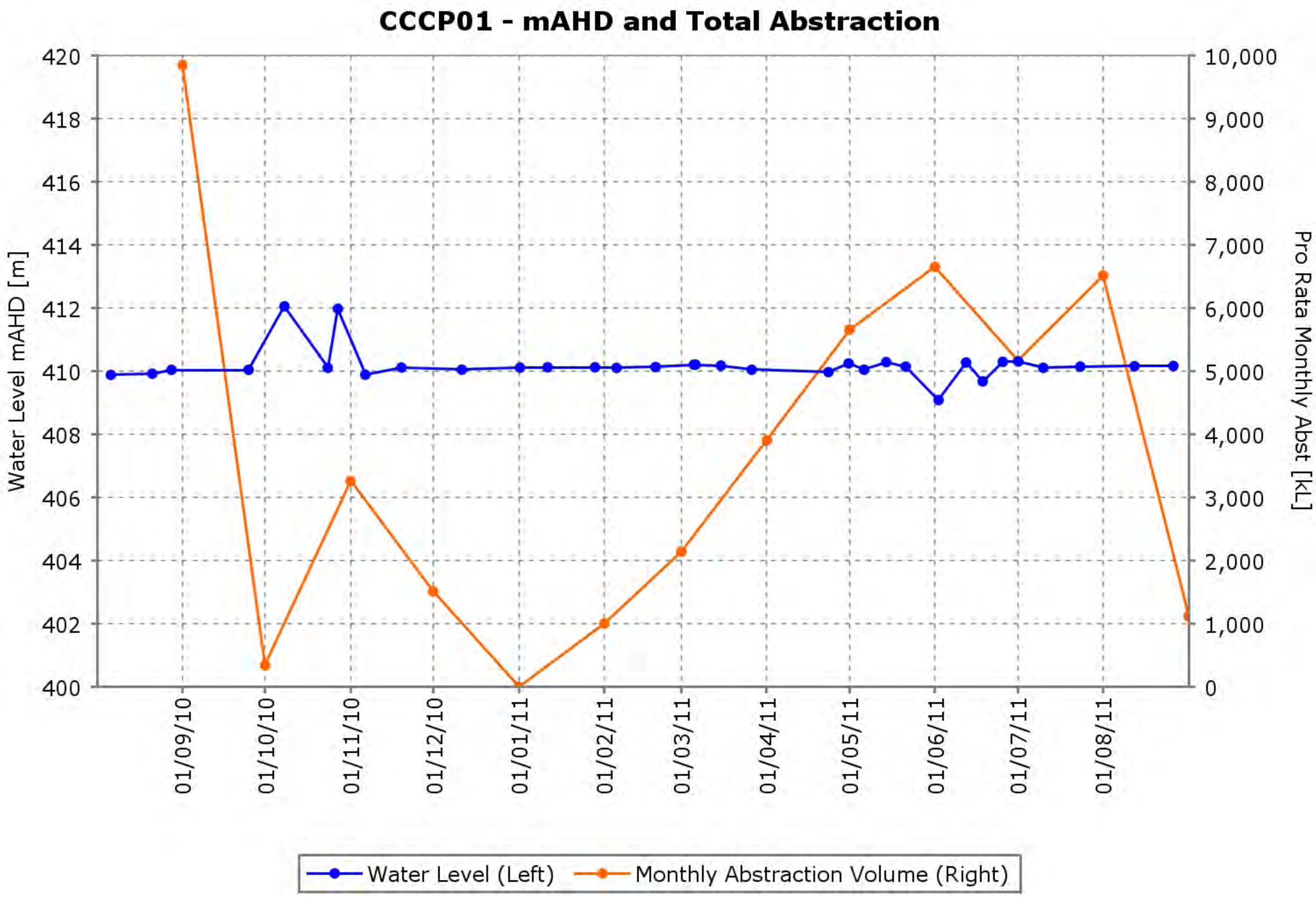
Bore	Location		Elevation (mAHD)	Date of construction	Screened aquifer	Purpose	Status
	Easting	Northing					
SAMB05_D	781455.01	7516358.88	418.05	4-Jul-2011	Calcrete	Monitoring	None
SAMB05_S	781455.01	7516358.88	418.05	4-Jul-2011	Gravel	Monitoring	None
SAMB06_D	783696.712	7515171.082	415.251	17-Jul-2011	Calcrete	Monitoring	None
SAMB06_S	783696.712	7515171.082	415.251	17-Jul-2011	Gravel	Monitoring	None
SAMB12_D	776022.633	7518262.394	415.921	19-Jun-2011	Calcrete	Monitoring	None
SAMB12_S	776022.633	7518262.394	415.921	19-Jun-2011	Gravel	Monitoring	None
SAMB13_D	777012.76	7519668.767	421.398	5-Jun-2011	BIF	Monitoring	None
SAMB13_I	777012.76	7519668.767	421.398	5-Jun-2011	Calcrete	Monitoring	None
SAMB13_S	777012.76	7519668.767	421.398	5-Jun-2011	Gravel	Monitoring	None
SAMB16_D	775413.49	7519477.823	417.327	13-Jun-2011	BIF	Monitoring	None
SAMB16_S	775413.49	7519477.823	417.327	13-Jun-2011	Gravel	Monitoring	None
SAMB21_D	780776.231	7516787.984	419.162	1-Jul-2011	BIF & Calcrete	Monitoring	None
SAMB21_S	780776.231	7516787.984	419.162	1-Jul-2011	Gravel	Monitoring	None
SAMB23_D	782873.154	7515546.706	415.666	15-Jul-2011	Calcrete	Monitoring	None
SAMB23_S	782873.154	7515546.706	415.666	15-Jul-2011	Gravel	Monitoring	None
SAMB25_D	782172.28	7515946.706	417.087	9-Jul-2011	Calcrete	Monitoring	None
SAMB25_S	782172.28	7515946.706	417.087	9-Jul-2011	Gravel	Monitoring	None
Thor Bore	794453	7517621	437	n/a	Gravel	Production	Monitored
WDP01	783183.6	7521890	436.738	30-Nov-2010	BIF	Production	Monitored
WDP05	784004.2	7521302	435.253	17-Nov-2010	BIF	Production	Monitored
WDP06	784198.5	7521234	434.842	18-Nov-2011	BIF	Production	Monitored
WDP07	784429	7521179	434.277	23-Nov-2011	BIF	Production	Monitored
Wild Bore	795604	7519278	442	n/a	BIF	Production	Monitored
WS19P2	770249.49	7524371.36	435.3	21-Aug-2008	BIF	Production	Monitored
WS19P3	769988.89	7523985.81	431.74	15-Aug-2008	BIF	Production	Monitored
WS20P1	776170.25	7523732.26	432.51	15-Aug-2008	BIF	Production	Producing in first quarter; monitored
WS20P2	776513.55	7523852.25	434.09	15-Aug-2008	BIF	Production	Monitored
WS20P3	775633.04	7523525.6	429.92	15-Aug-2008	BIF	Production	Monitored
WS21P1	781564.8	7518964.34	426.88	3-Aug-2008	Gravel	Production	Producing in first quarter; monitored
WS21P3	781523.45	7518415.74	425.29	15-Aug-2008	Calcrete	Production	Producing in first and second quarter;

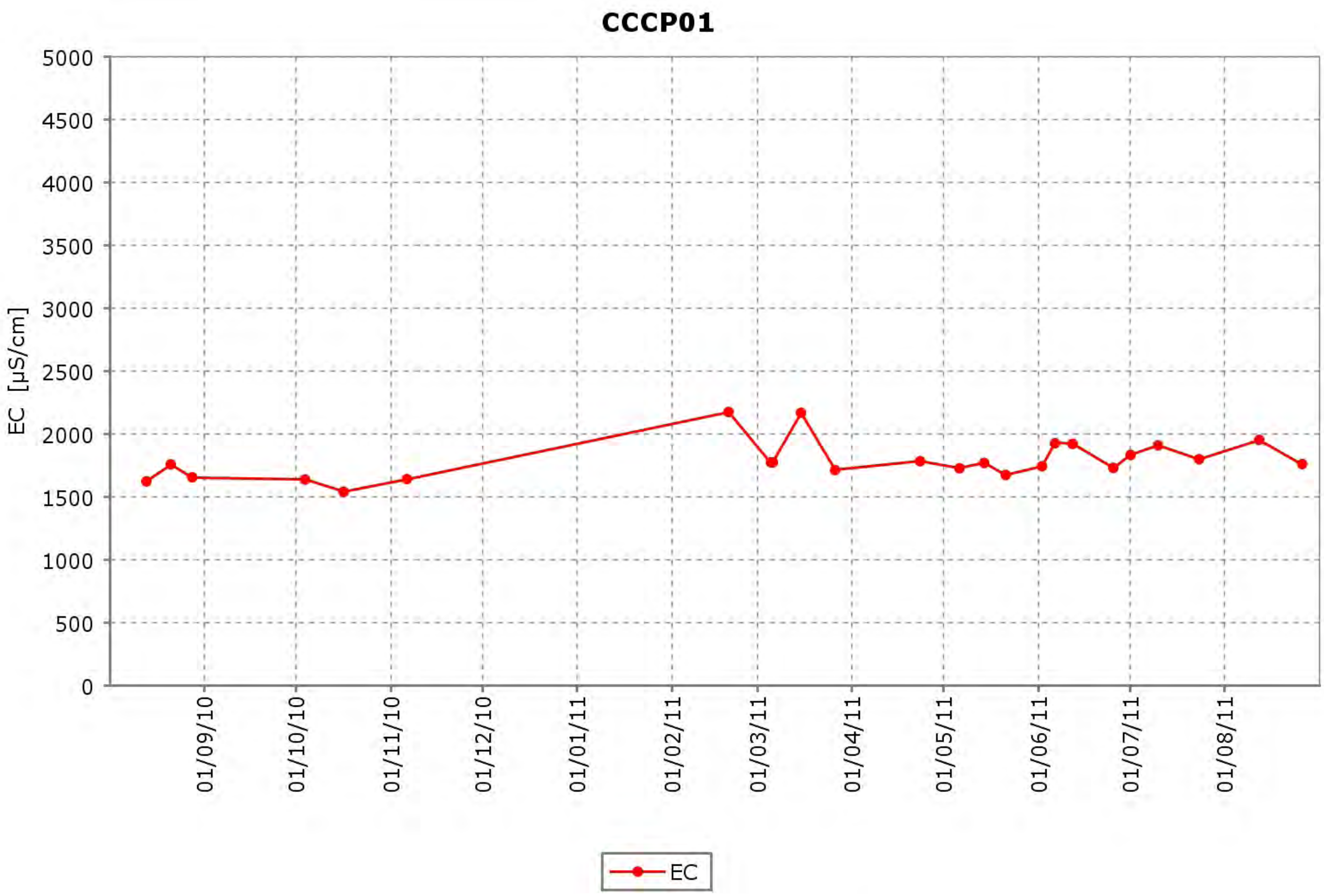
[This page has been left blank intentionally]

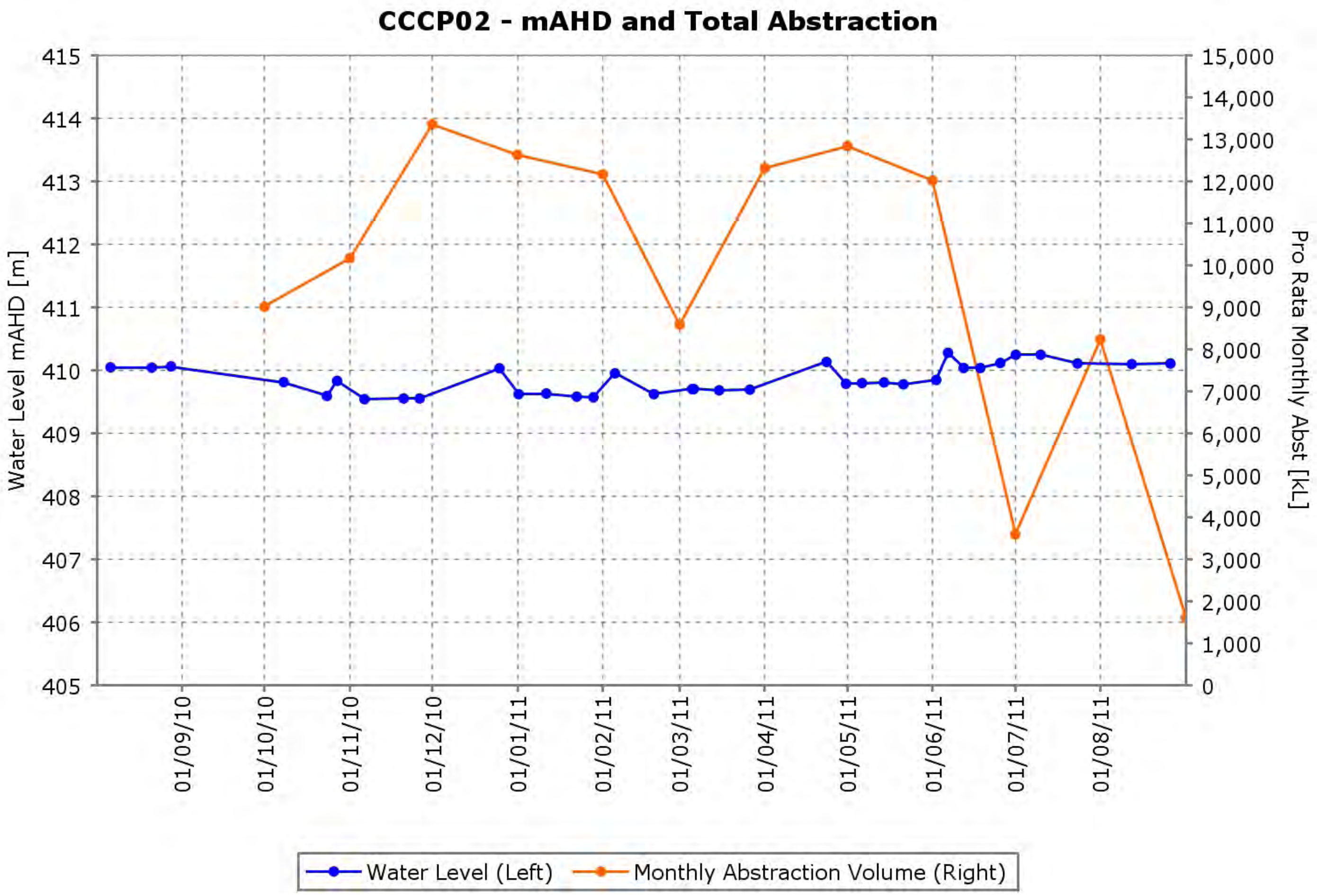
Appendix C

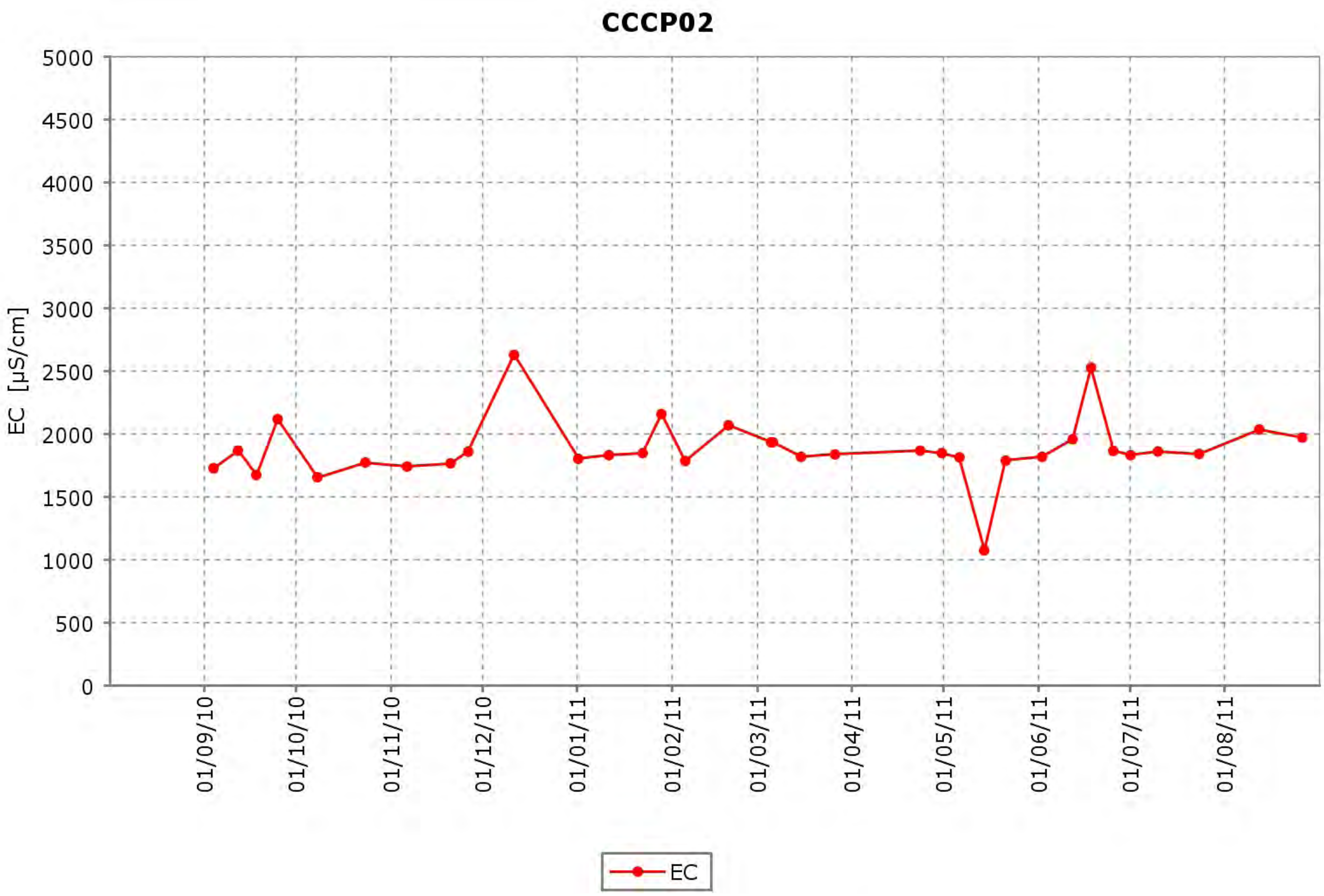
Graphs of groundwater level, abstraction and electrical conductivity for producing bores

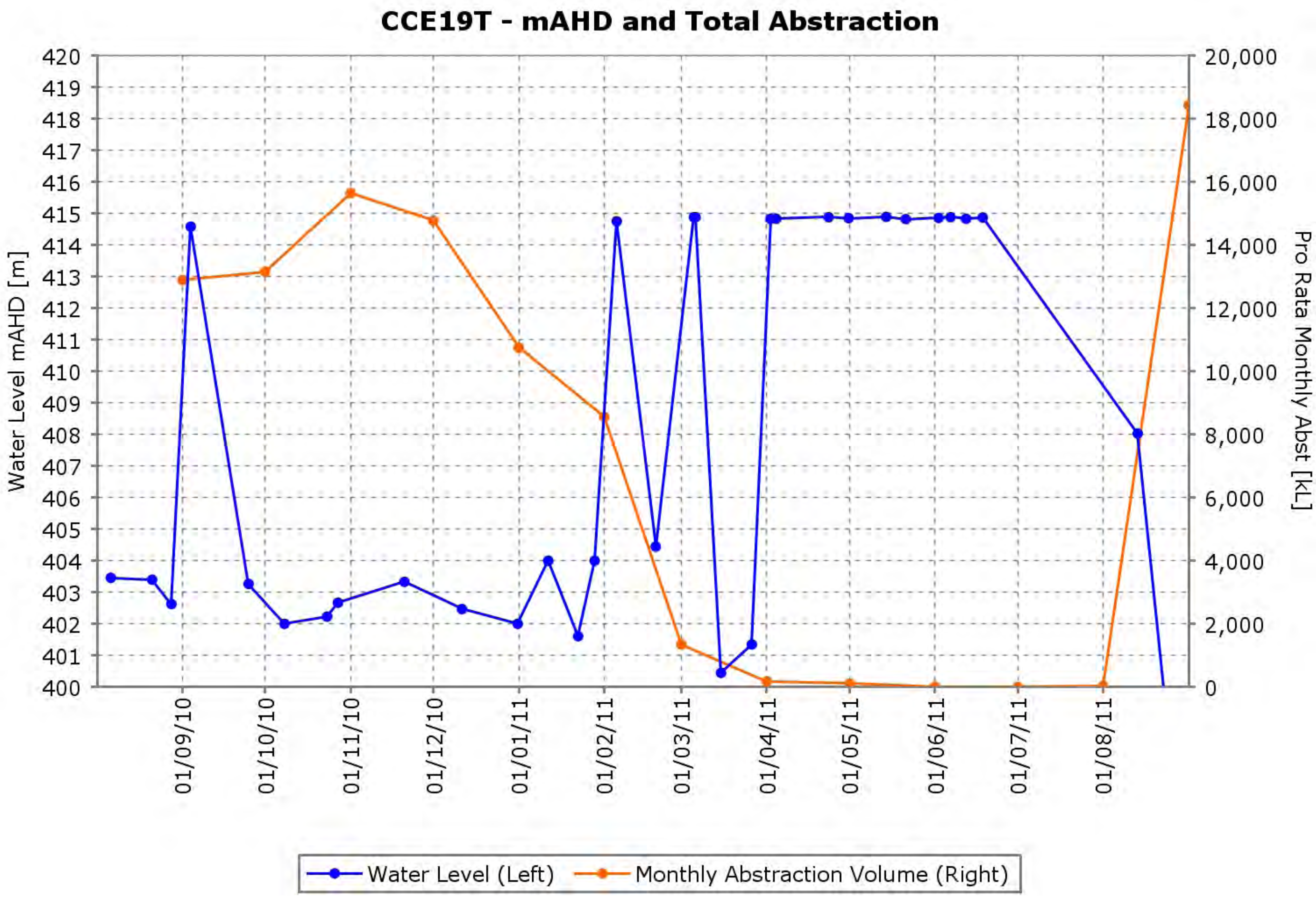
[This page has been left blank intentionally]

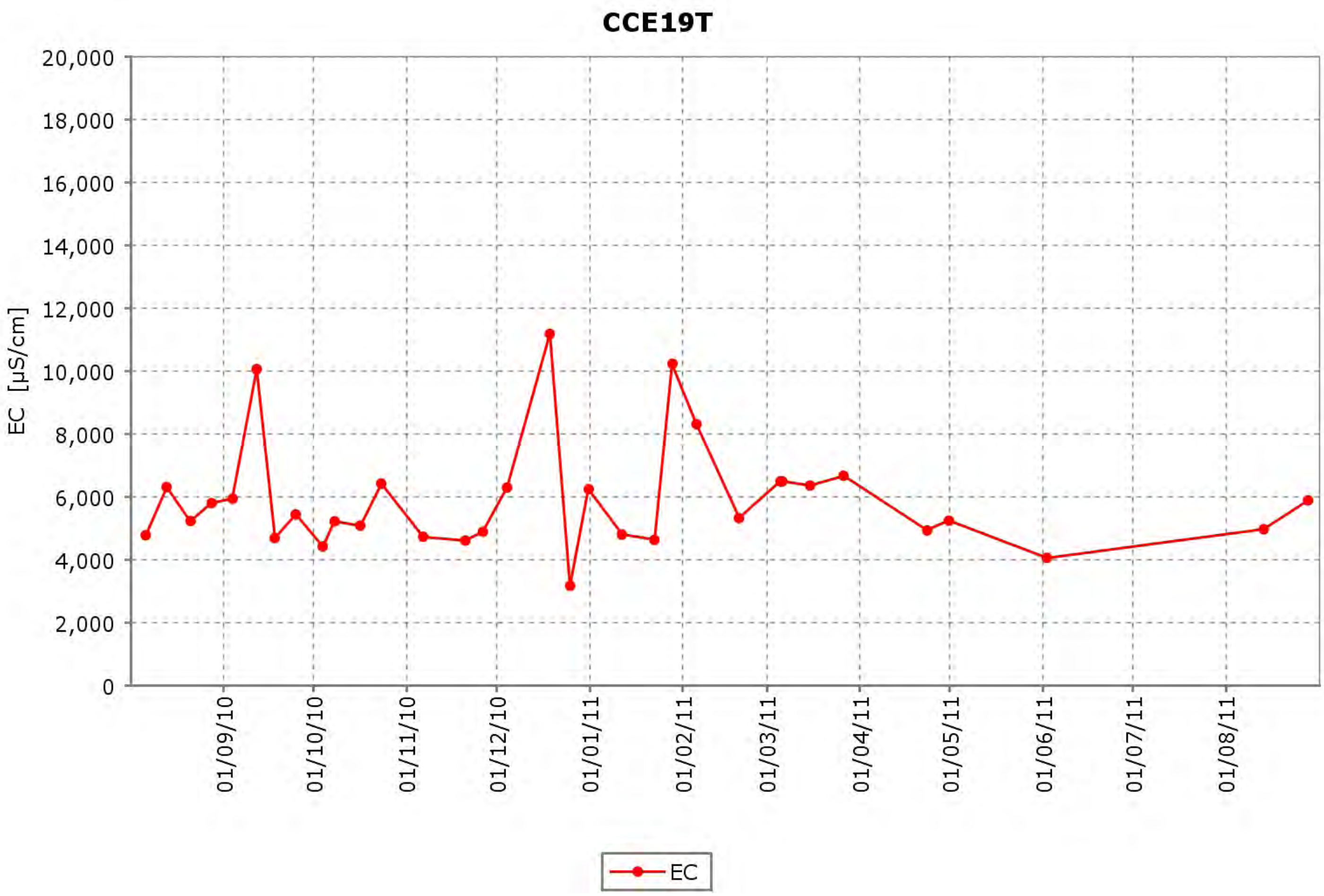

CCCP01 - mAHD and Total Abstraction
Water Level mAHD [m]
Pro Rata Monthly Abst [kL]
420
418
416
414
412
410
408
406
404
402
400
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
01/09/10
01/10/10
01/11/10
01/12/10
01/01/11
01/02/11
01/03/11
01/04/11
01/05/11
01/06/11
01/07/11
01/08/11
Water Level (Left)
Monthly Abstraction Volume (Right)

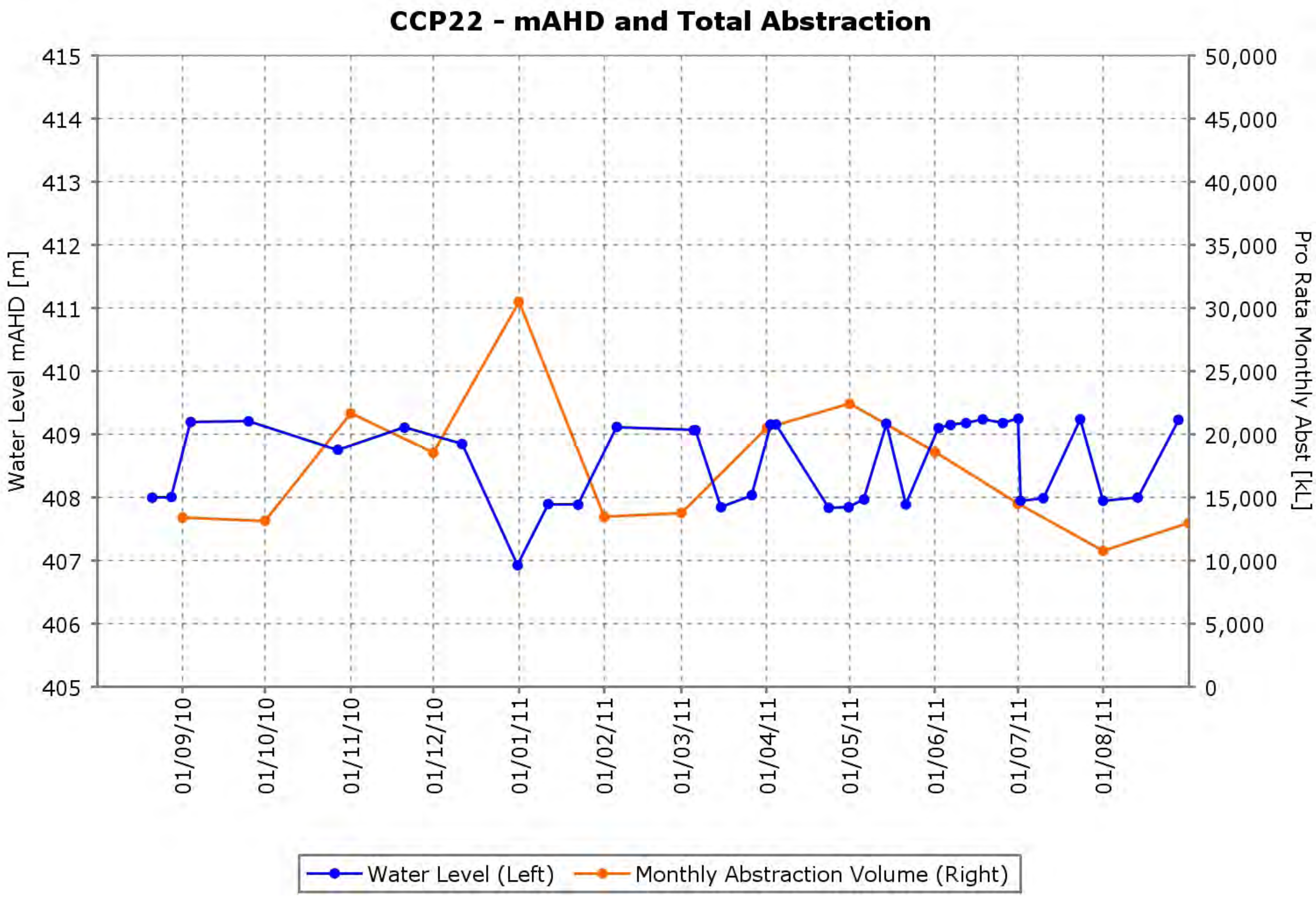

CCCP01
EC [µS/cm]
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
01/09/10
01/10/10
01/11/10
01/12/10
01/01/11
01/02/11
01/03/11
01/04/11
01/05/11
01/06/11
01/07/11
01/08/11
EC

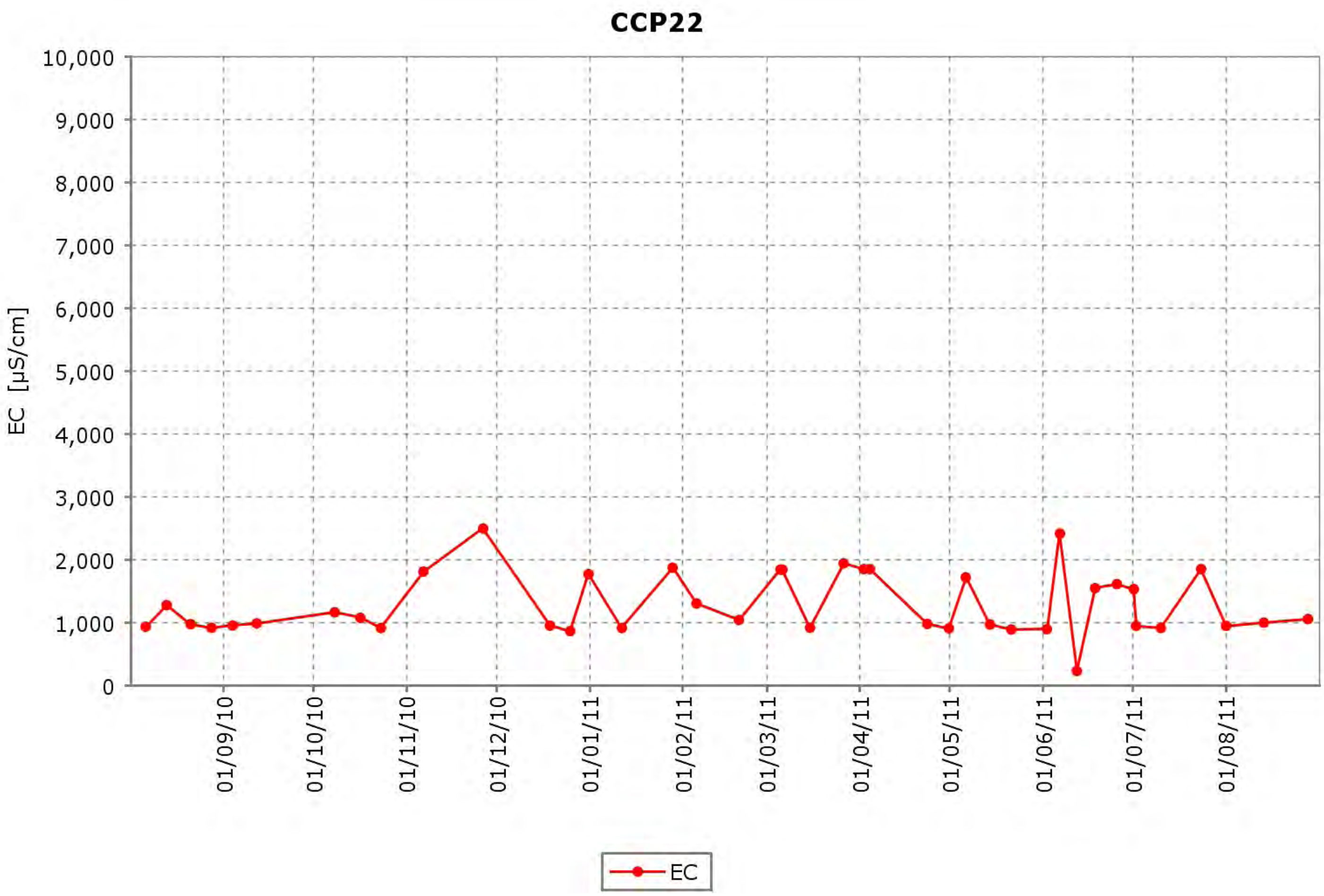

CCCP02 - mAHD and Total Abstraction
Water Level mAHD [m]
415
414
413
412
411
410
409
408
407
406
405
Pro Rata Monthly Abst [kL]
15,000
14,000
13,000
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
01/09/10
01/10/10
01/11/10
01/12/10
01/01/11
01/02/11
01/03/11
01/04/11
01/05/11
01/06/11
01/07/11
01/08/11
Water Level (Left)
Monthly Abstraction Volume (Right)

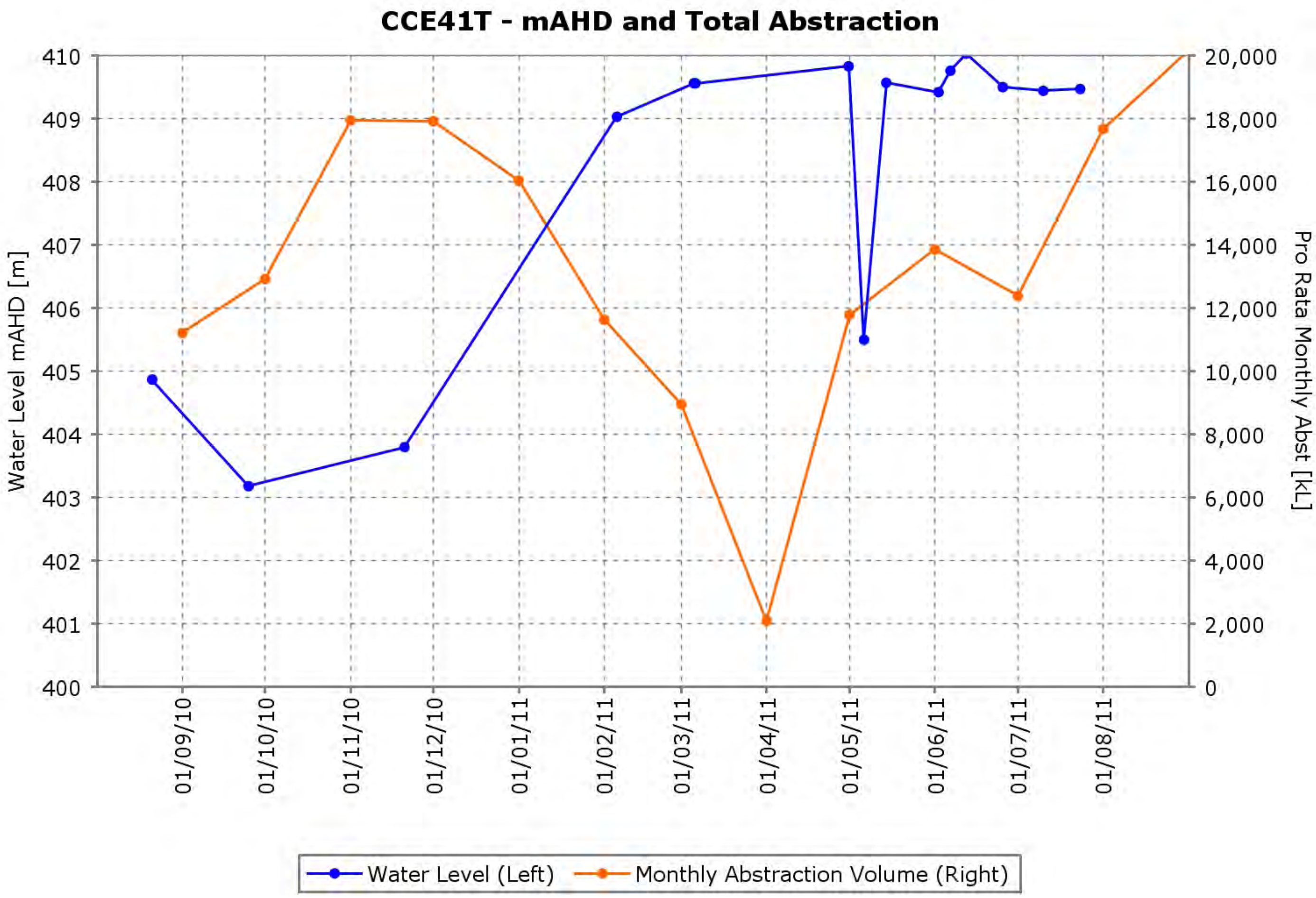

CCCP02
EC [µS/cm]
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
01/09/10
01/10/10
01/11/10
01/12/10
01/01/11
01/02/11
01/03/11
01/04/11
01/05/11
01/06/11
01/07/11
01/08/11
EC

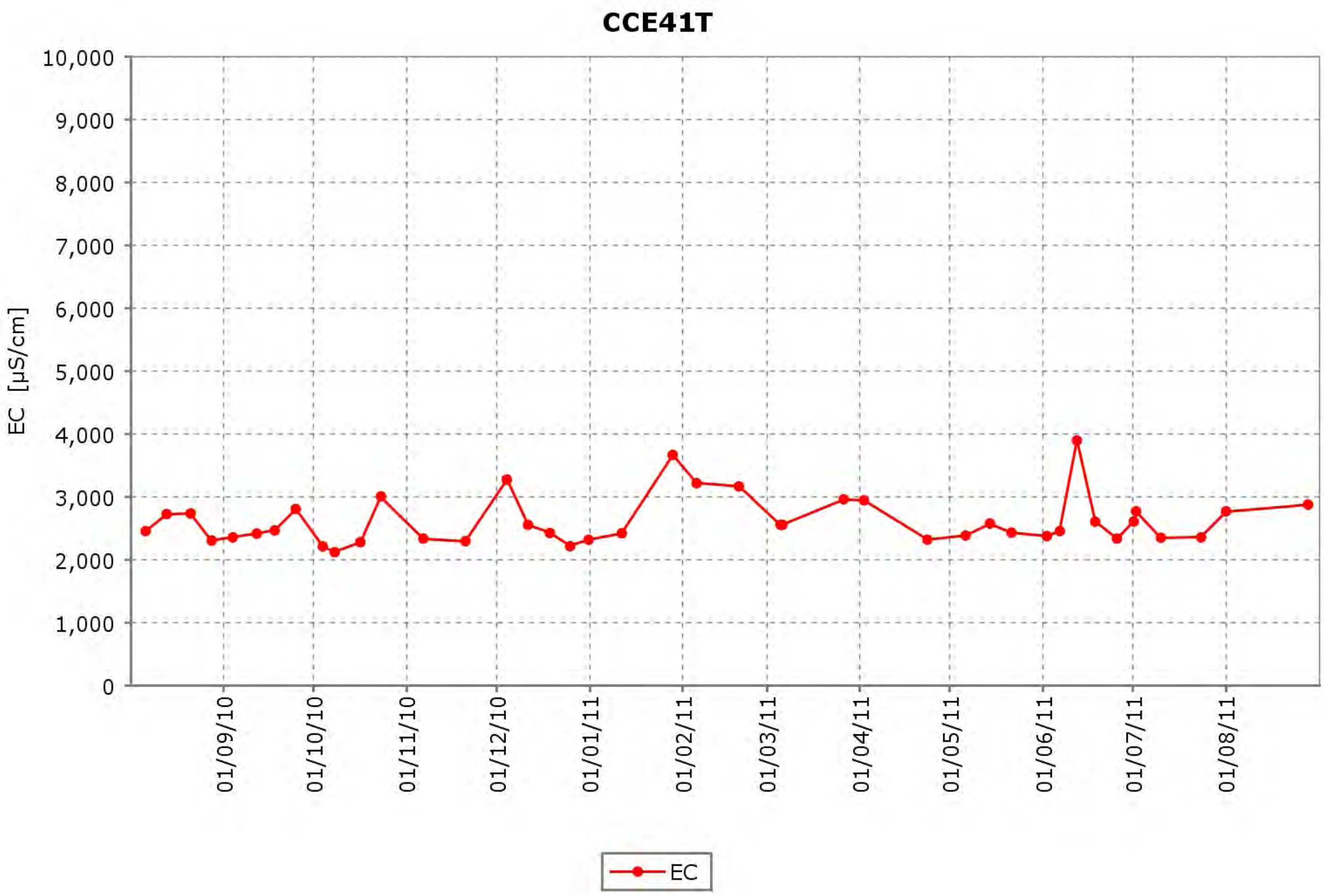

CCE19T - mAHD and Total Abstraction
Water Level mAHD [m]
Pro Rata Monthly Abst [kL]
420
419
418
417
416
415
414
413
412
411
410
409
408
407
406
405
404
403
402
401
400
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
01/09/10
01/10/10
01/11/10
01/12/10
01/01/11
01/02/11
01/03/11
01/04/11
01/05/11
01/06/11
01/07/11
01/08/11
Water Level (Left)
Monthly Abstraction Volume (Right)

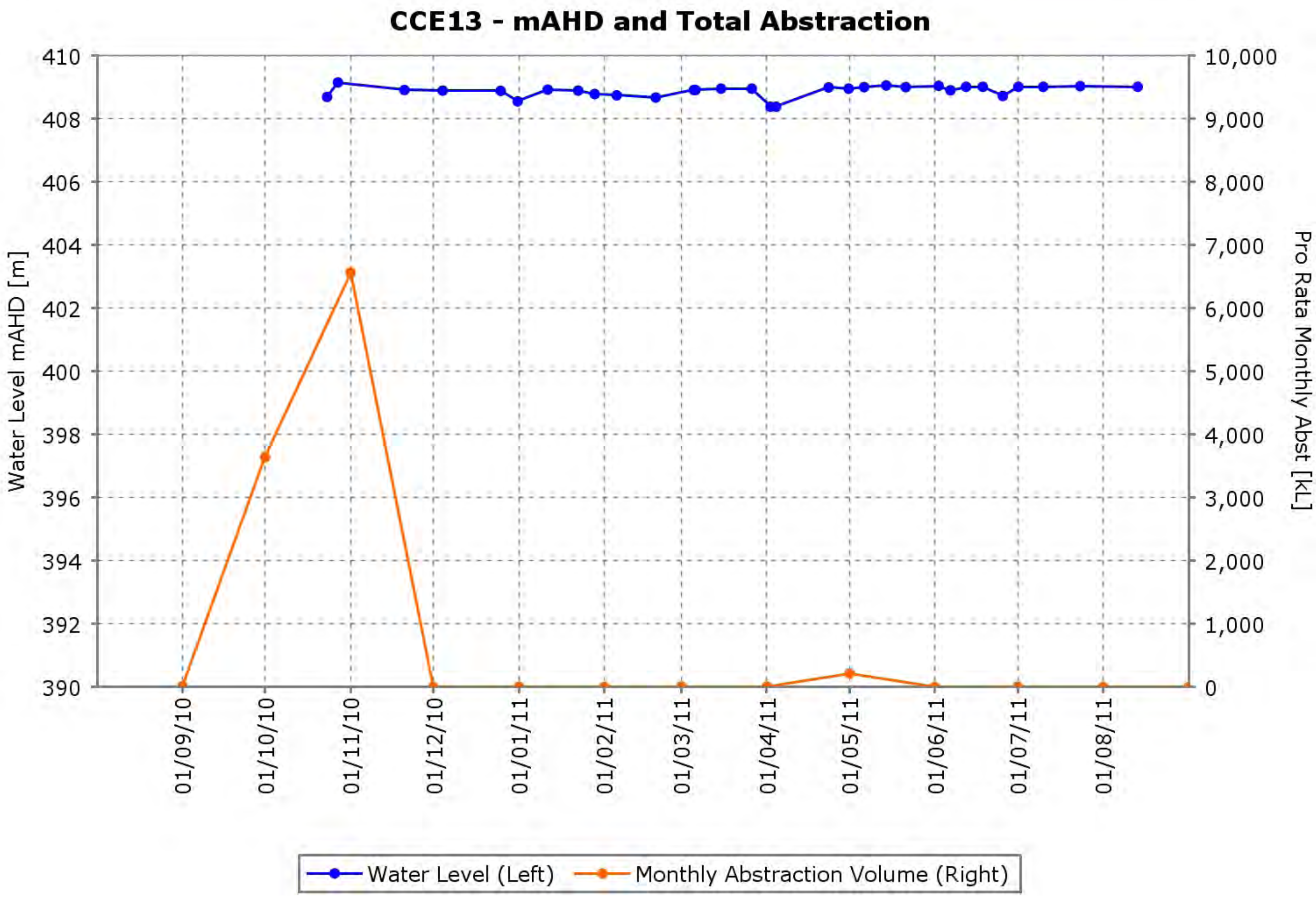

CCE19T
EC [µS/cm]
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
01/09/10
01/10/10
01/11/10
01/12/10
01/01/11
01/02/11
01/03/11
01/04/11
01/05/11
01/06/11
01/07/11
01/08/11
EC

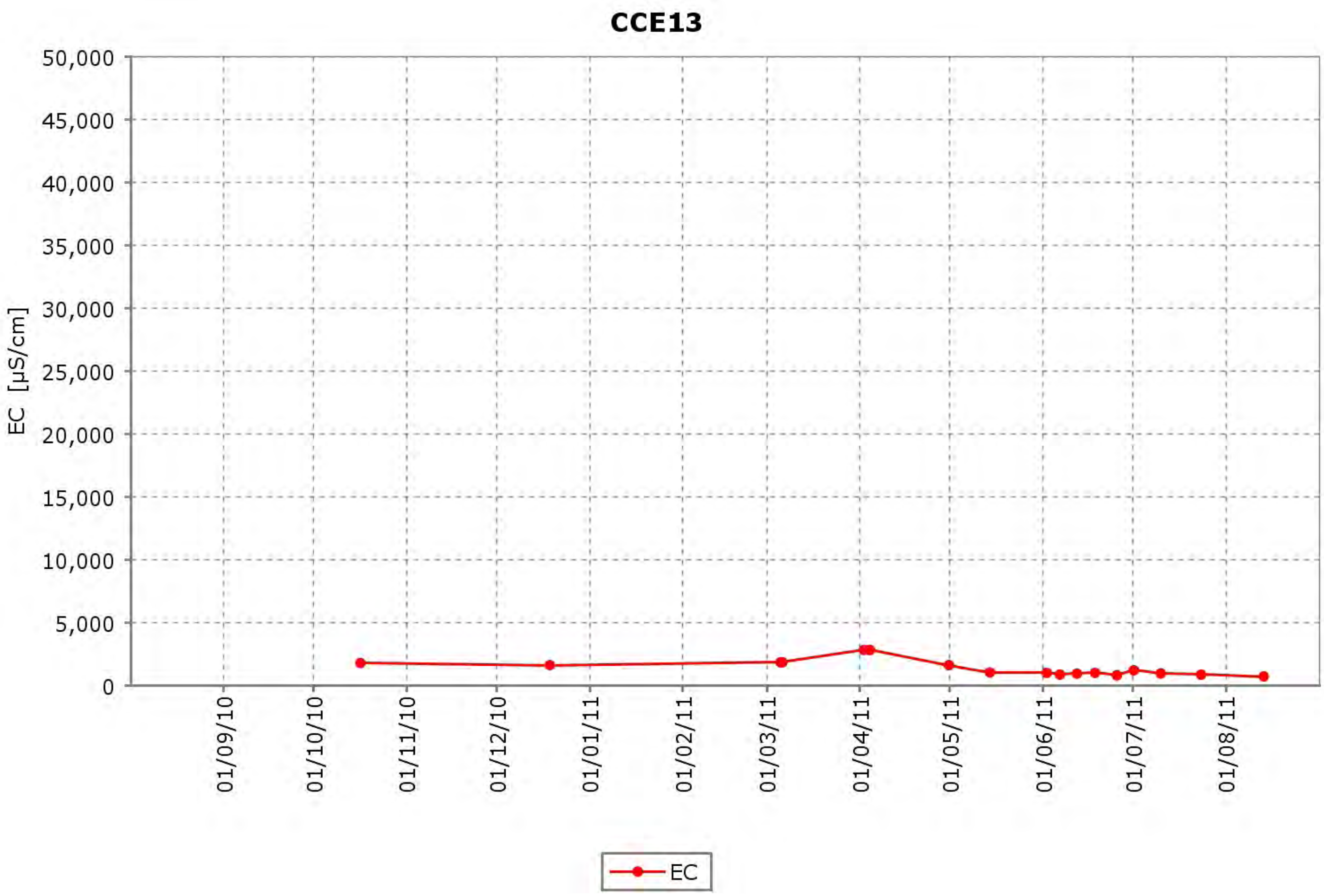

CCP22 - mAHD and Total Abstraction
Water Level mAHD [m]
Pro Rata Monthly Abst [kL]
415
414
413
412
411
410
409
408
407
406
405
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
01/09/10
01/10/10
01/11/10
01/12/10
01/01/11
01/02/11
01/03/11
01/04/11
01/05/11
01/06/11
01/07/11
01/08/11
Water Level (Left)
Monthly Abstraction Volume (Right)

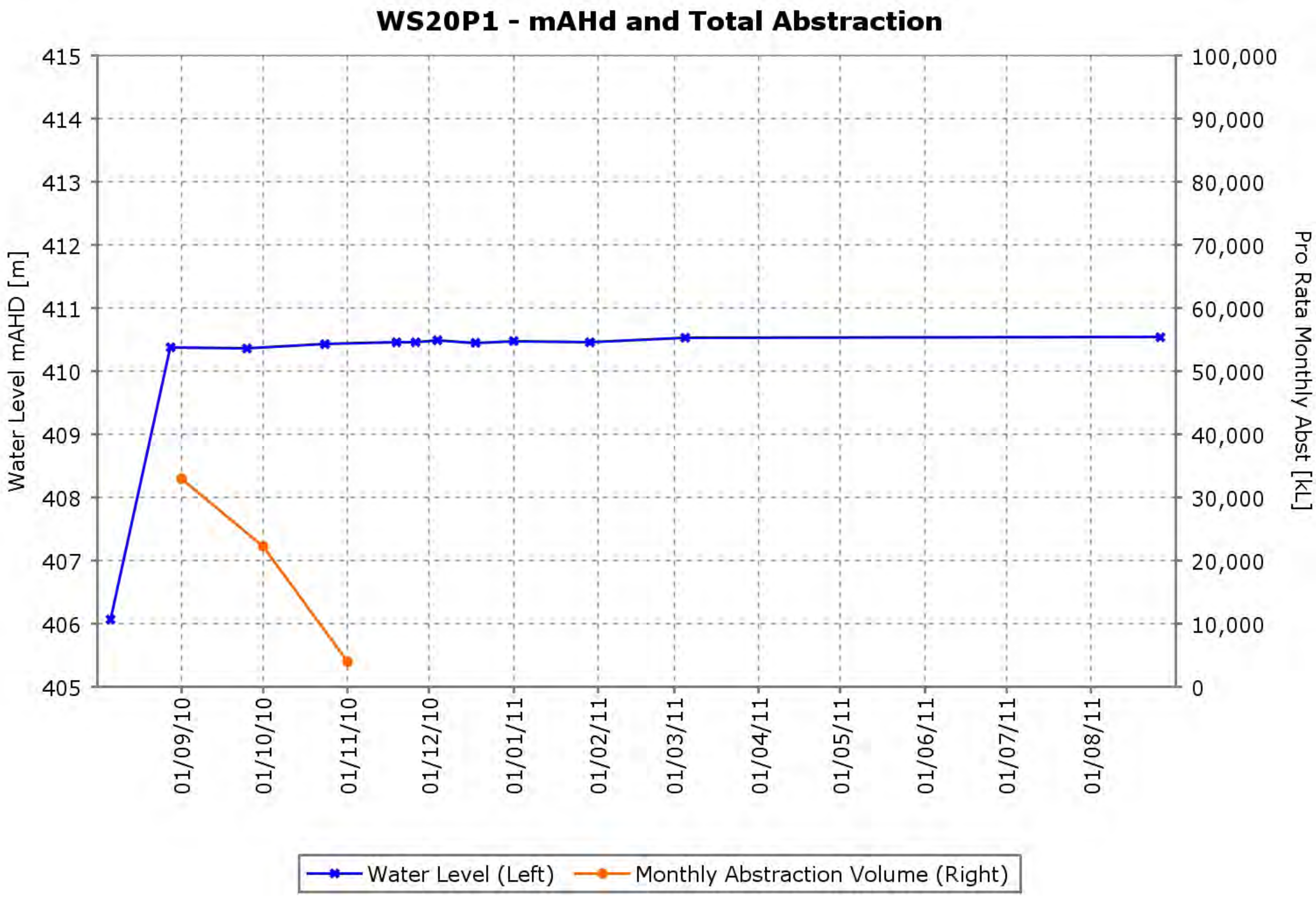

CCP22
EC [µS/cm]
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
01/09/10
01/10/10
01/11/10
01/12/10
01/01/11
01/02/11
01/03/11
01/04/11
01/05/11
01/06/11
01/07/11
01/08/11
EC

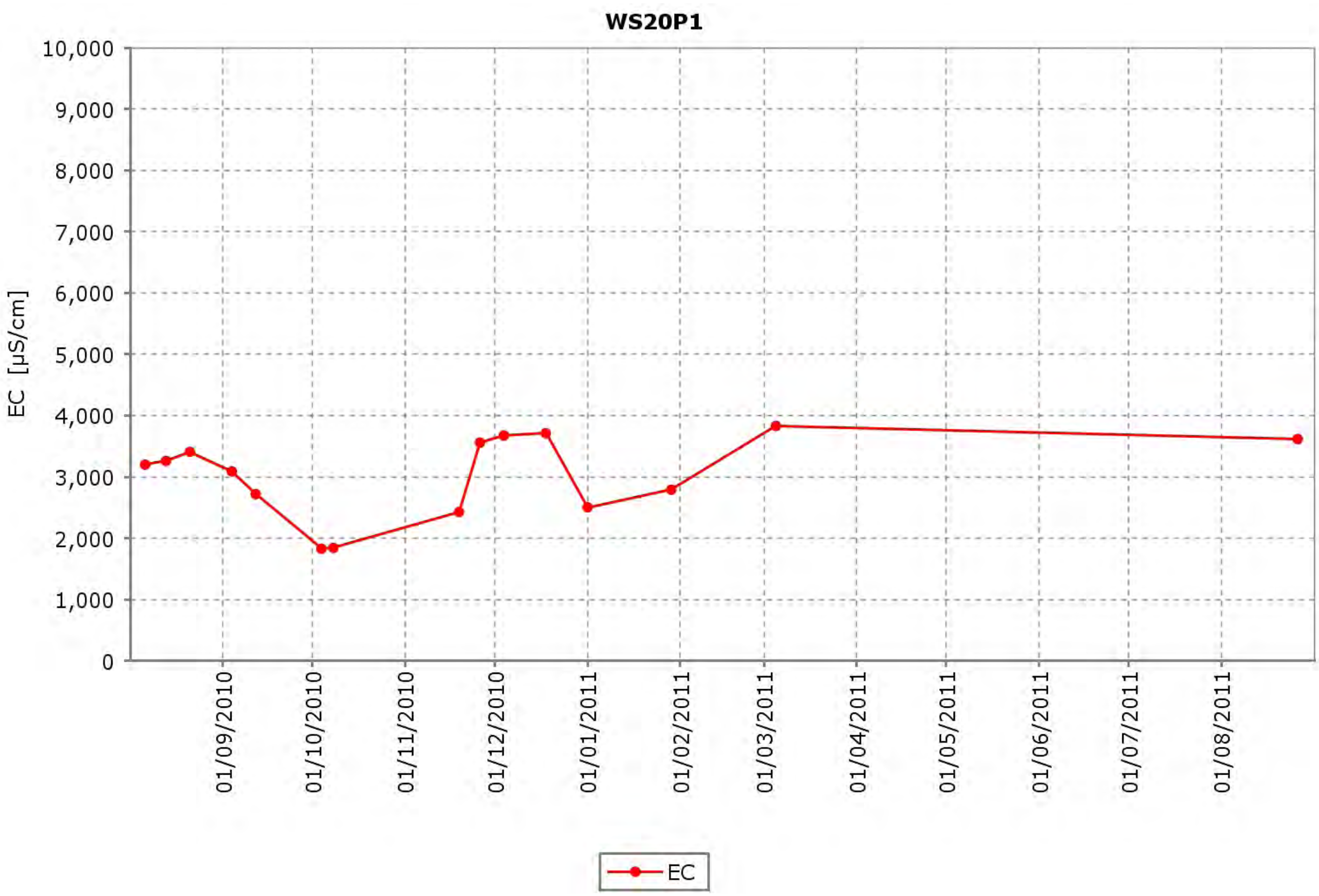

CCE41T - mAHD and Total Abstraction
Water Level mAHD [m]
Pro Rata Monthly Abst [kL]
410
409
408
407
406
405
404
403
402
401
400
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
01/09/10
01/10/10
01/11/10
01/12/10
01/01/11
01/02/11
01/03/11
01/04/11
01/05/11
01/06/11
01/07/11
01/08/11
Water Level (Left)
Monthly Abstraction Volume (Right)

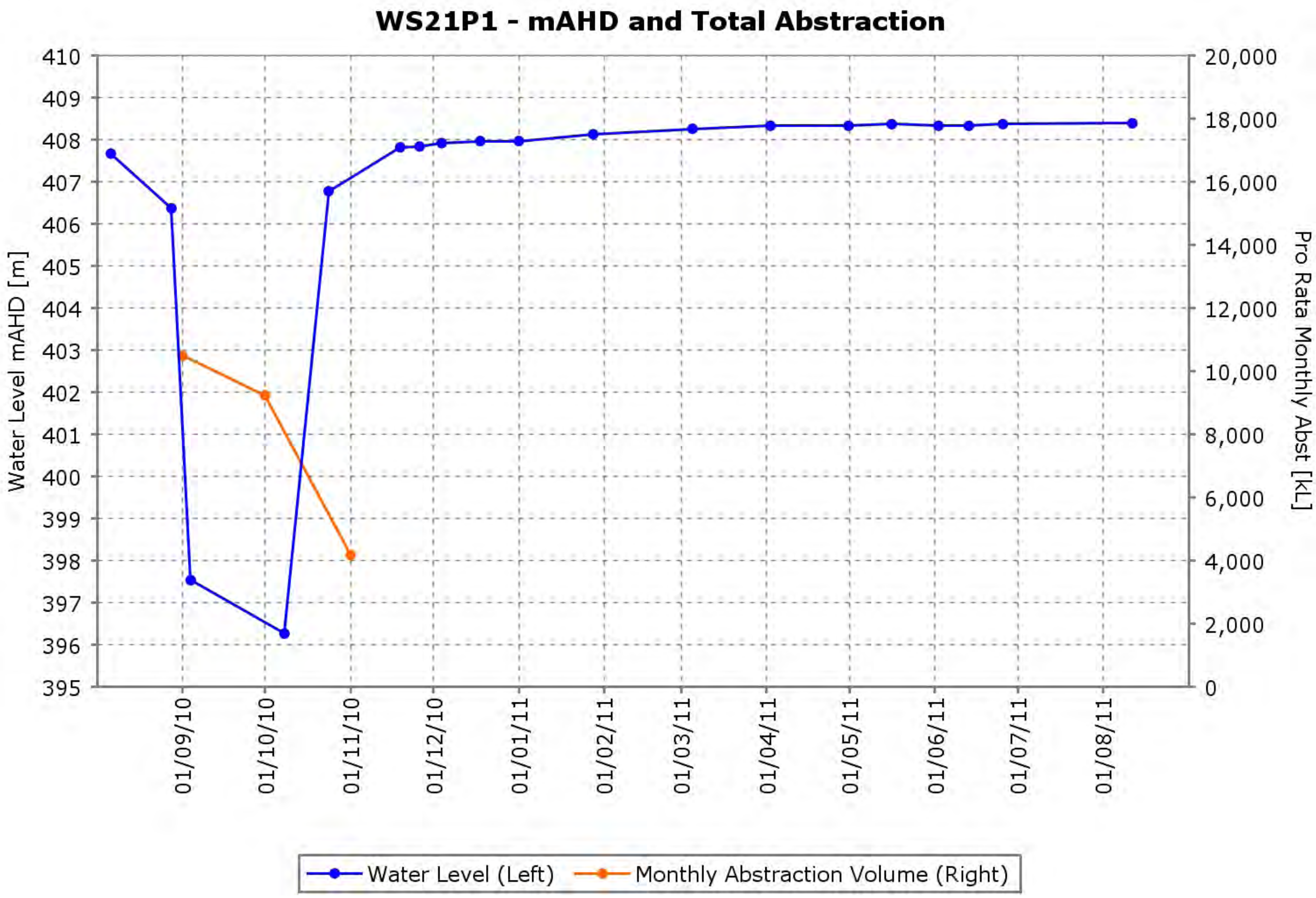

CCE41T
EC [µS/cm]
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
01/09/10
01/10/10
01/11/10
01/12/10
01/01/11
01/02/11
01/03/11
01/04/11
01/05/11
01/06/11
01/07/11
01/08/11
EC


CCE13 - mAHD and Total Abstraction
Water Level mAHD [m]
Pro Rata Monthly Abst [kL]
410
408
406
404
402
400
398
396
394
392
390
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
01/09/10
01/10/10
01/11/10
01/12/10
01/01/11
01/02/11
01/03/11
01/04/11
01/05/11
01/06/11
01/07/11
01/08/11
Water Level (Left)
Monthly Abstraction Volume (Right)

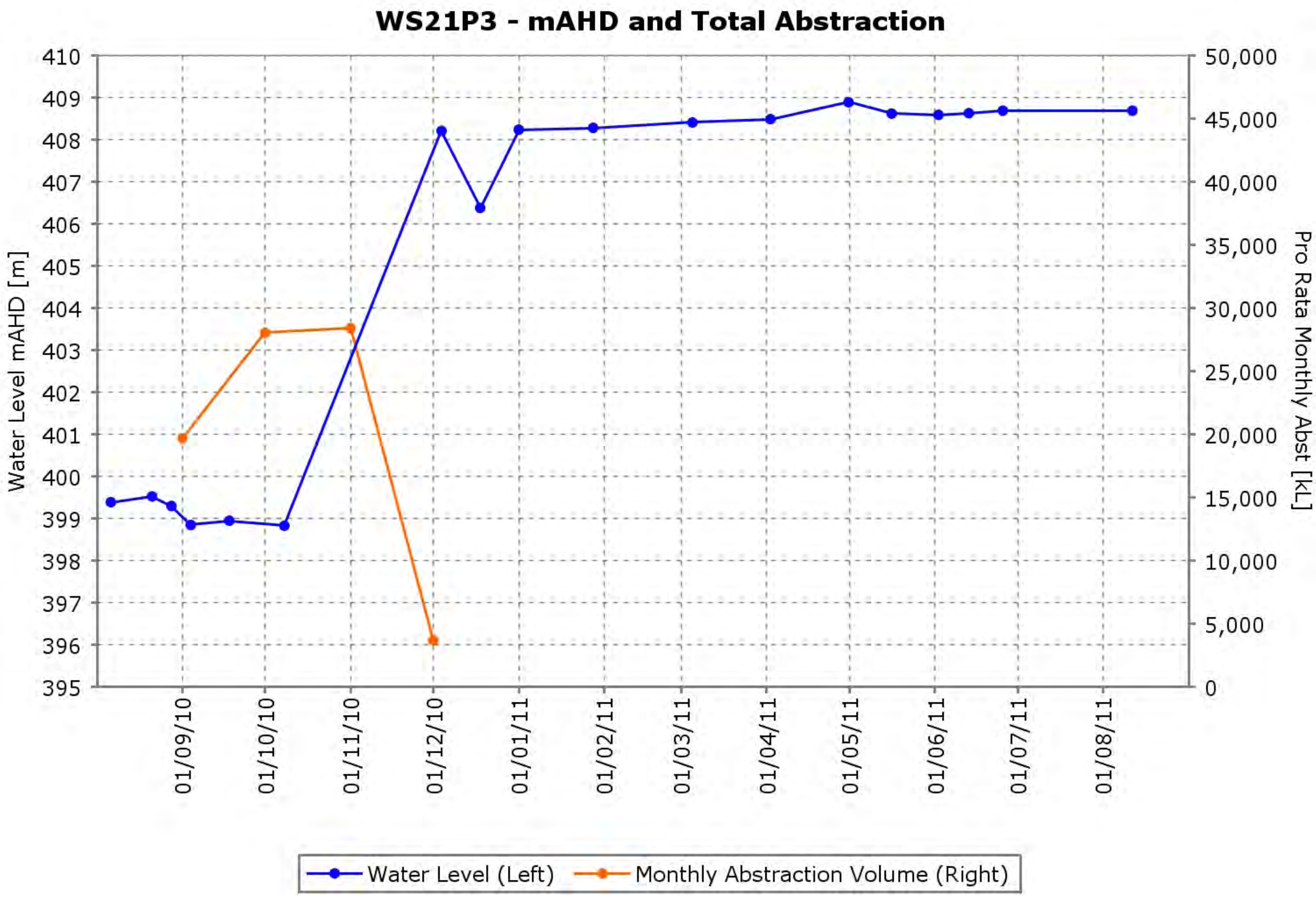

CCE13
EC [µS/cm]
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
01/09/10
01/10/10
01/11/10
01/12/10
01/01/11
01/02/11
01/03/11
01/04/11
01/05/11
01/06/11
01/07/11
01/08/11
EC

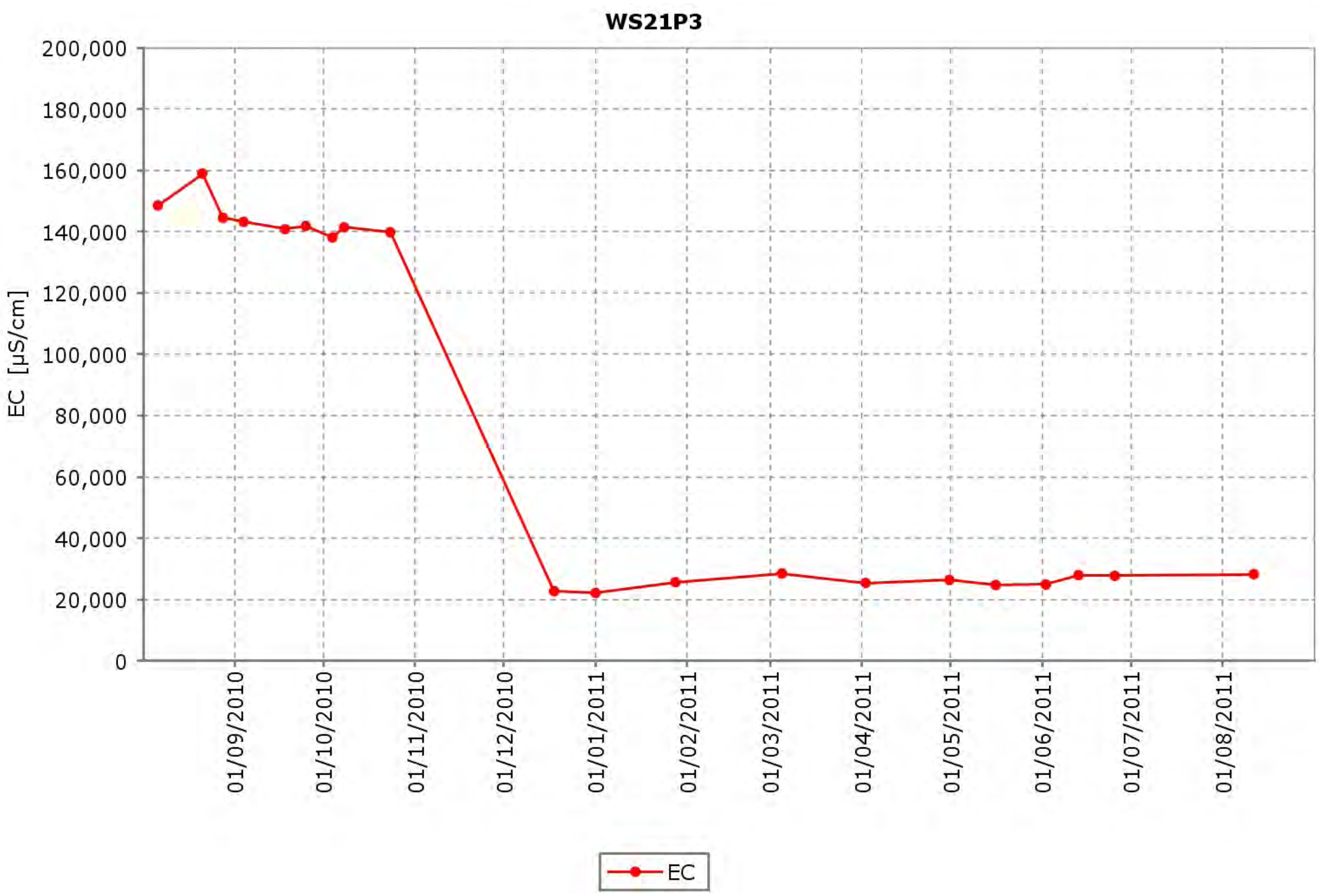

WS20P1 - mAHd and Total Abstraction
Water Level mAHD [m]
415
414
413
412
411
410
409
408
407
406
405
Pro Rata Monthly Abst [kL]
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
01/09/10
01/10/10
01/11/10
01/12/10
01/01/11
01/02/11
01/03/11
01/04/11
01/05/11
01/06/11
01/07/11
01/08/11
Water Level (Left)
Monthly Abstraction Volume (Right)

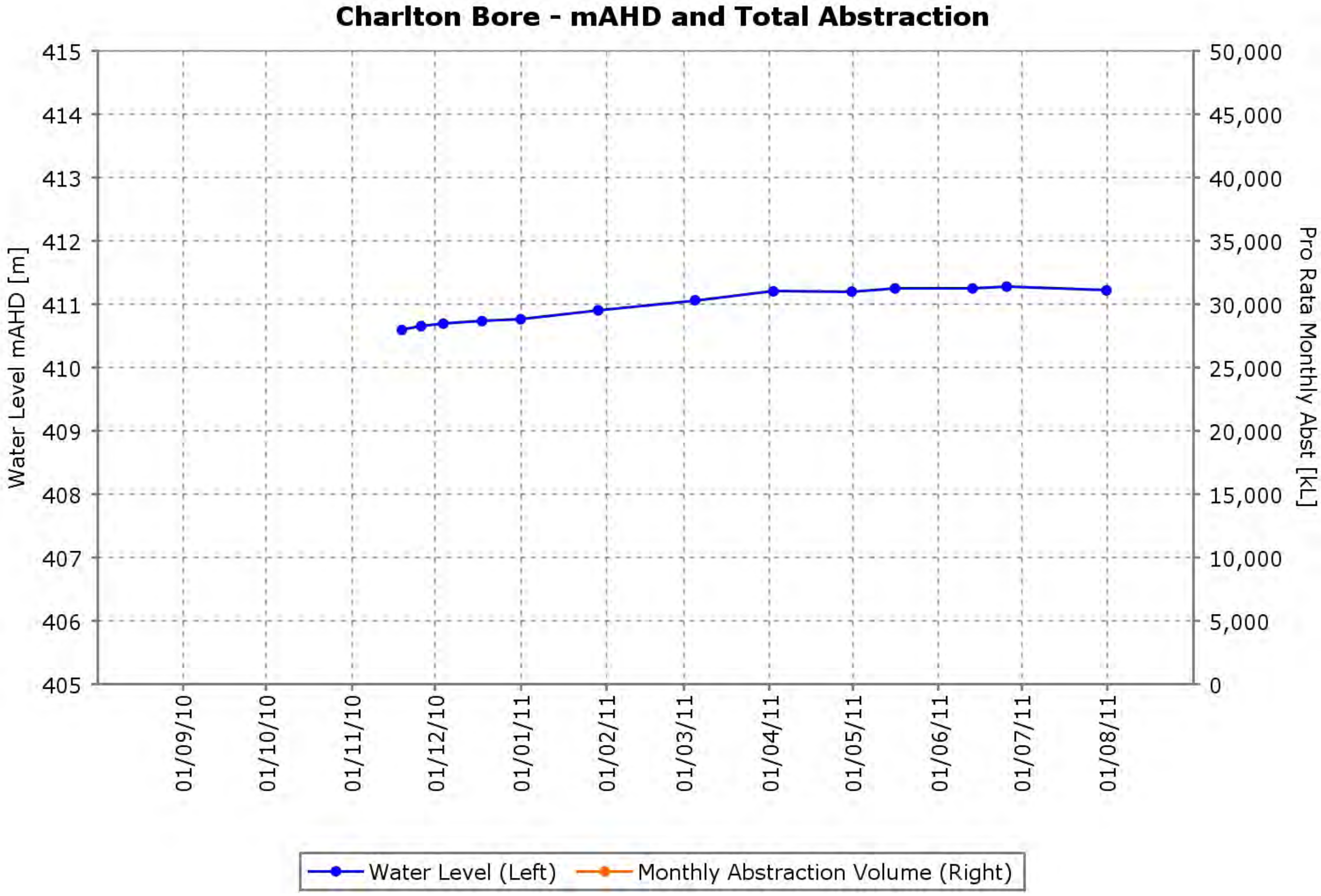

WS20P1
EC [µS/cm]
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
EC

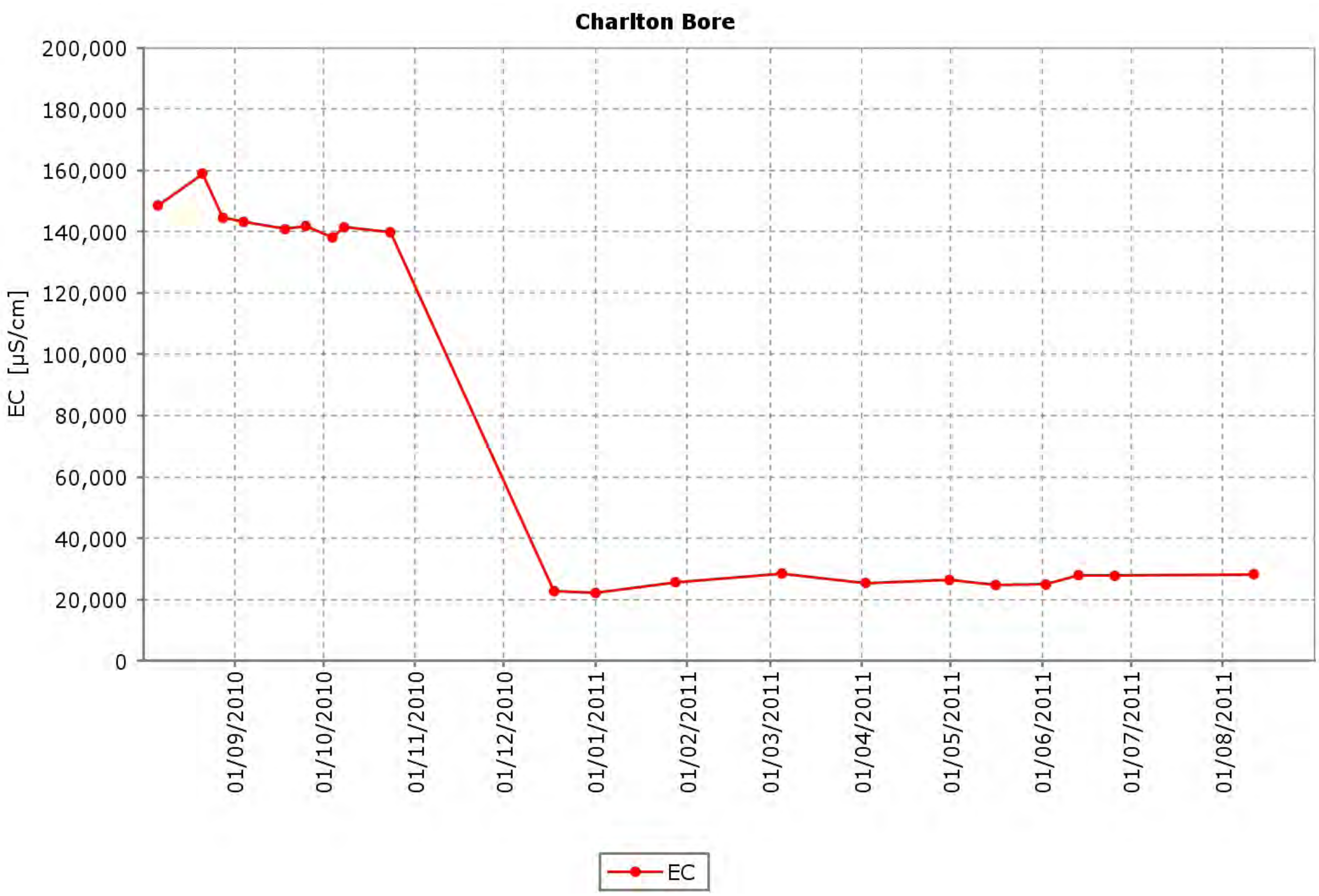

WS21P1 - mAHD and Total Abstraction
Water Level mAHD [m]
Pro Rata Monthly Abst [kL]
410
409
408
407
406
405
404
403
402
401
400
399
398
397
396
395
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
01/09/10
01/10/10
01/11/10
01/12/10
01/01/11
01/02/11
01/03/11
01/04/11
01/05/11
01/06/11
01/07/11
01/08/11
Water Level (Left)
Monthly Abstraction Volume (Right)

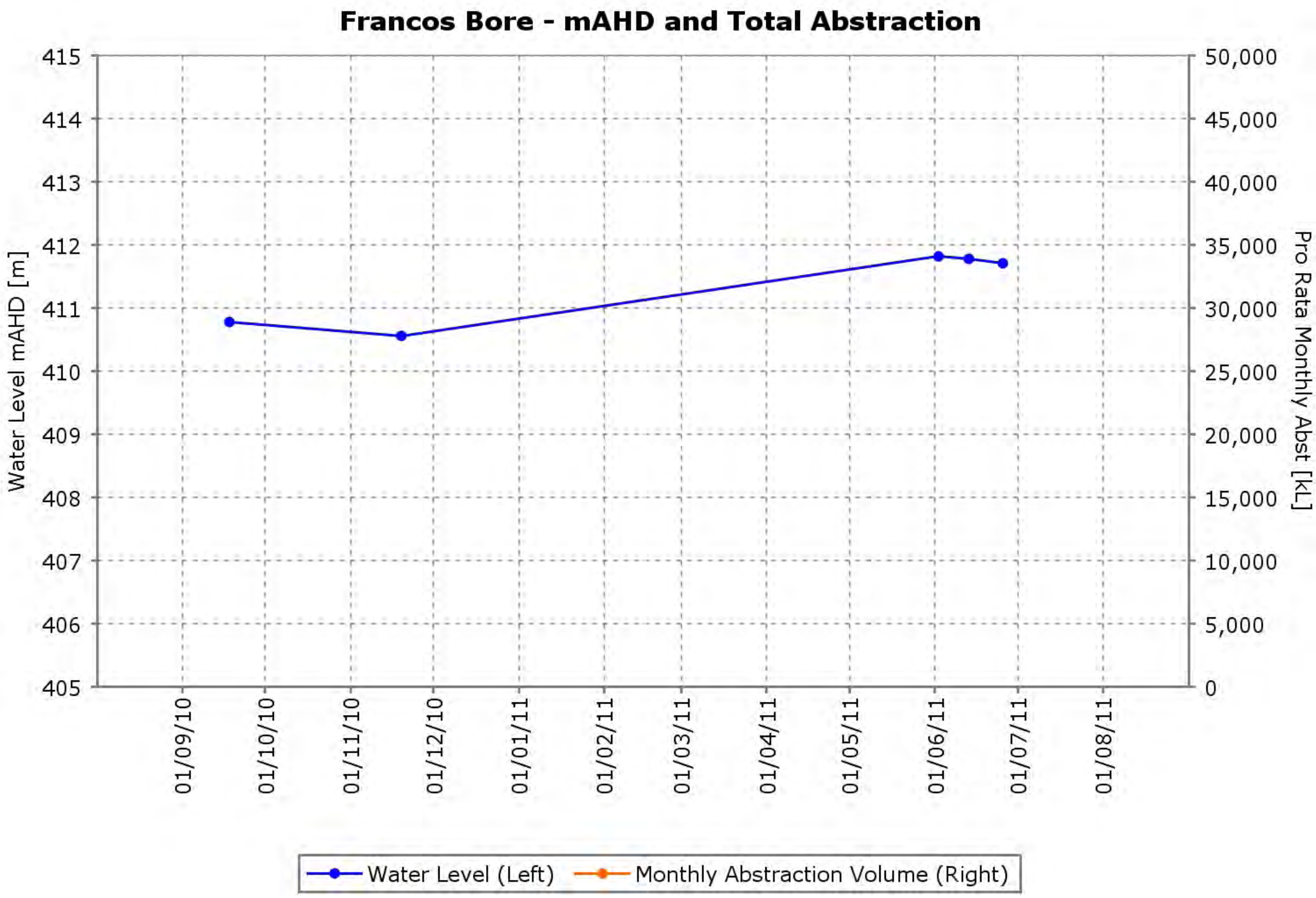

WS21P1
EC [µS/cm]
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
EC

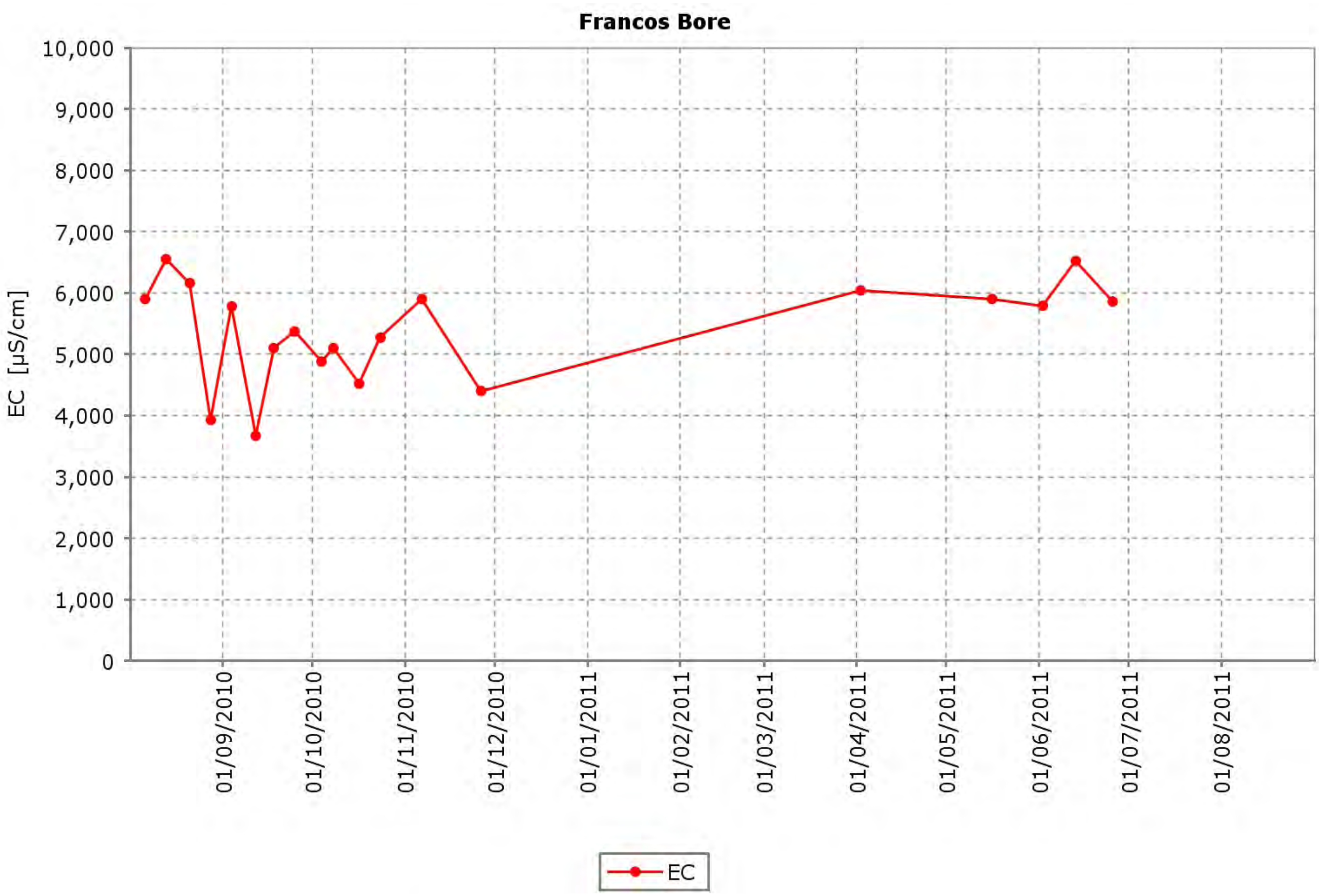

WS21P3 - mAHD and Total Abstraction
Water Level mAHD [m]
410
409
408
407
406
405
404
403
402
401
400
399
398
397
396
395
Pro Rata Monthly Abst [kL]
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
01/09/10
01/10/10
01/11/10
01/12/10
01/01/11
01/02/11
01/03/11
01/04/11
01/05/11
01/06/11
01/07/11
01/08/11
Water Level (Left)
Monthly Abstraction Volume (Right)


WS21P3
EC [µS/cm]
200,000
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
EC


Charlton Bore - mAHD and Total Abstraction
Water Level mAHD [m]
415
414
413
412
411
410
409
408
407
406
405
Pro Rata Monthly Abst [kL]
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
01/09/10
01/10/10
01/11/10
01/12/10
01/01/11
01/02/11
01/03/11
01/04/11
01/05/11
01/06/11
01/07/11
01/08/11
Water Level (Left)
Monthly Abstraction Volume (Right)

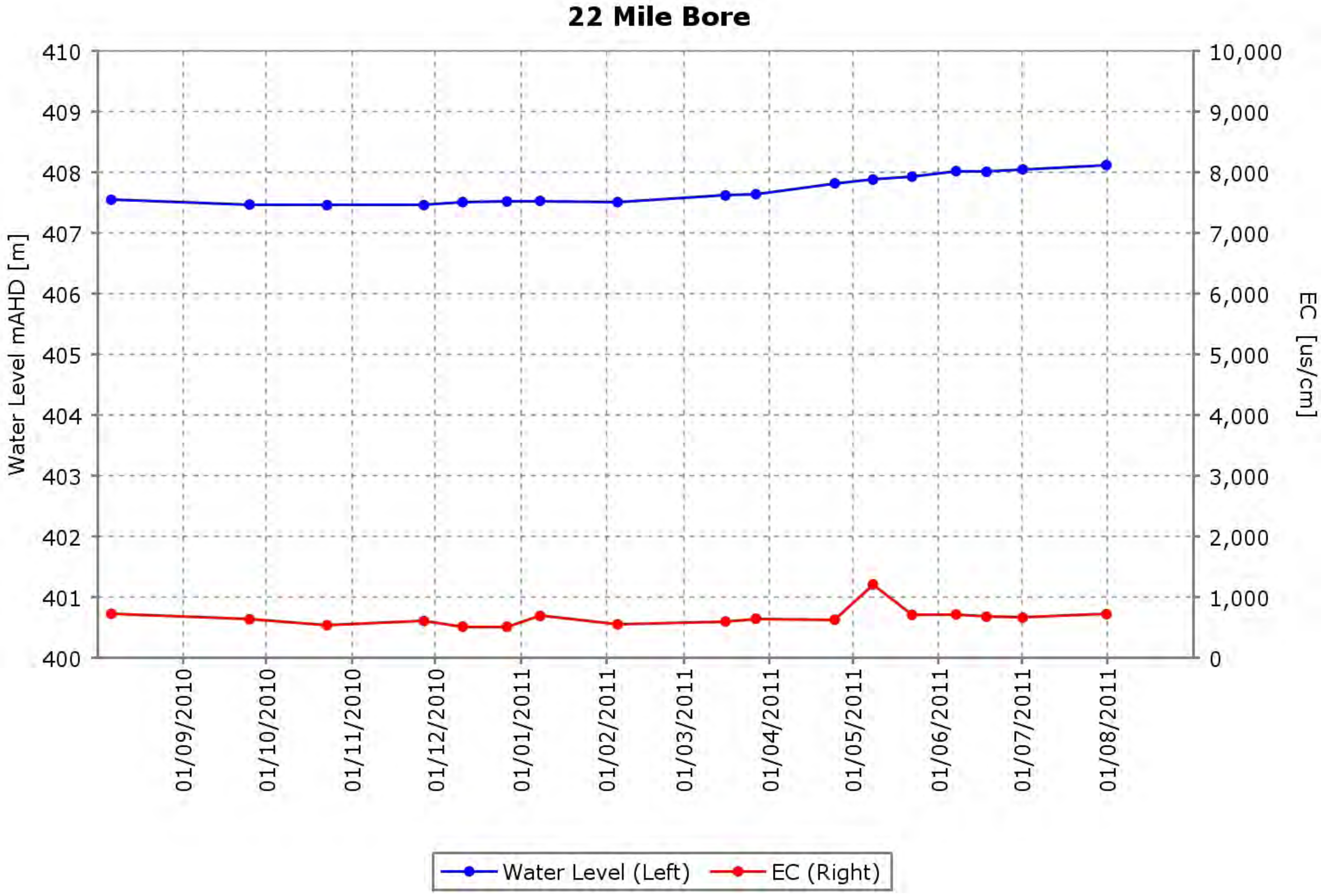

Charlton Bore
EC [µS/cm]
200,000
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
EC

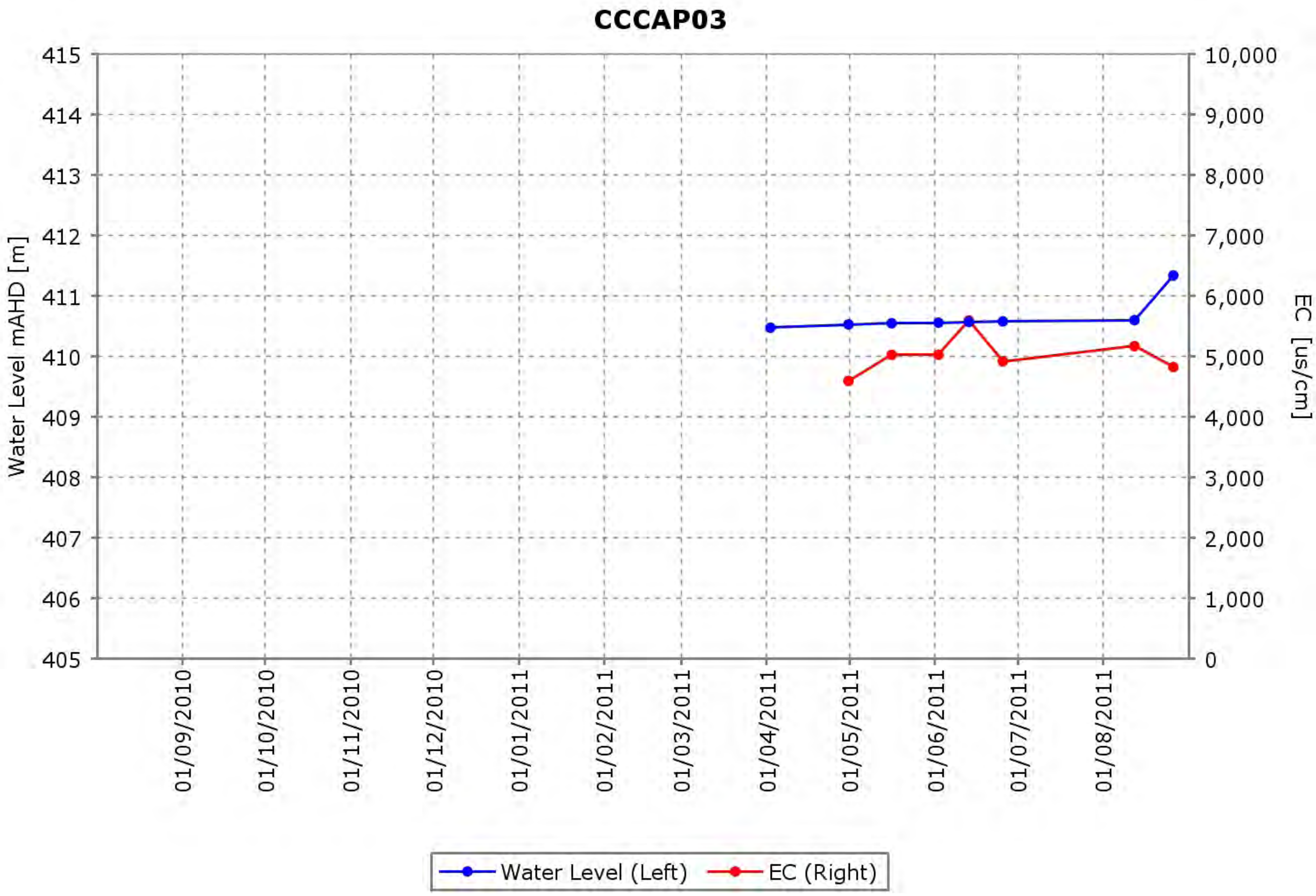

Francos Bore - mAHD and Total Abstraction
Water Level mAHD [m]
Pro Rata Monthly Abst [kL]
415
414
413
412
411
410
409
408
407
406
405
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
01/09/10
01/10/10
01/11/10
01/12/10
01/01/11
01/02/11
01/03/11
01/04/11
01/05/11
01/06/11
01/07/11
01/08/11
Water Level (Left)
Monthly Abstraction Volume (Right)

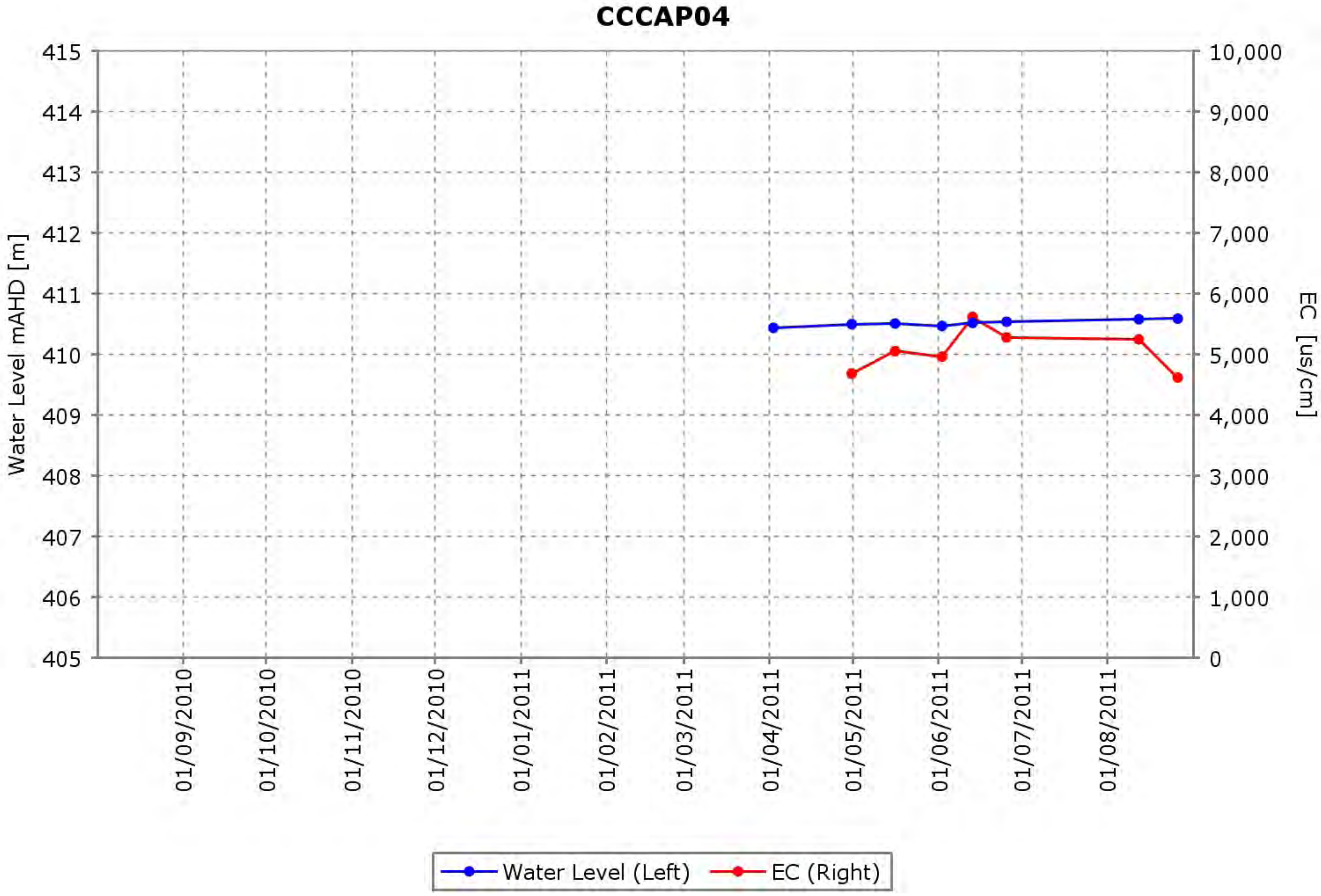

Francos Bore
EC [µS/cm]
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
EC

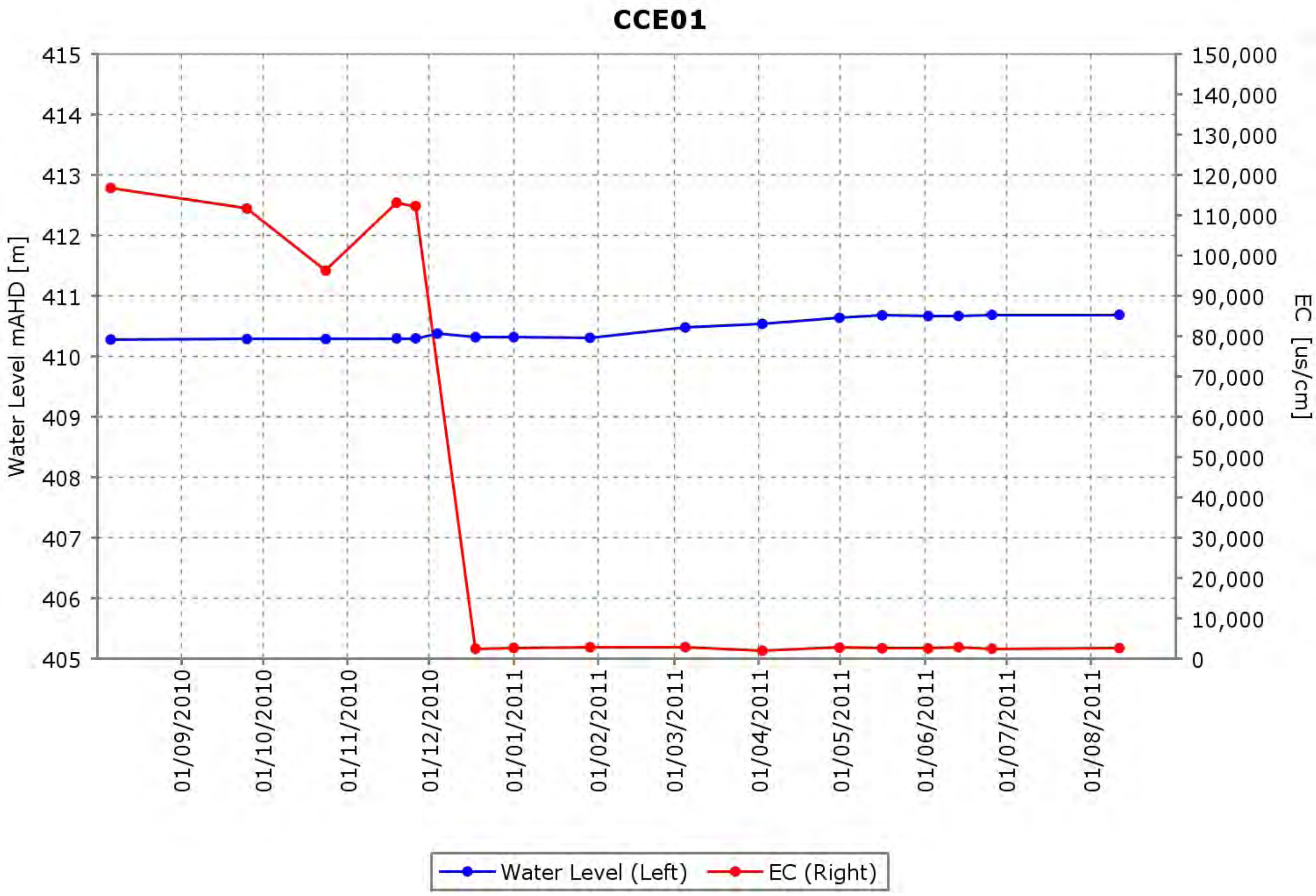
Appendix D

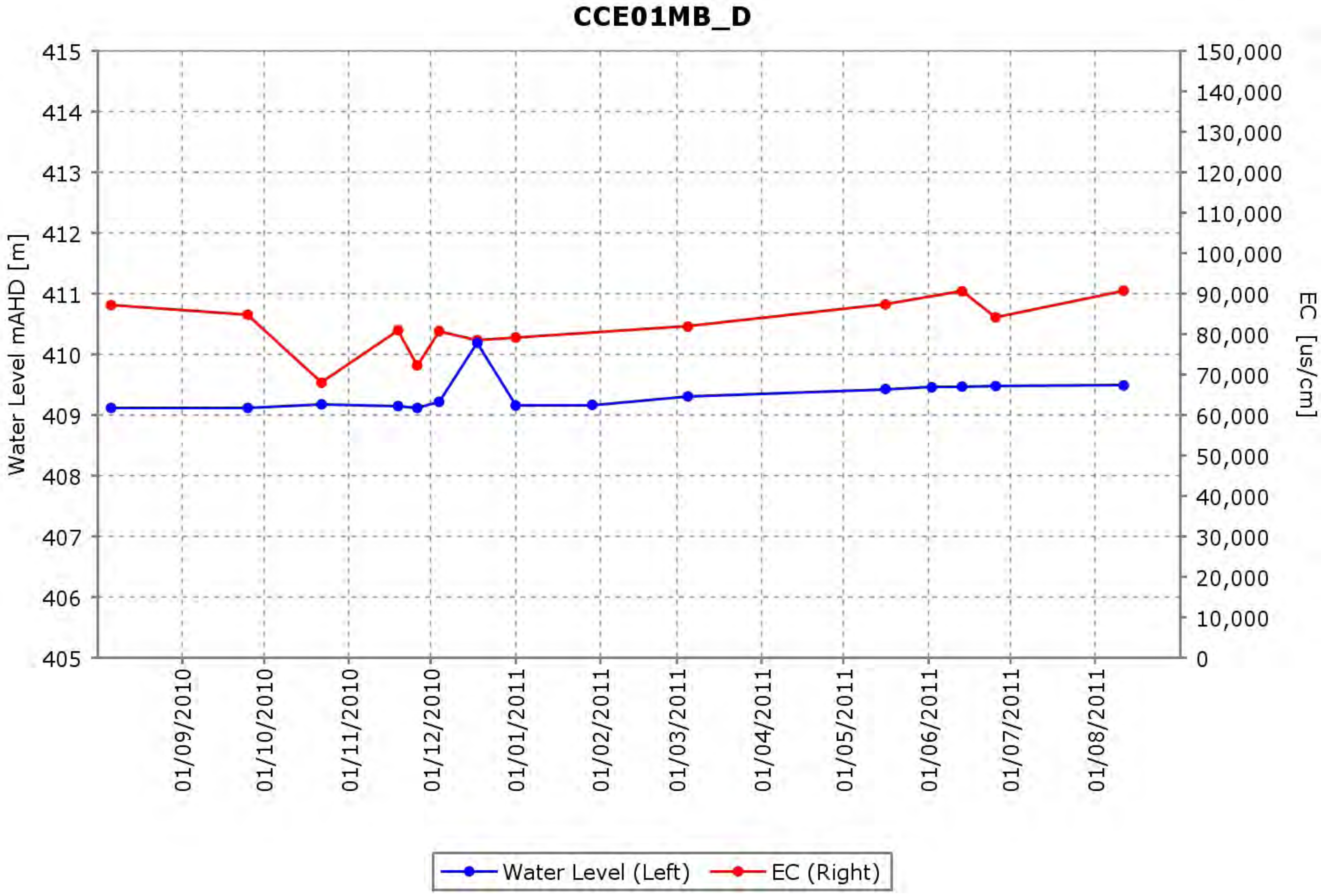
Graphs of groundwater level and electrical conductivity for monitored bores

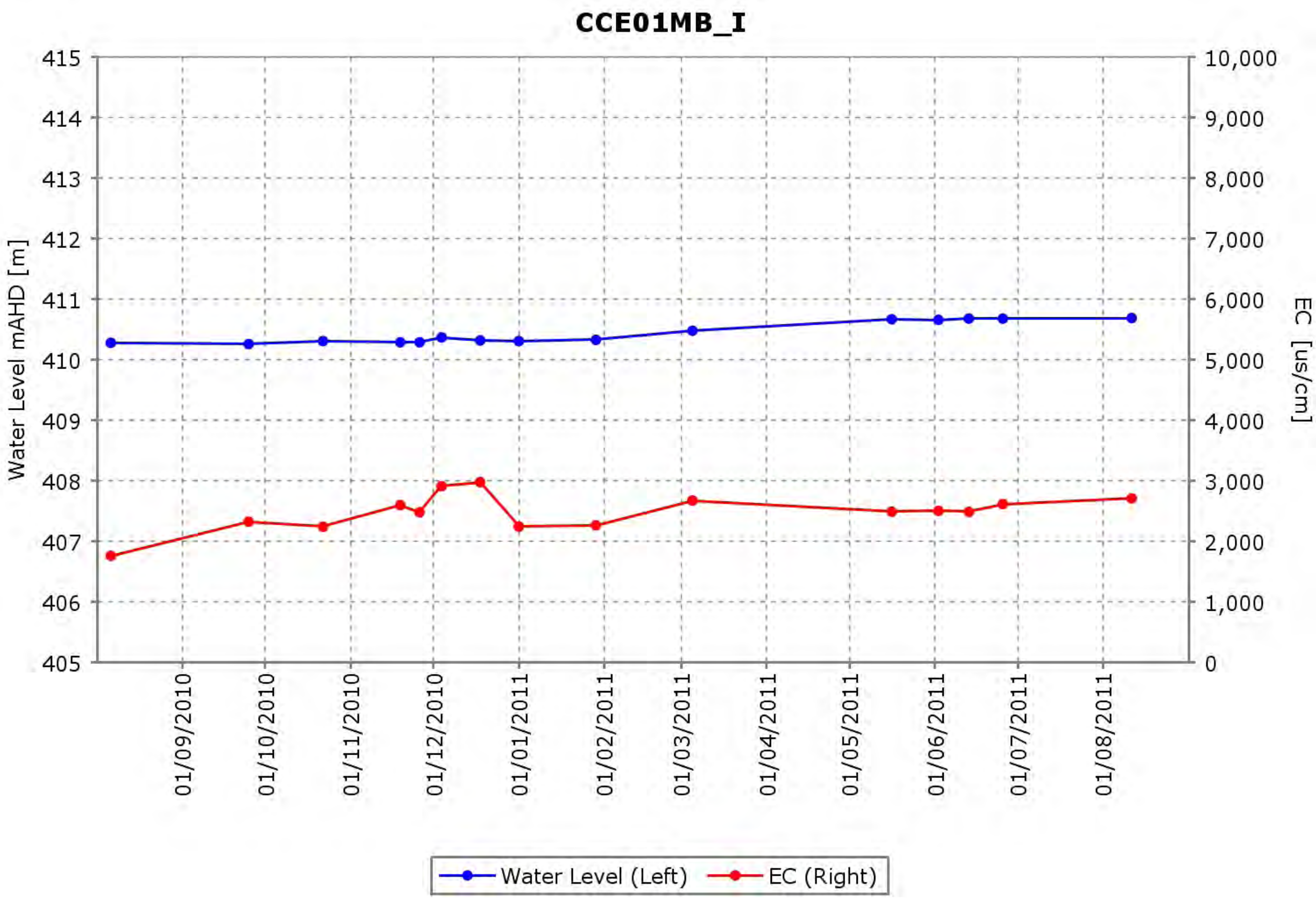

22 Mile Bore
Water Level mAHD [m]
EC [us/cm]
410
409
408
407
406
405
404
403
402
401
400
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

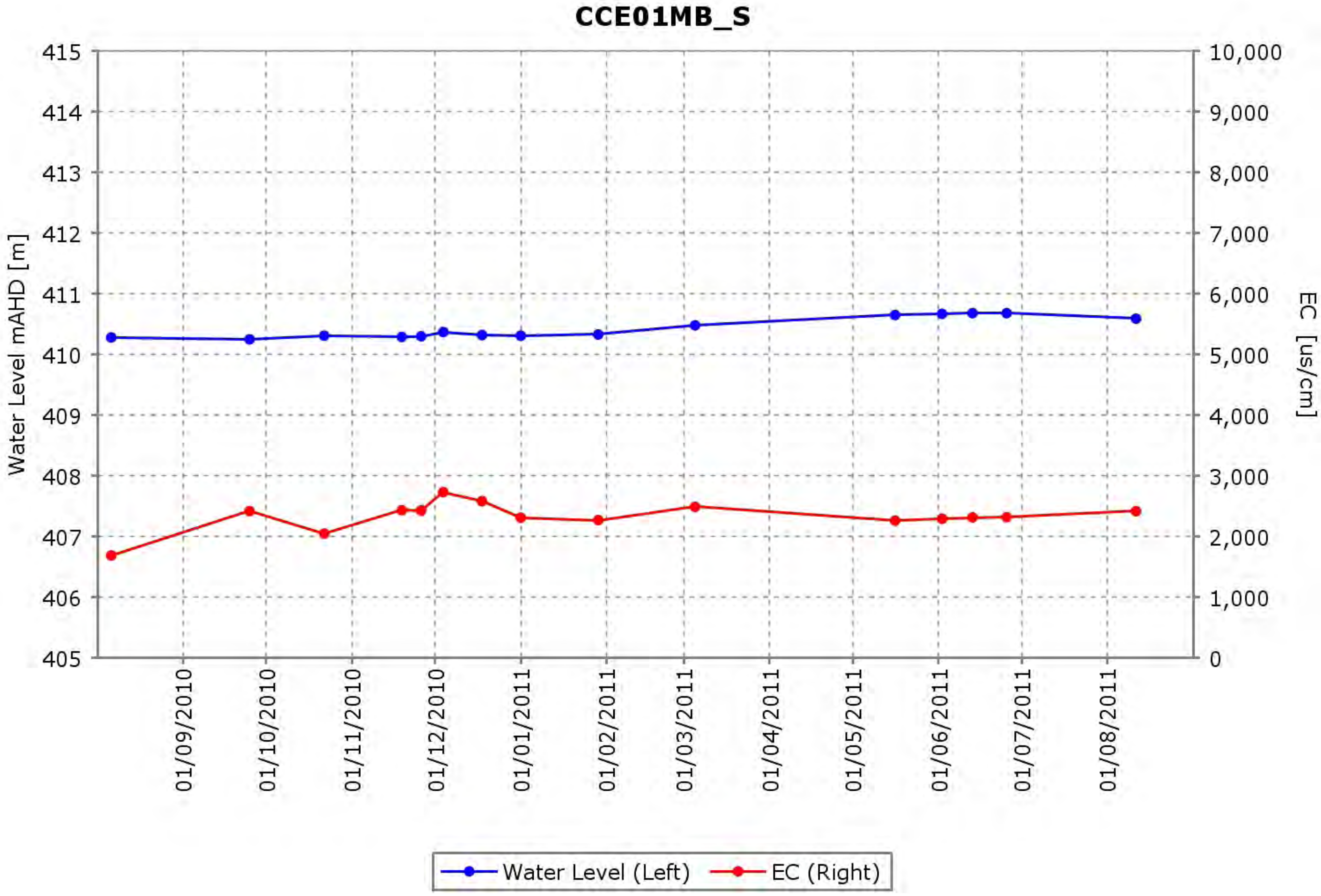

CCCAP03
Water Level mAHD [m]
EC [us/cm]
415
414
413
412
411
410
409
408
407
406
405
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

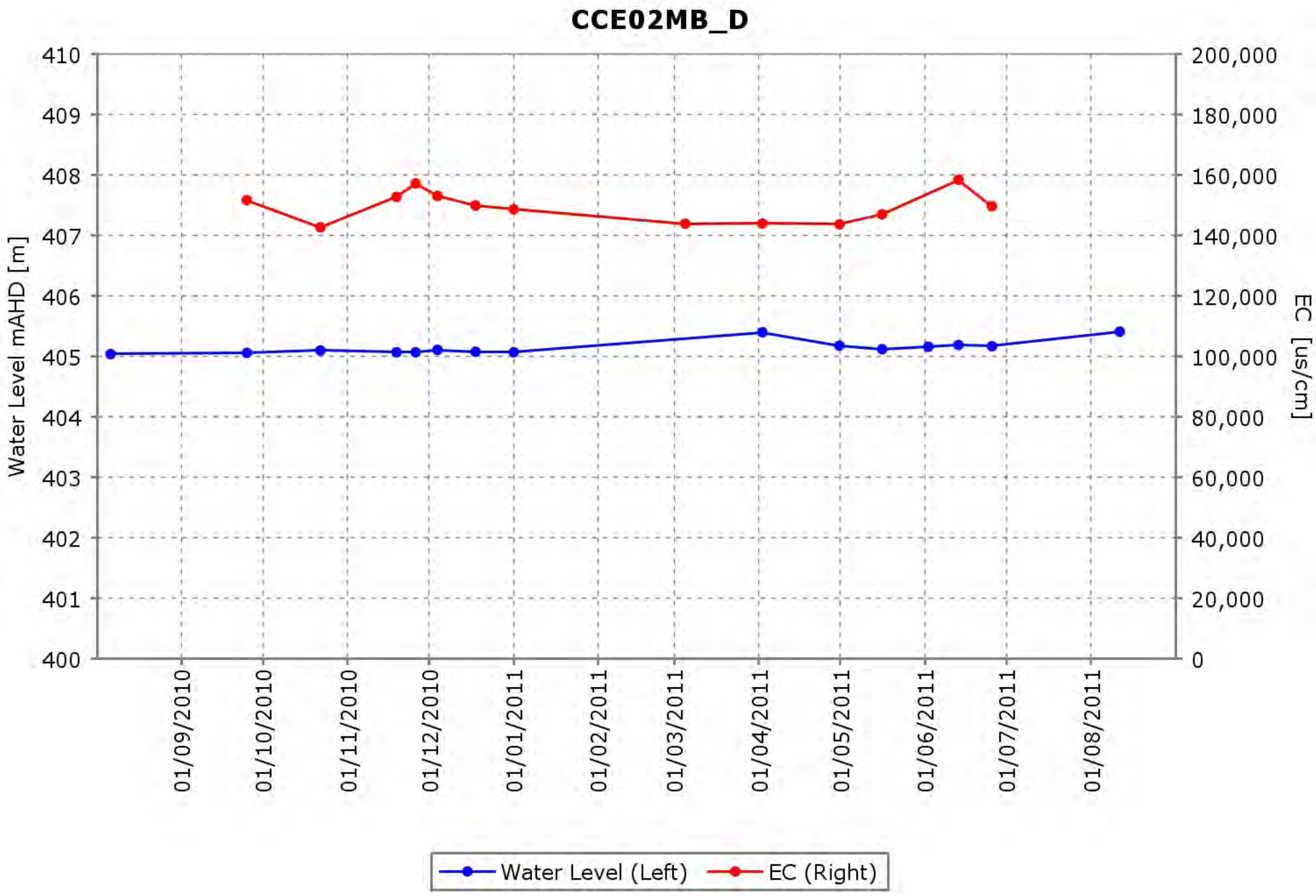

CCCAP04
Water Level mAHD [m]
415
414
413
412
411
410
409
408
407
406
405
EC [us/cm]
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

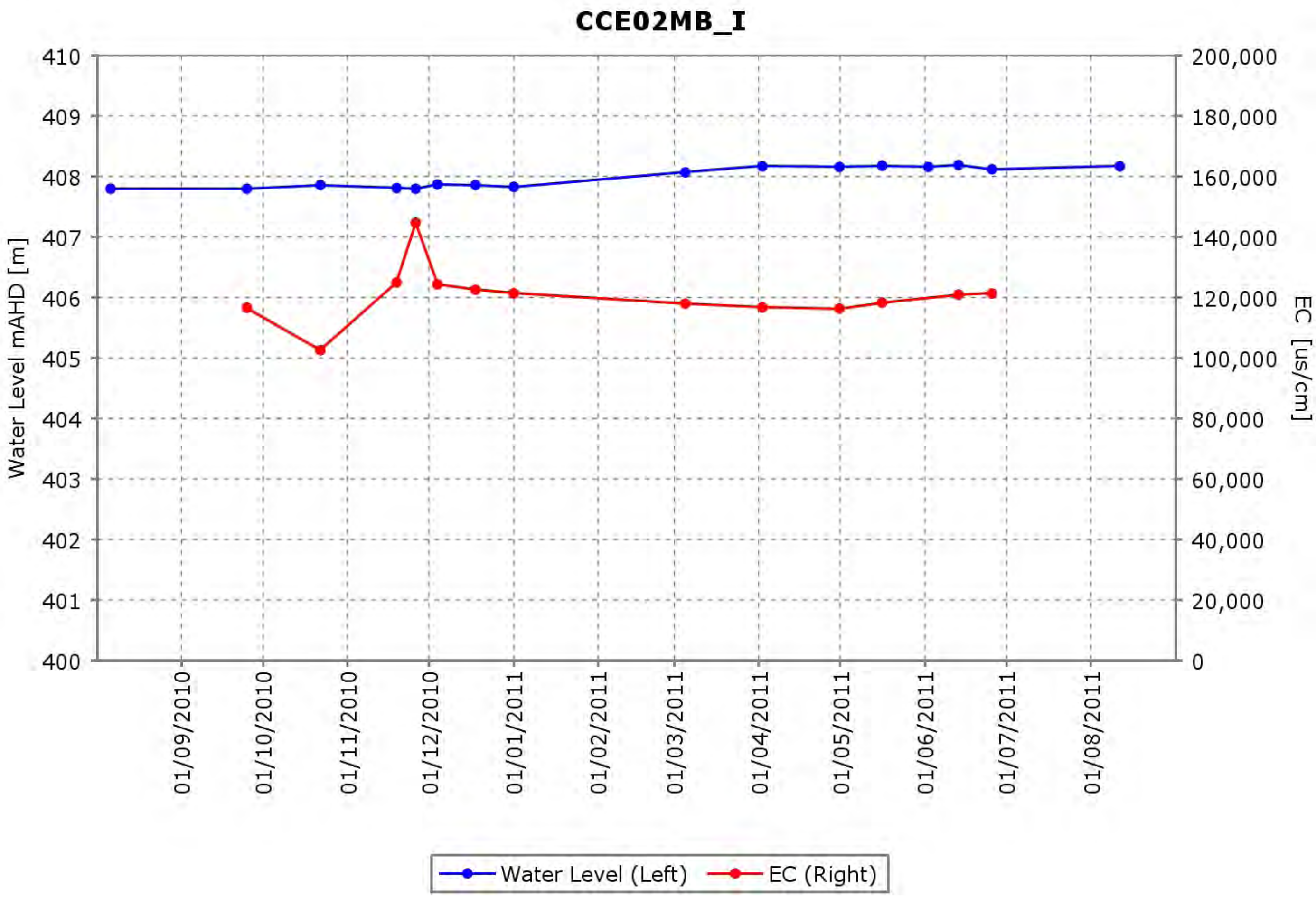

CCE01
Water Level mAHD [m]
415
414
413
412
411
410
409
408
407
406
405
EC [us/cm]
150,000
140,000
130,000
120,000
110,000
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

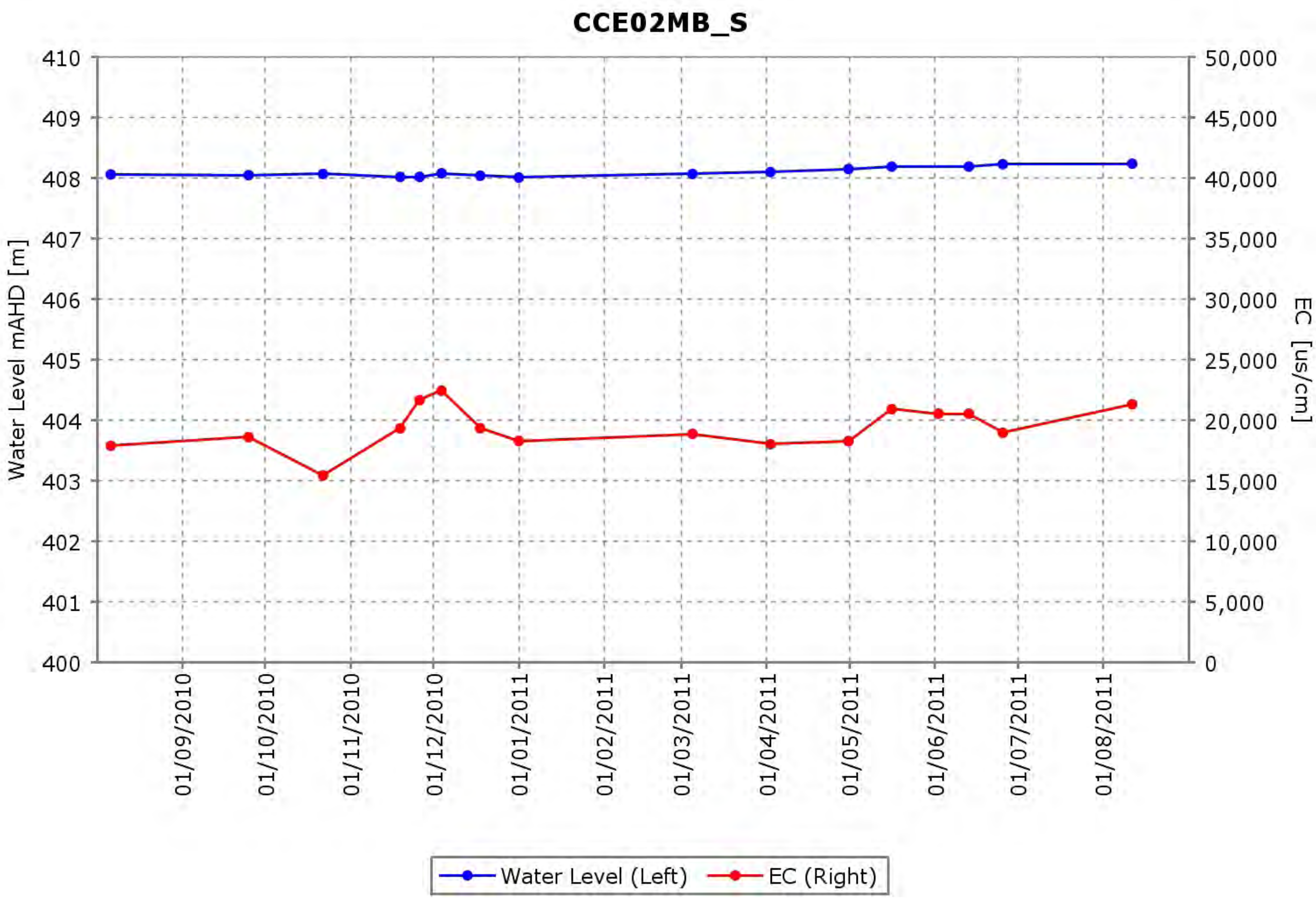

CCE01MB_D
Water Level mAHD [m]
EC [us/cm]
415
414
413
412
411
410
409
408
407
406
405
150,000
140,000
130,000
120,000
110,000
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

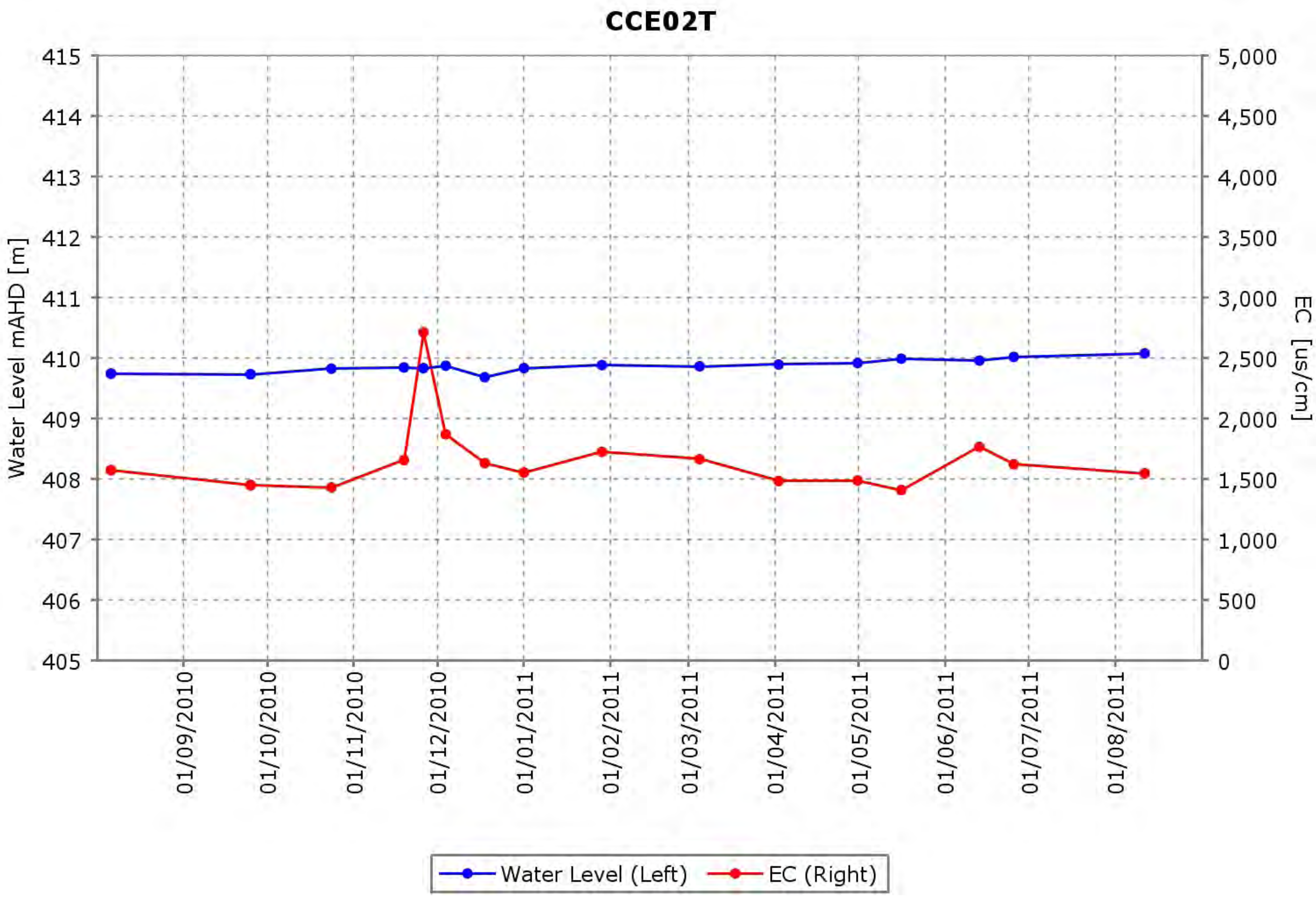

CCE01MB_I
Water Level mAHD [m]
EC [us/cm]
415
414
413
412
411
410
409
408
407
406
405
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

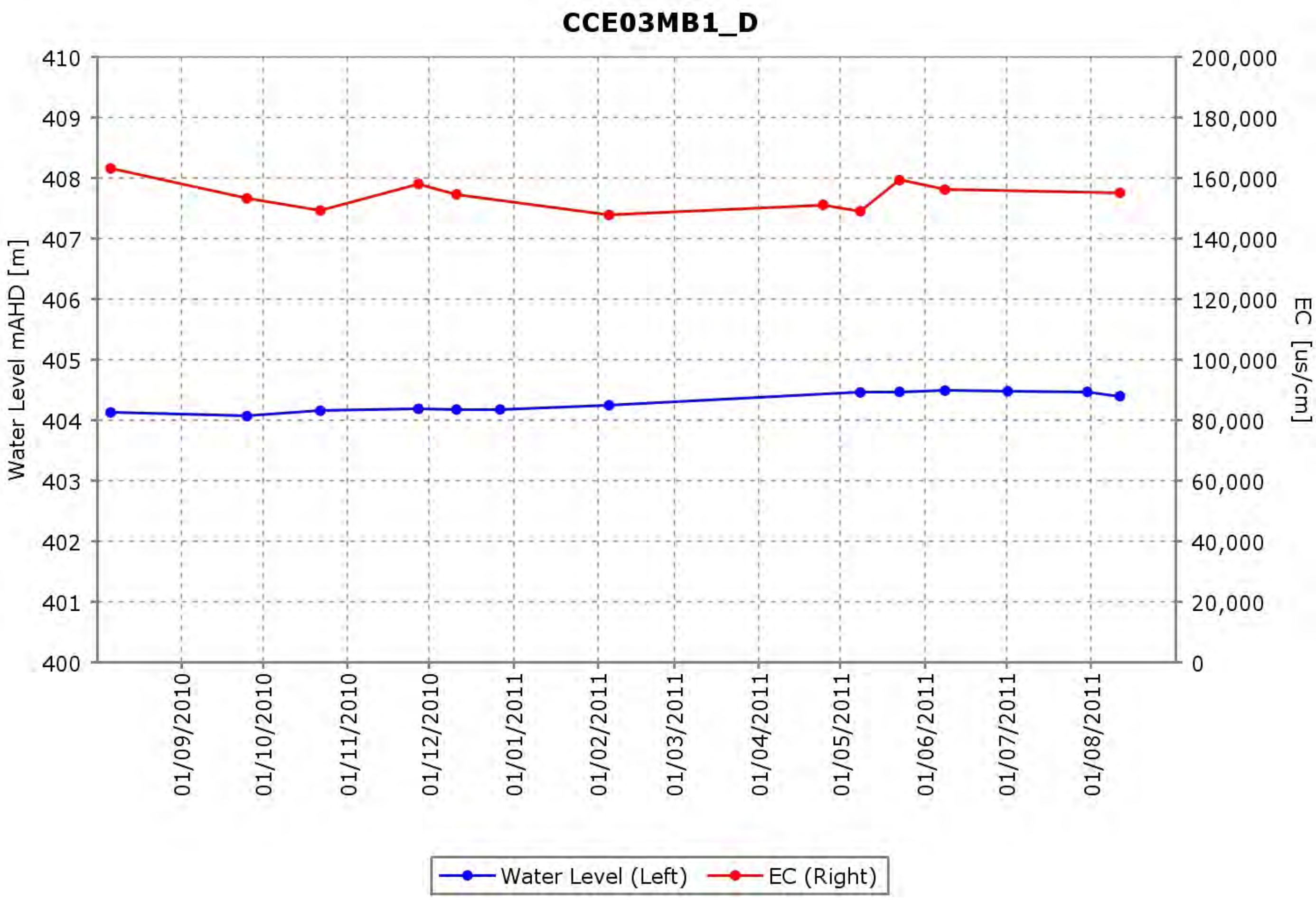

CCE01MB_S
Water Level mAHD [m]
EC [us/cm]
415
414
413
412
411
410
409
408
407
406
405
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

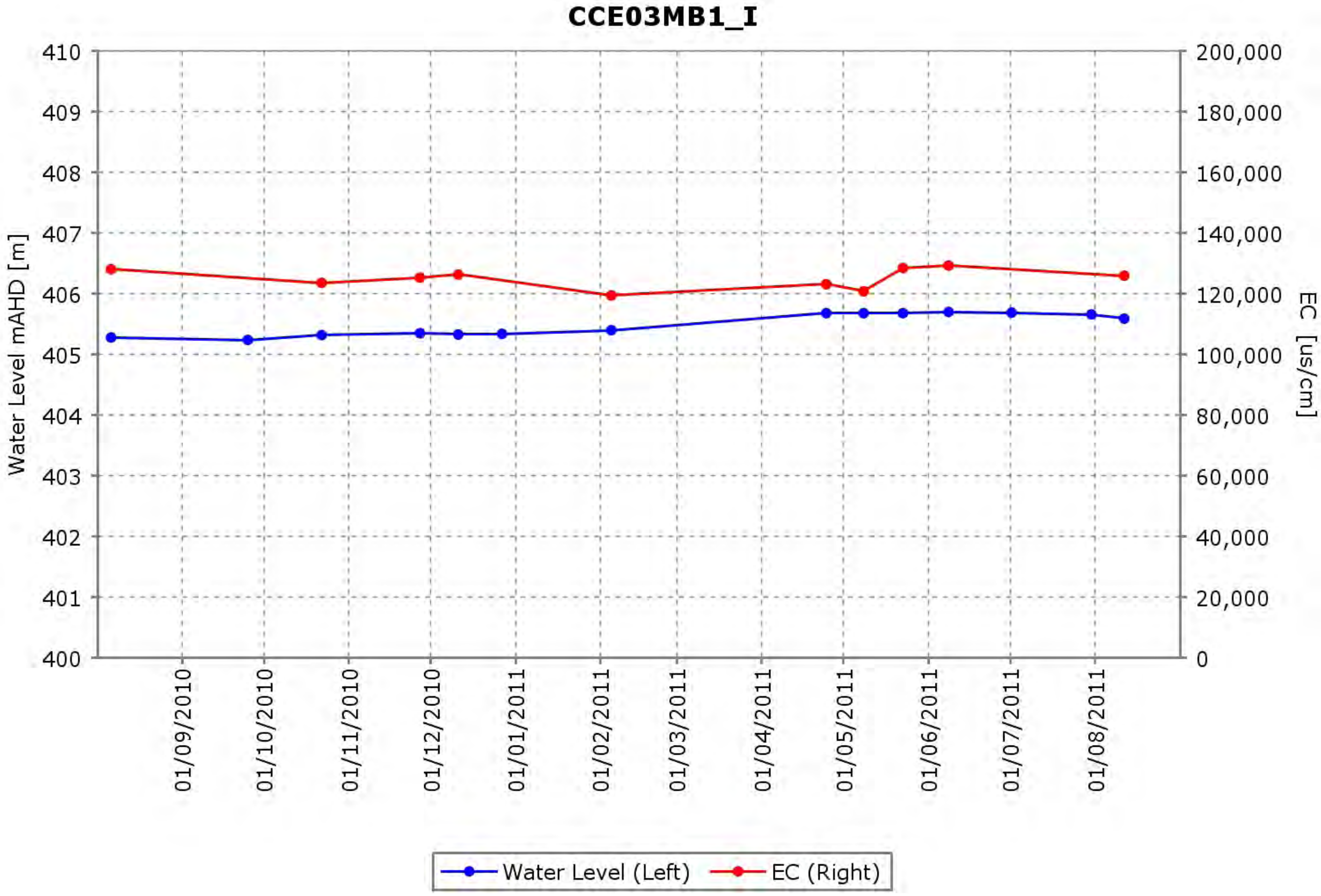

CCE02MB_D
Water Level mAHD [m]
EC [us/cm]
410
409
408
407
406
405
404
403
402
401
400
200,000
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

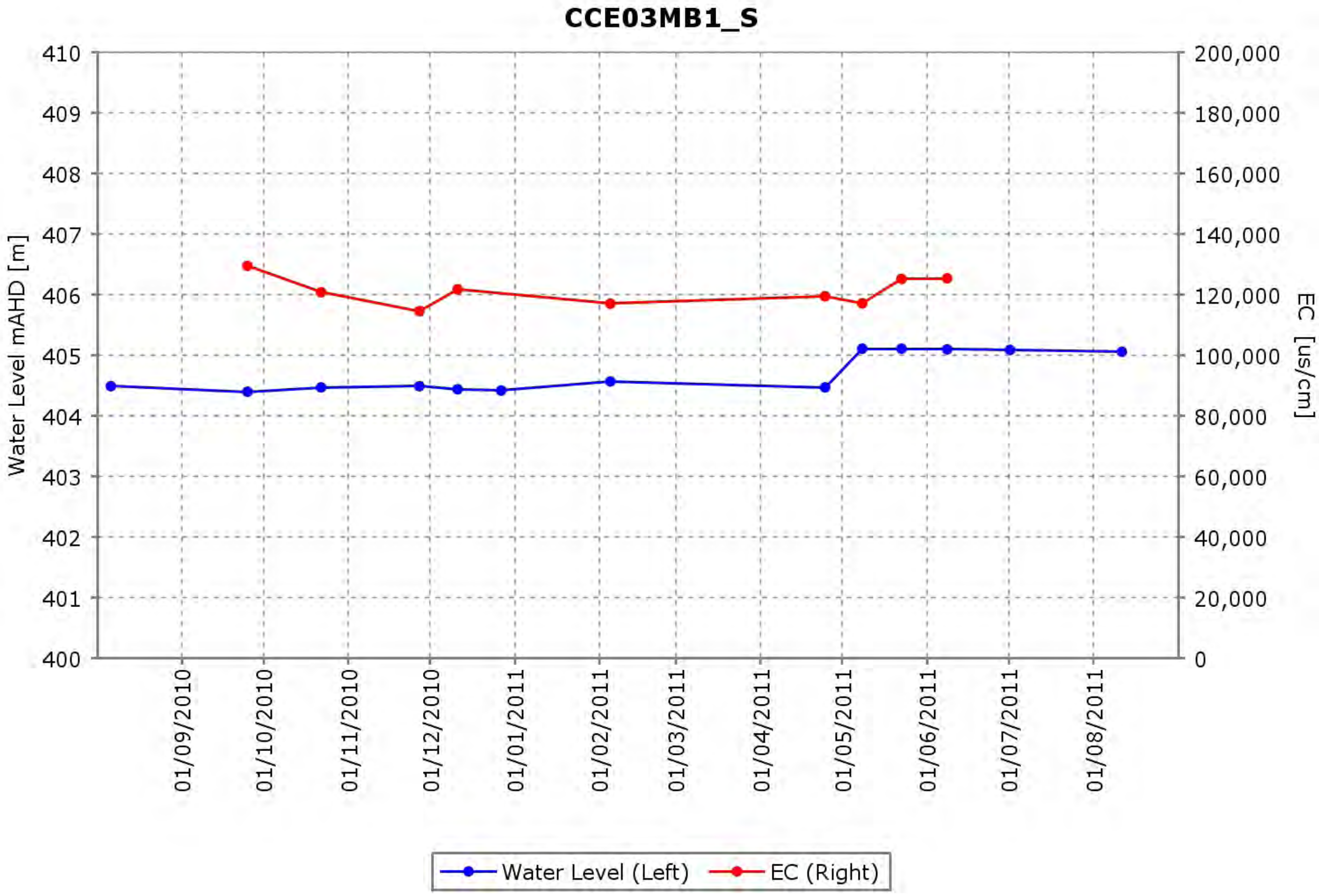

CCE02MB_I
Water Level mAHD [m]
EC [us/cm]
410
409
408
407
406
405
404
403
402
401
400
200,000
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

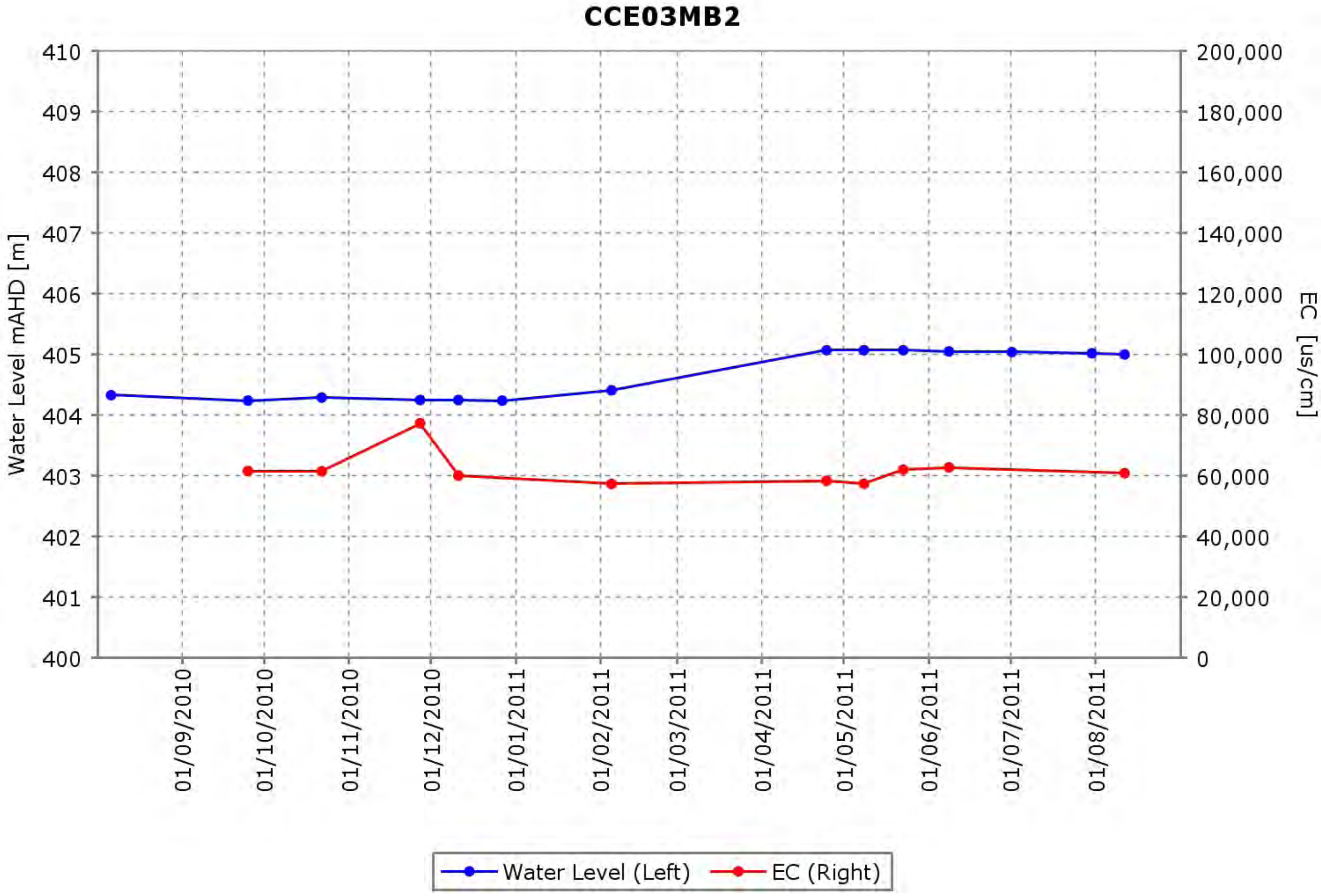

CCE02MB_S
Water Level mAHD [m]
EC [us/cm]
410
409
408
407
406
405
404
403
402
401
400
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

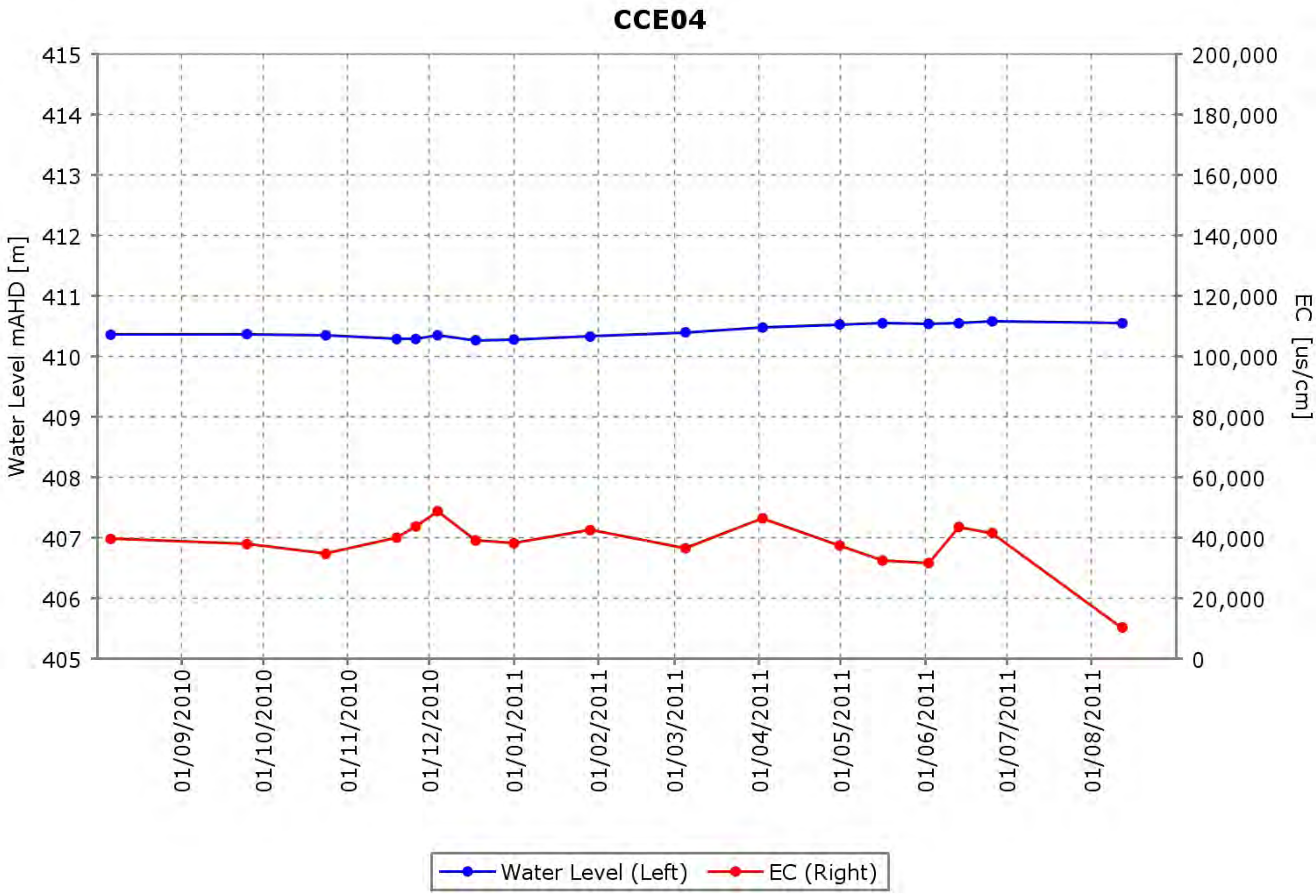

CCE02T
Water Level mAHD [m]
EC [us/cm]
415
414
413
412
411
410
409
408
407
406
405
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

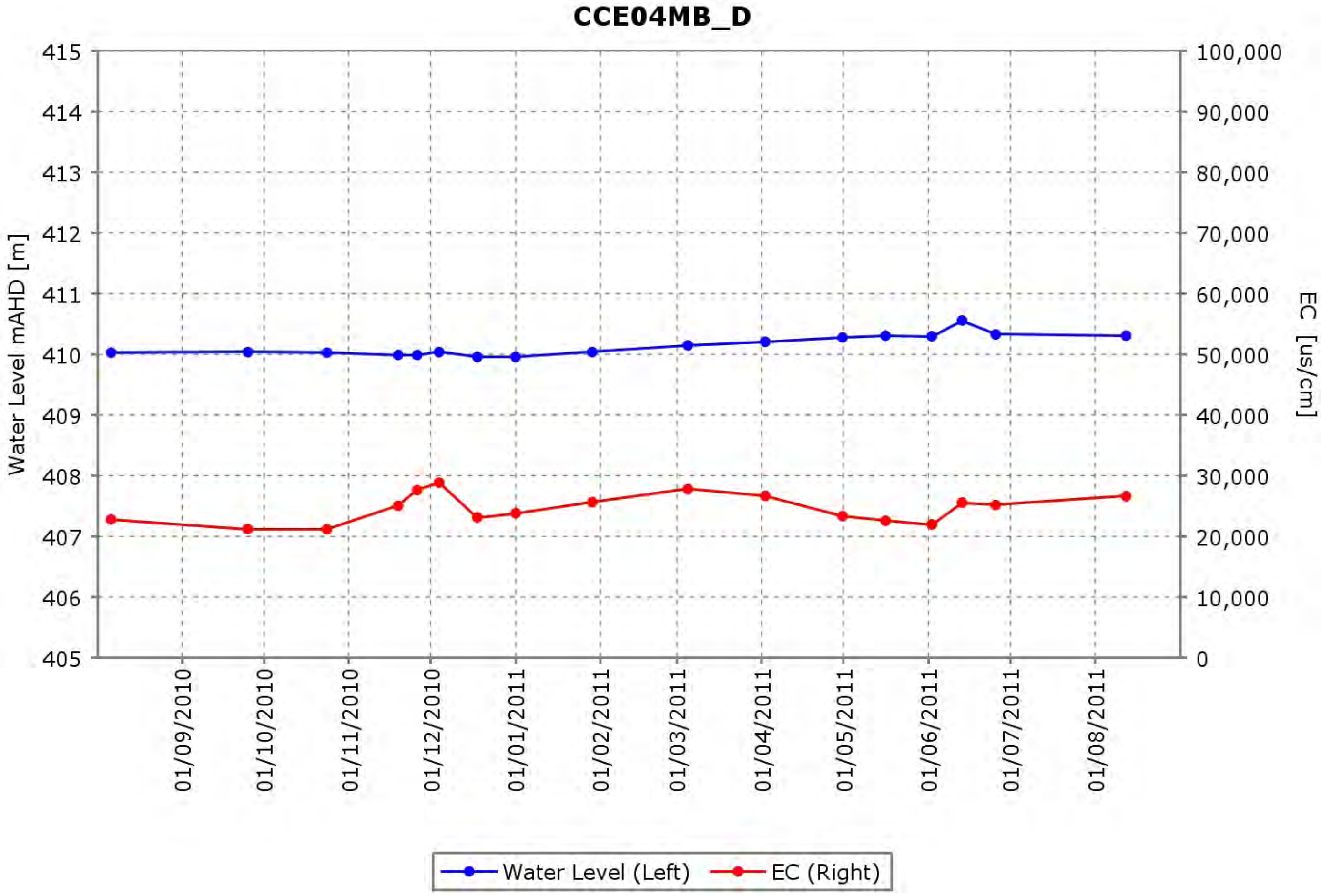

CCE03MB1_D
Water Level mAHD [m]
EC [us/cm]
410
409
408
407
406
405
404
403
402
401
400
200,000
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

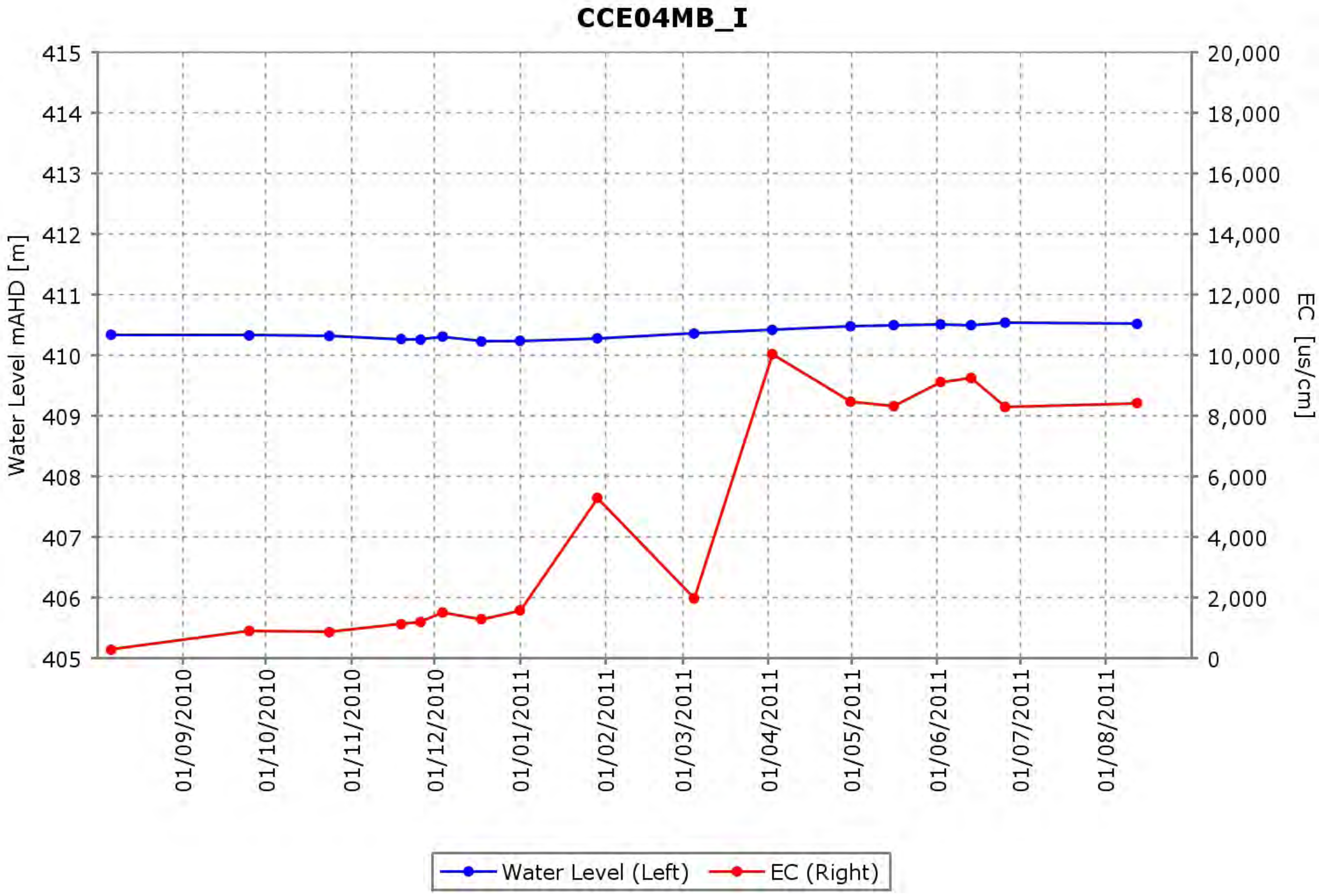

CCE03MB1_I
Water Level mAHD [m]
EC [us/cm]
410
409
408
407
406
405
404
403
402
401
400
200,000
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

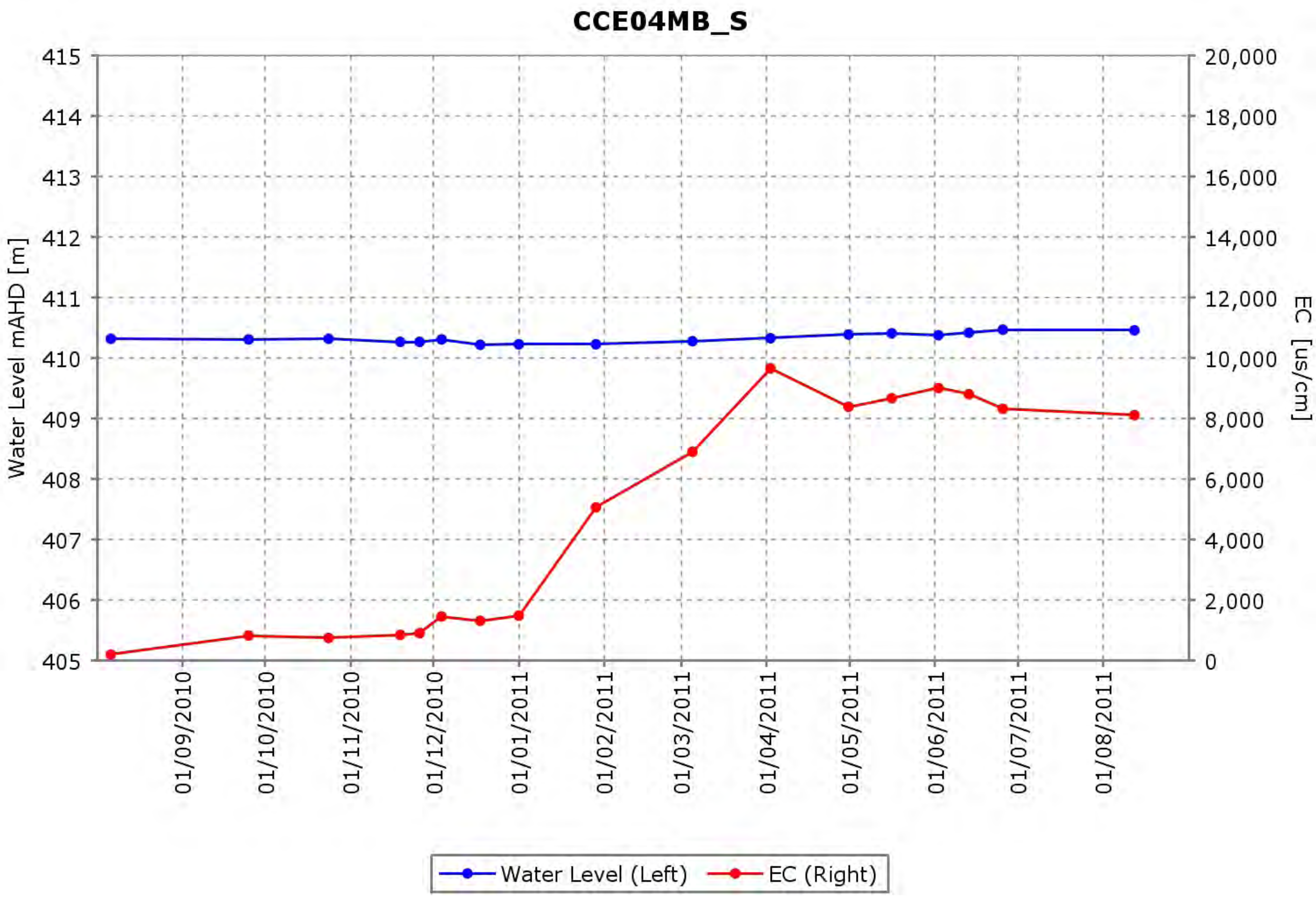

CCE03MB1_S
Water Level mAHD [m]
EC [us/cm]
410
409
408
407
406
405
404
403
402
401
400
200,000
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

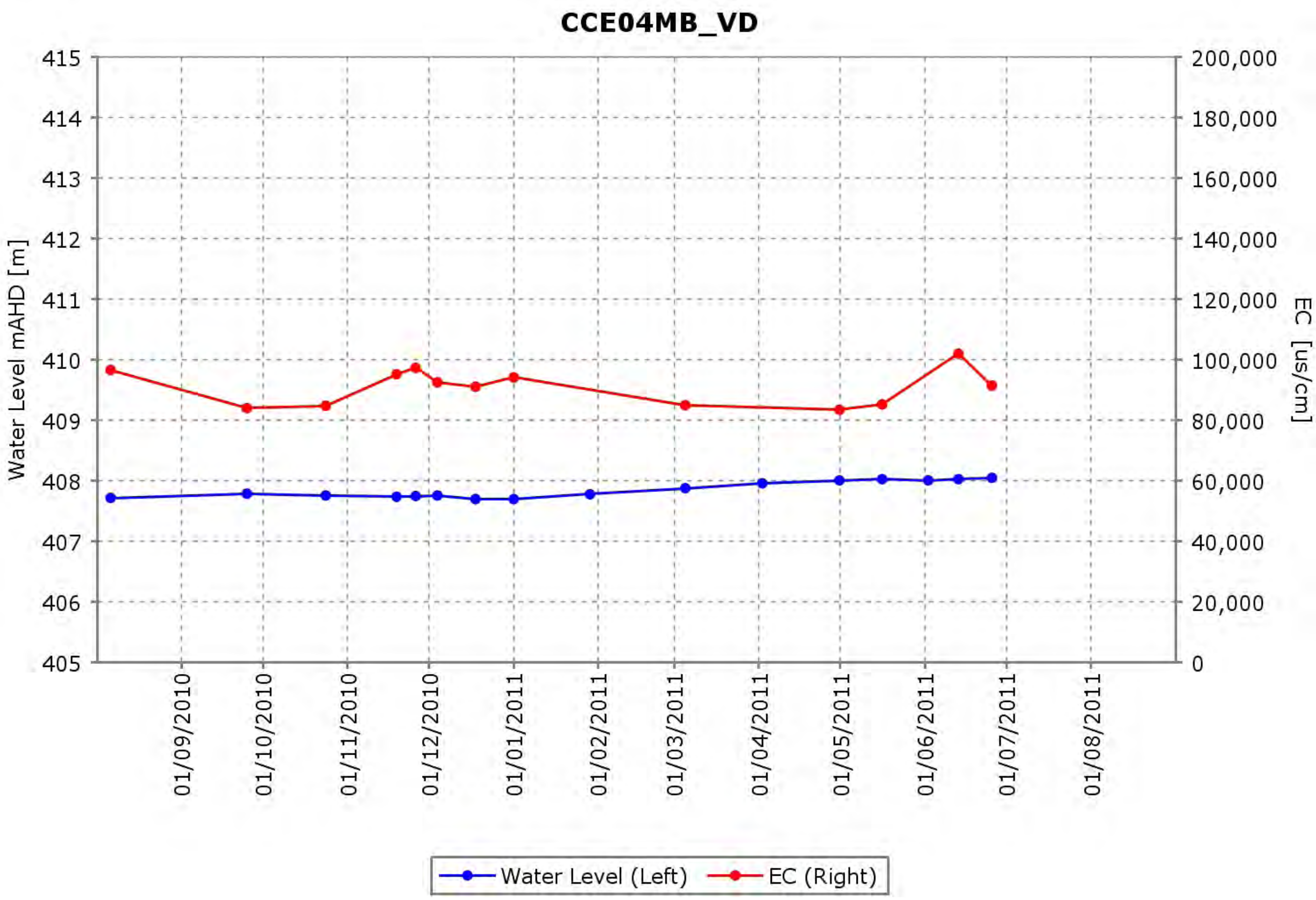

CCE03MB2
Water Level mAHD [m]
EC [us/cm]
410
409
408
407
406
405
404
403
402
401
400
200,000
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

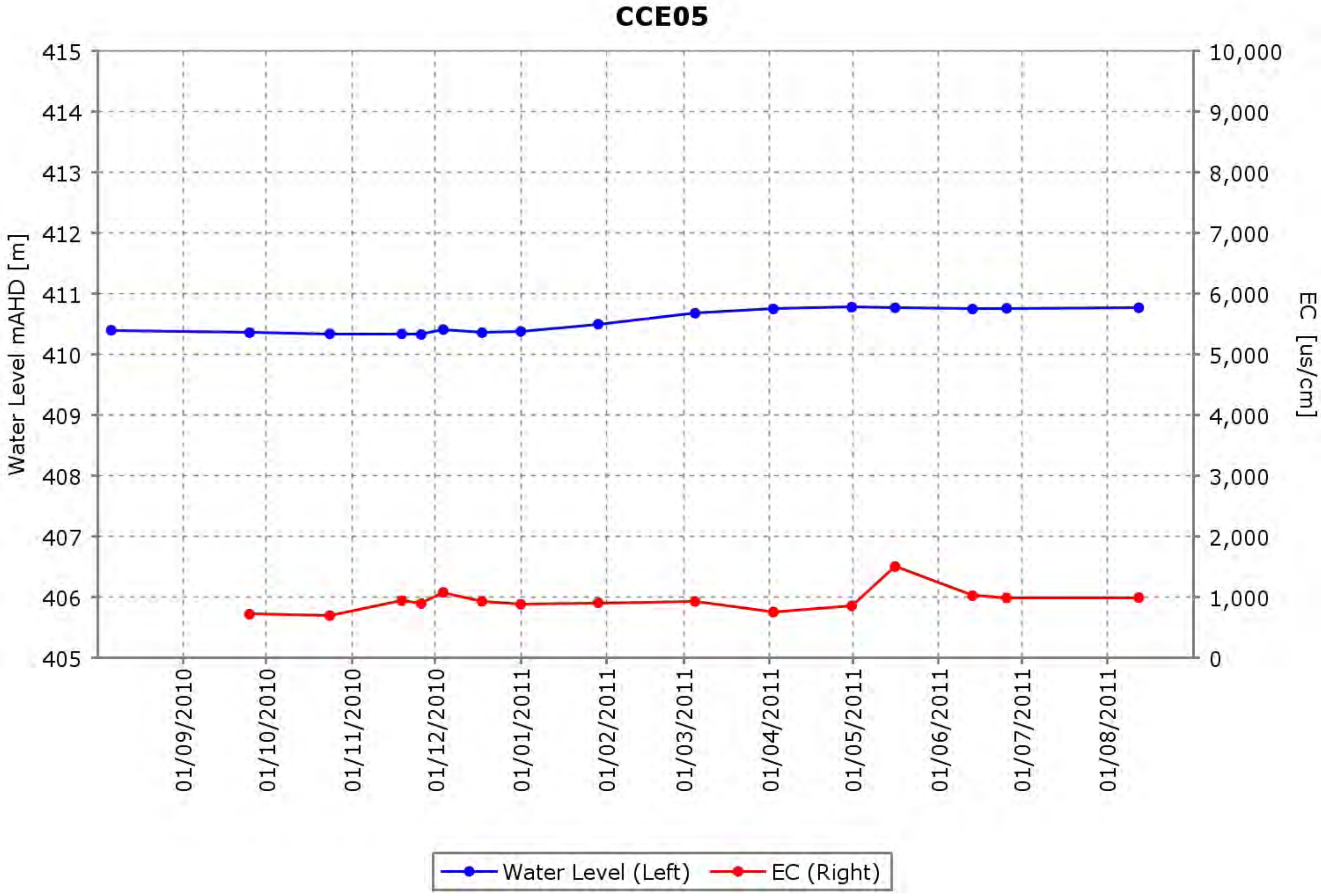

CCE04
Water Level mAHD [m]
EC [us/cm]
415
414
413
412
411
410
409
408
407
406
405
200,000
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

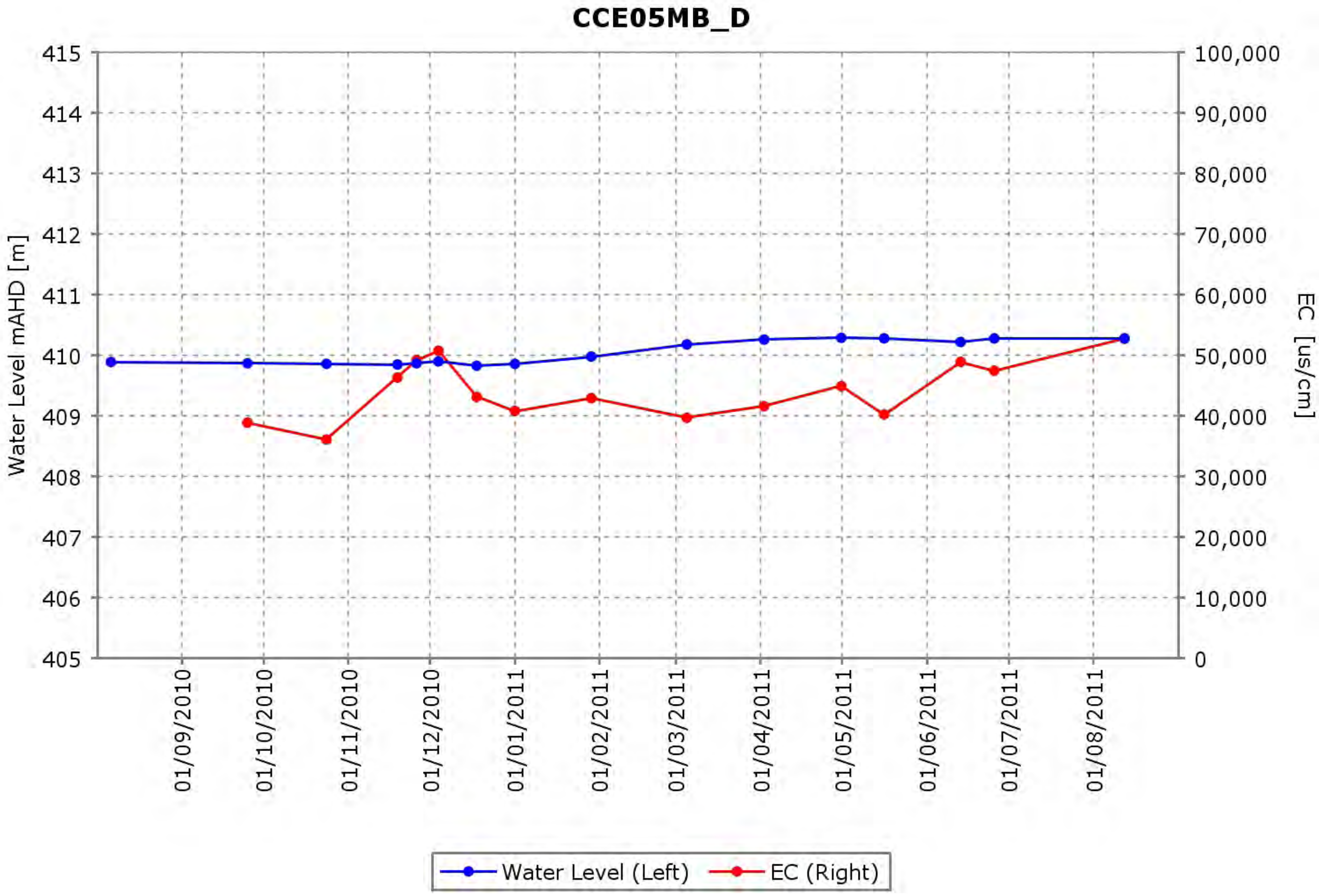

CCE04MB_D
Water Level mAHD [m]
EC [us/cm]
415
414
413
412
411
410
409
408
407
406
405
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

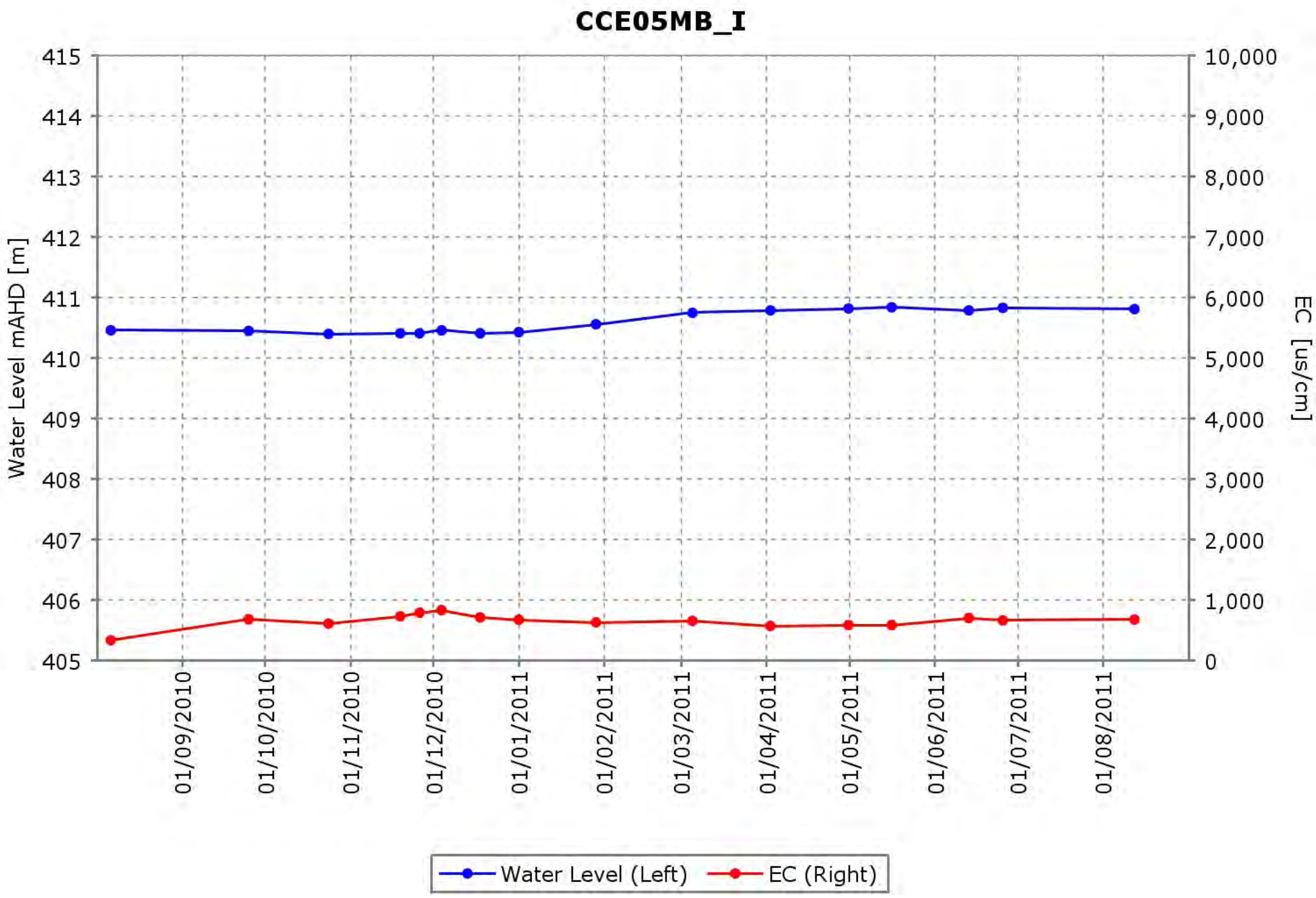

CCE04MB_I
Water Level mAHD [m]
EC [us/cm]
415
414
413
412
411
410
409
408
407
406
405
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

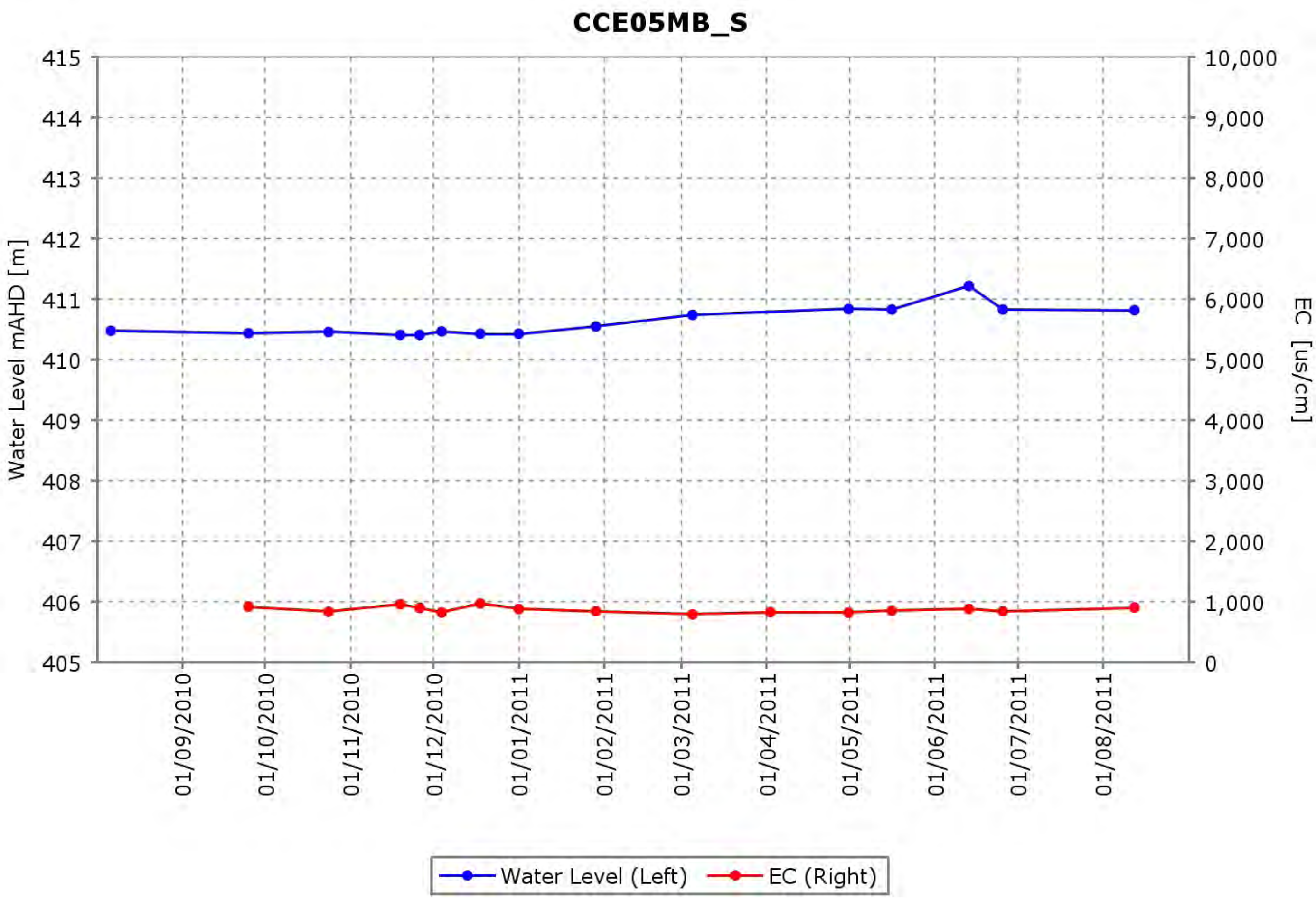

CCE04MB_S
Water Level mAHD [m]
EC [us/cm]
415
414
413
412
411
410
409
408
407
406
405
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

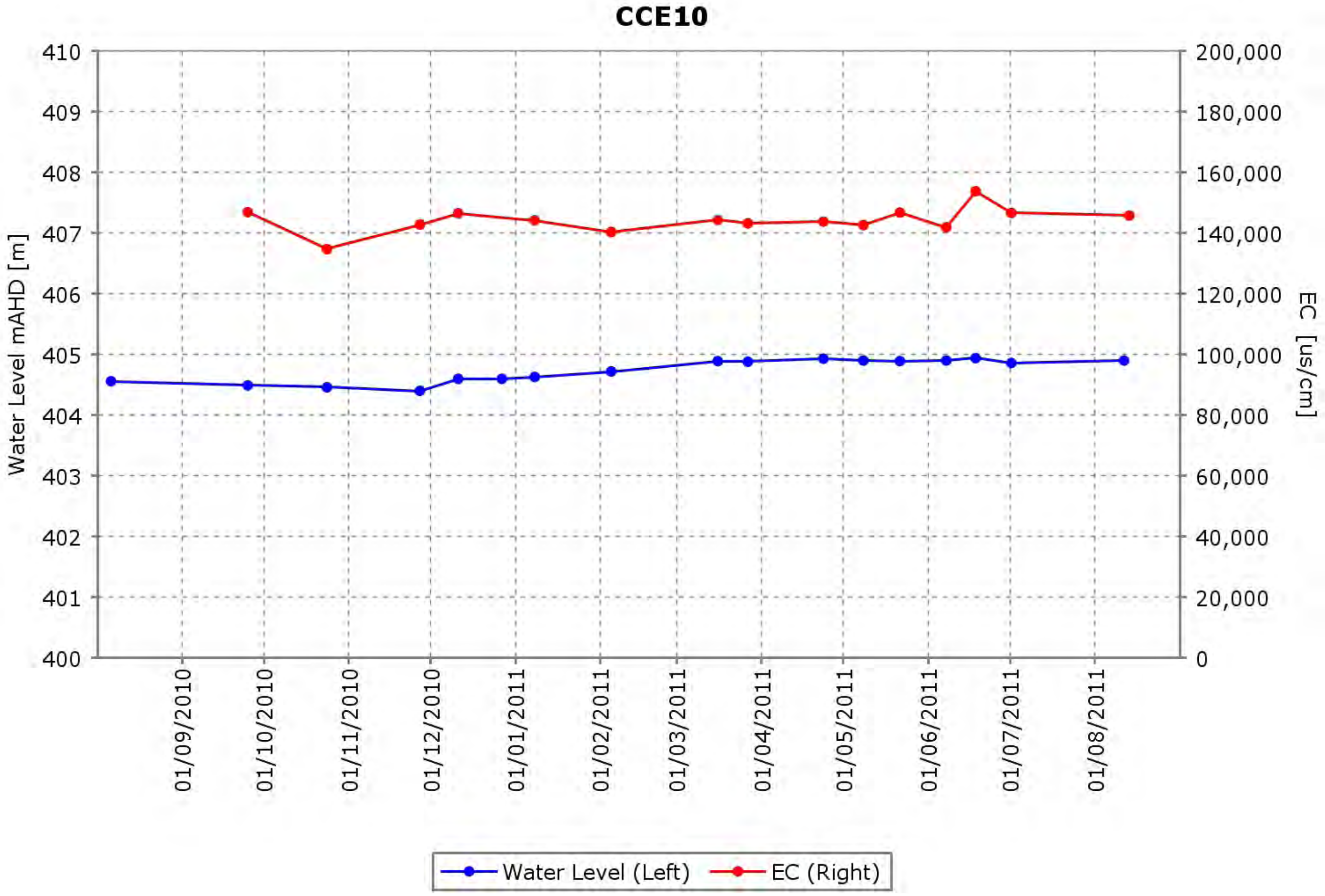

CCE04MB_VD
Water Level mAHD [m]
EC [us/cm]
415
414
413
412
411
410
409
408
407
406
405
200,000
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

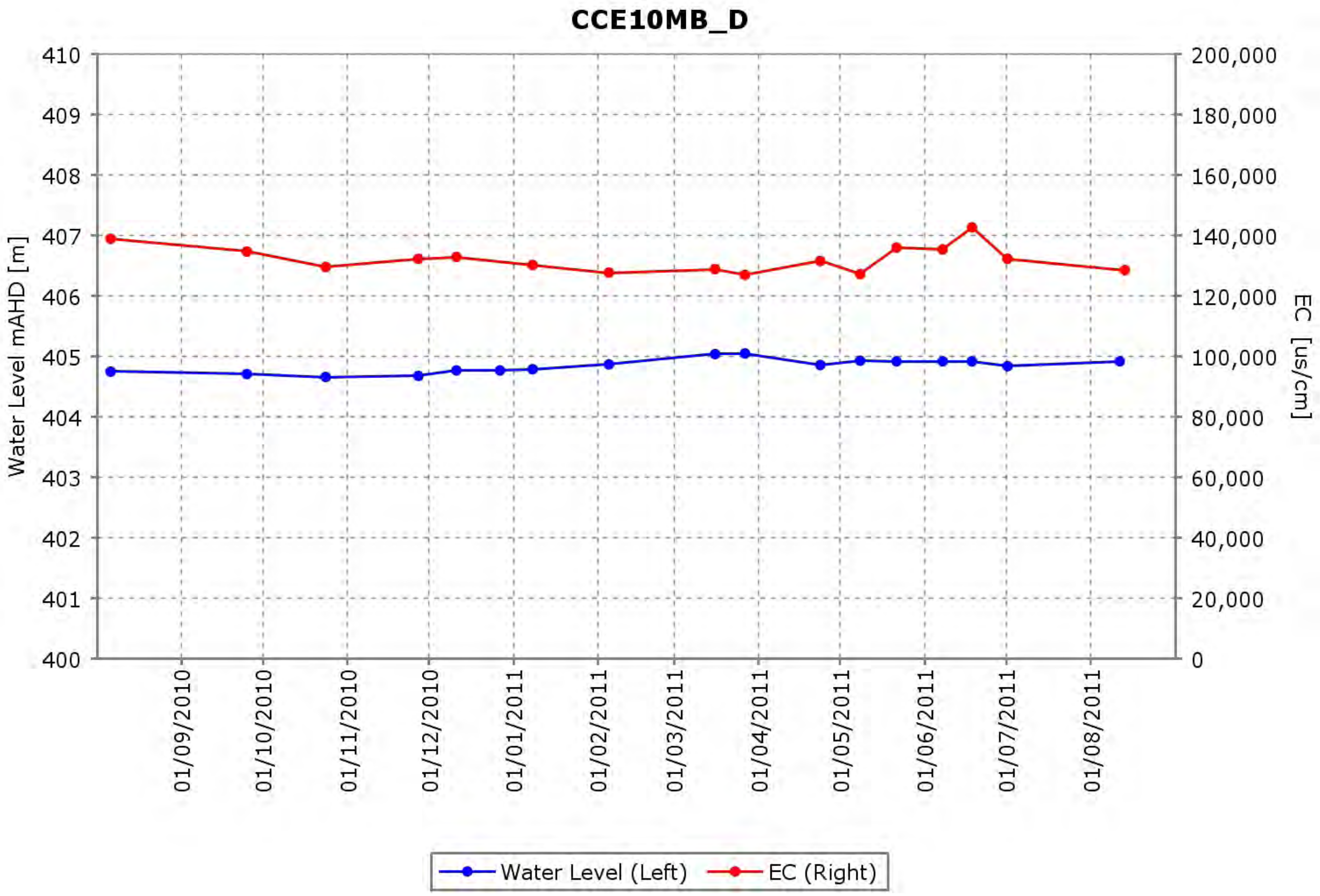

CCE05
Water Level mAHD [m]
EC [us/cm]
415
414
413
412
411
410
409
408
407
406
405
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

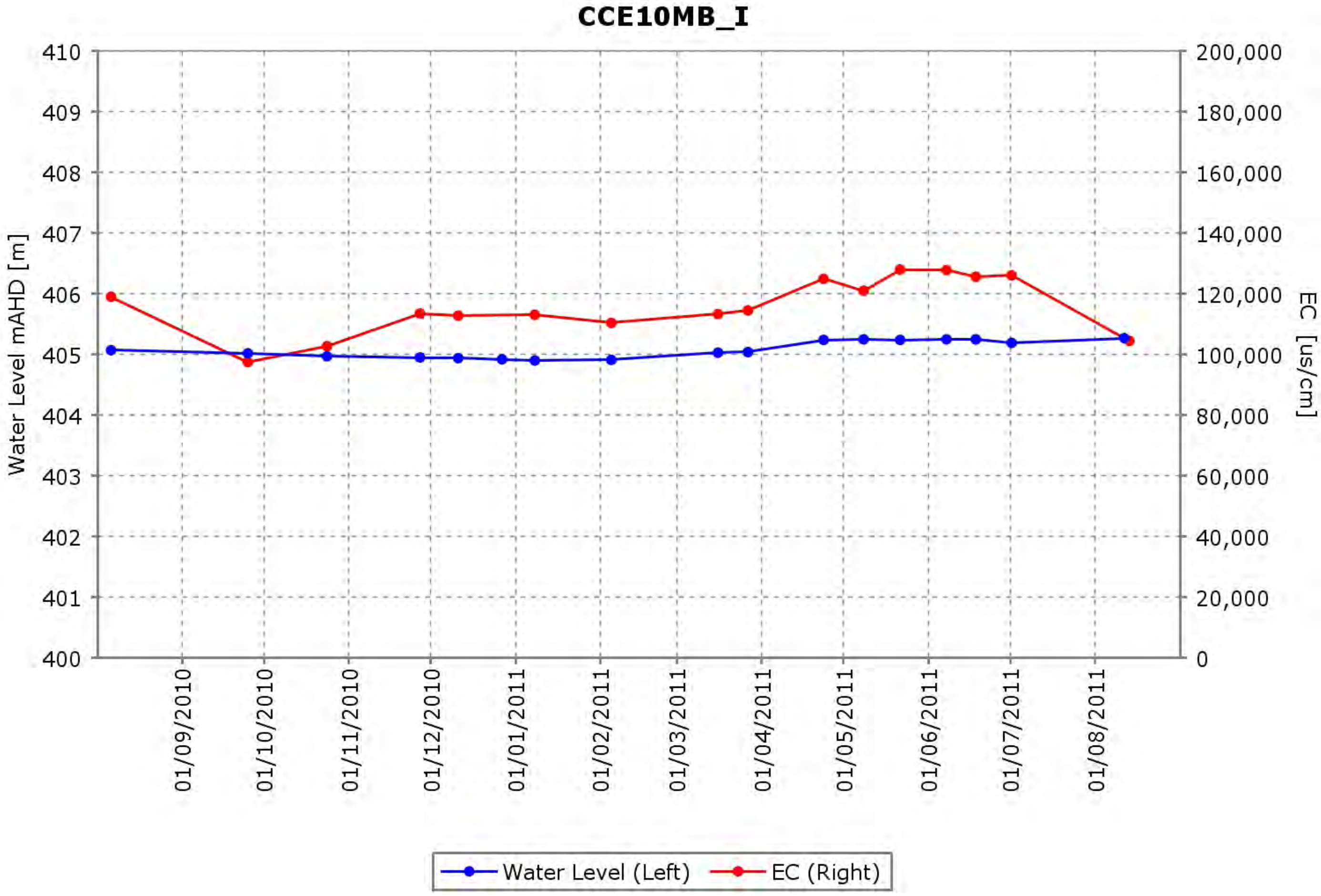

CCE05MB_D
Water Level mAHD [m]
EC [us/cm]
415
414
413
412
411
410
409
408
407
406
405
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

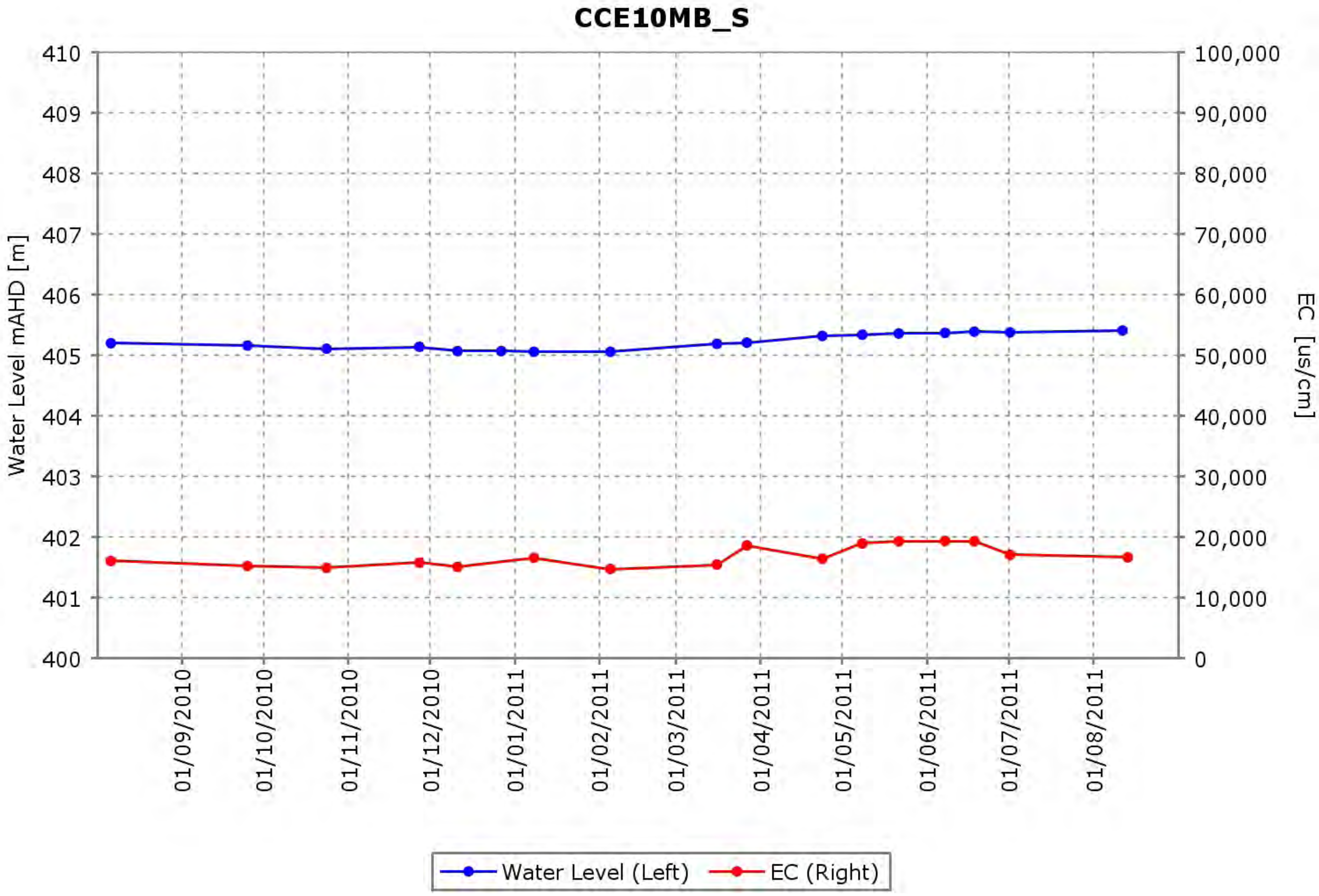

CCE05MB_I
Water Level mAHD [m]
EC [us/cm]
415
414
413
412
411
410
409
408
407
406
405
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

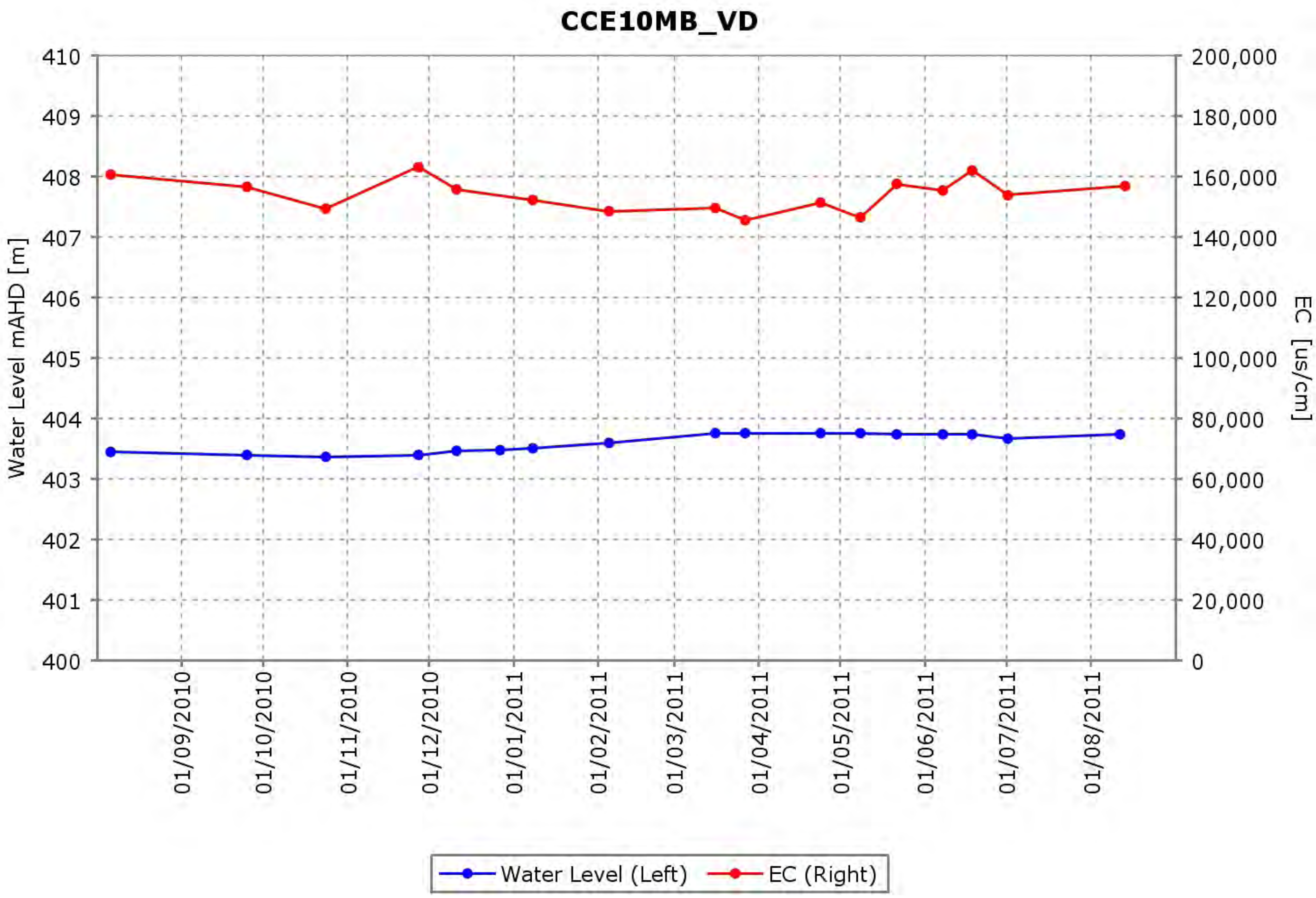

CCE05MB_S
Water Level mAHD [m]
EC [us/cm]
415
414
413
412
411
410
409
408
407
406
405
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

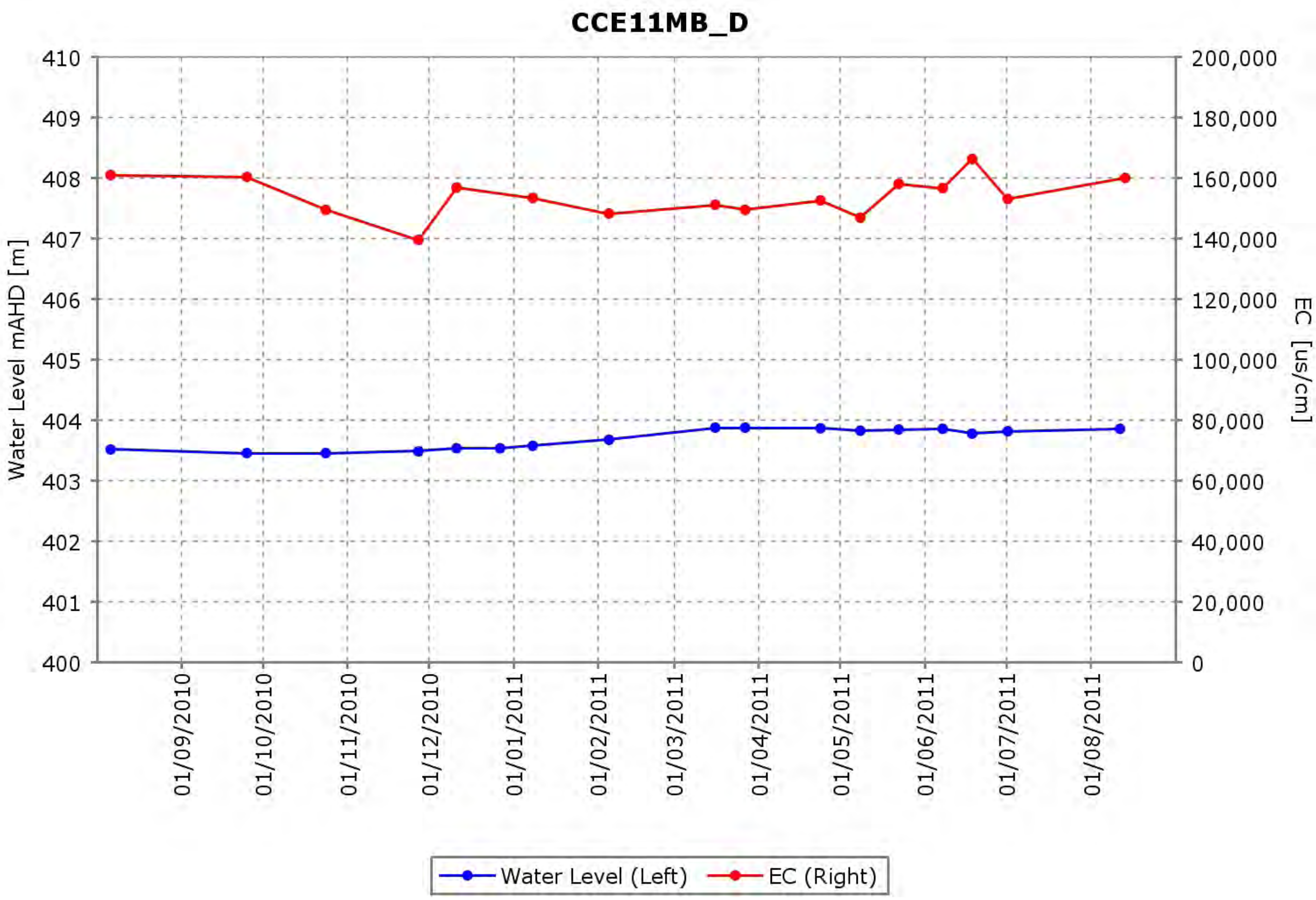

CCE10
Water Level mAHD [m]
EC [us/cm]
410
409
408
407
406
405
404
403
402
401
400
200,000
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

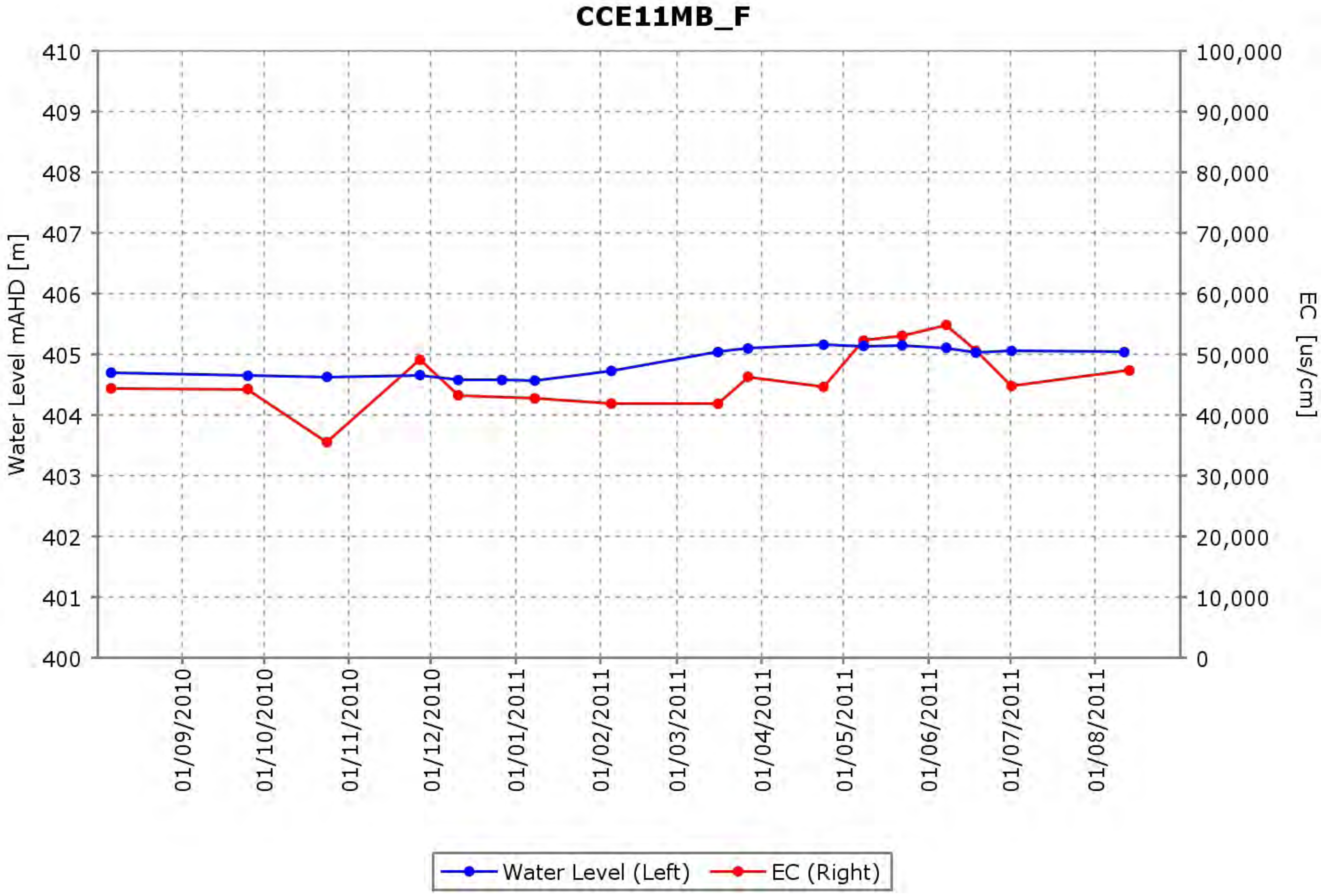

CCE10MB_D
Water Level mAHD [m]
EC [us/cm]
410
409
408
407
406
405
404
403
402
401
400
200,000
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

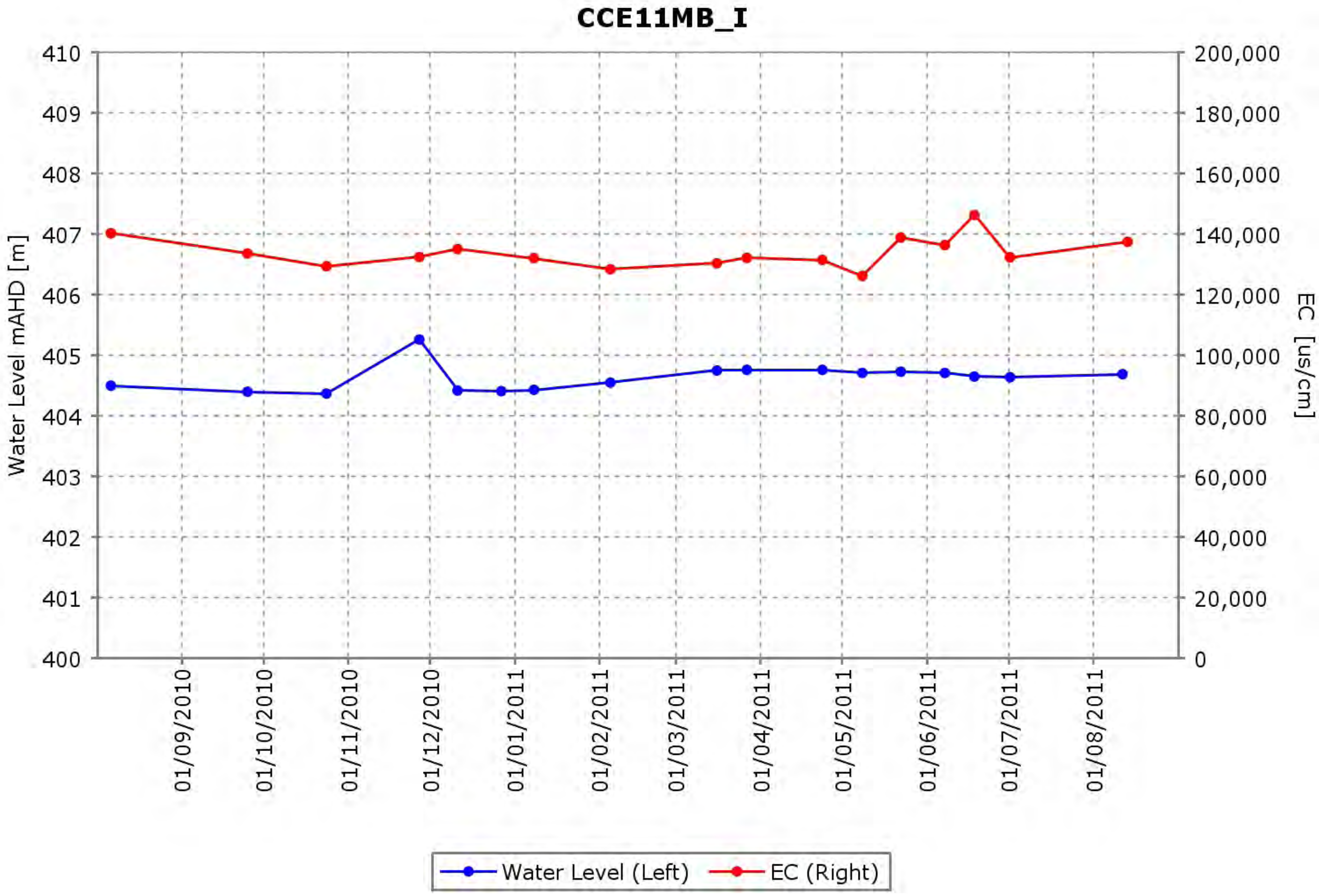

CCE10MB_I
Water Level mAHD [m]
EC [us/cm]
410
409
408
407
406
405
404
403
402
401
400
200,000
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

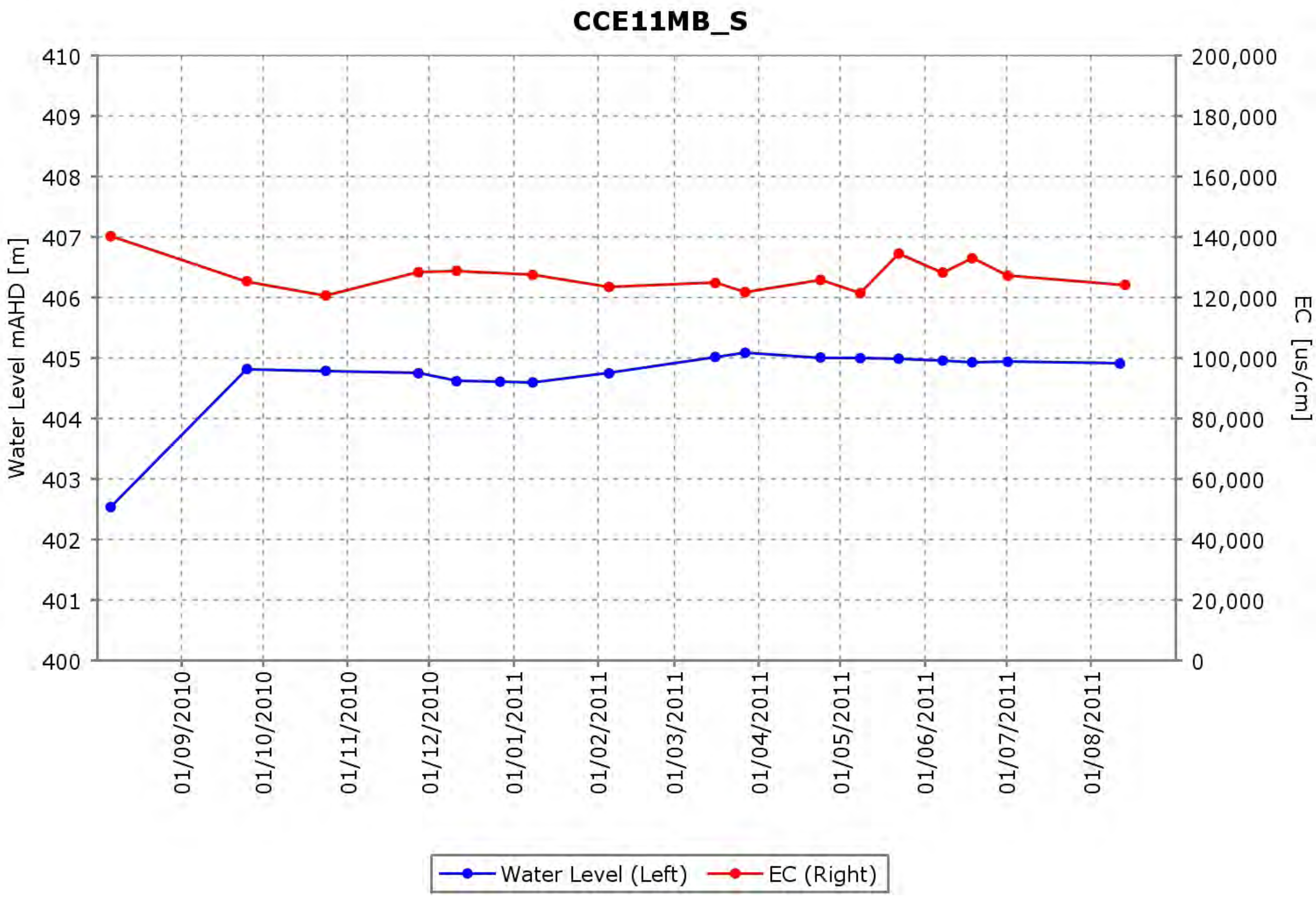

CCE10MB_S
Water Level mAHD [m]
EC [us/cm]
410
409
408
407
406
405
404
403
402
401
400
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

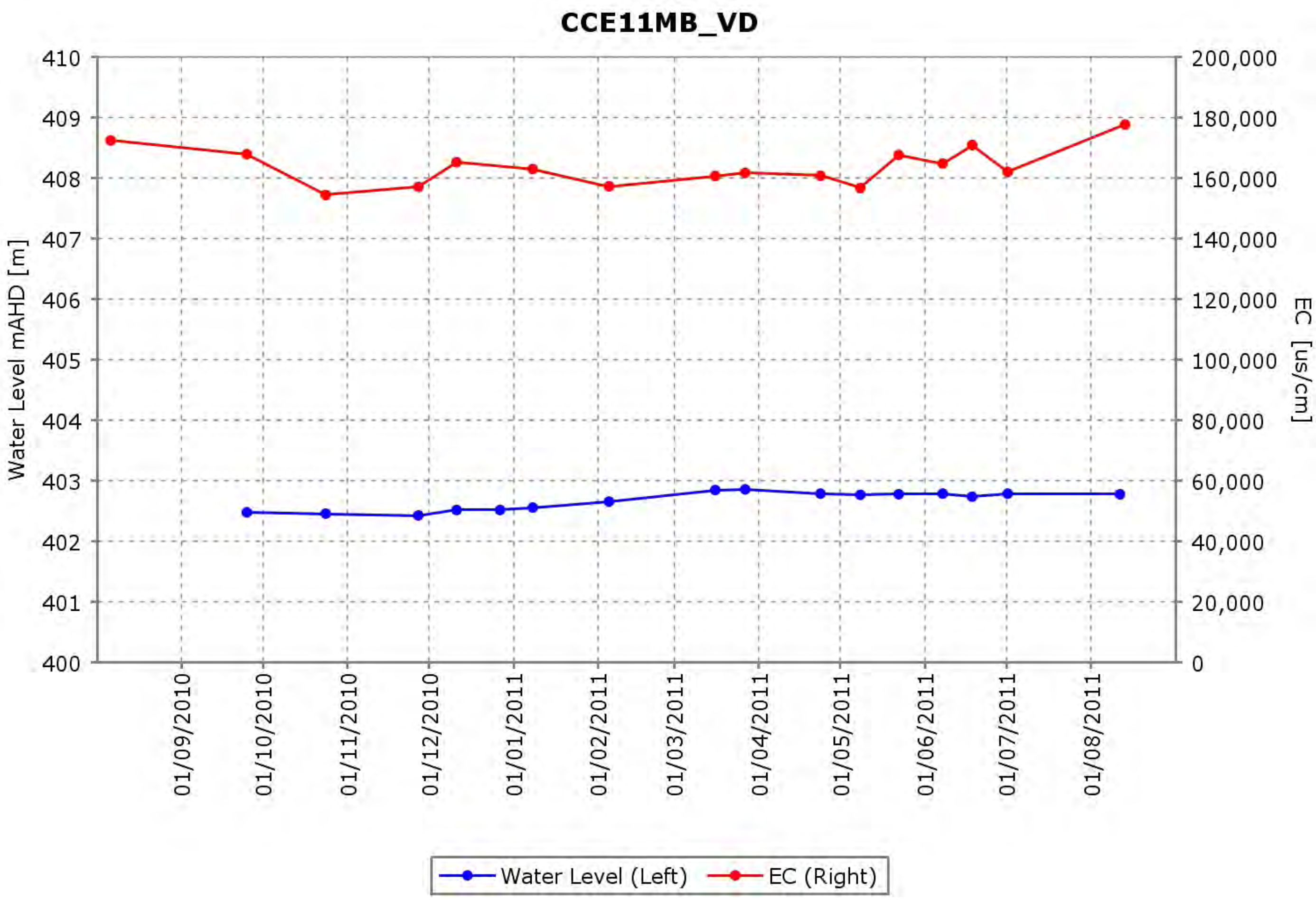

CCE10MB_VD
Water Level mAHD [m]
410
409
408
407
406
405
404
403
402
401
400
EC [us/cm]
200,000
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

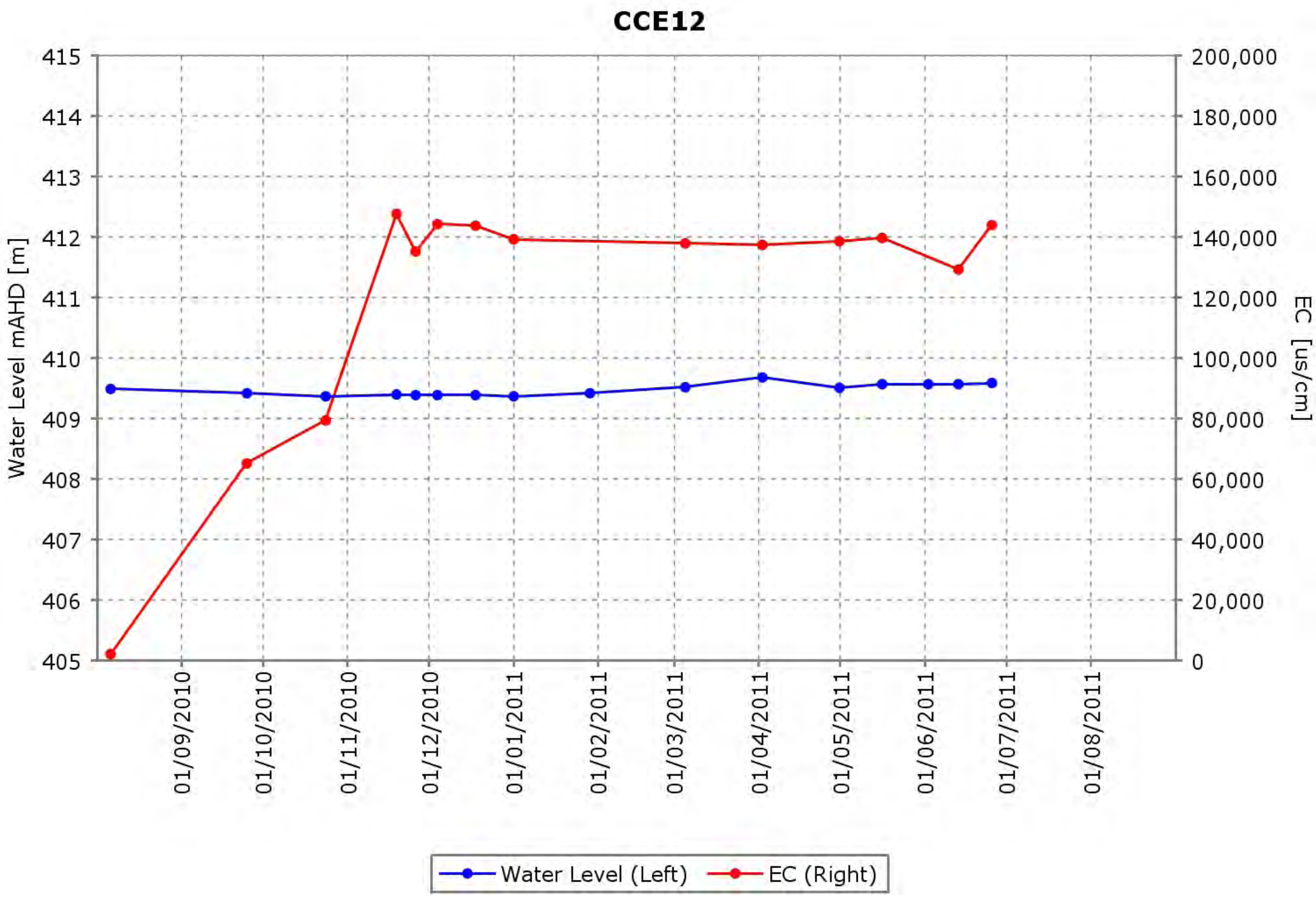

CCE11MB_D
Water Level mAHD [m]
410
409
408
407
406
405
404
403
402
401
400
EC [us/cm]
200,000
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

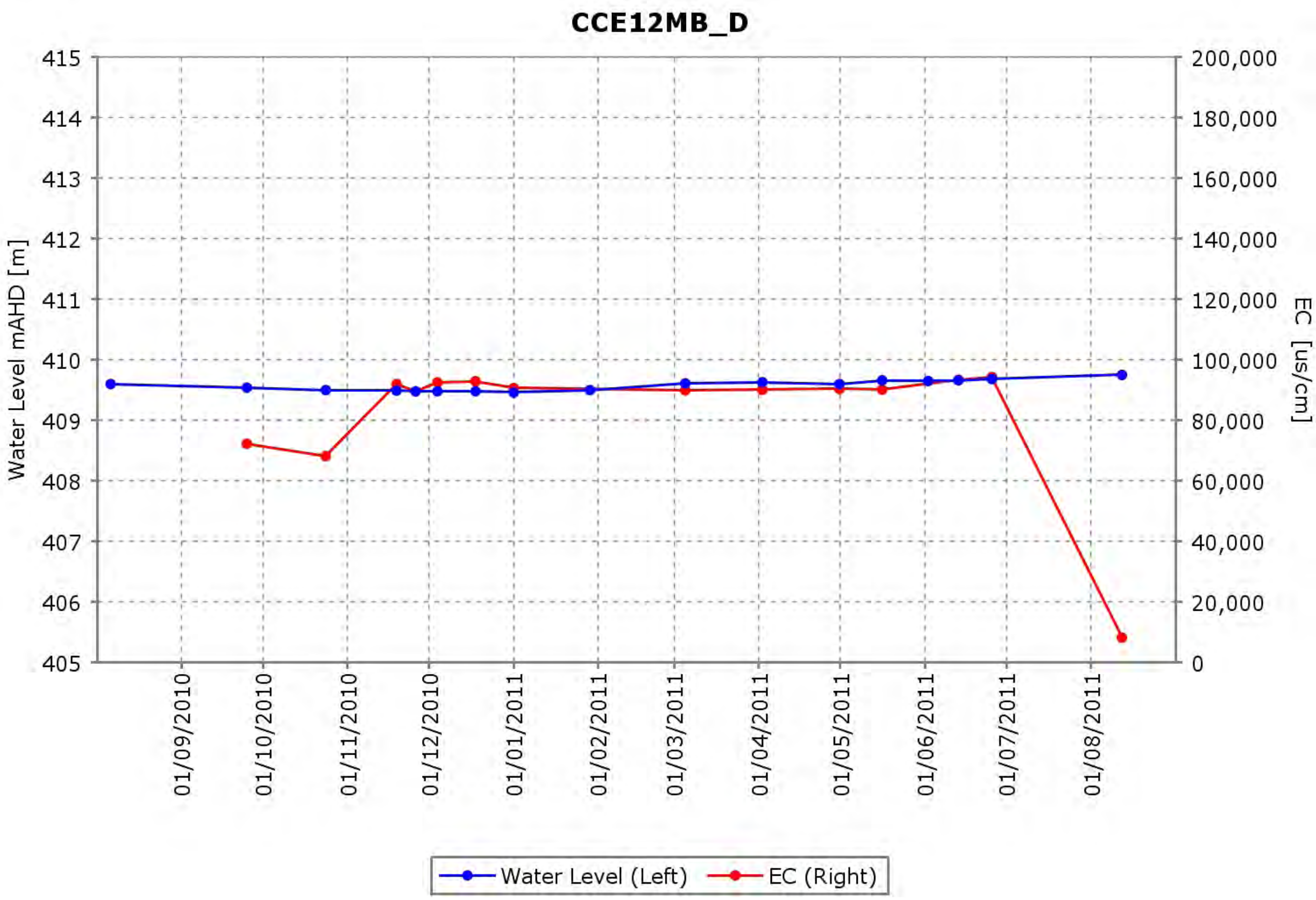

CCE11MB_F
Water Level mAHD [m]
410
409
408
407
406
405
404
403
402
401
400
EC [us/cm]
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

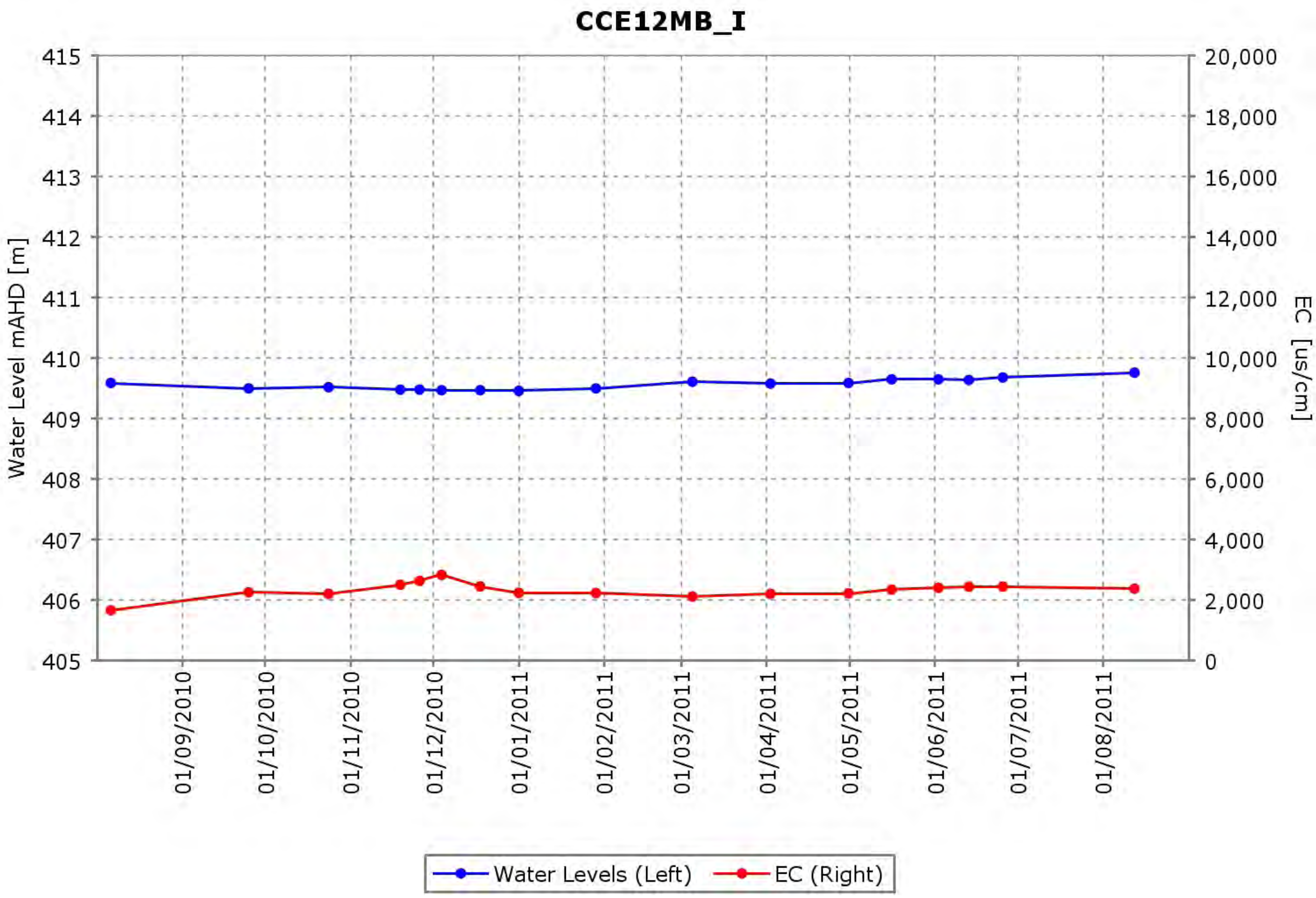

CCE11MB_I
Water Level mAHD [m]
410
409
408
407
406
405
404
403
402
401
400
EC [us/cm]
200,000
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

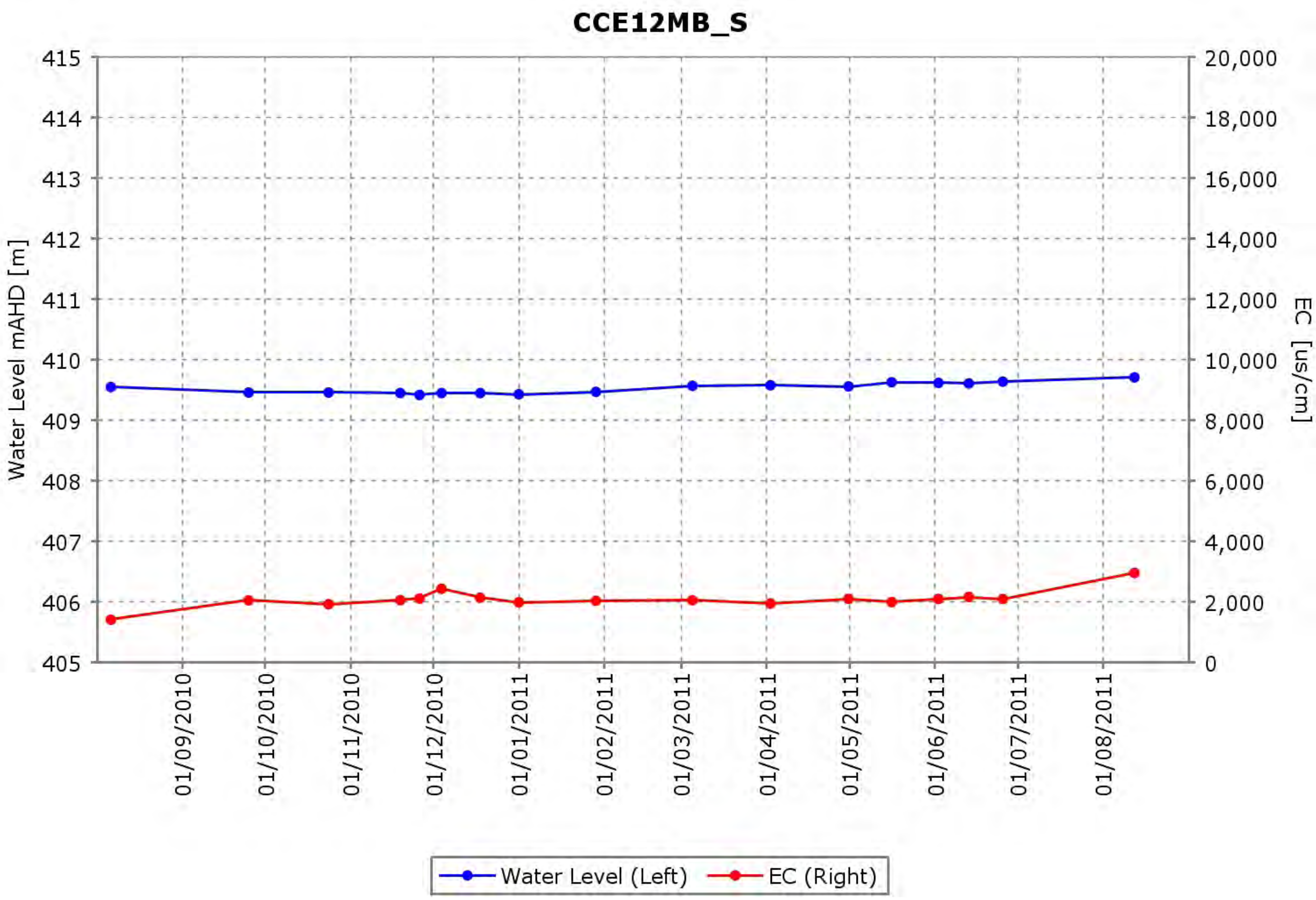

CCE11MB_S
Water Level mAHD [m]
EC [us/cm]
410
409
408
407
406
405
404
403
402
401
400
200,000
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

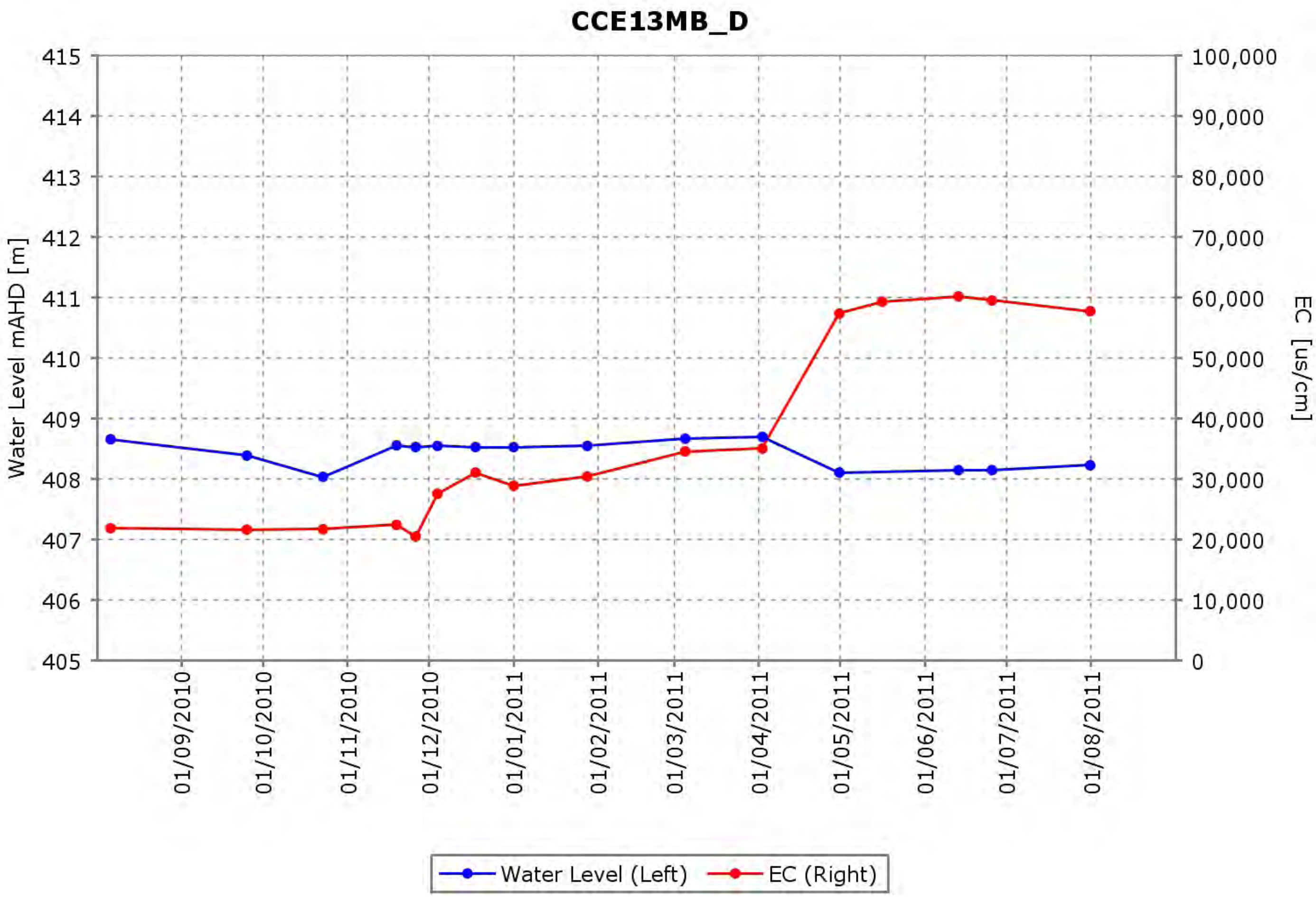

CCE11MB_VD
Water Level mAHD [m]
EC [us/cm]
410
409
408
407
406
405
404
403
402
401
400
200,000
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

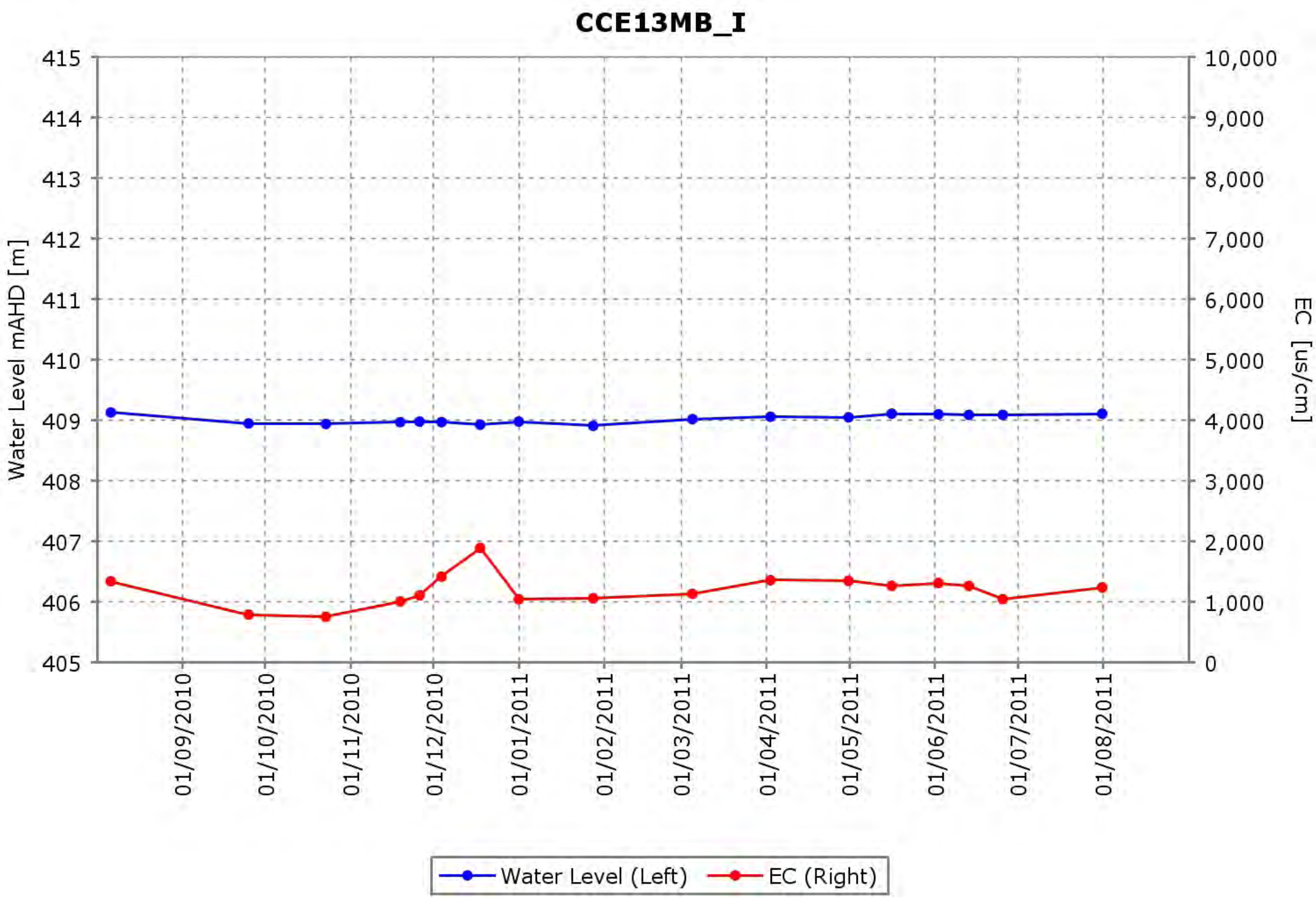

CCE12
Water Level mAHD [m]
EC [us/cm]
415
414
413
412
411
410
409
408
407
406
405
200,000
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

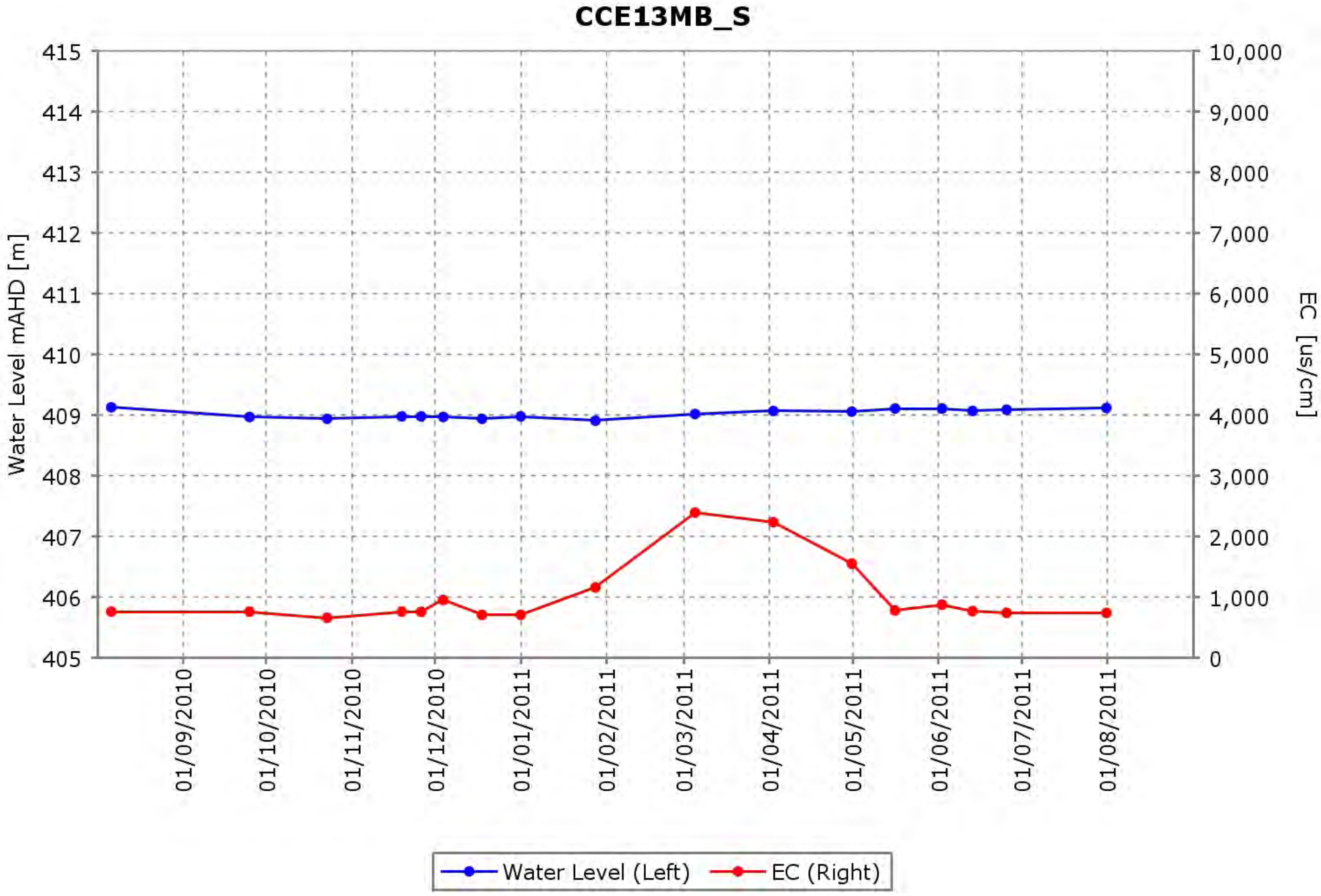

CCE12MB_D
Water Level mAHD [m]
EC [us/cm]
415
414
413
412
411
410
409
408
407
406
405
200,000
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

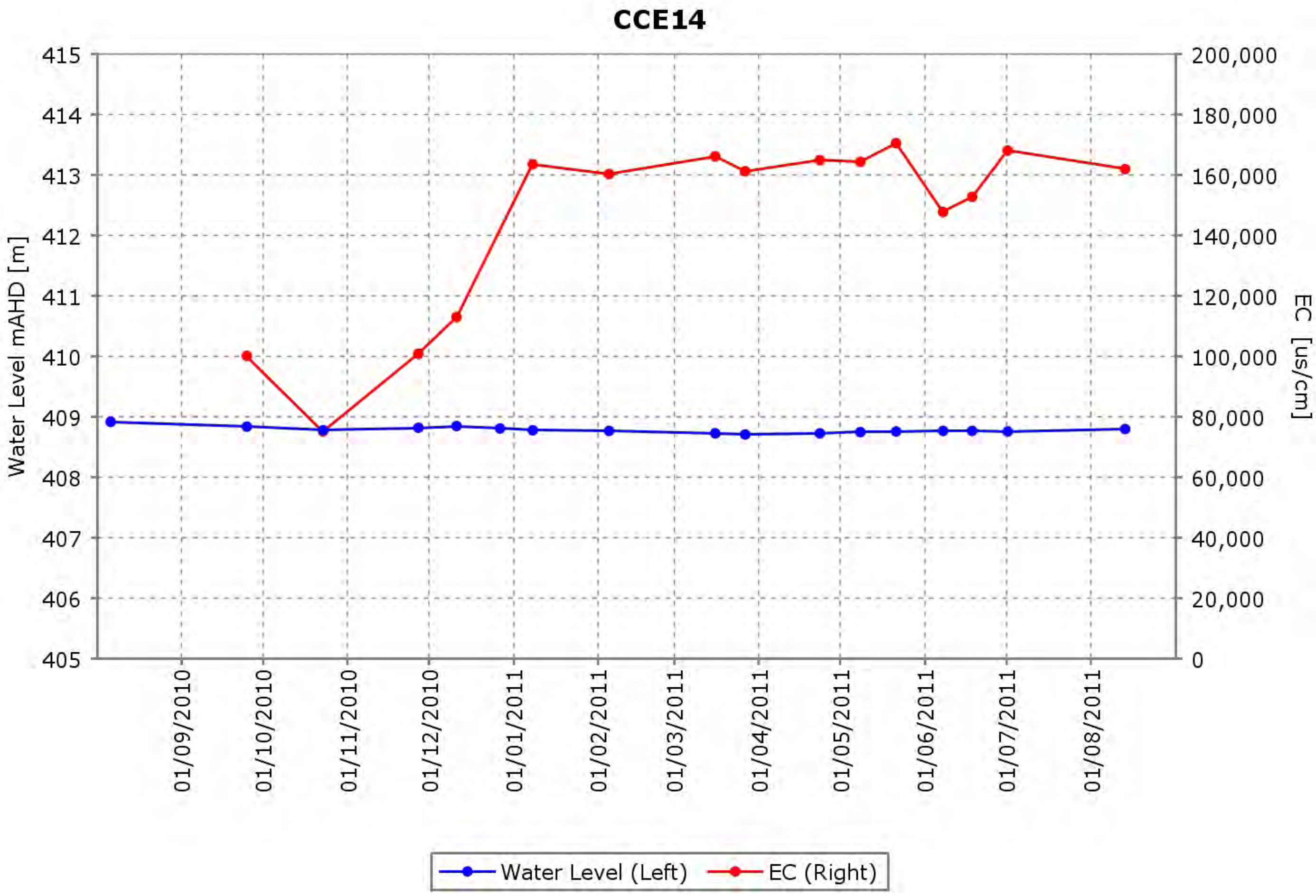

CCE12MB_I
415
414
413
412
411
410
409
408
407
406
405
Water Level mAHD [m]
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
EC [us/cm]
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Levels (Left)
EC (Right)

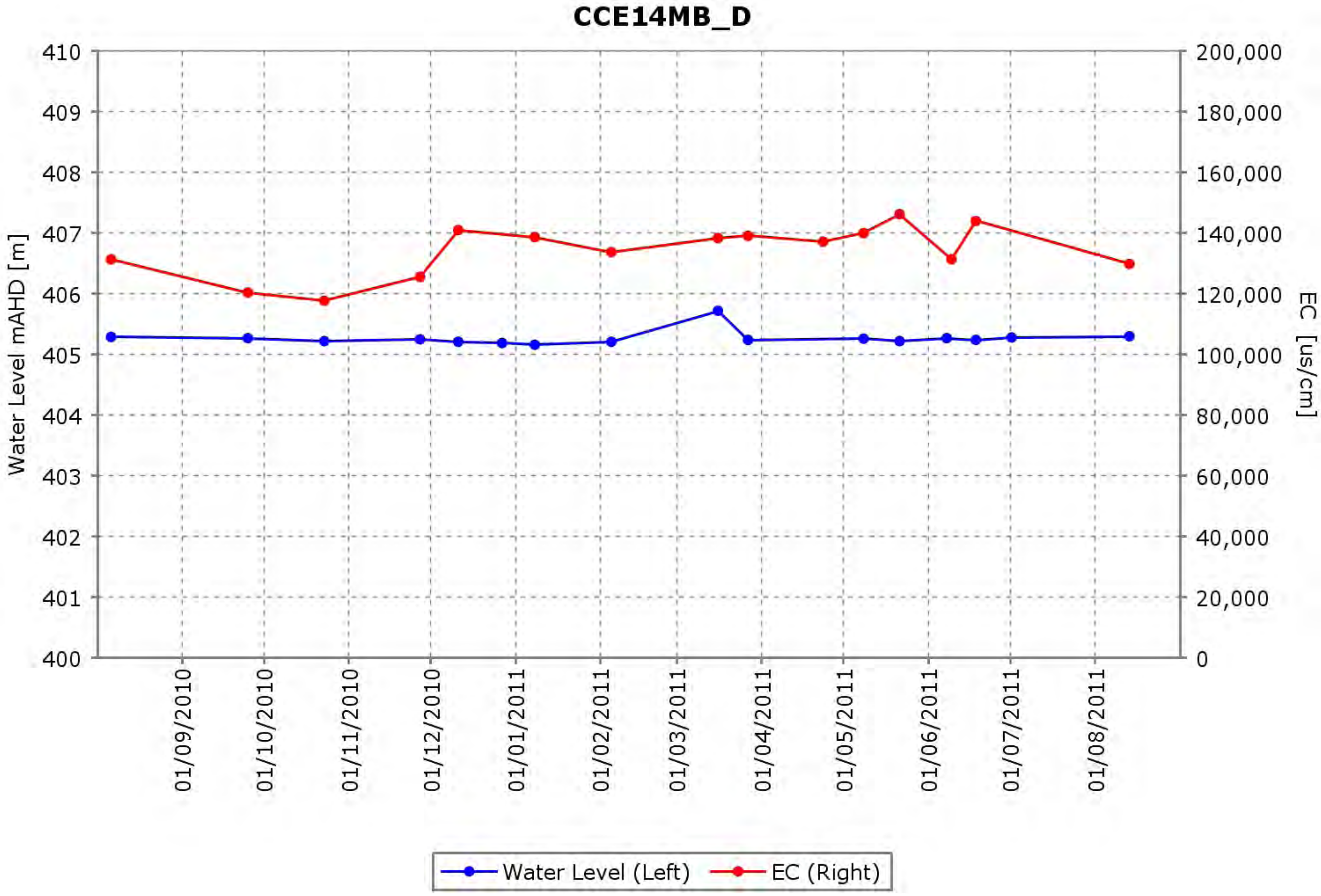

CCE12MB_S
415
414
413
412
411
410
409
408
407
406
405
Water Level mAHD [m]
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
EC [us/cm]
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

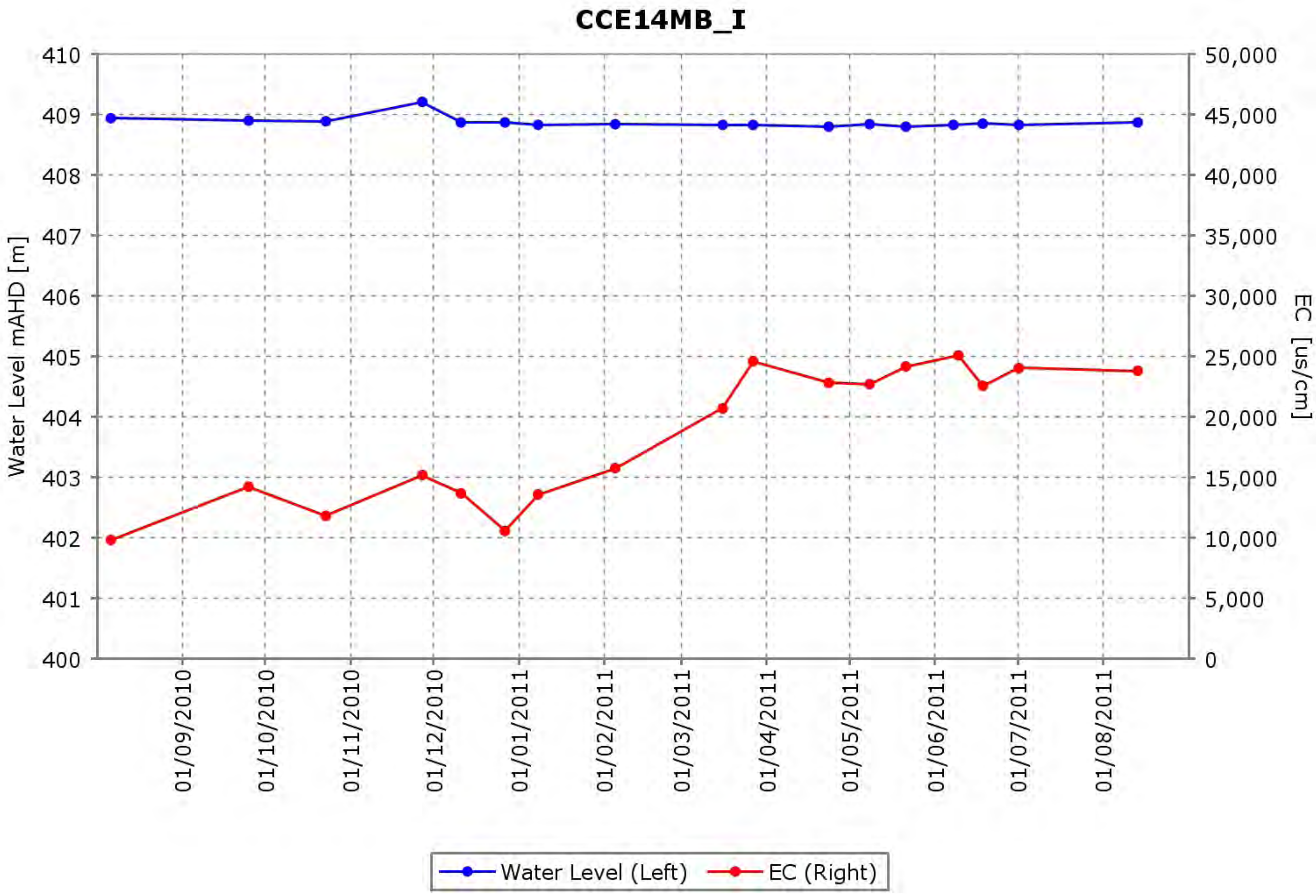

CCE13MB_D
Water Level mAHD [m]
EC [us/cm]
415
414
413
412
411
410
409
408
407
406
405
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

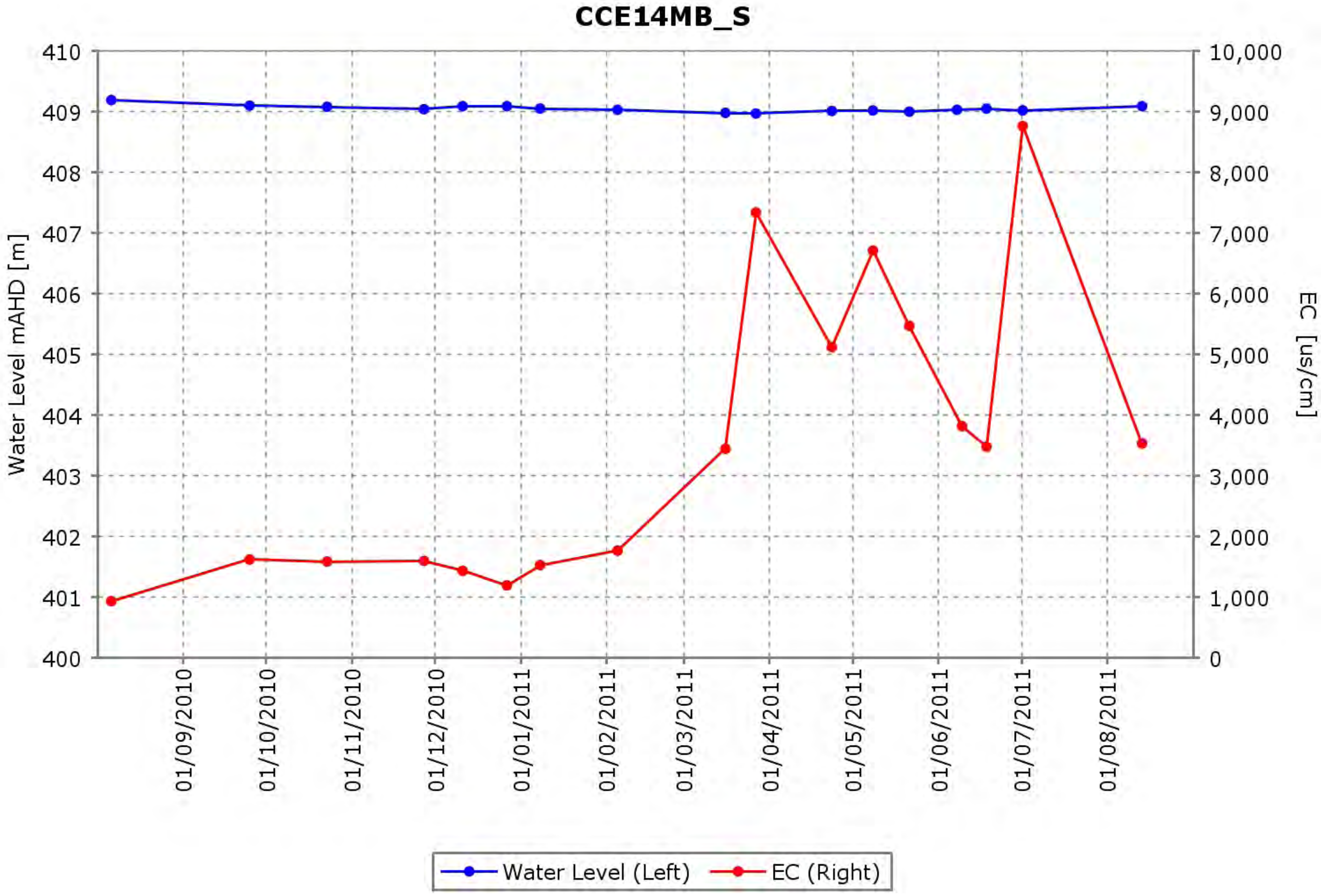

CCE13MB_I
Water Level mAHD [m]
EC [us/cm]
415
414
413
412
411
410
409
408
407
406
405
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

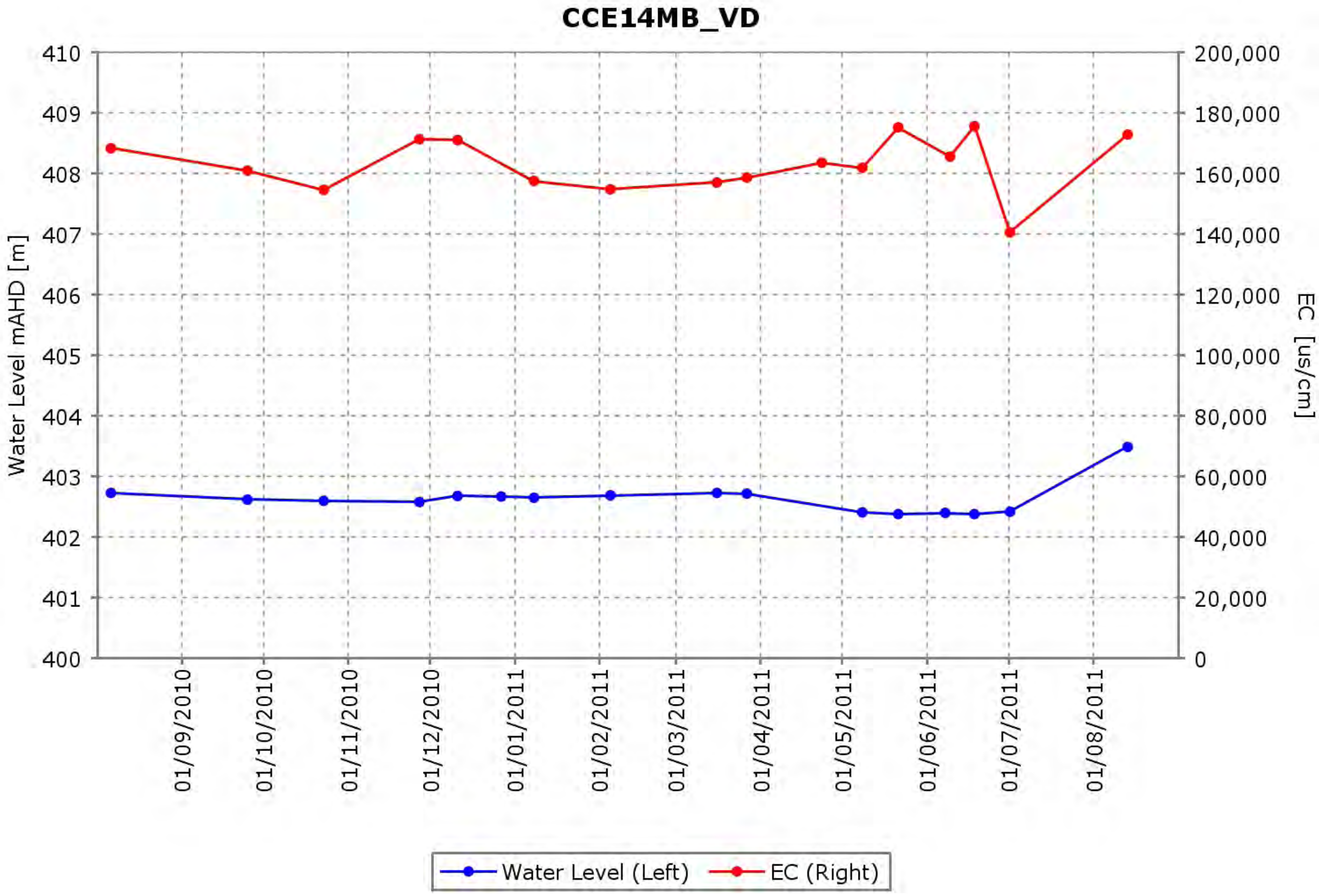

CCE13MB_S
Water Level mAHD [m]
EC [us/cm]
415
414
413
412
411
410
409
408
407
406
405
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

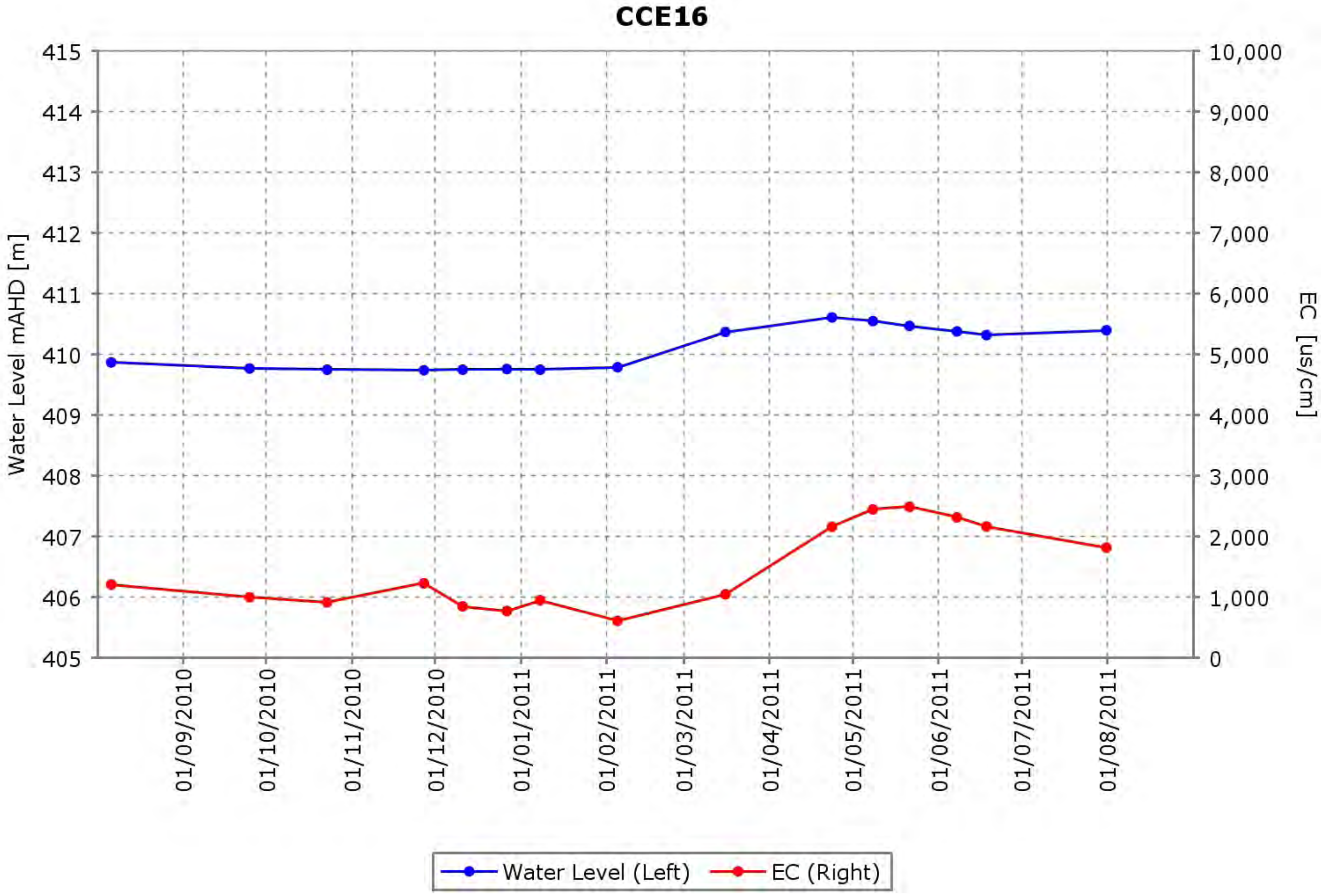

CCE14
Water Level mAHD [m]
EC [us/cm]
415
414
413
412
411
410
409
408
407
406
405
200,000
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

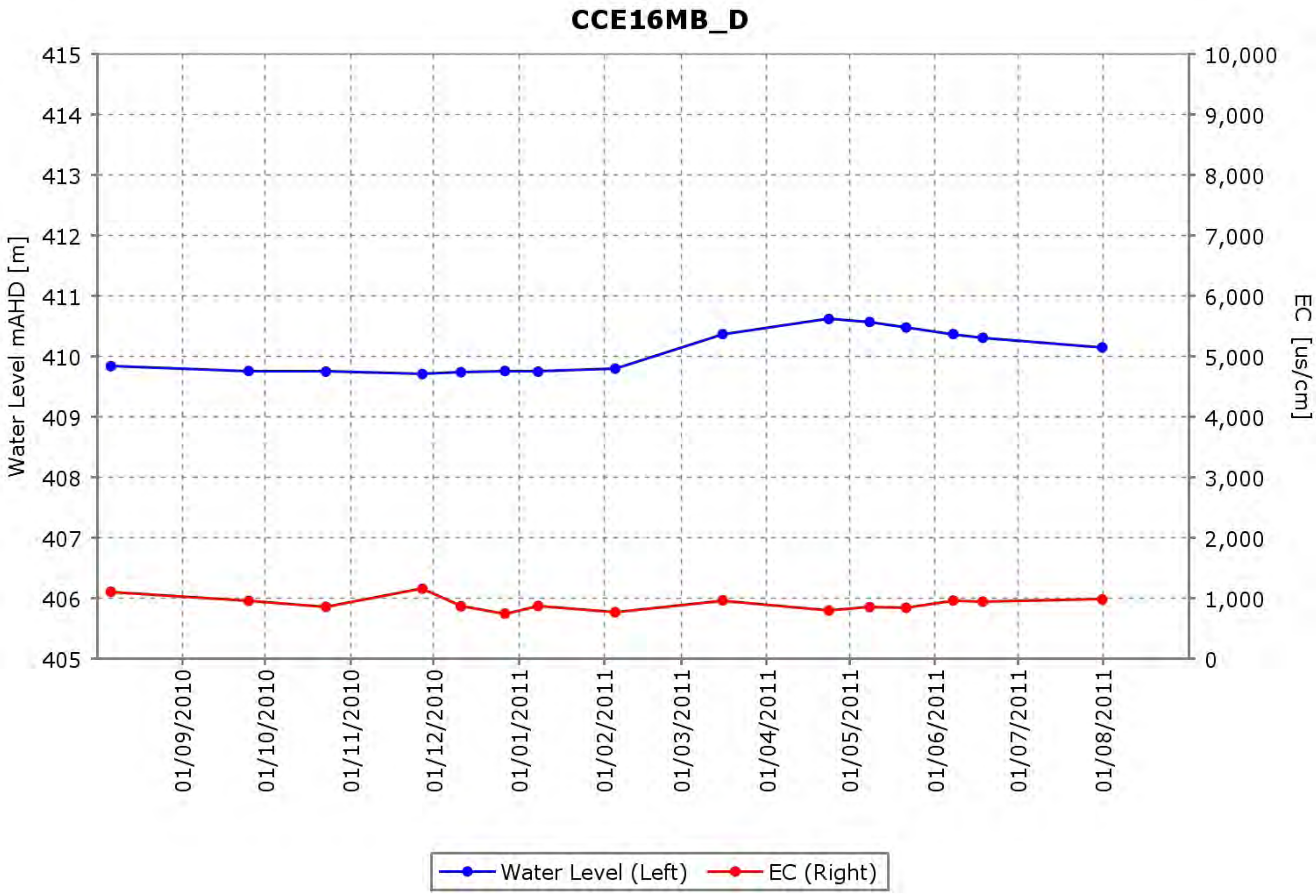

CCE14MB_D
Water Level mAHD [m]
EC [us/cm]
410
409
408
407
406
405
404
403
402
401
400
200,000
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

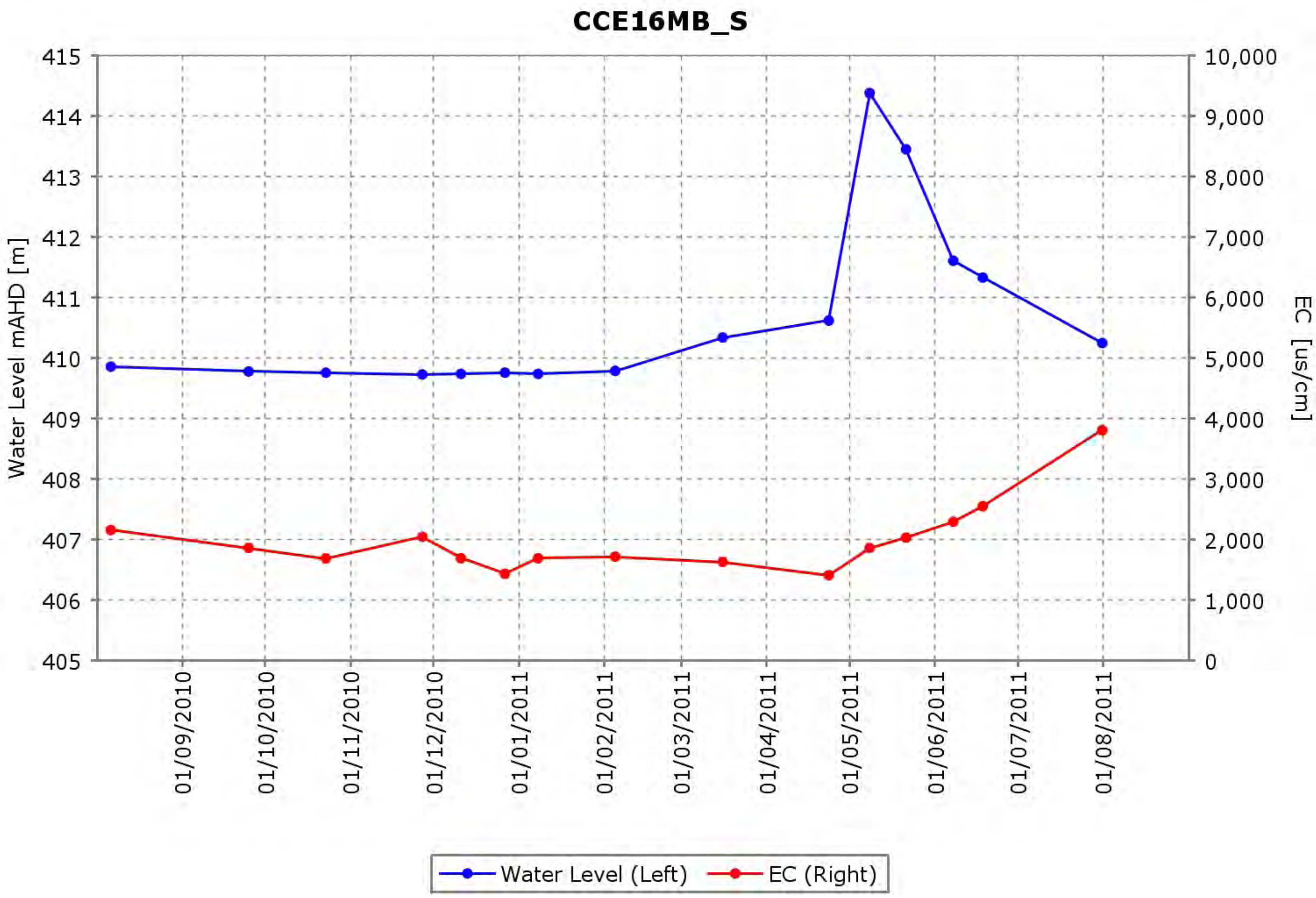

CCE14MB_I
Water Level mAHD [m]
EC [us/cm]
410
409
408
407
406
405
404
403
402
401
400
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

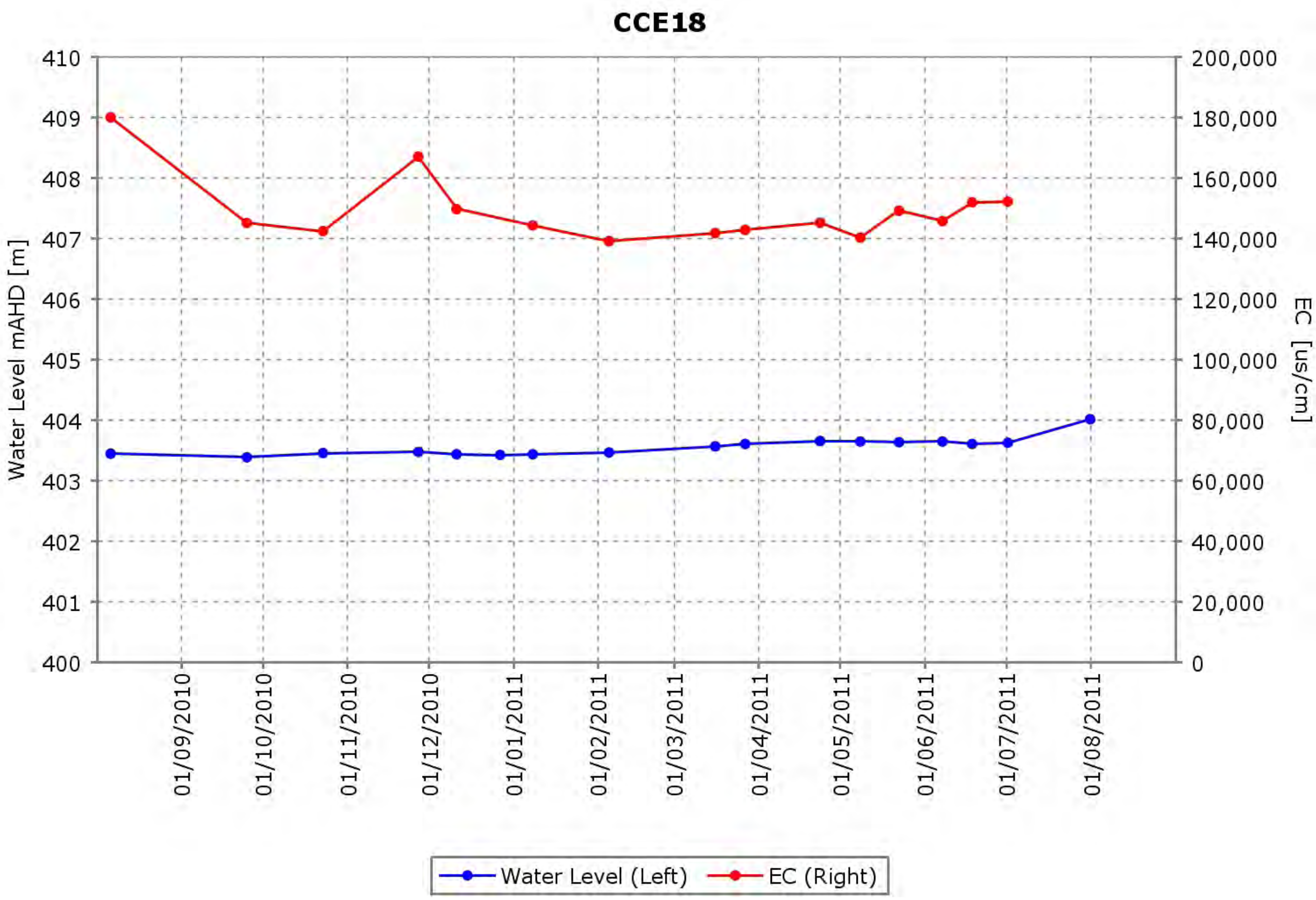

CCE14MB_S
Water Level mAHD [m]
EC [us/cm]
410
409
408
407
406
405
404
403
402
401
400
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

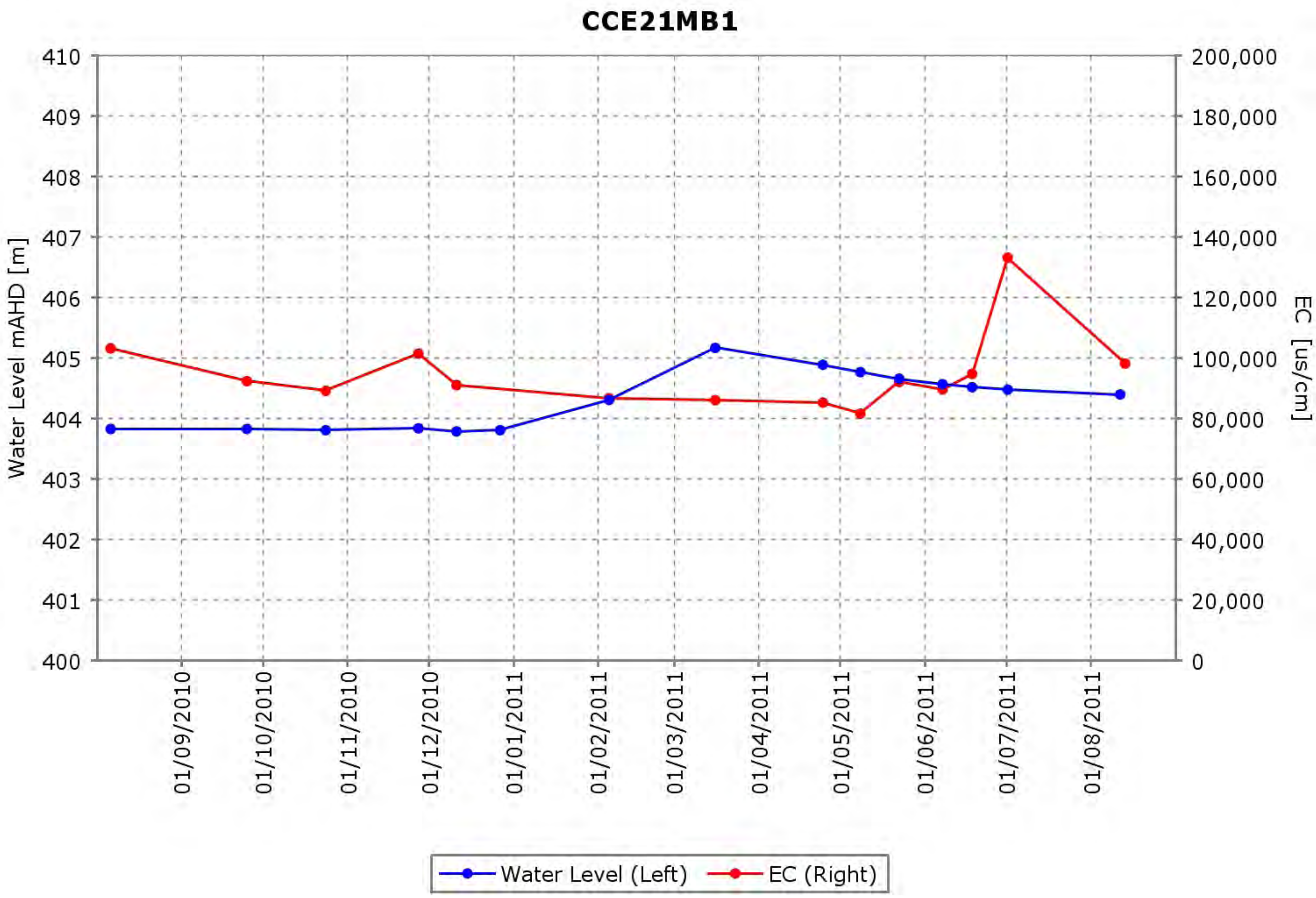

CCE14MB_VD
Water Level mAHD [m]
EC [us/cm]
410
409
408
407
406
405
404
403
402
401
400
200,000
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

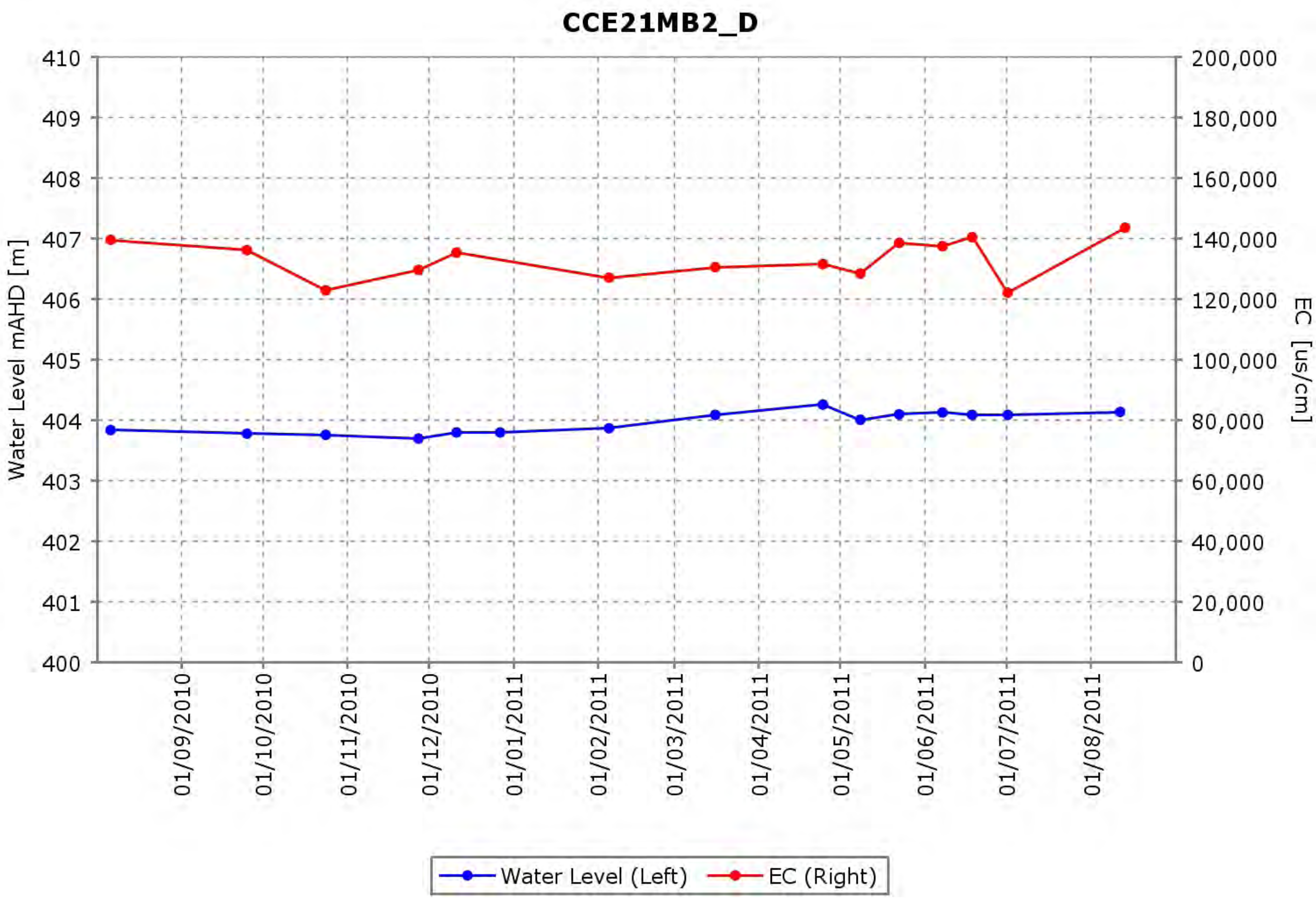

CCE16
Water Level mAHD [m]
415
414
413
412
411
410
409
408
407
406
405
EC [us/cm]
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

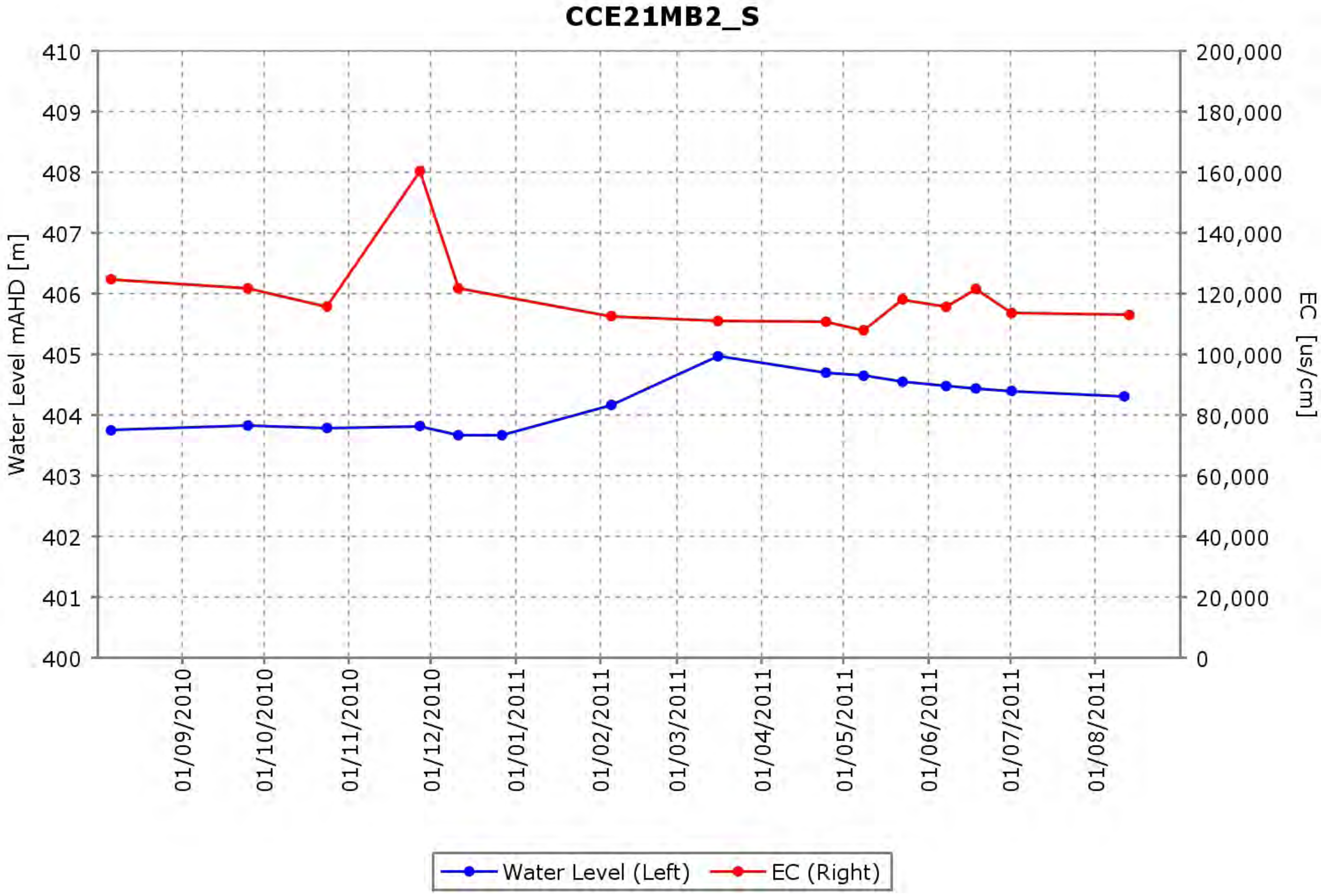

CCE16MB_D
Water Level mAHD [m]
415
414
413
412
411
410
409
408
407
406
405
EC [us/cm]
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

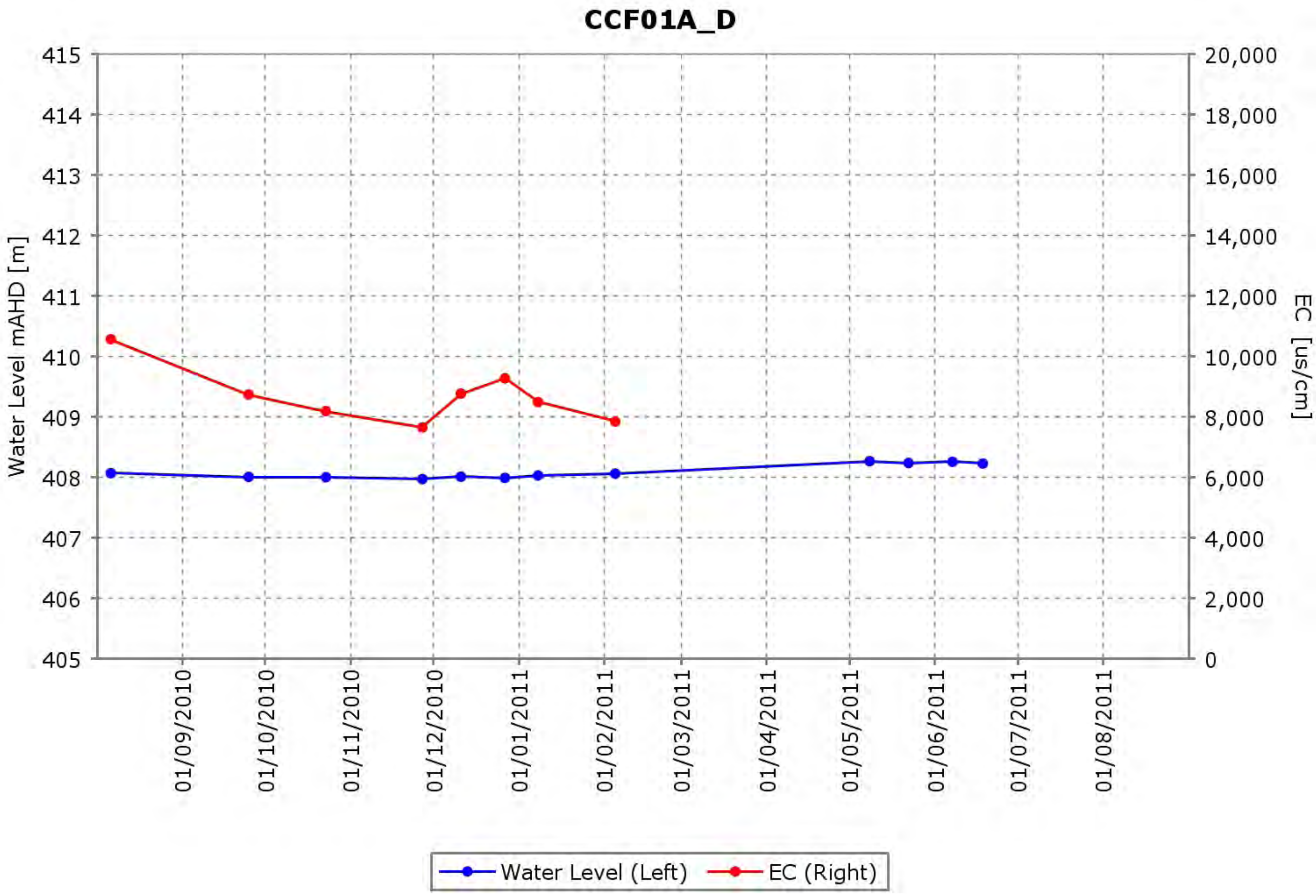

CCE16MB_S
Water Level mAHD [m]
EC [us/cm]
415
414
413
412
411
410
409
408
407
406
405
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

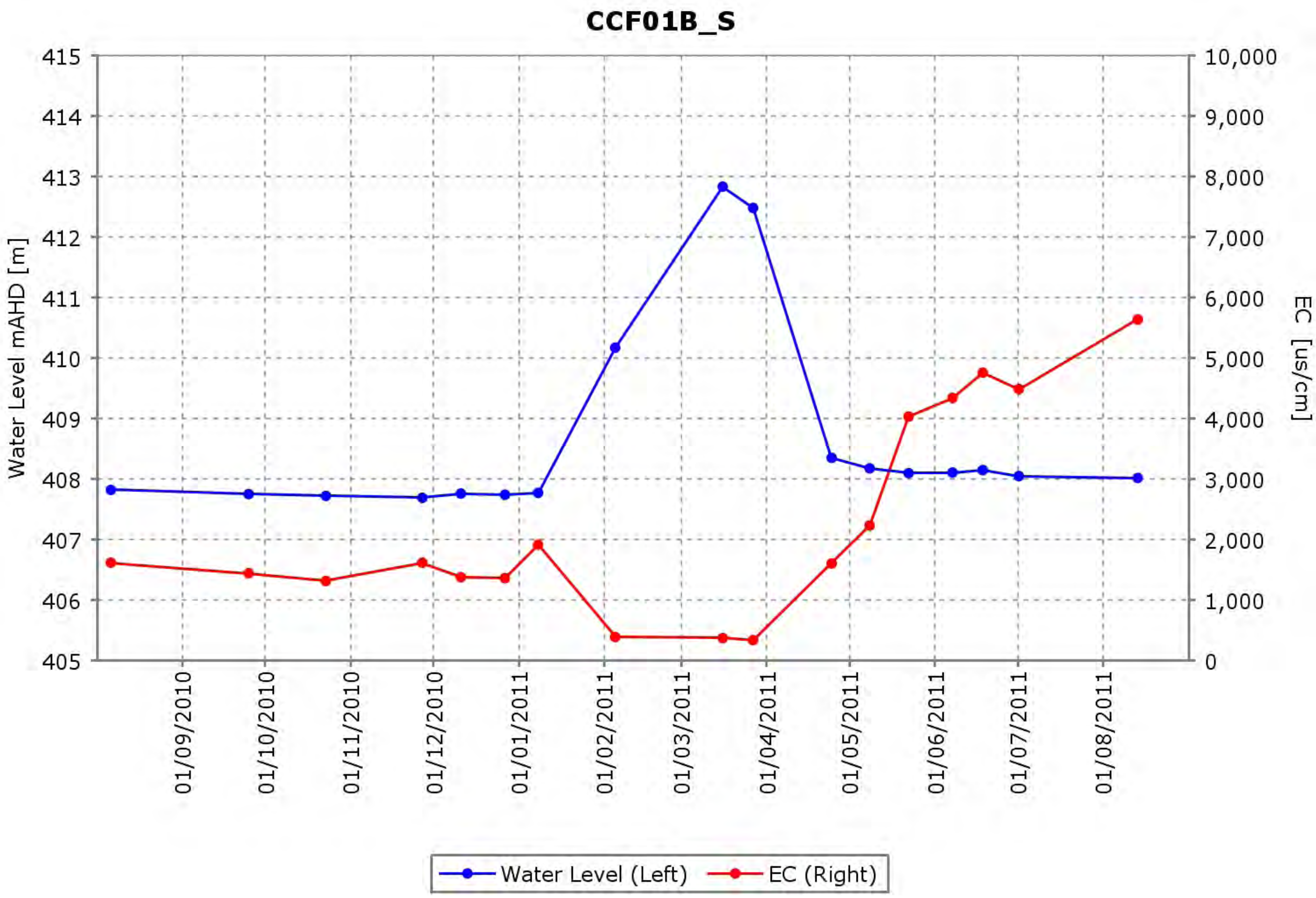

CCE18
Water Level mAHD [m]
EC [us/cm]
410
409
408
407
406
405
404
403
402
401
400
200,000
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

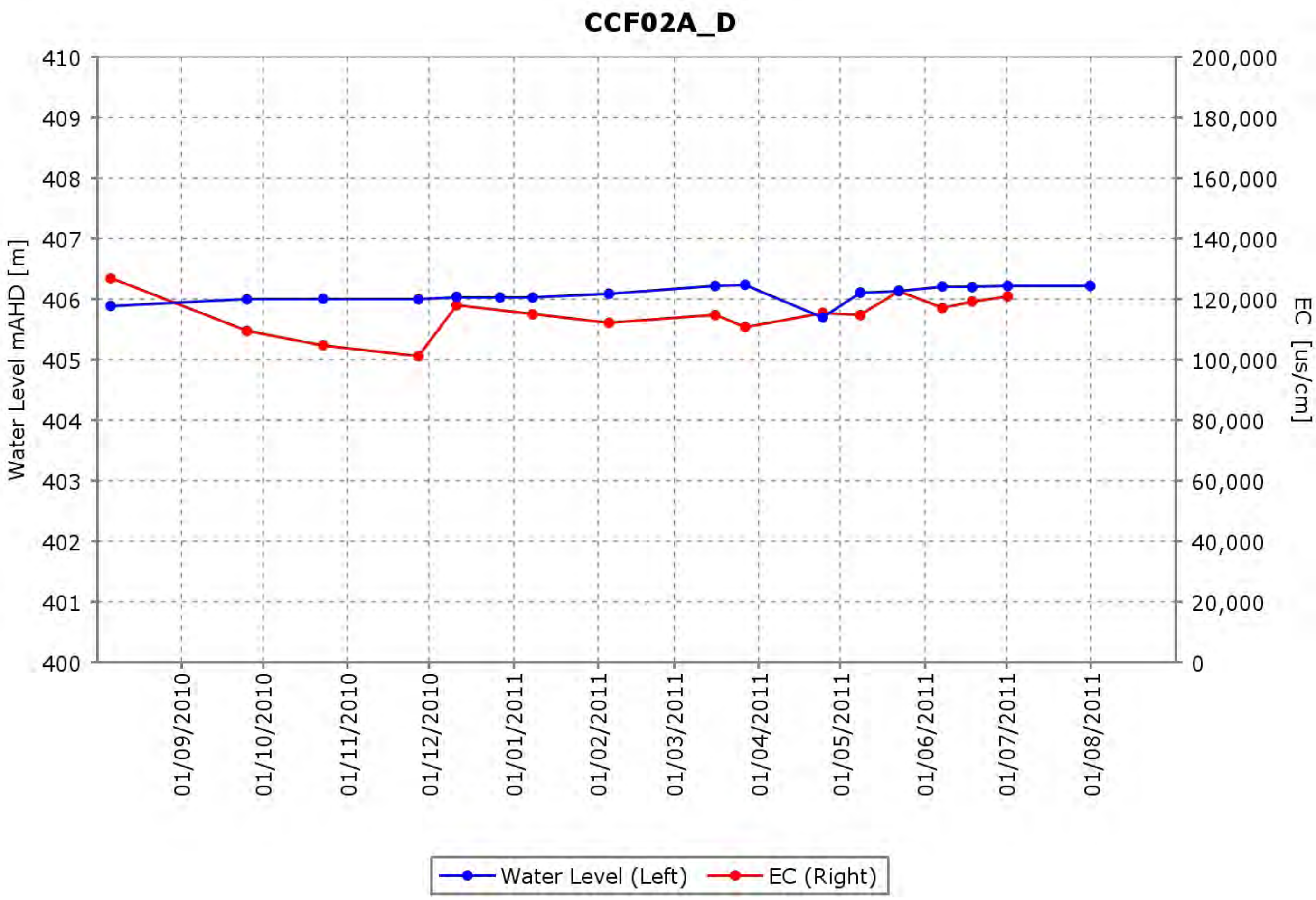

CCE21MB1
Water Level mAHD [m]
EC [us/cm]
410
409
408
407
406
405
404
403
402
401
400
200,000
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)


CCE21MB2_D
Water Level mAHD [m]
EC [us/cm]
410
409
408
407
406
405
404
403
402
401
400
200,000
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

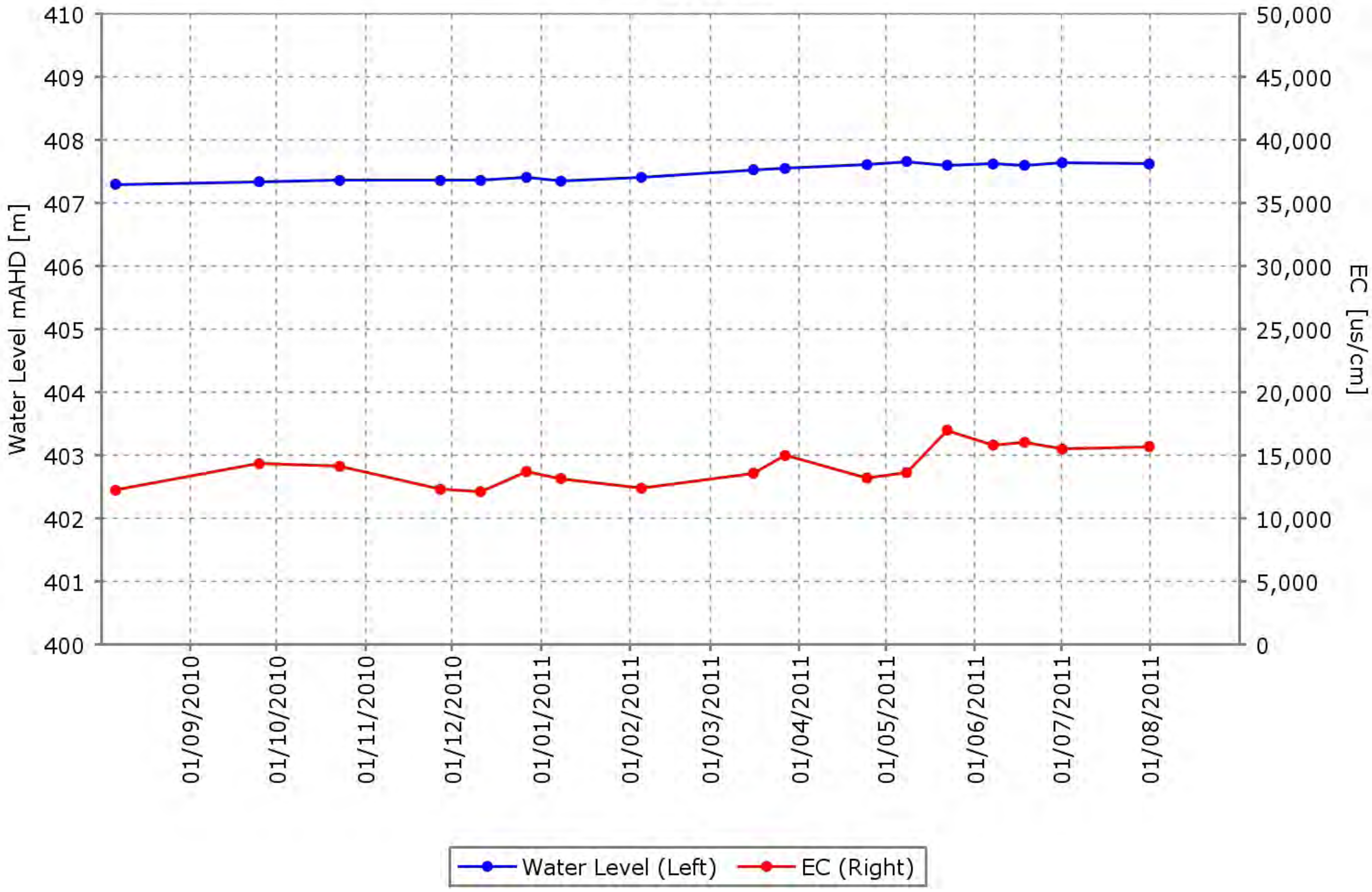

CCE21MB2_S
Water Level mAHD [m]
EC [us/cm]
410
409
408
407
406
405
404
403
402
401
400
200,000
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)


CCF01A_D
Water Level mAHD [m]
EC [us/cm]
415
414
413
412
411
410
409
408
407
406
405
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

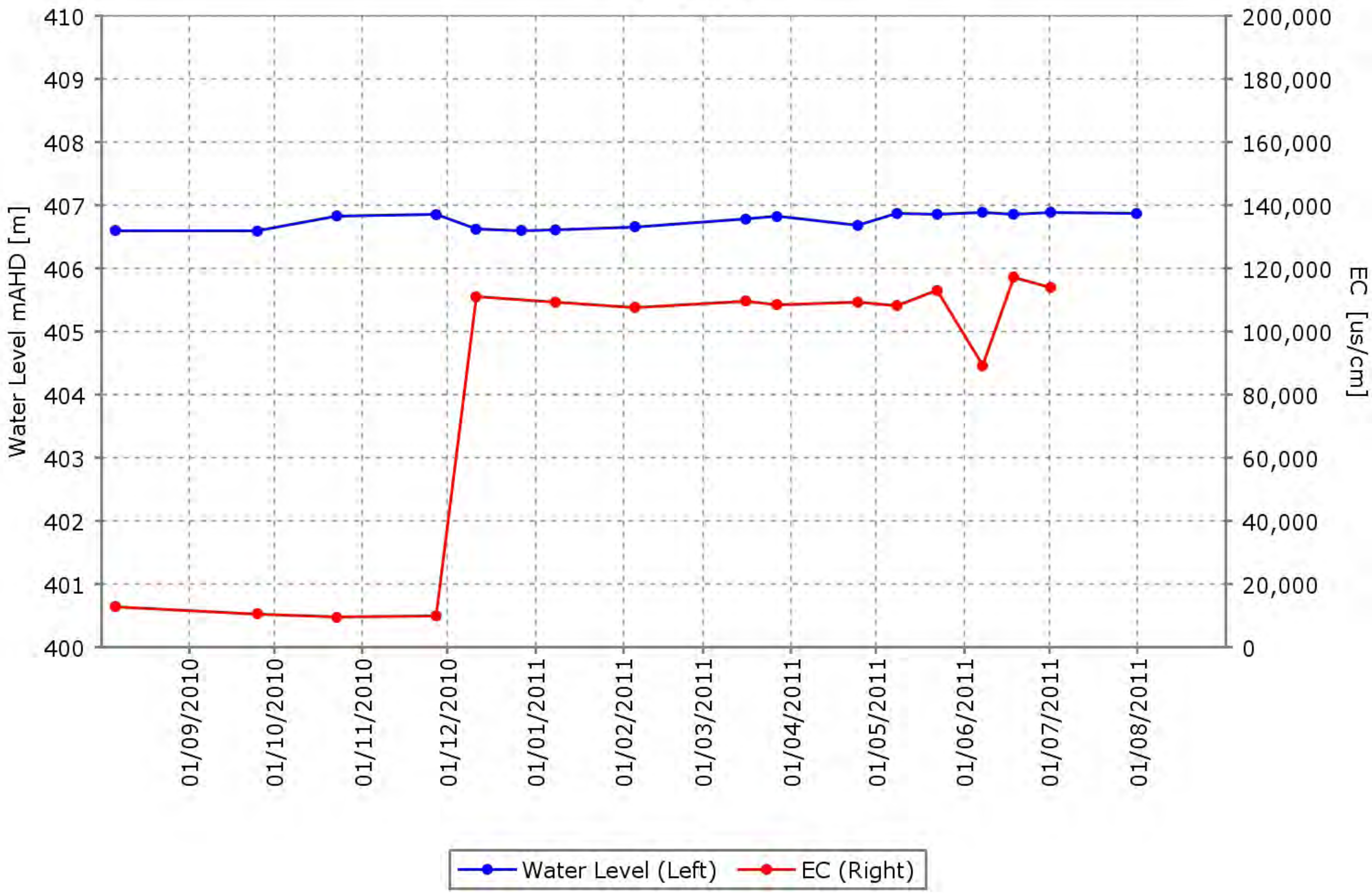

CCF01B_S
Water Level mAHD [m]
EC [us/cm]
415
414
413
412
411
410
409
408
407
406
405
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

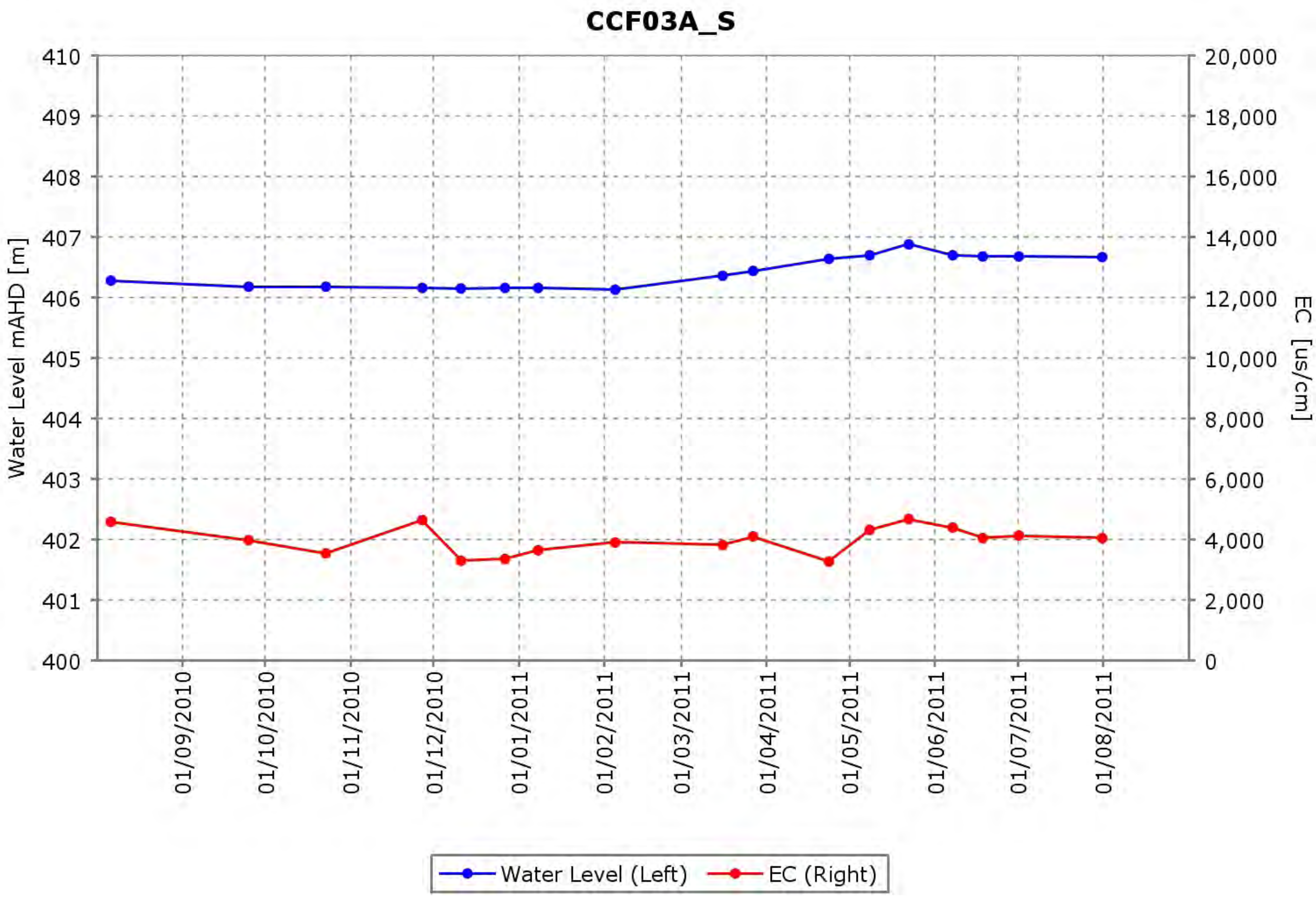

CCF02A_D
Water Level mAHD [m]
EC [us/cm]
410
409
408
407
406
405
404
403
402
401
400
200,000
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

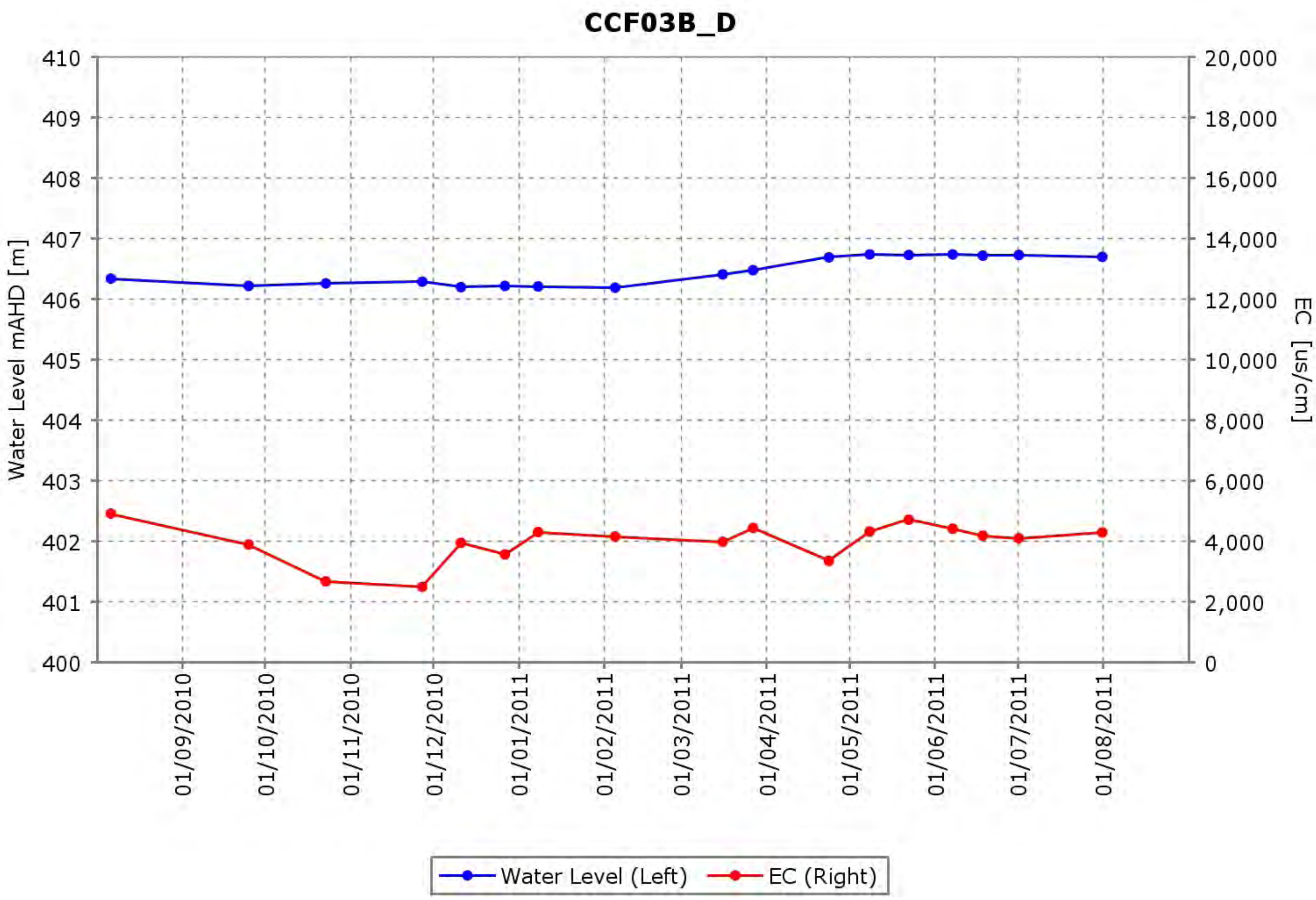
CCF02B_S



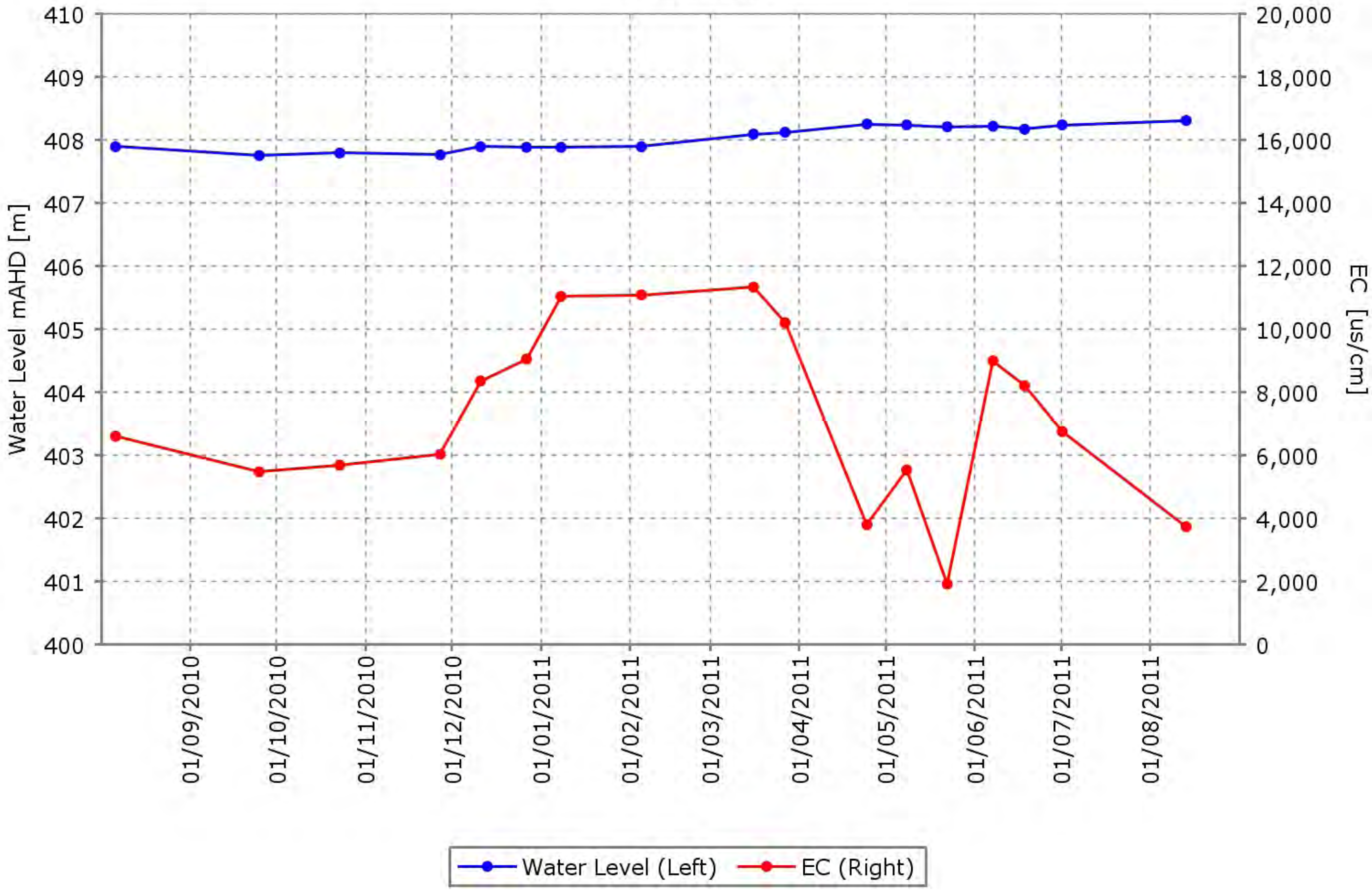
CCF02T



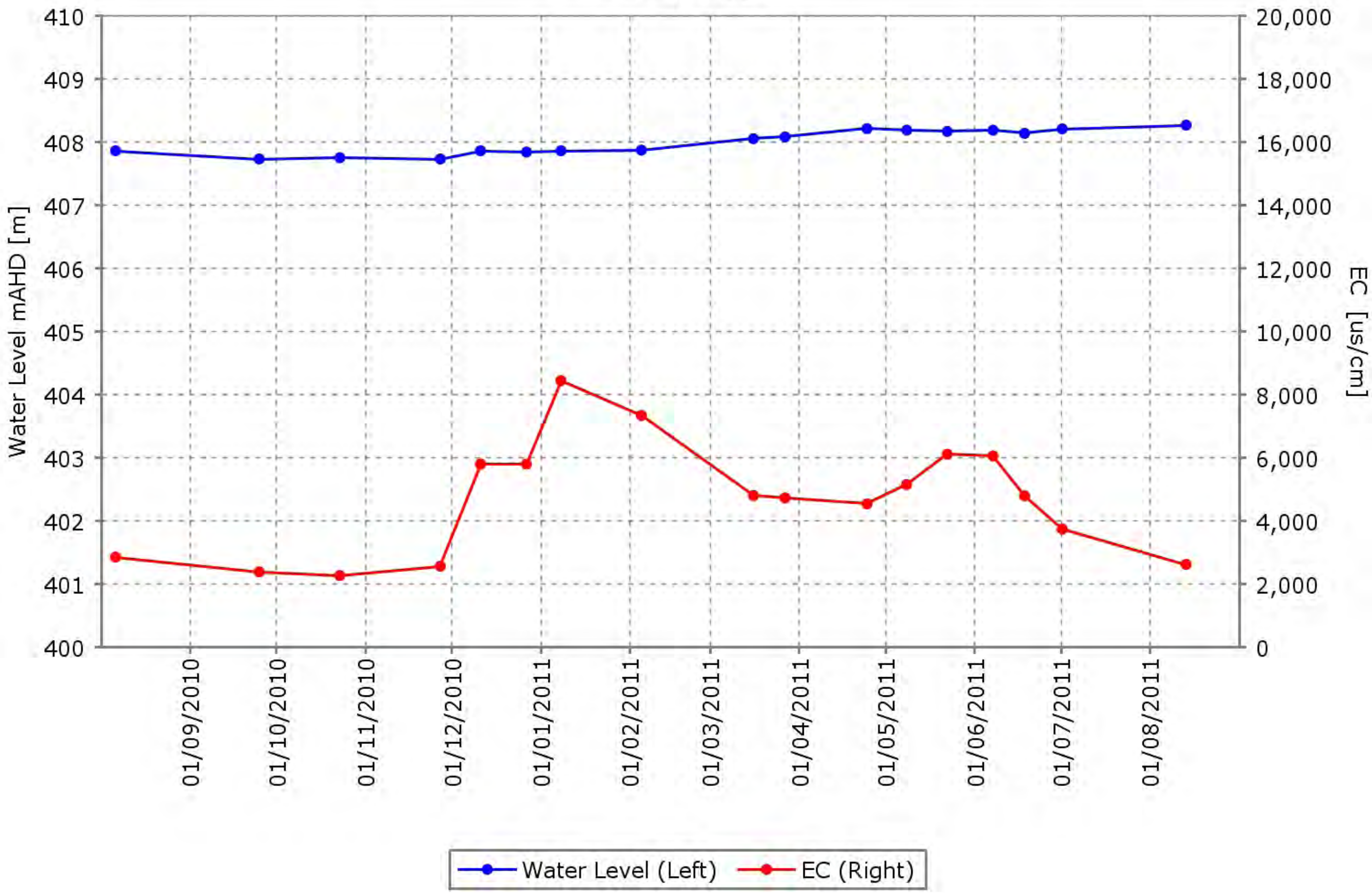

CCF03A_S
Water Level mAHD [m]
EC [us/cm]
410
409
408
407
406
405
404
403
402
401
400
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

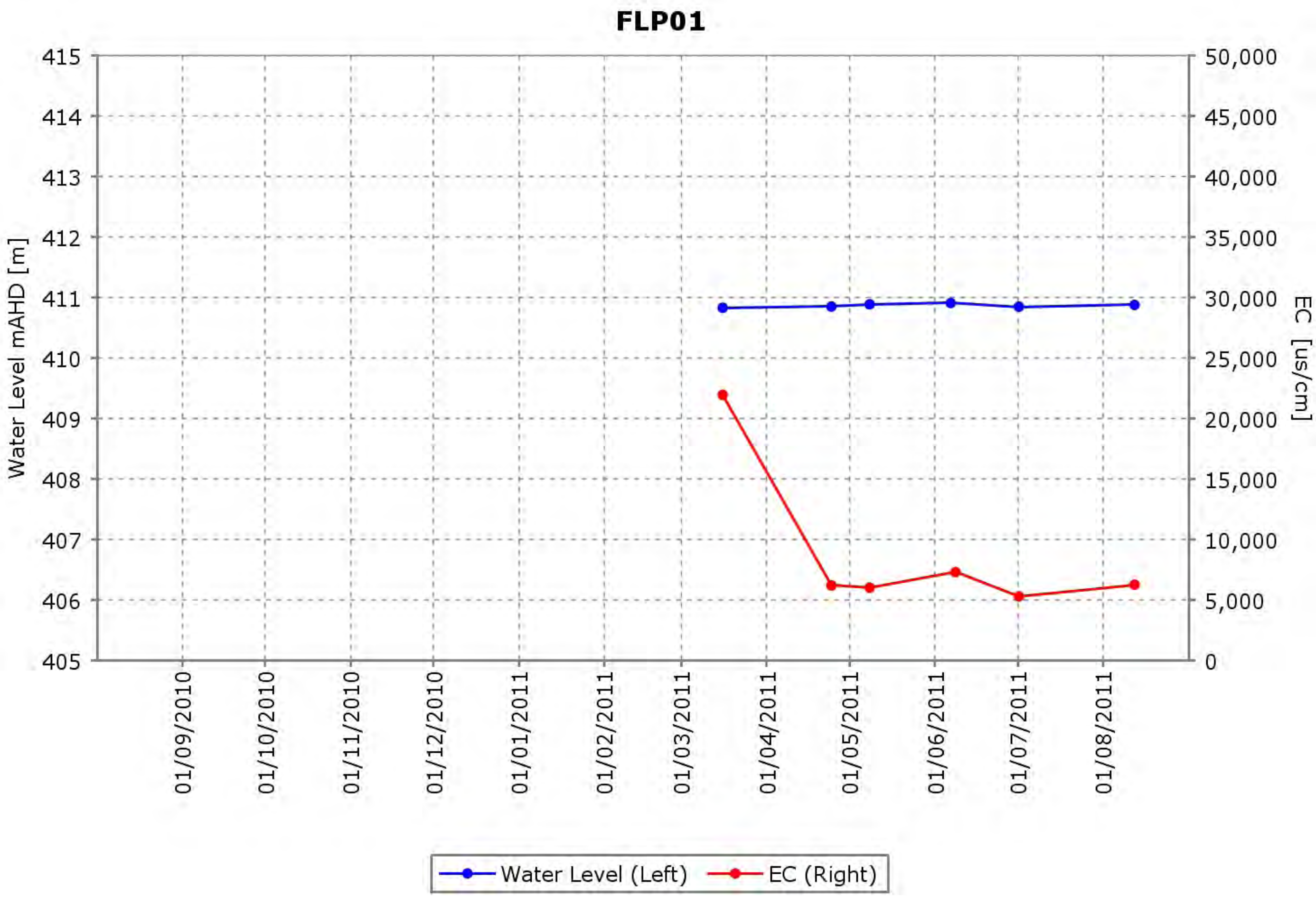

CCF03B_D
Water Level mAHD [m]
EC [us/cm]
410
409
408
407
406
405
404
403
402
401
400
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

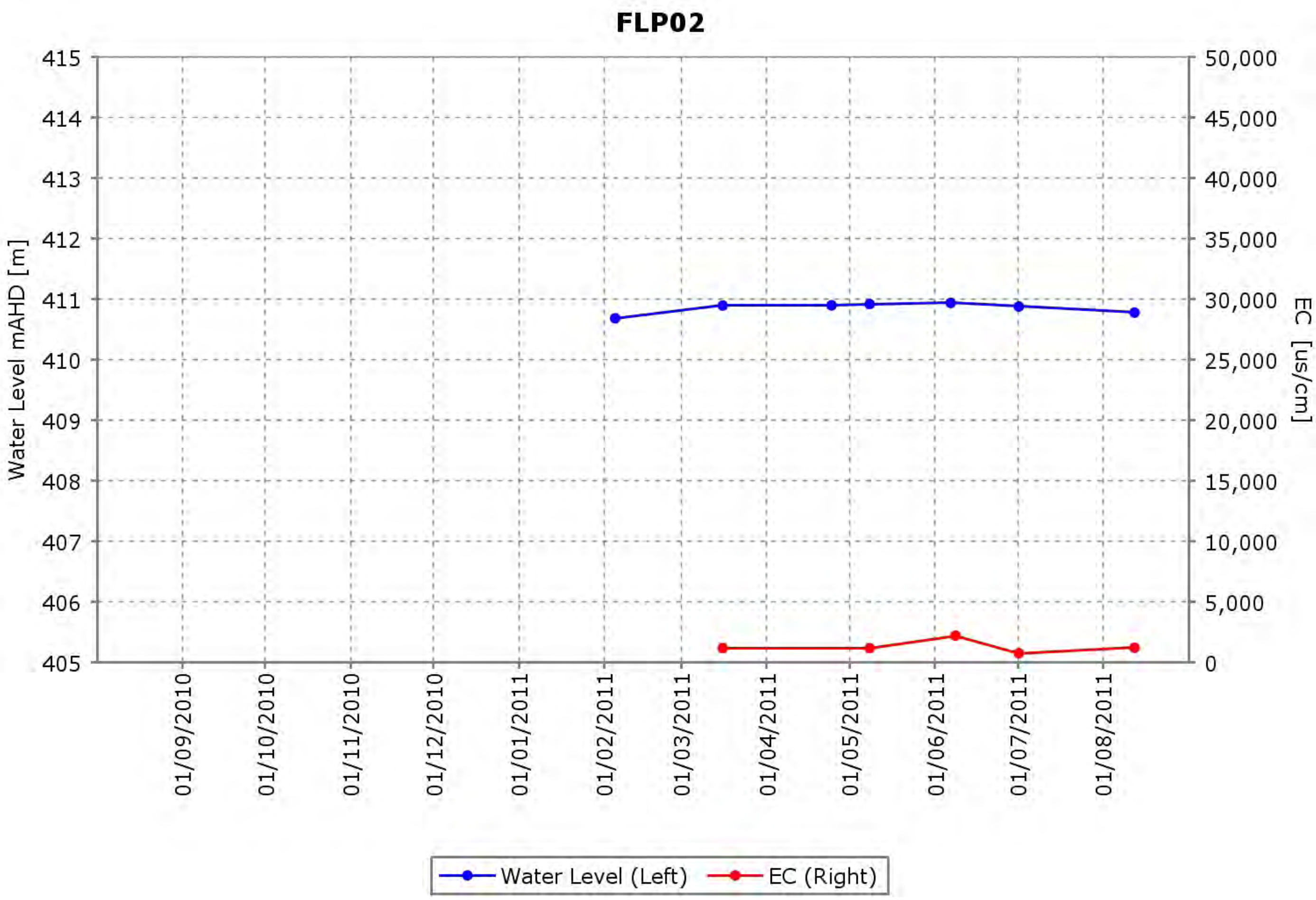
CCF07A_D

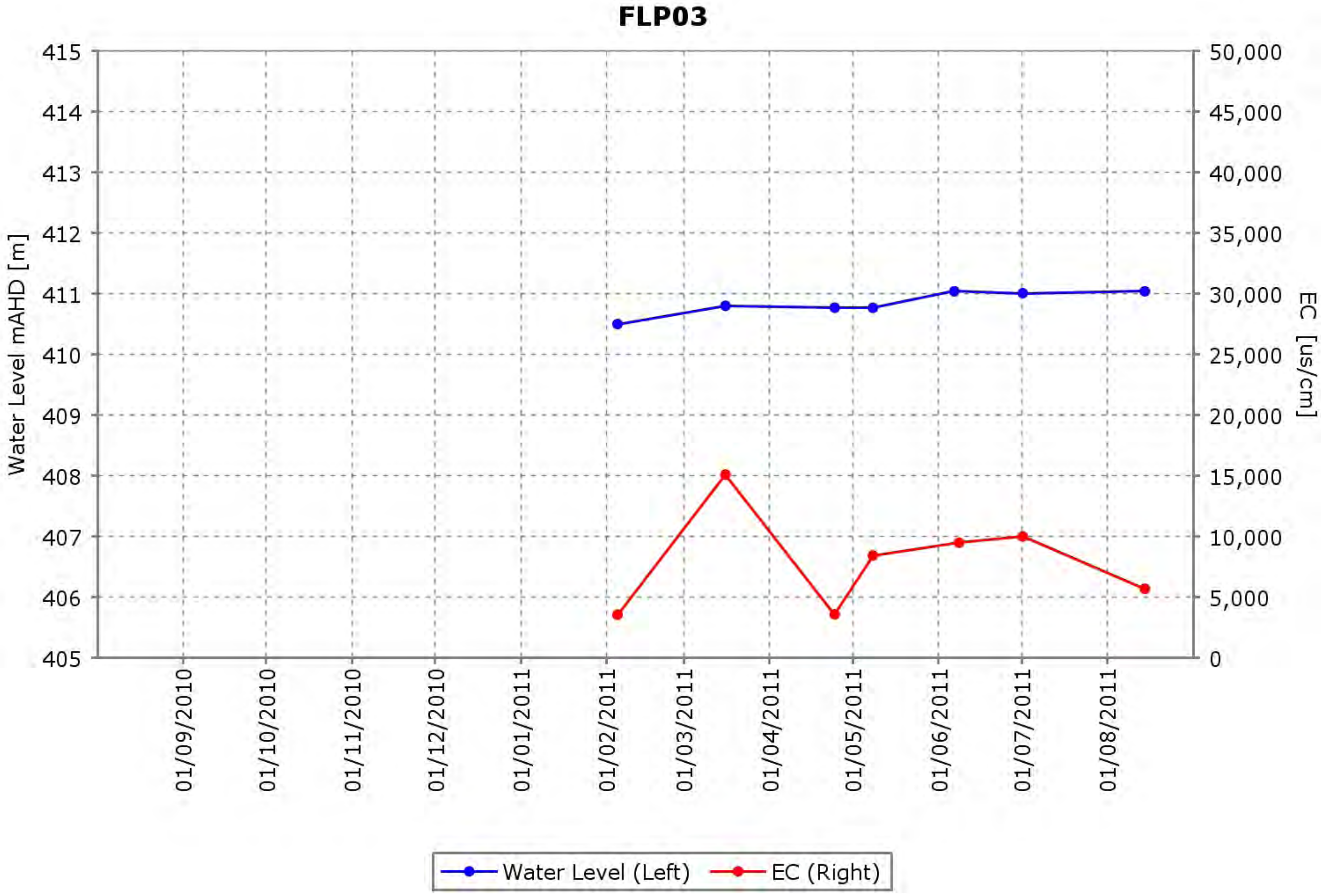


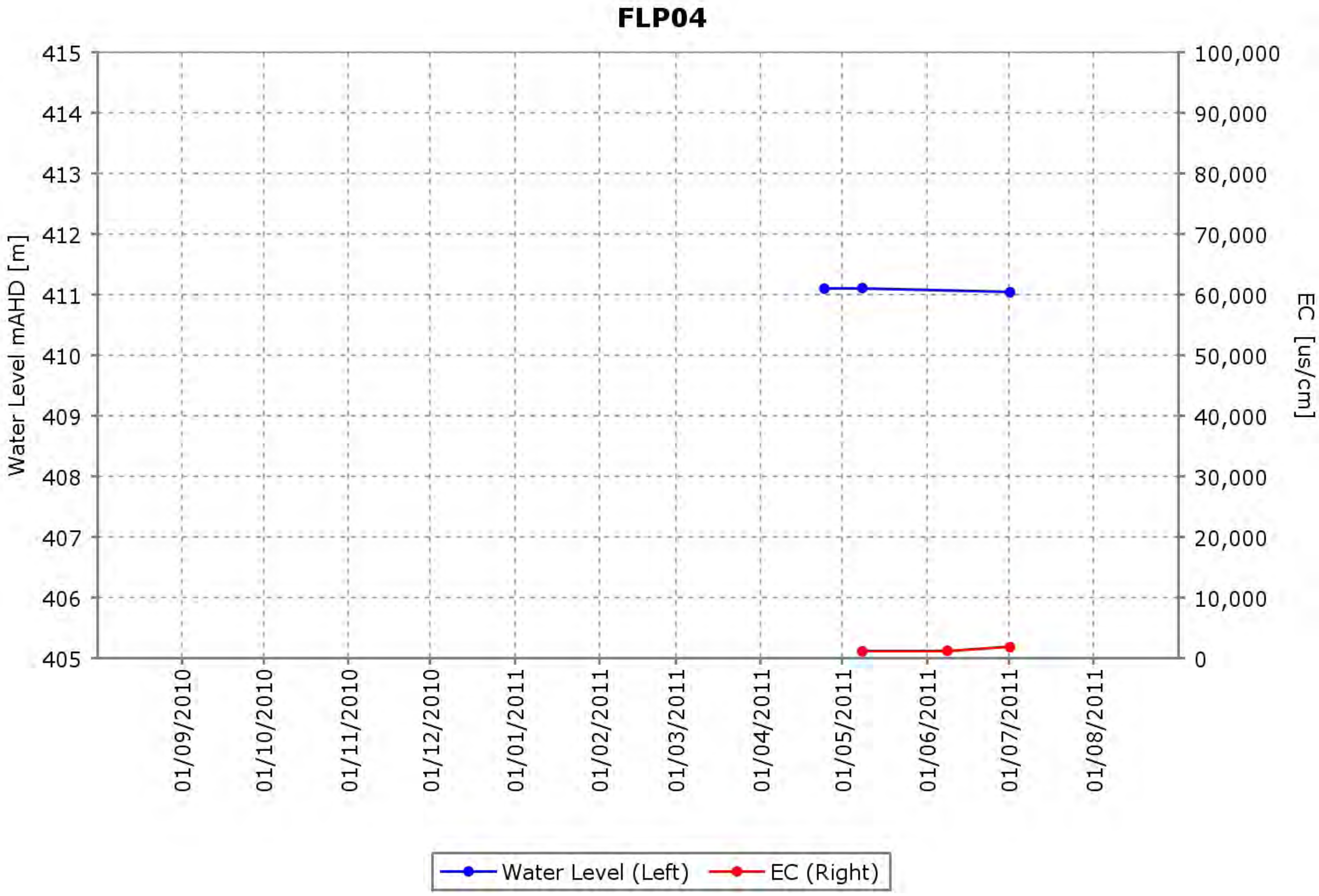
CCF07B_S

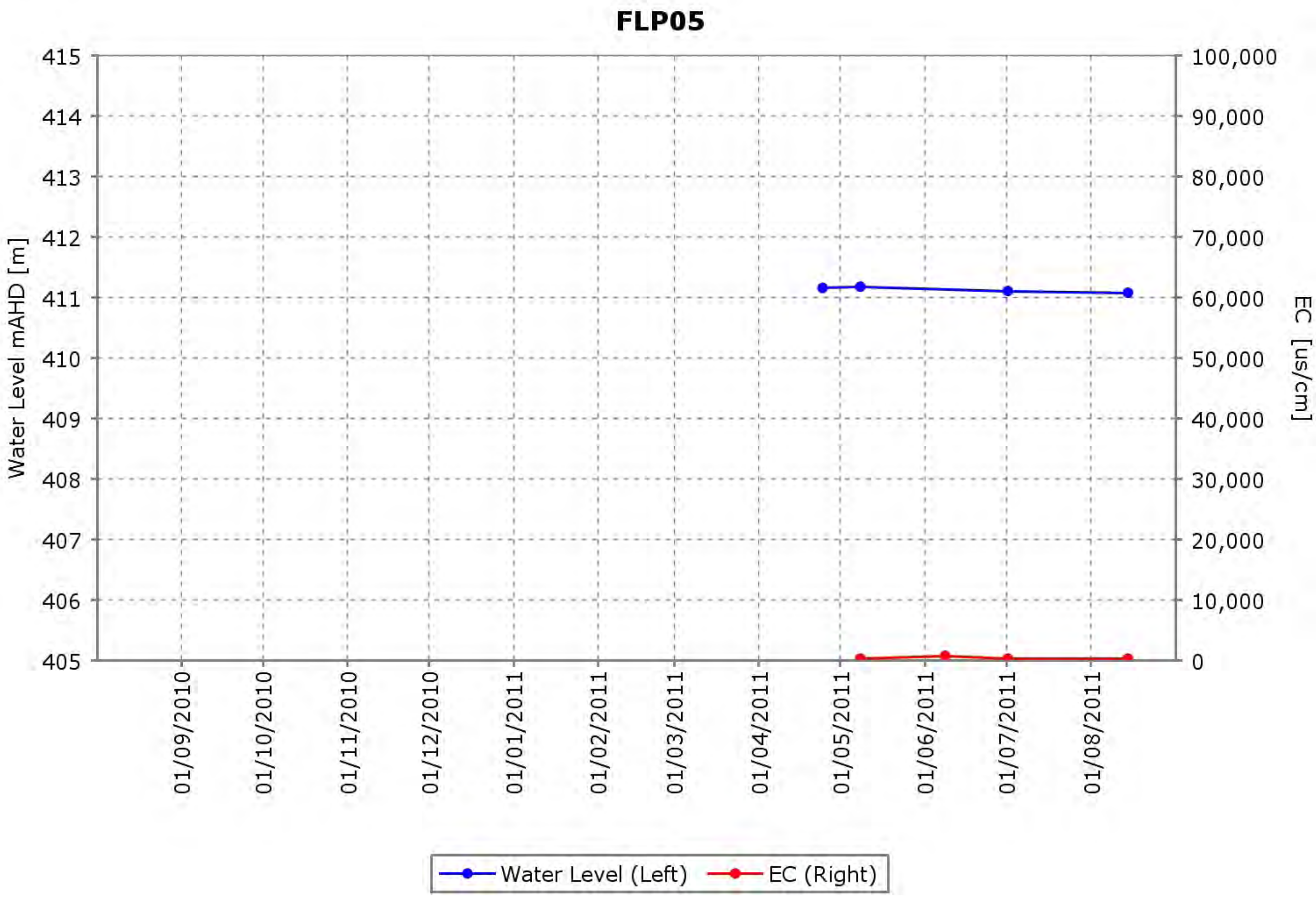


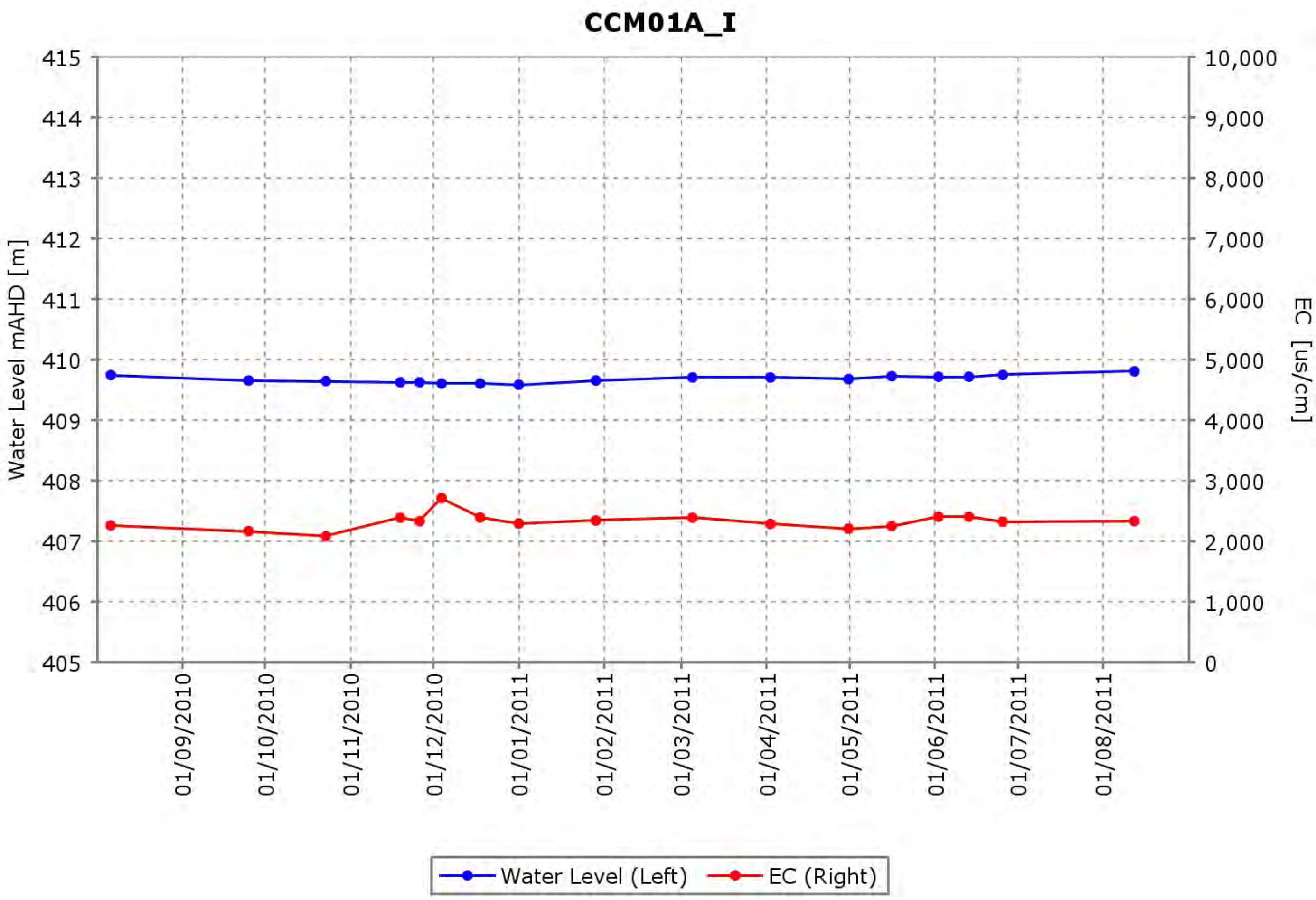

FLP01
415
414
413
412
411
410
409
408
407
406
405
Water Level mAHD [m]
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
EC [us/cm]
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

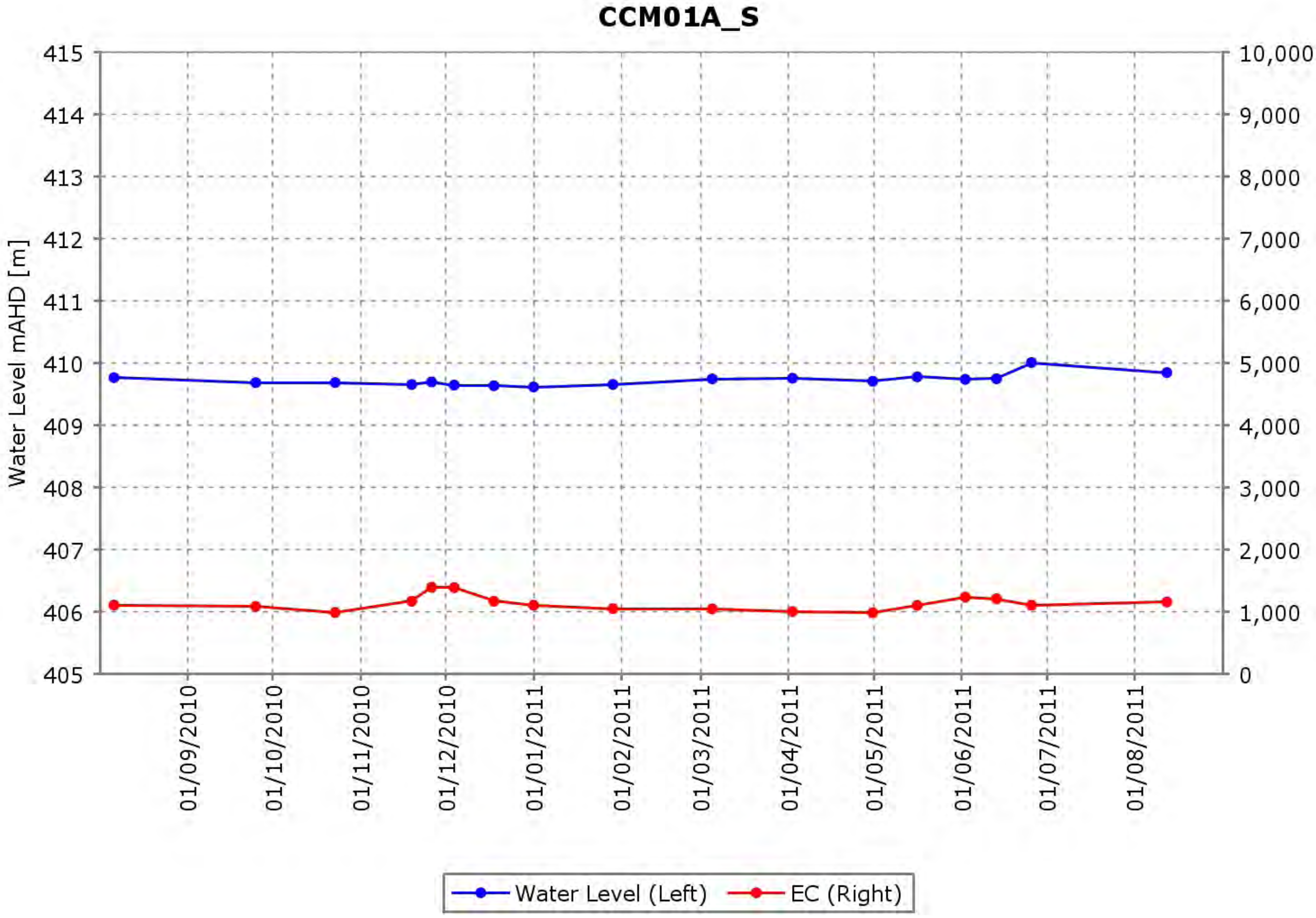

FLP02
415
414
413
412
411
410
409
408
407
406
405
Water Level mAHD [m]
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
EC [us/cm]
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

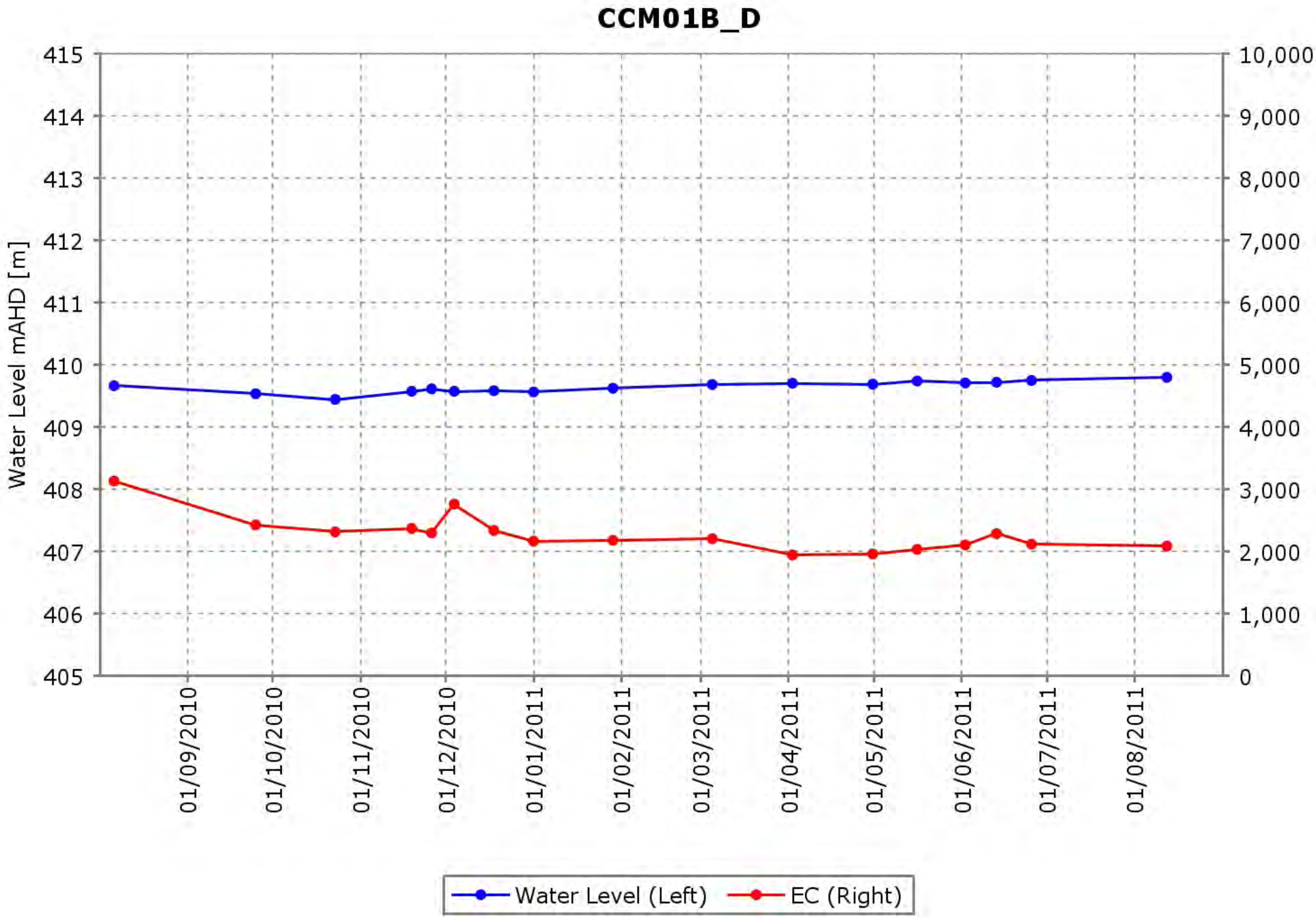

FLP03
Water Level mAHD [m]
EC [us/cm]
415
414
413
412
411
410
409
408
407
406
405
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)


FLP04
Water Level mAHD [m]
EC [us/cm]
415
414
413
412
411
410
409
408
407
406
405
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

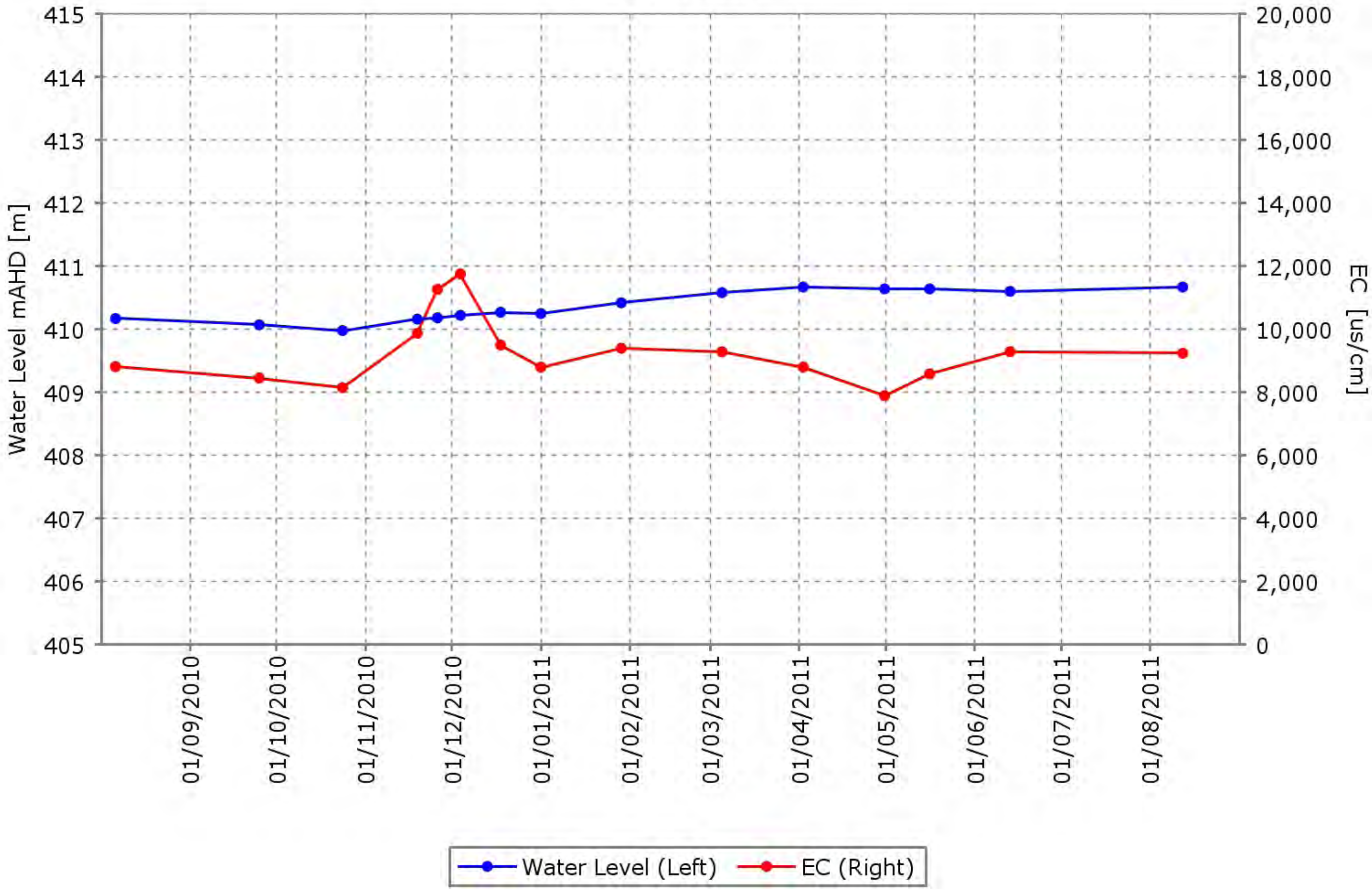

FLP05
Water Level mAHD [m]
415
414
413
412
411
410
409
408
407
406
405
EC [us/cm]
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)


CCM01A_I
Water Level mAHD [m]
415
414
413
412
411
410
409
408
407
406
405
EC [us/cm]
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

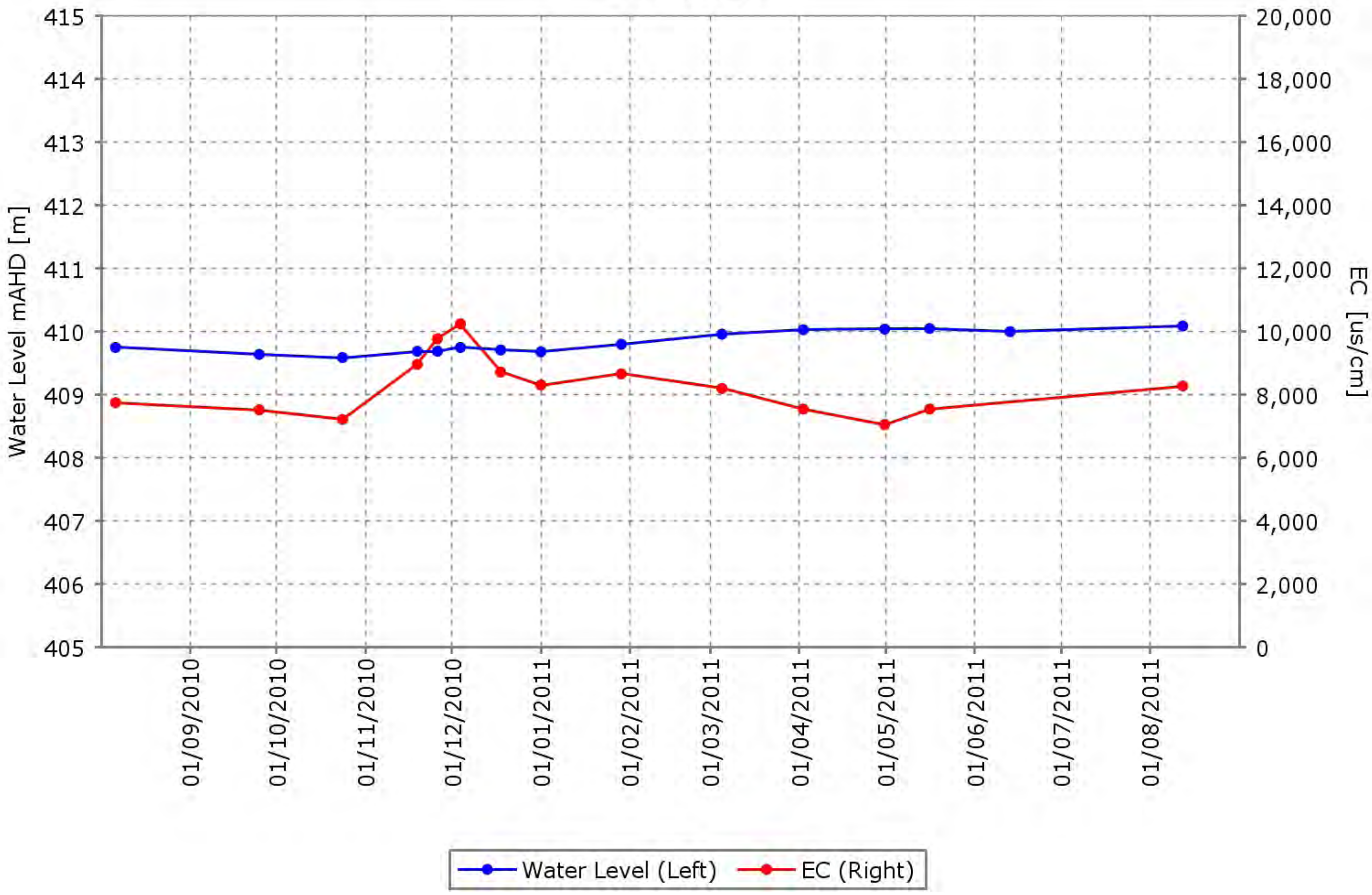

CCM01A_S
Water Level mAHD [m]
EC [us/cm]
415
414
413
412
411
410
409
408
407
406
405
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

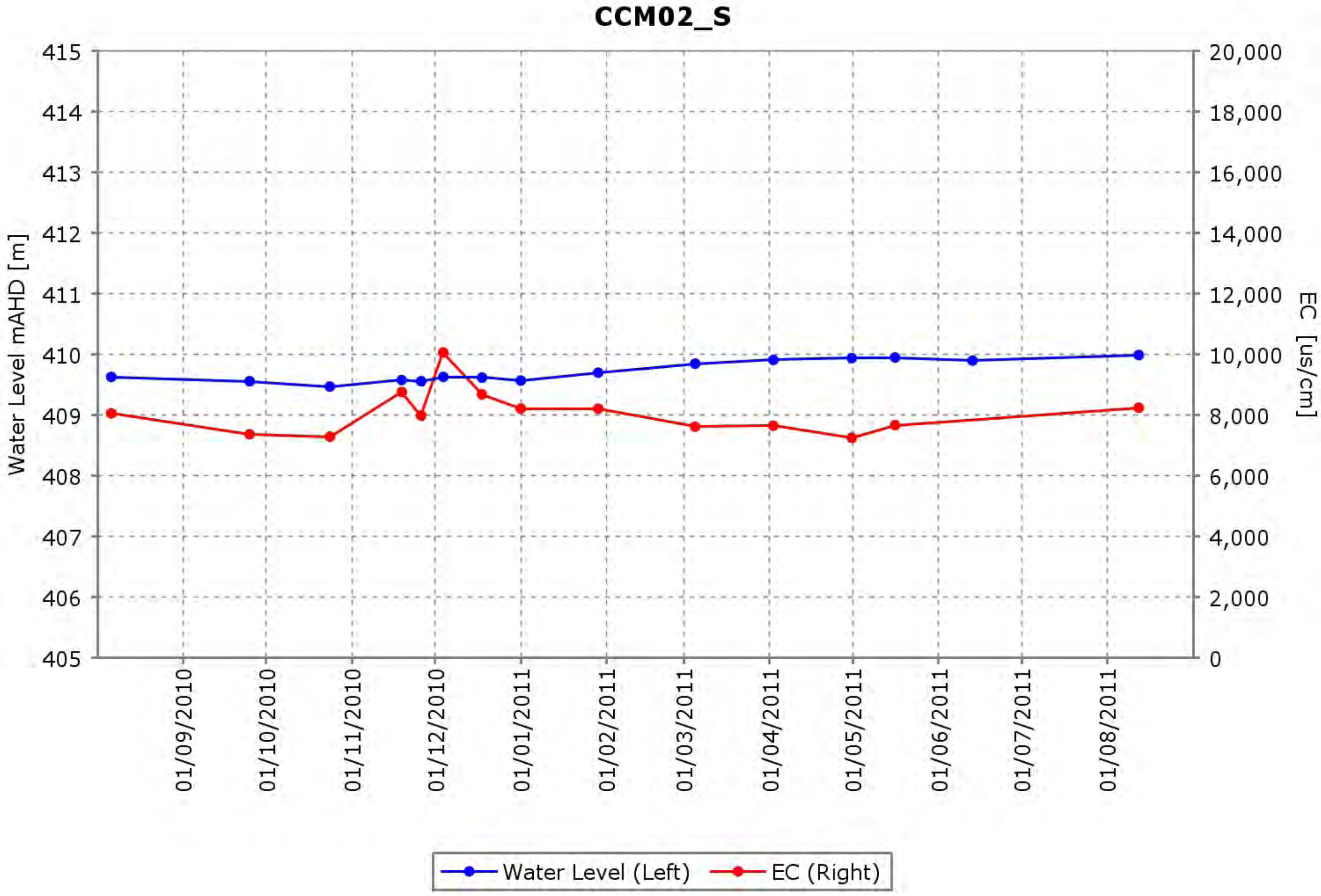

CCM01B_D
Water Level mAHD [m]
EC [us/cm]
415
414
413
412
411
410
409
408
407
406
405
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

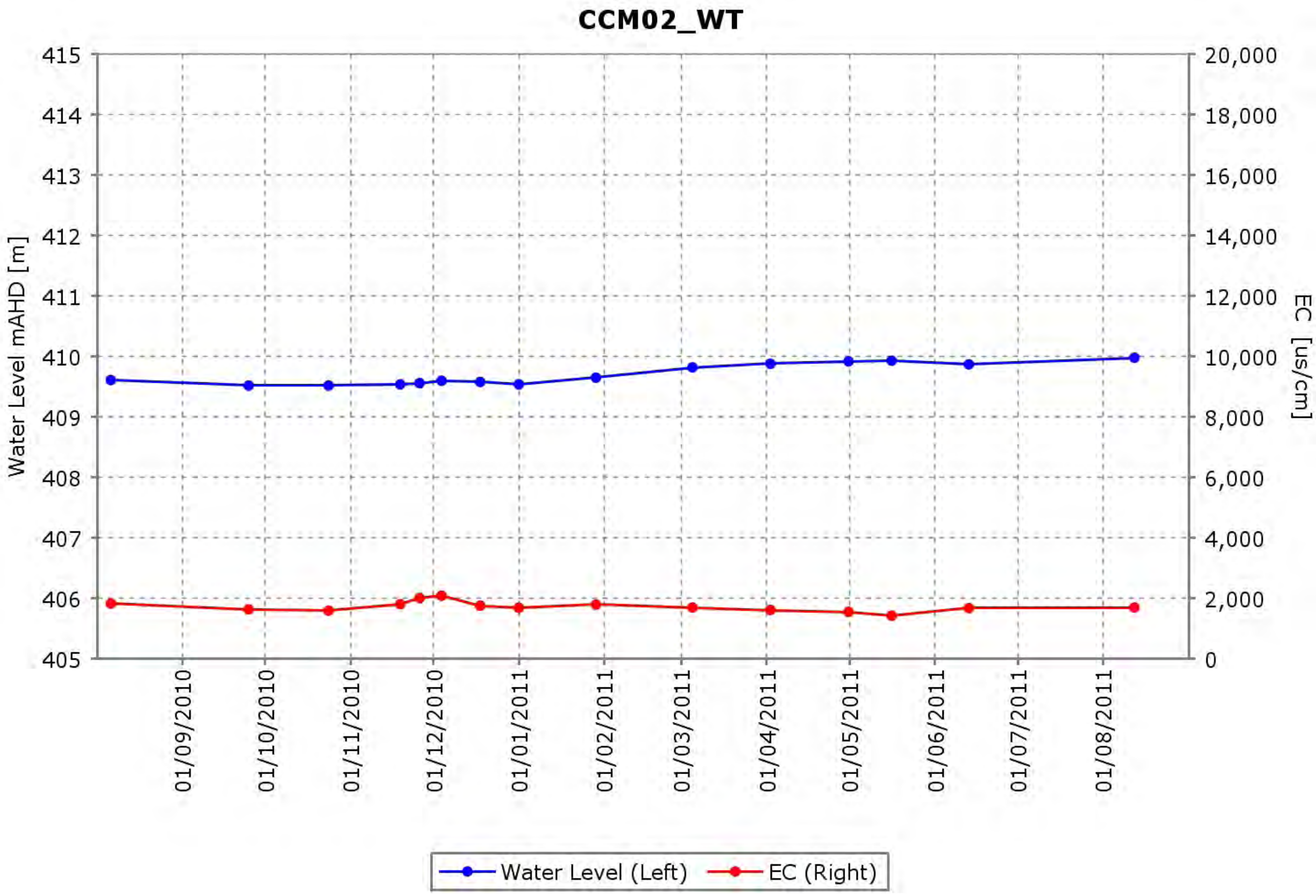
CCM02_D

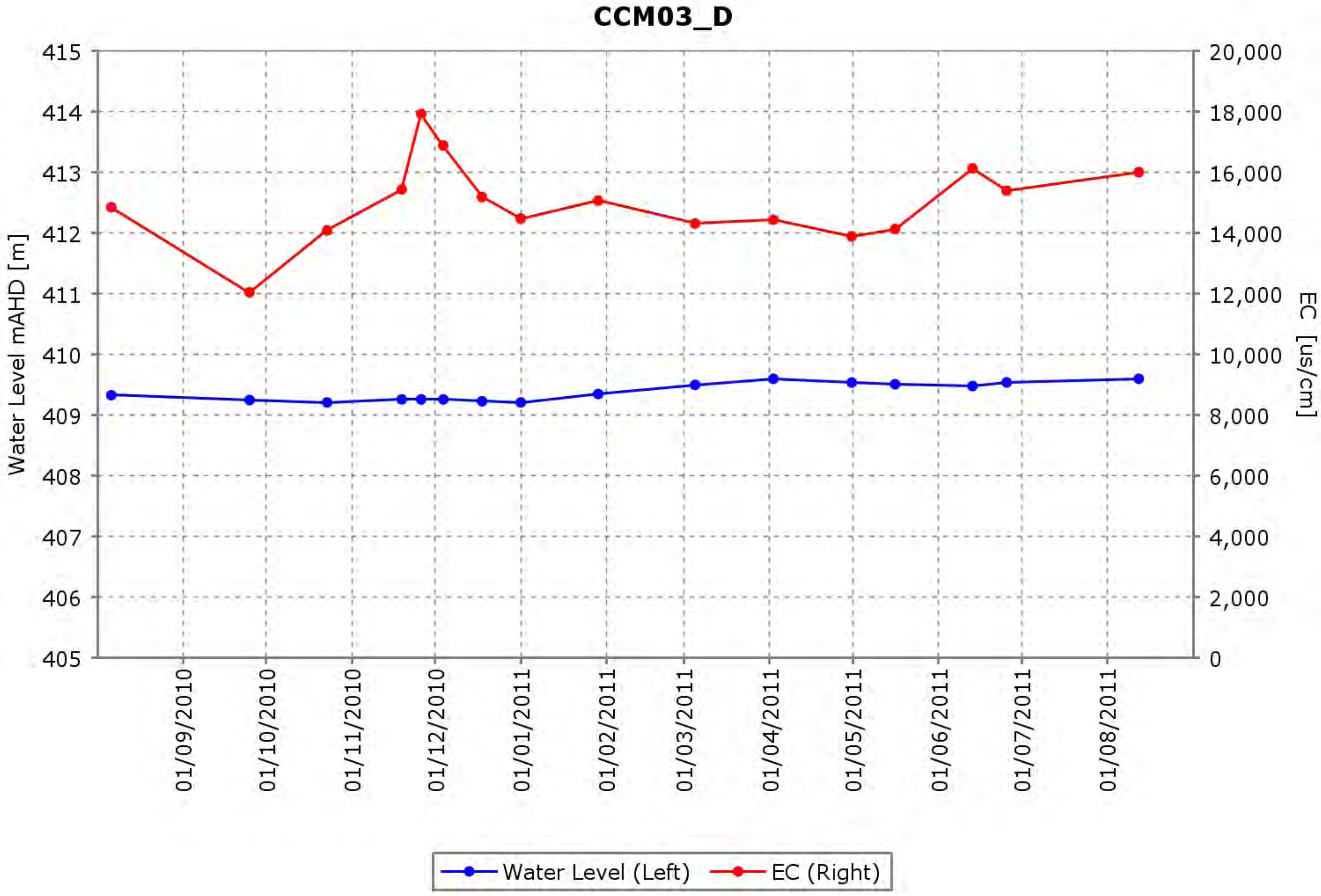


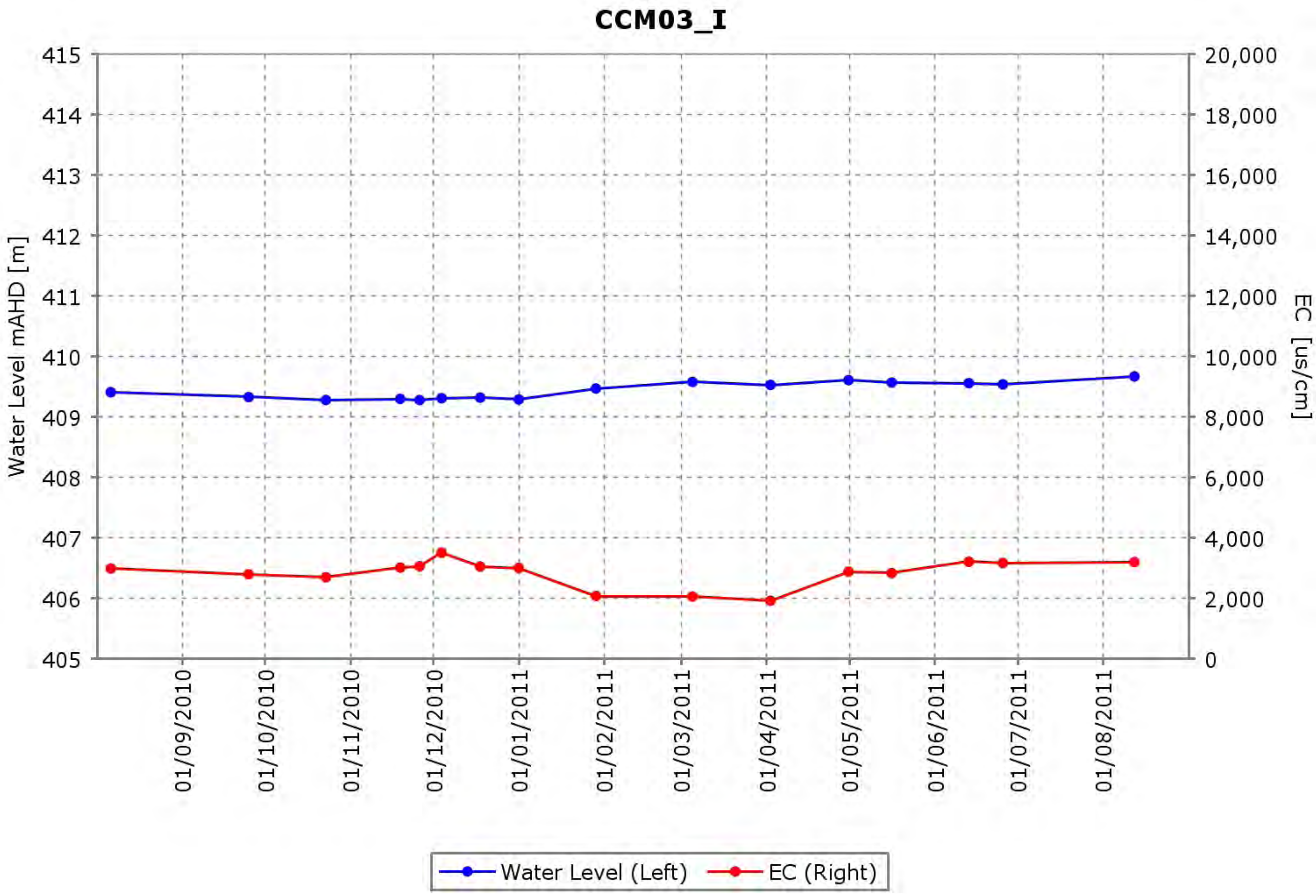
CCM02_I

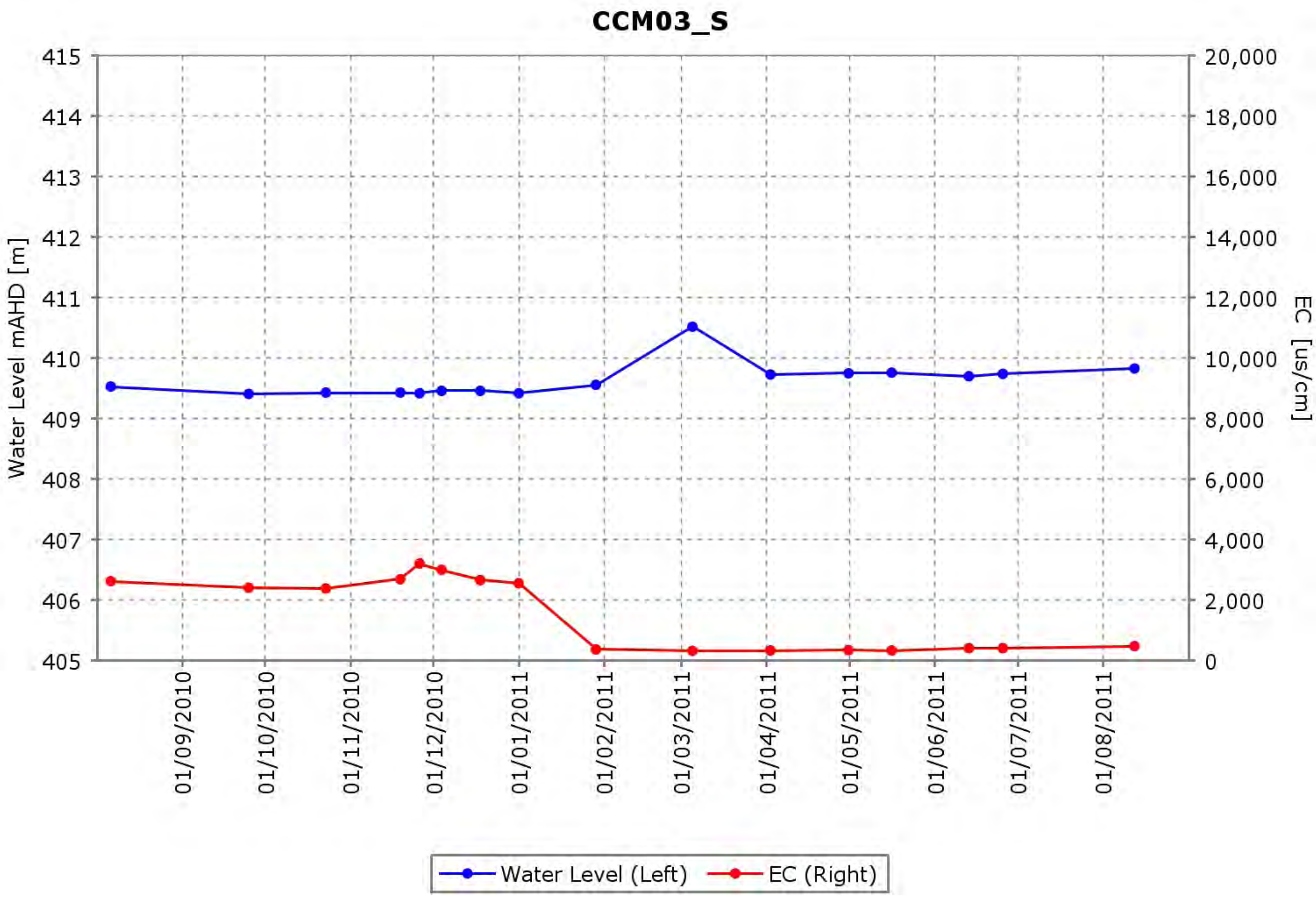


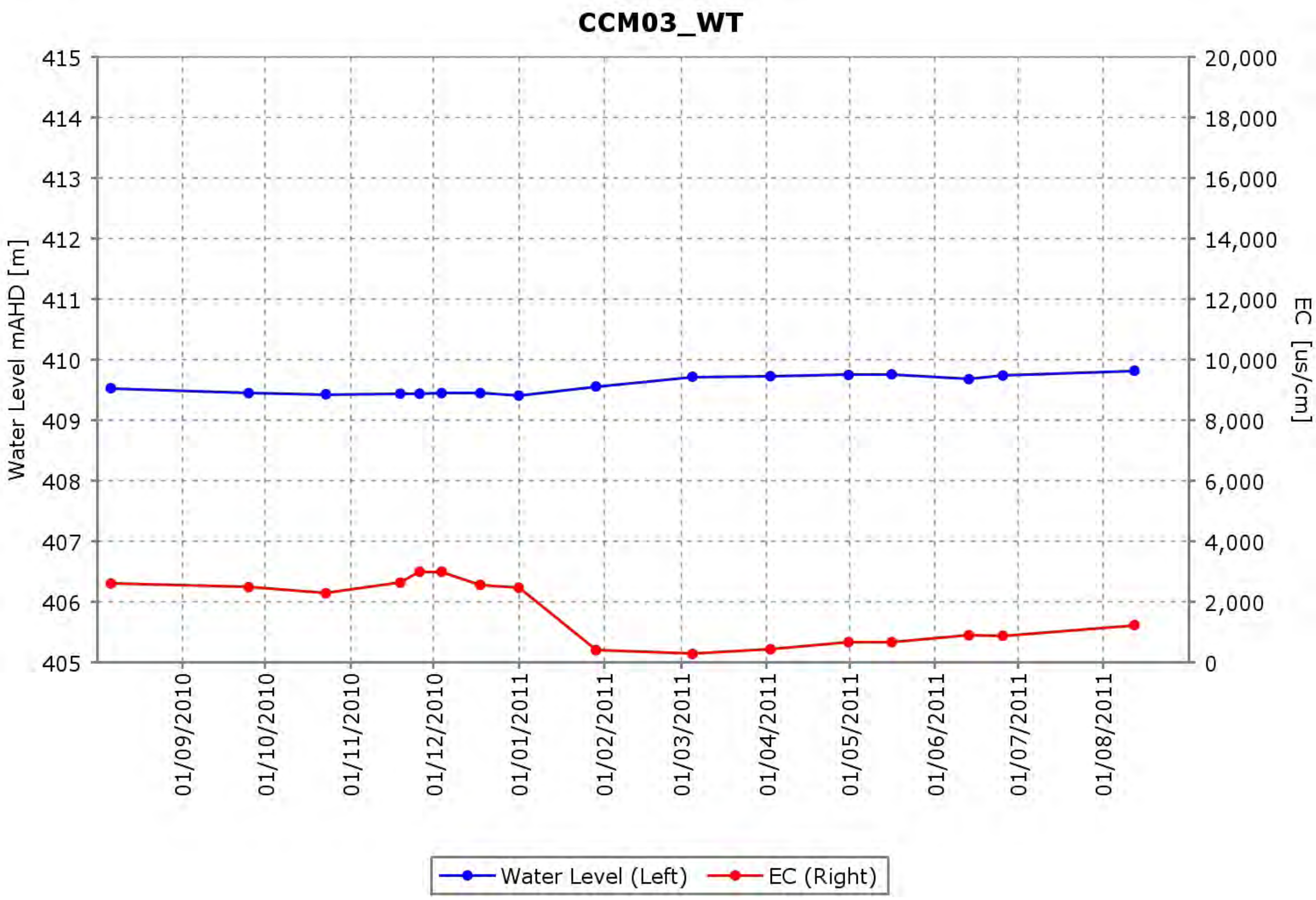

CCM02_S
Water Level mAHD [m]
EC [us/cm]
415
414
413
412
411
410
409
408
407
406
405
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

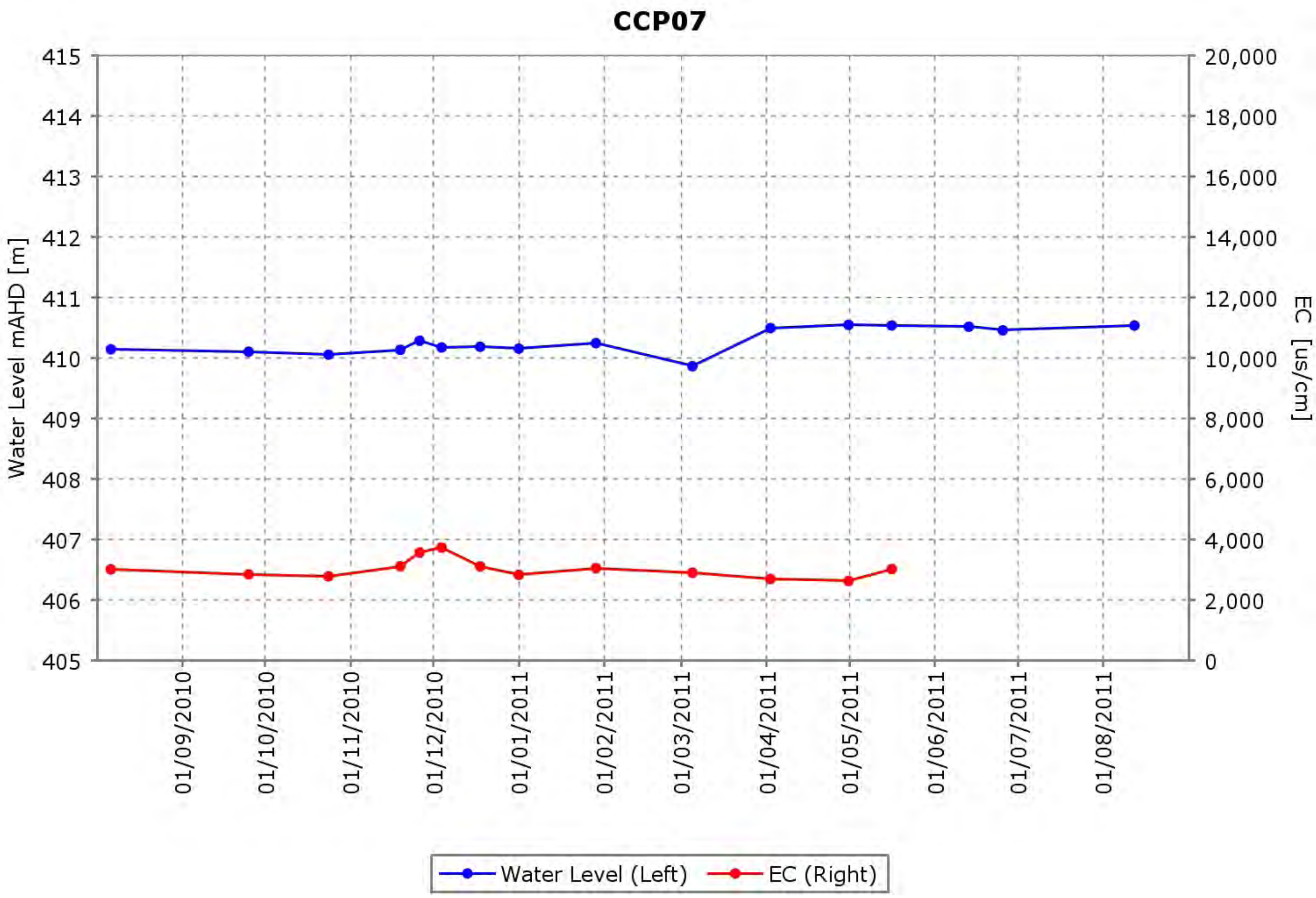

CCM02_WT
Water Level mAHD [m]
EC [us/cm]
415
414
413
412
411
410
409
408
407
406
405
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

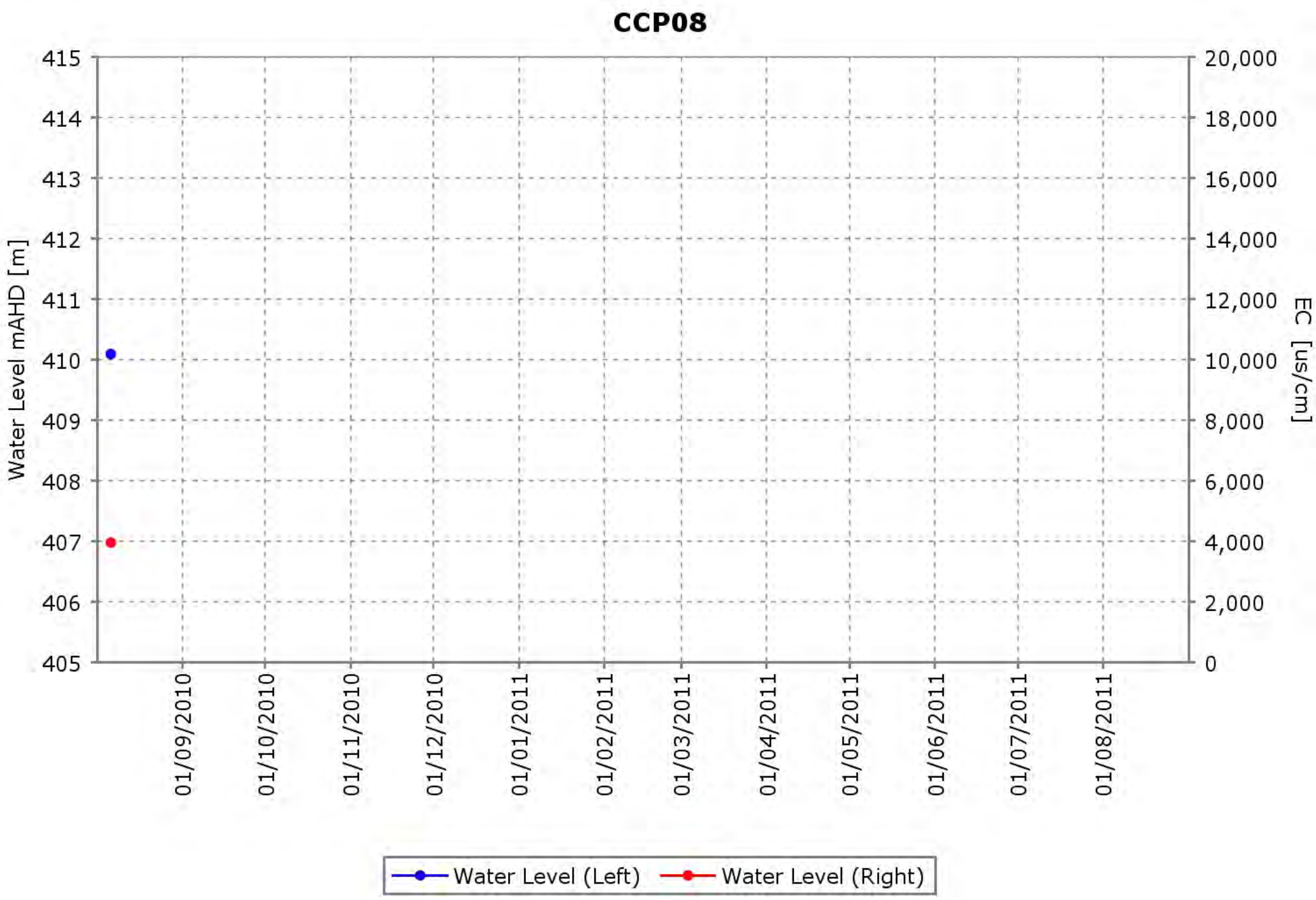

CCM03_D
415
414
413
412
411
410
409
408
407
406
405
Water Level mAHD [m]
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
EC [us/cm]
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

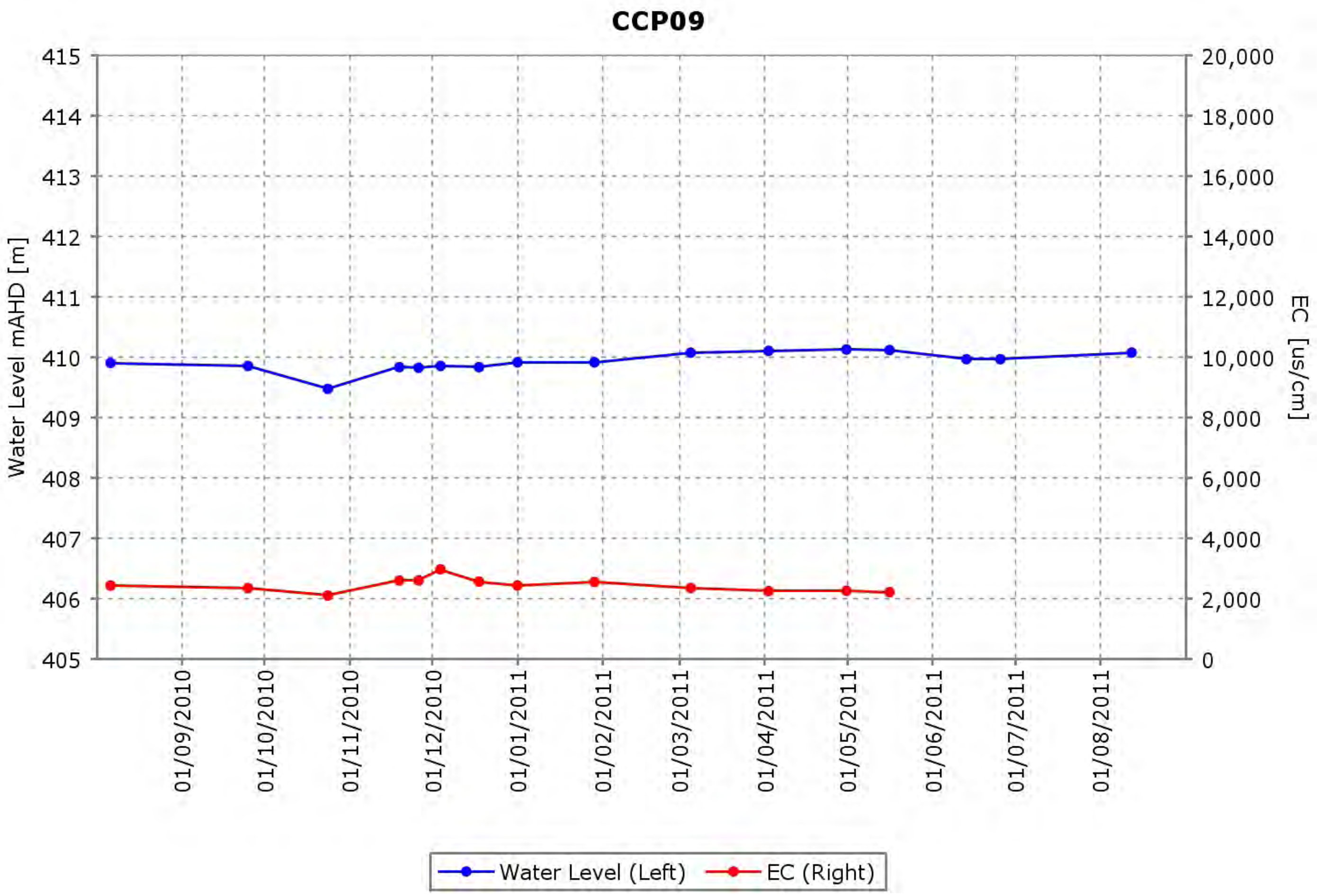

CCM03_I
415
414
413
412
411
410
409
408
407
406
405
Water Level mAHD [m]
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
EC [us/cm]
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

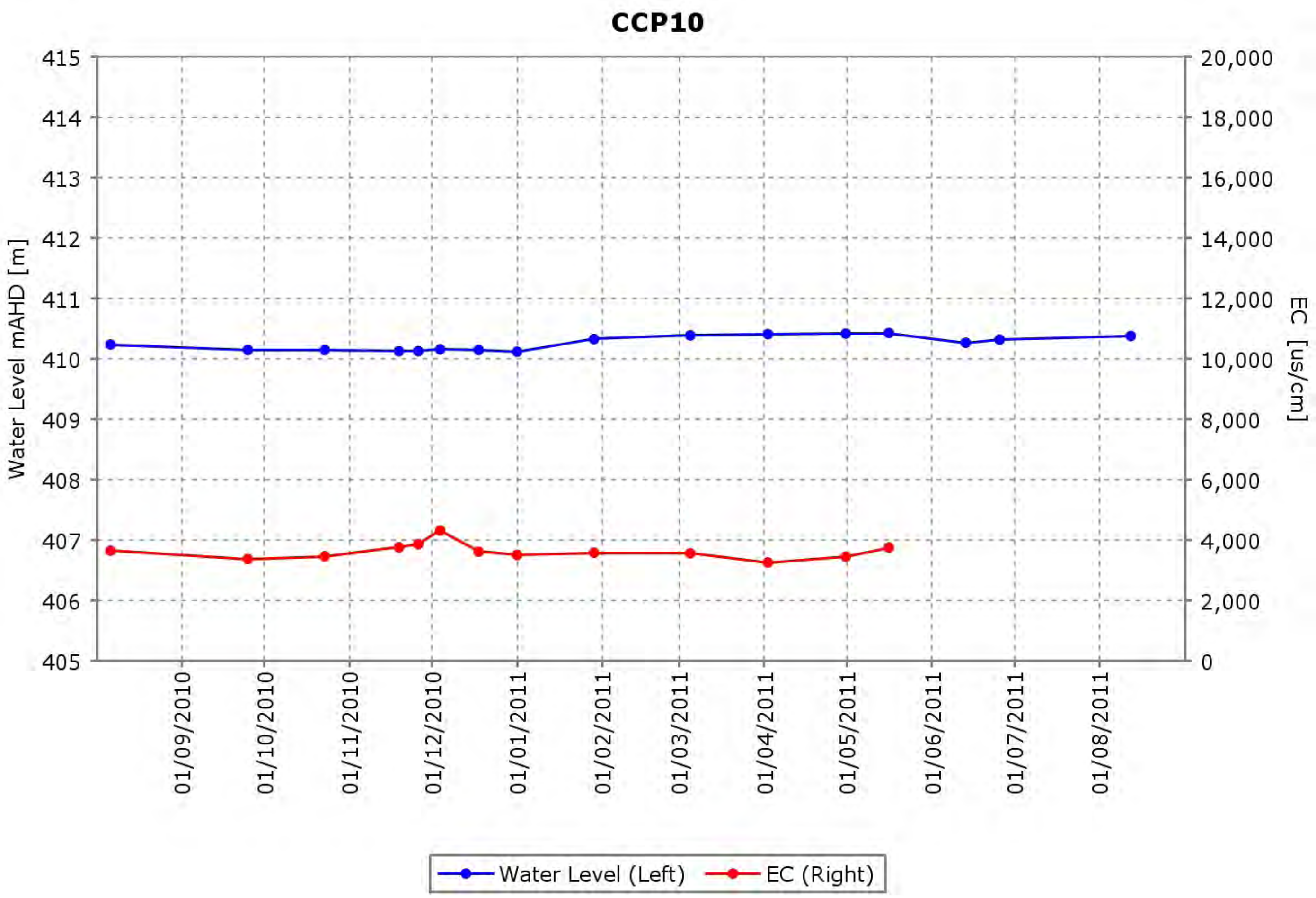

CCM03_S
Water Level mAHD [m]
415
414
413
412
411
410
409
408
407
406
405
EC [us/cm]
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

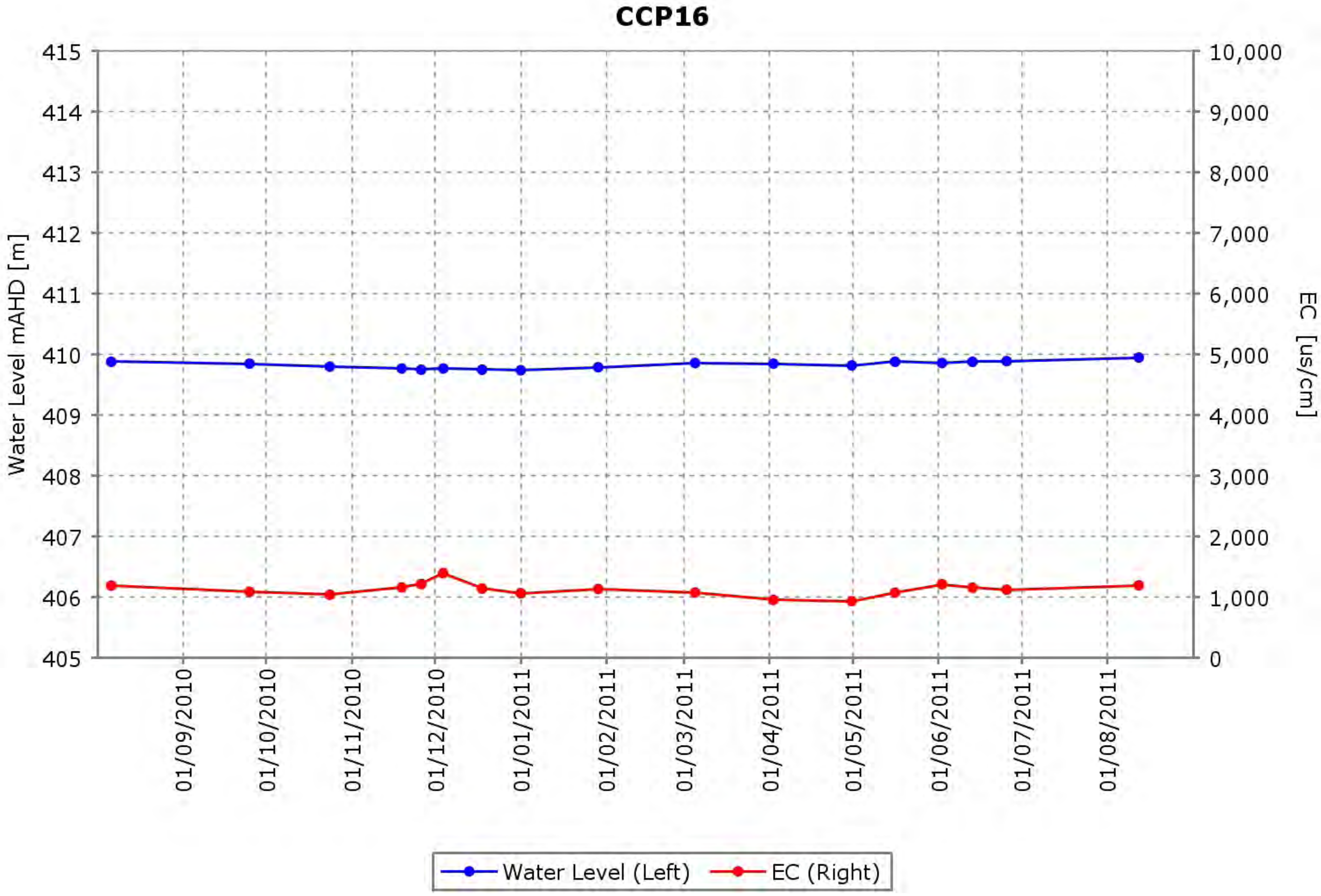

CCM03_WT
Water Level mAHD [m]
415
414
413
412
411
410
409
408
407
406
405
EC [us/cm]
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

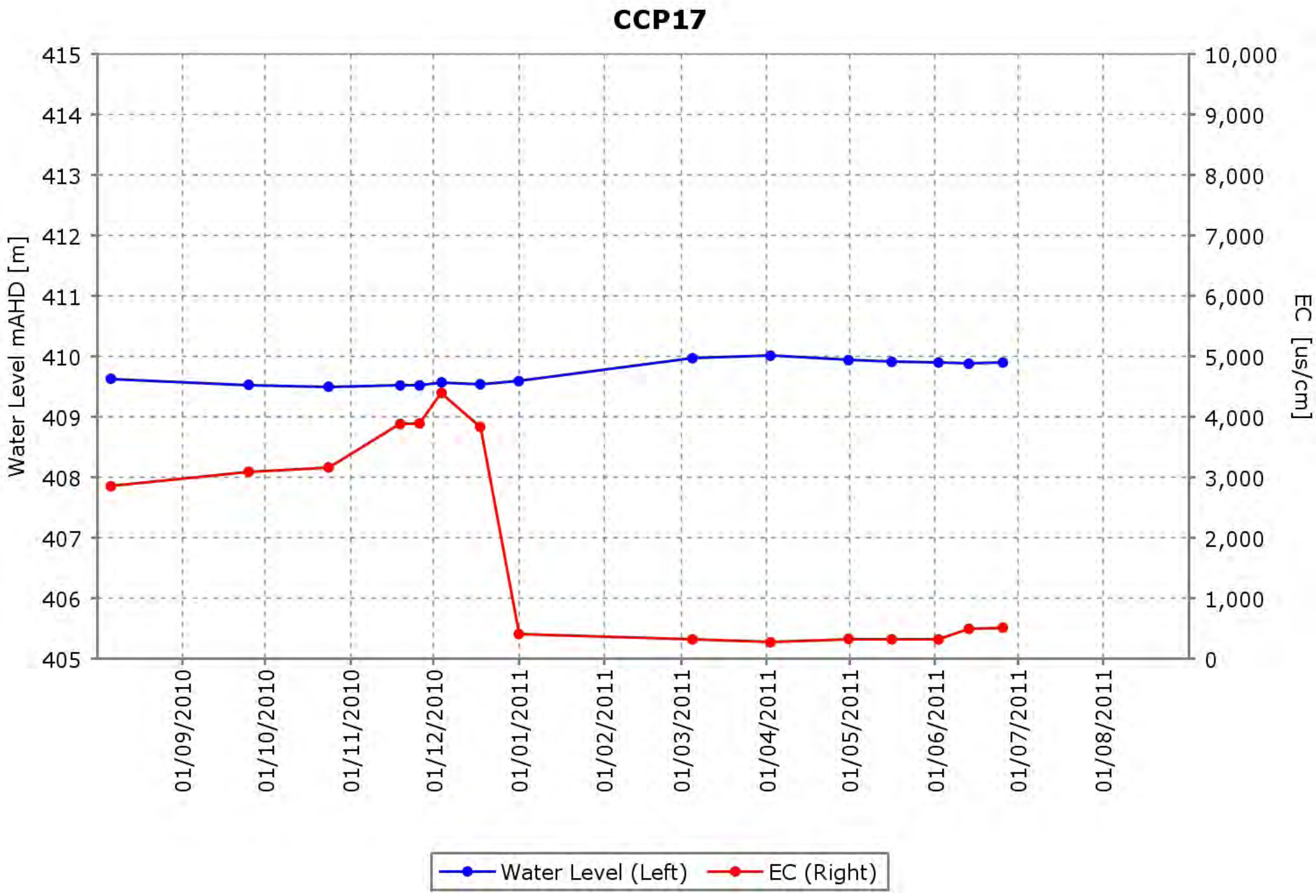

CCP07
Water Level mAHD [m]
EC [us/cm]
415
414
413
412
411
410
409
408
407
406
405
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

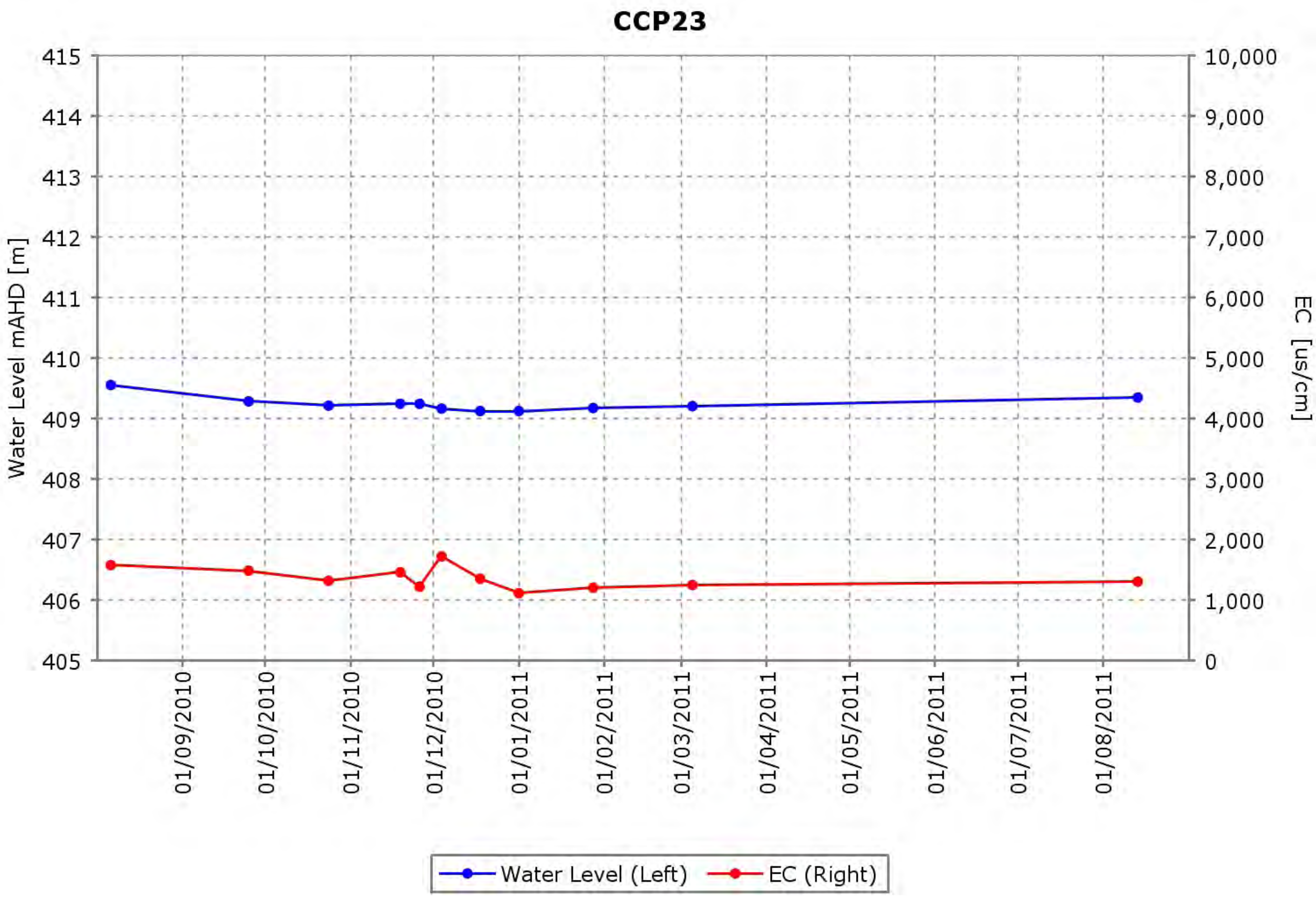

CCP08
Water Level mAHD [m]
EC [us/cm]
415
414
413
412
411
410
409
408
407
406
405
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
Water Level (Right)

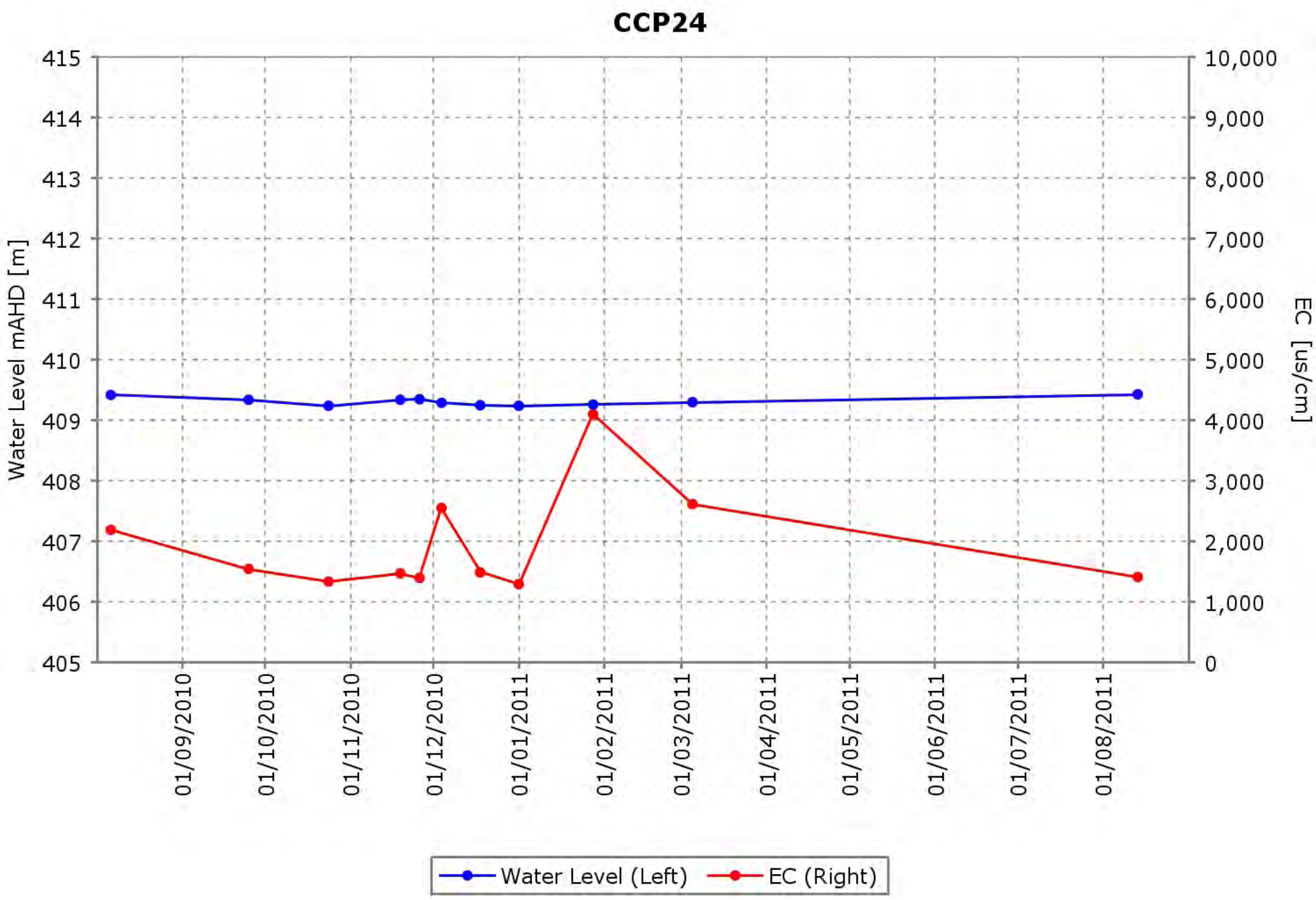

CCP09
Water Level mAHD [m]
EC [us/cm]
415
414
413
412
411
410
409
408
407
406
405
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

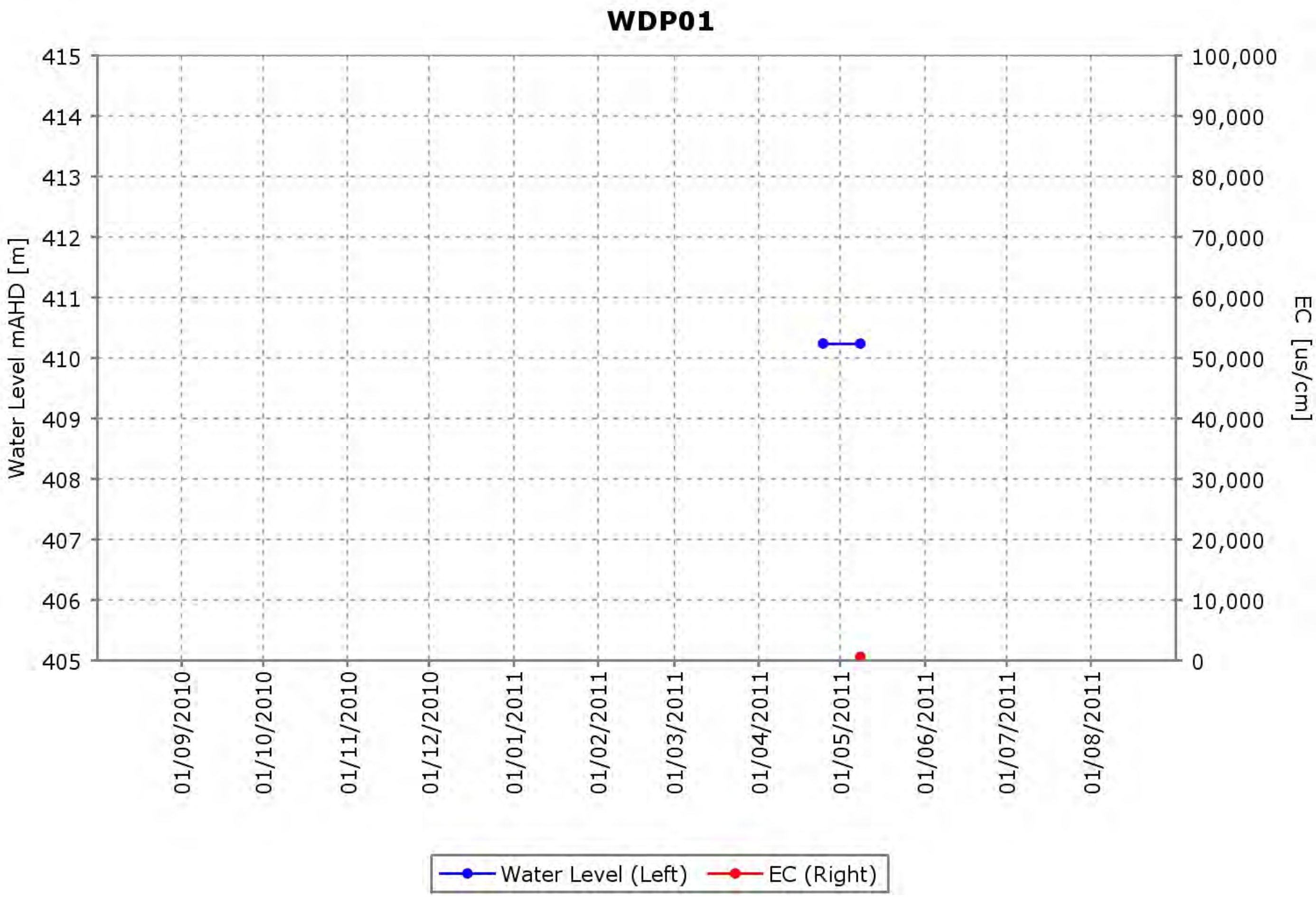

CCP10
Water Level mAHD [m]
EC [us/cm]
415
414
413
412
411
410
409
408
407
406
405
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

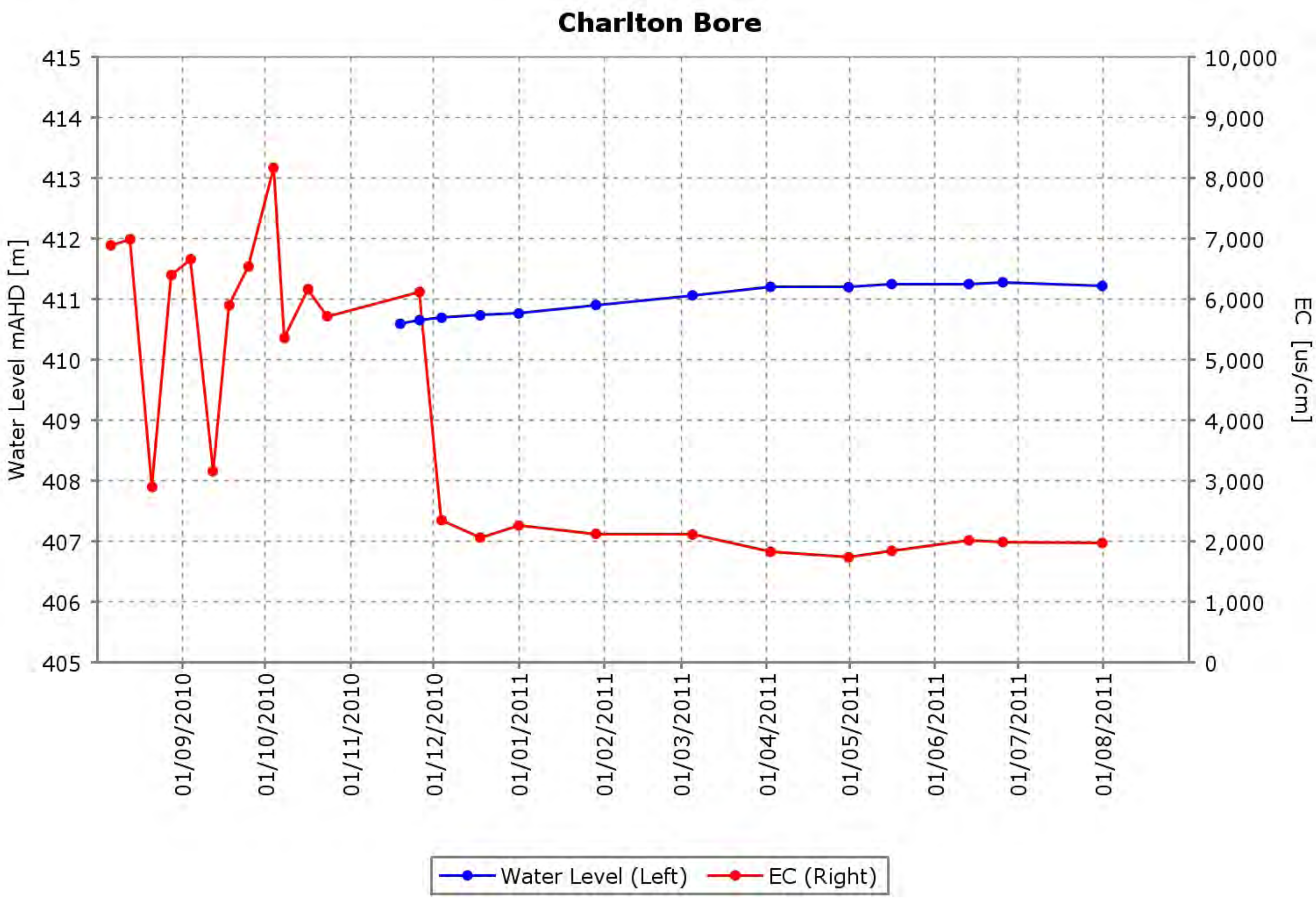

CCP16
Water Level mAHD [m]
415
414
413
412
411
410
409
408
407
406
405
EC [us/cm]
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

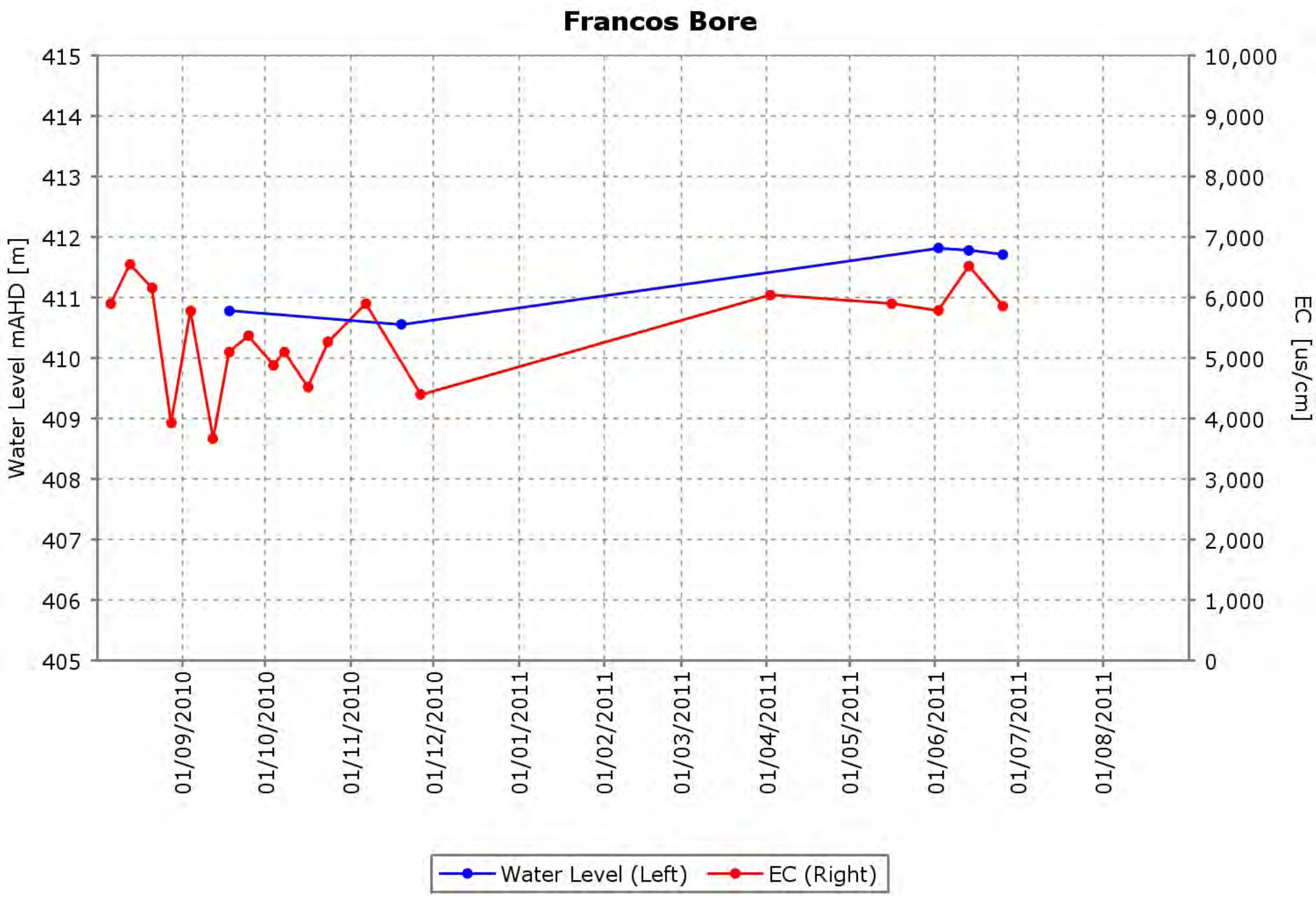

CCP17
Water Level mAHD [m]
415
414
413
412
411
410
409
408
407
406
405
EC [us/cm]
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

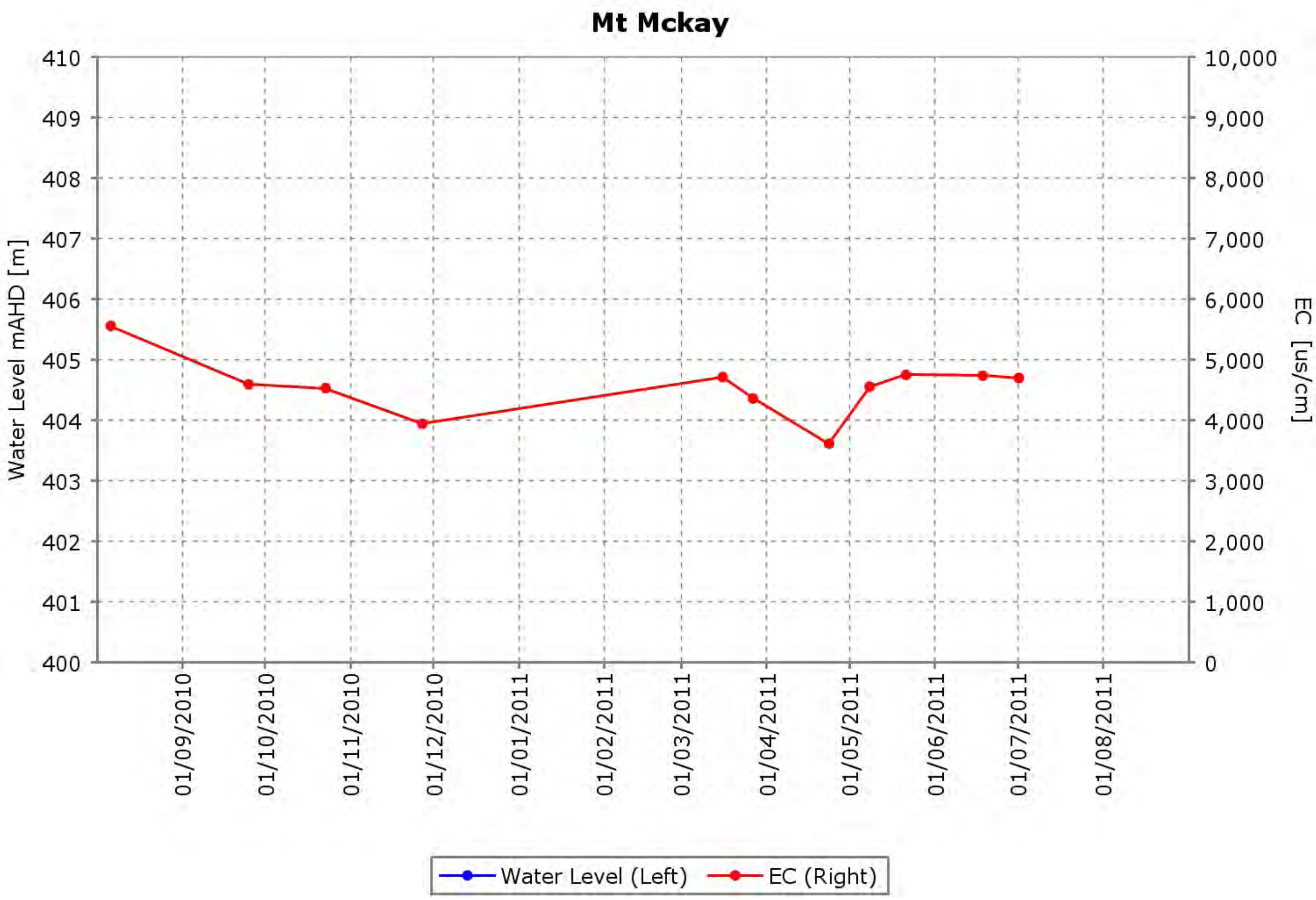

CCP23
Water Level mAHD [m]
EC [us/cm]
415
414
413
412
411
410
409
408
407
406
405
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

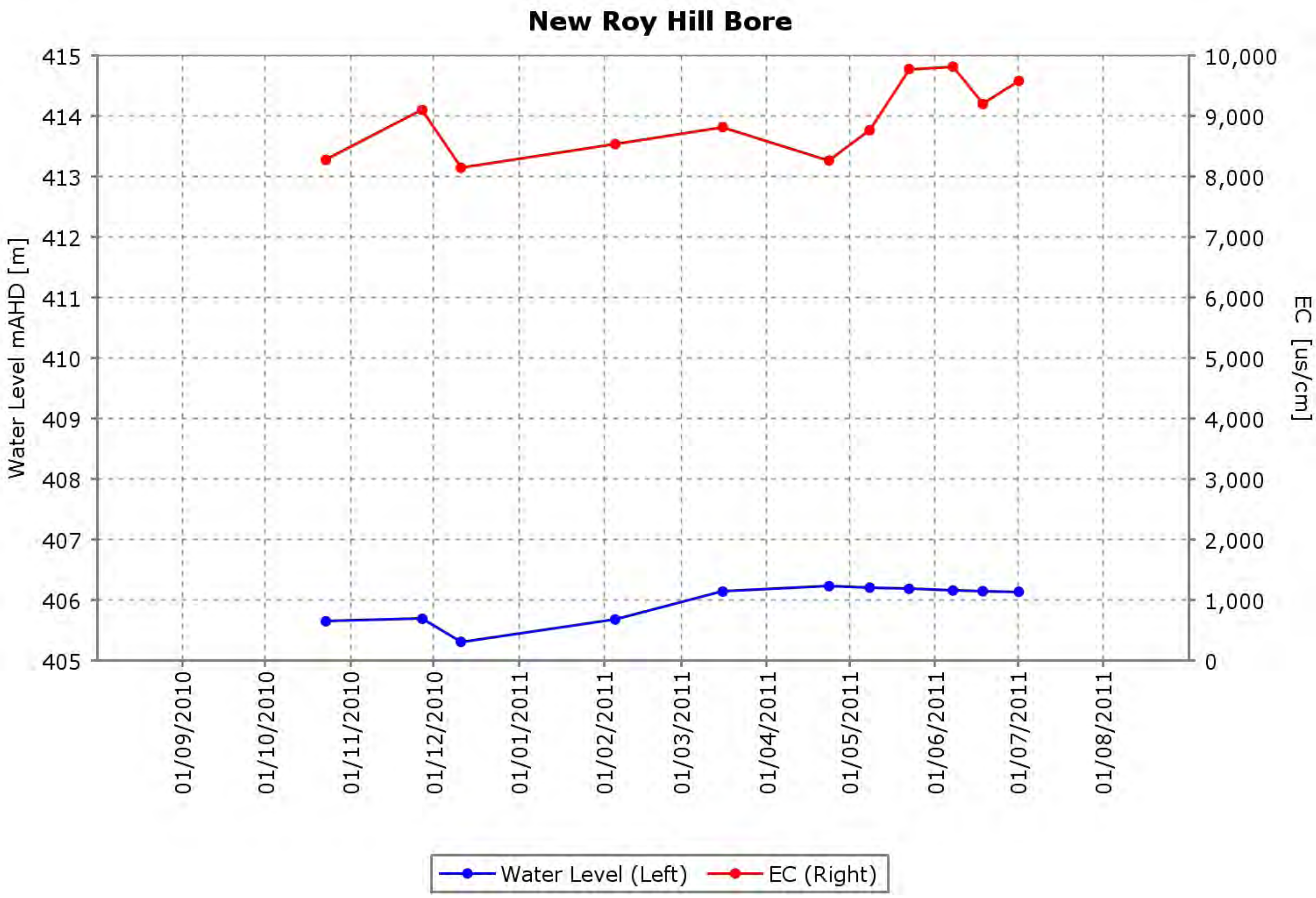

CCP24
Water Level mAHD [m]
EC [us/cm]
415
414
413
412
411
410
409
408
407
406
405
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

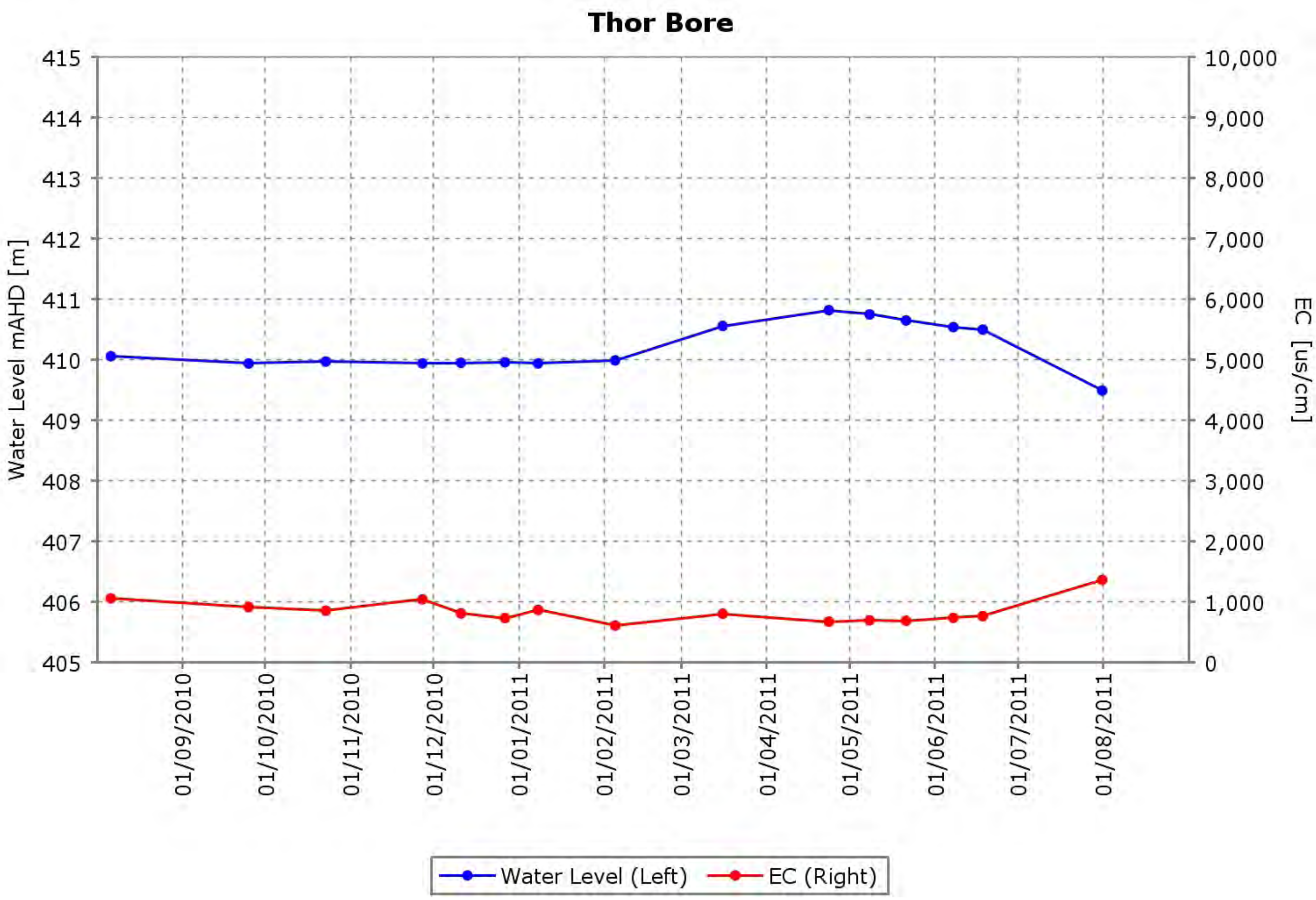

WDP01
Water Level mAHD [m]
EC [us/cm]
415
414
413
412
411
410
409
408
407
406
405
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

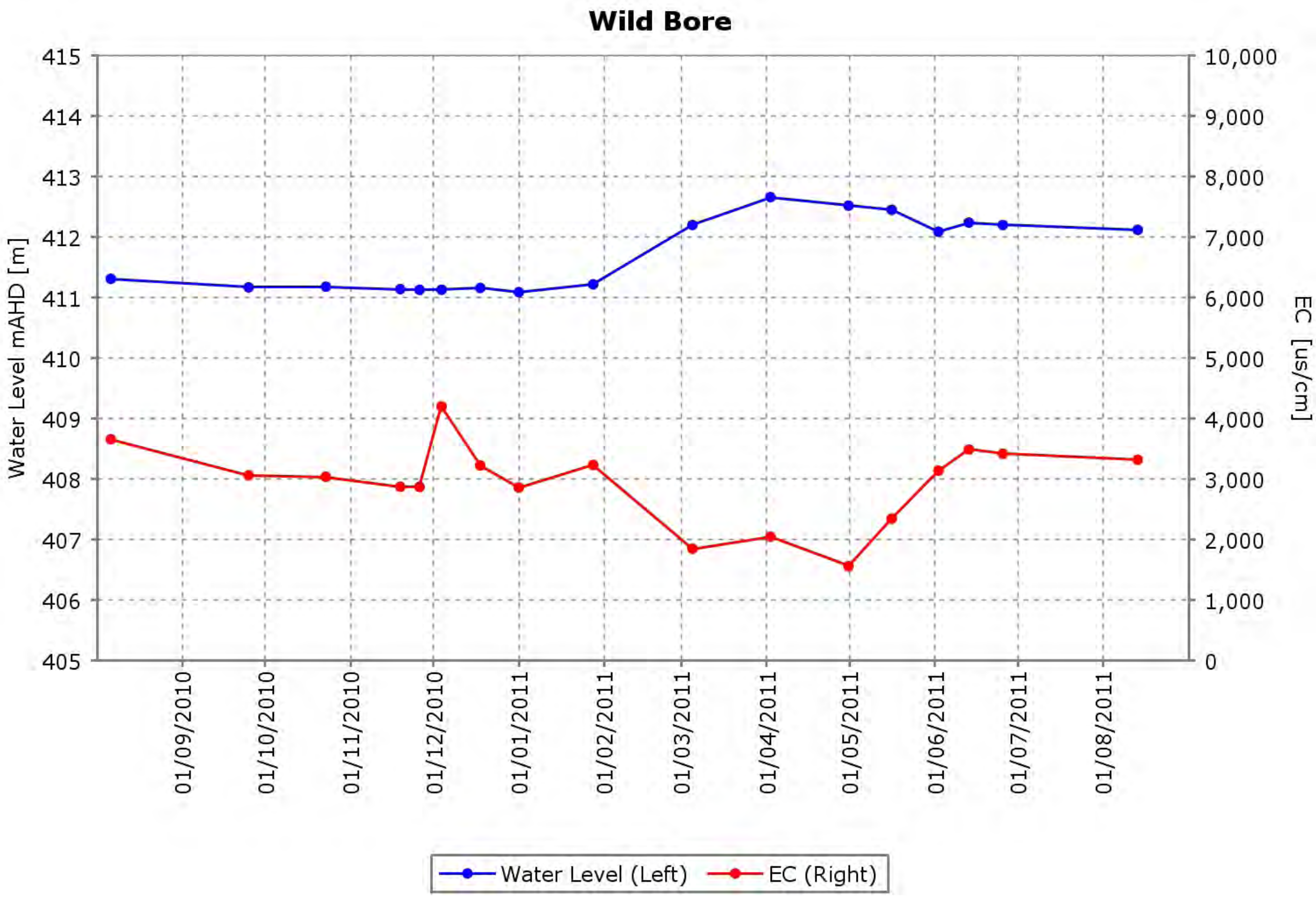

Charlton Bore
Water Level mAHD [m]
EC [us/cm]
415
414
413
412
411
410
409
408
407
406
405
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

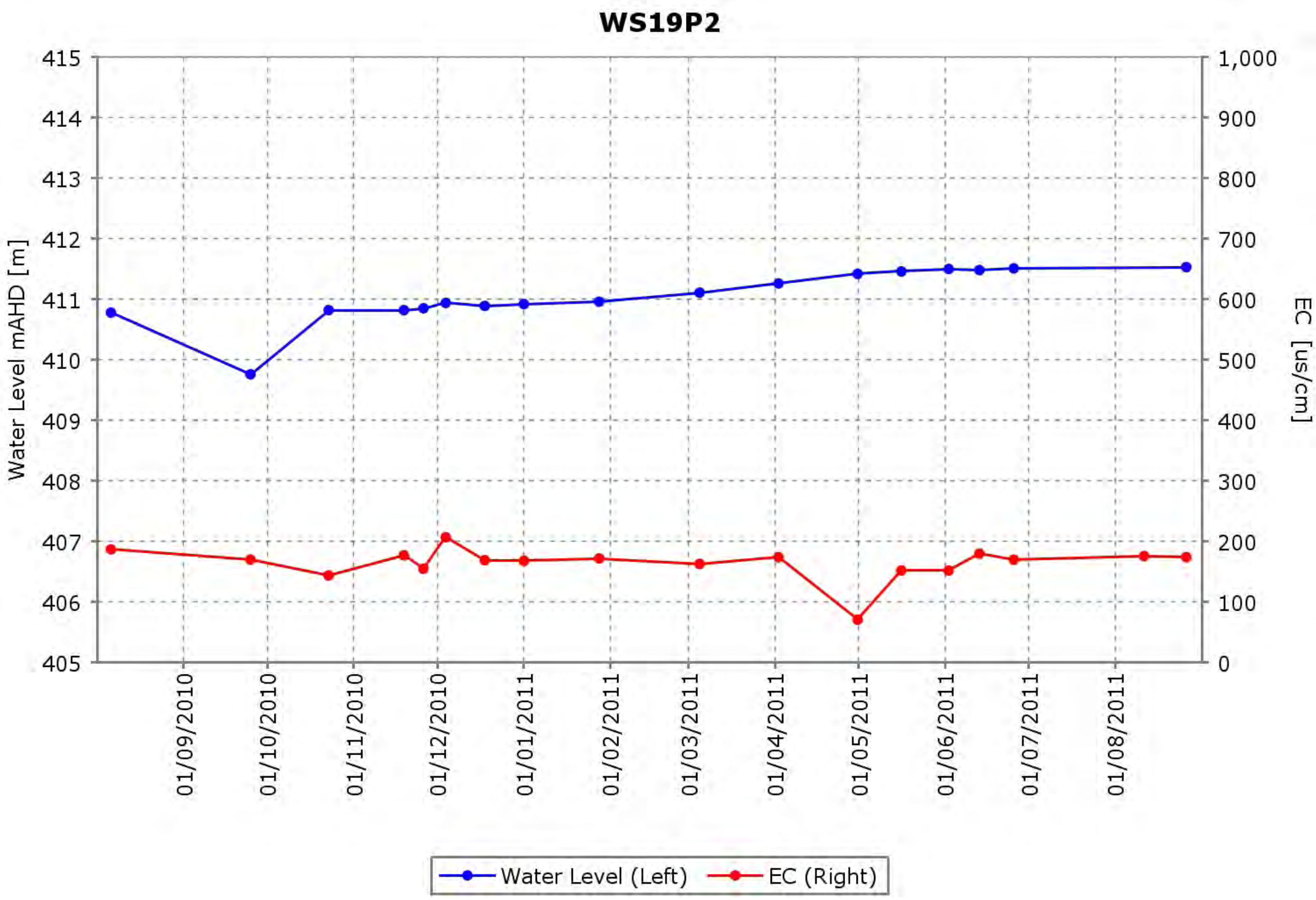

Francos Bore
Water Level mAHD [m]
EC [us/cm]
415
414
413
412
411
410
409
408
407
406
405
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

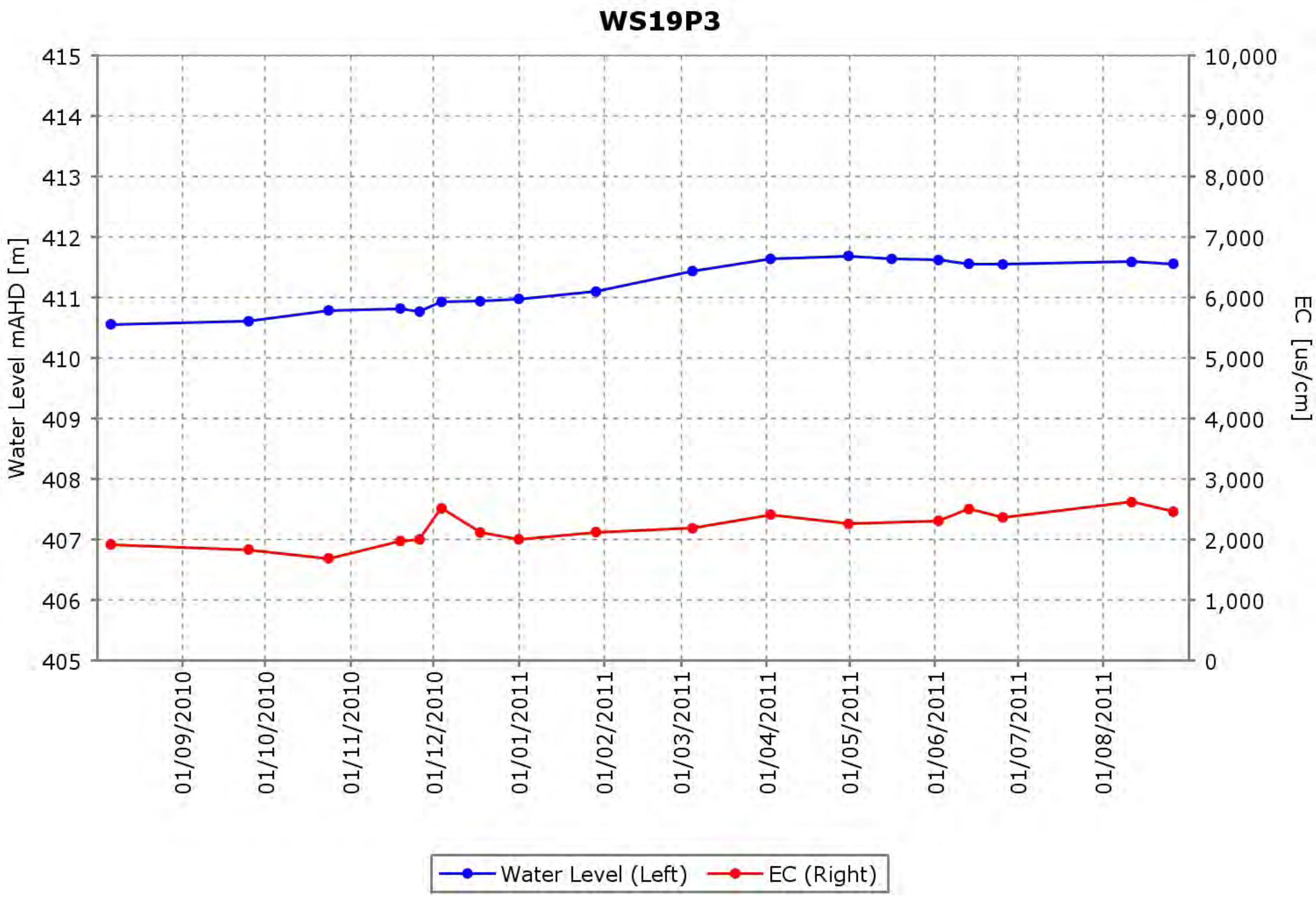

Mt Mckay
Water Level mAHD [m]
EC [us/cm]
410
409
408
407
406
405
404
403
402
401
400
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

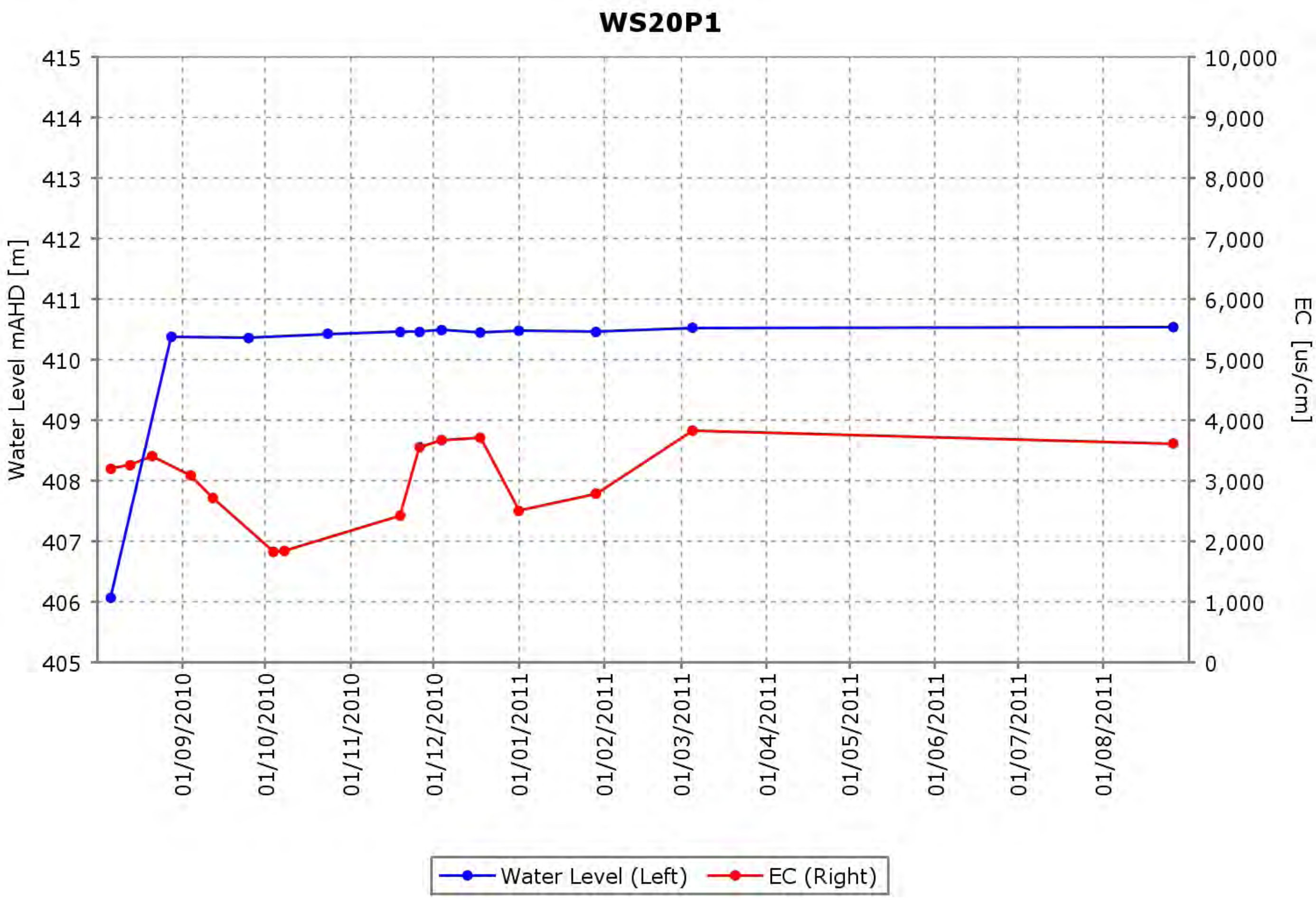

New Roy Hill Bore
Water Level mAHD [m]
EC [us/cm]
415
414
413
412
411
410
409
408
407
406
405
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

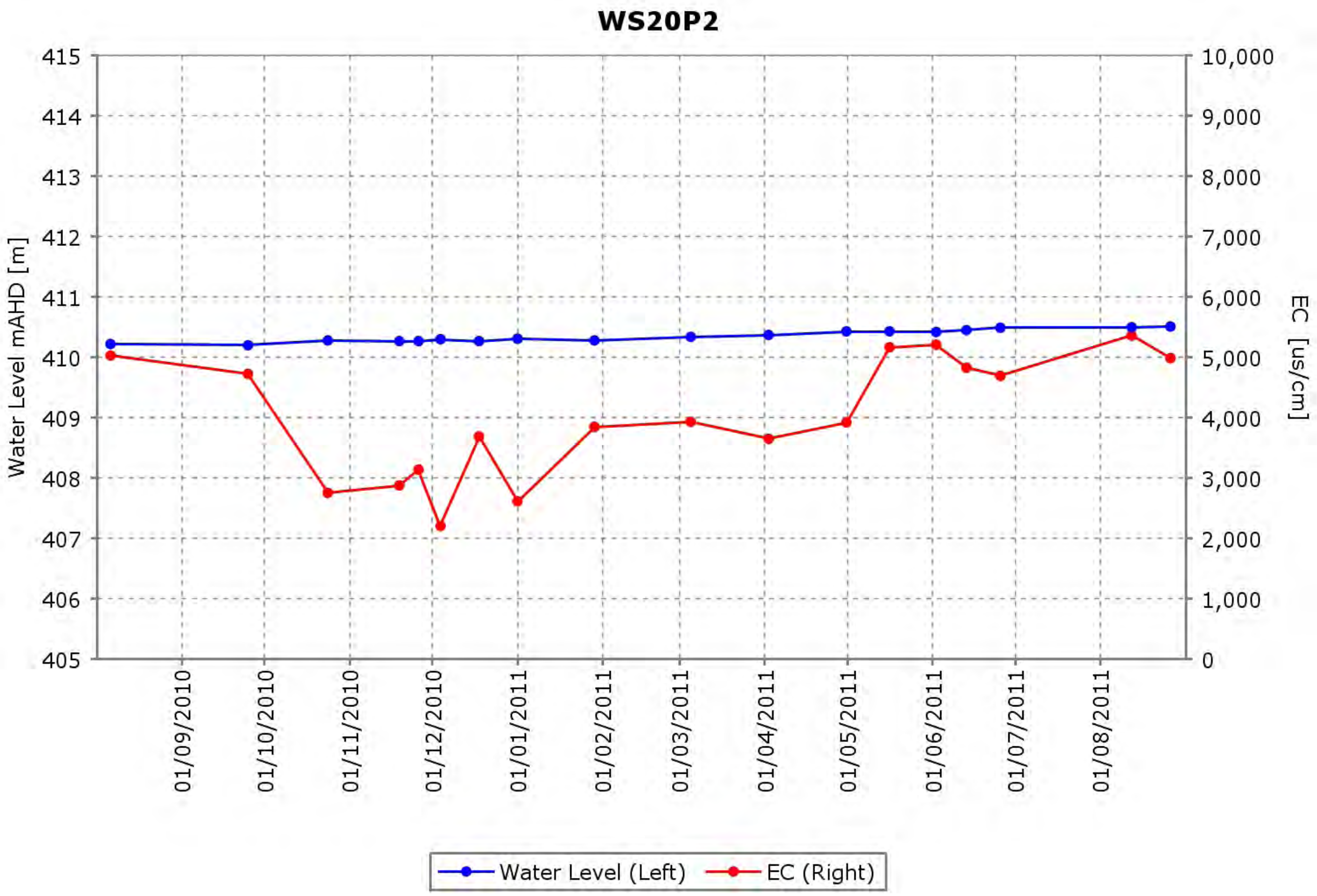

Thor Bore
Water Level mAHD [m]
EC [us/cm]
415
414
413
412
411
410
409
408
407
406
405
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

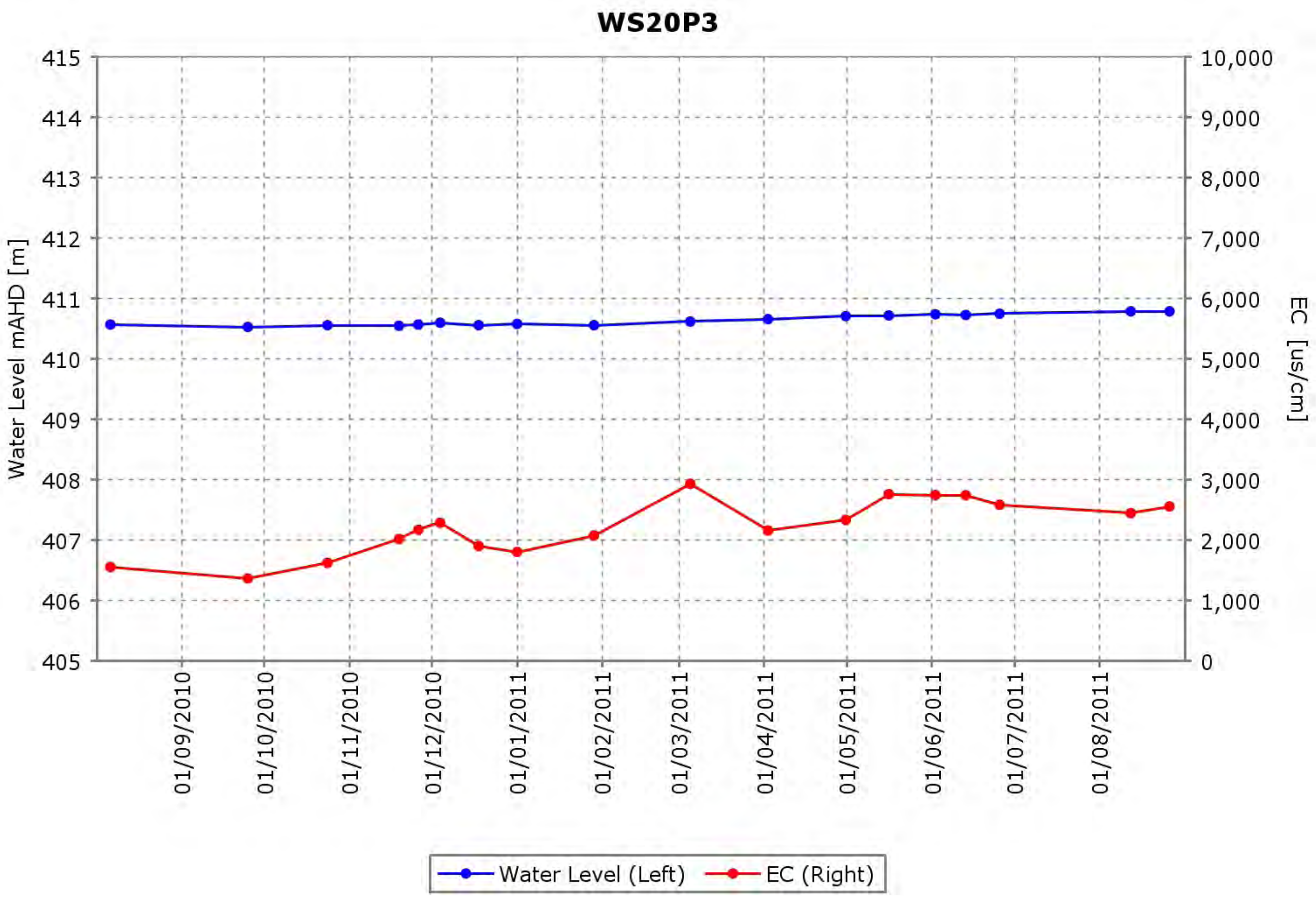

Wild Bore
Water Level mAHD [m]
EC [us/cm]
415
414
413
412
411
410
409
408
407
406
405
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

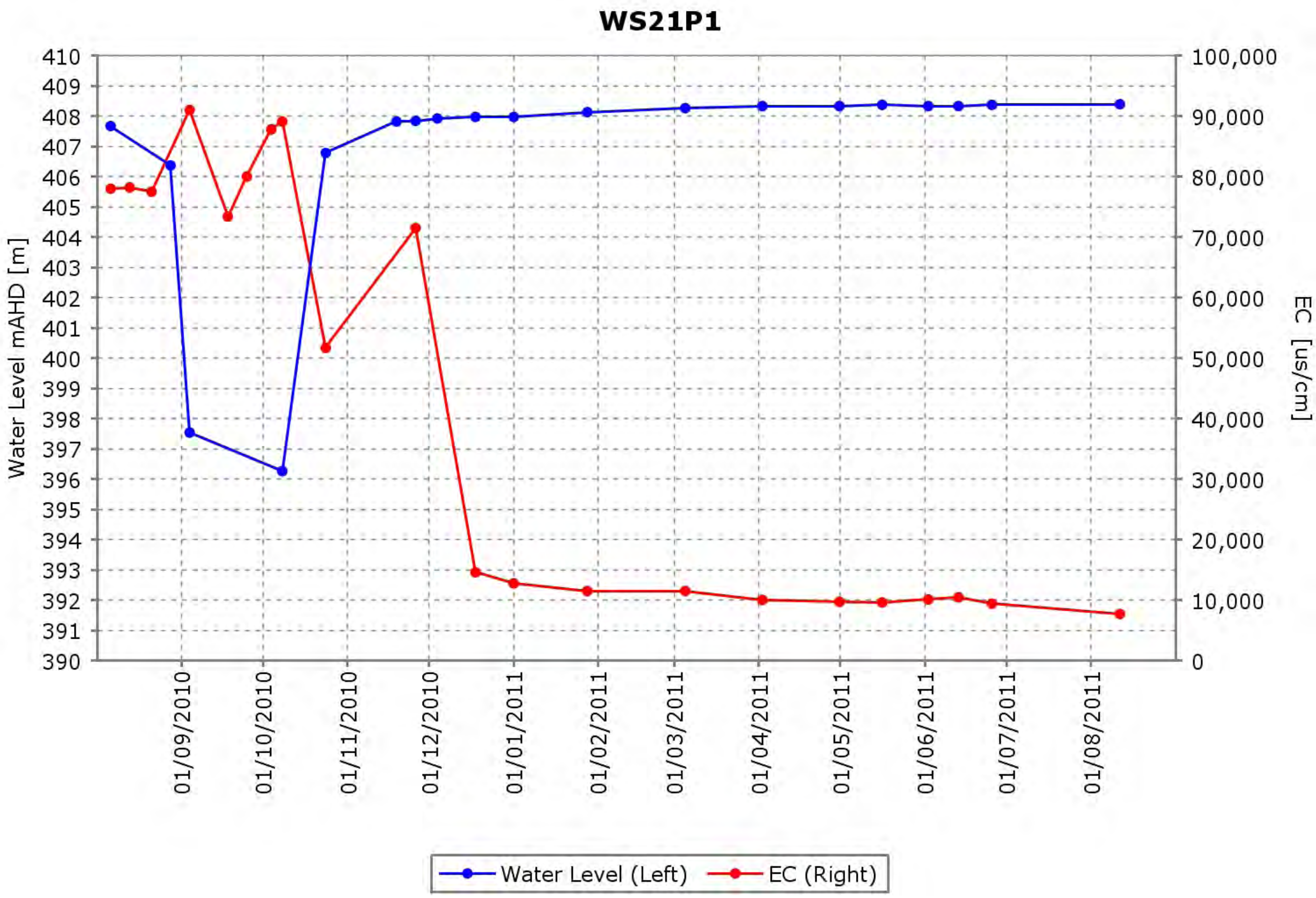

WS19P2
Water Level mAHD [m]
EC [us/cm]
415
414
413
412
411
410
409
408
407
406
405
1,000
900
800
700
600
500
400
300
200
100
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

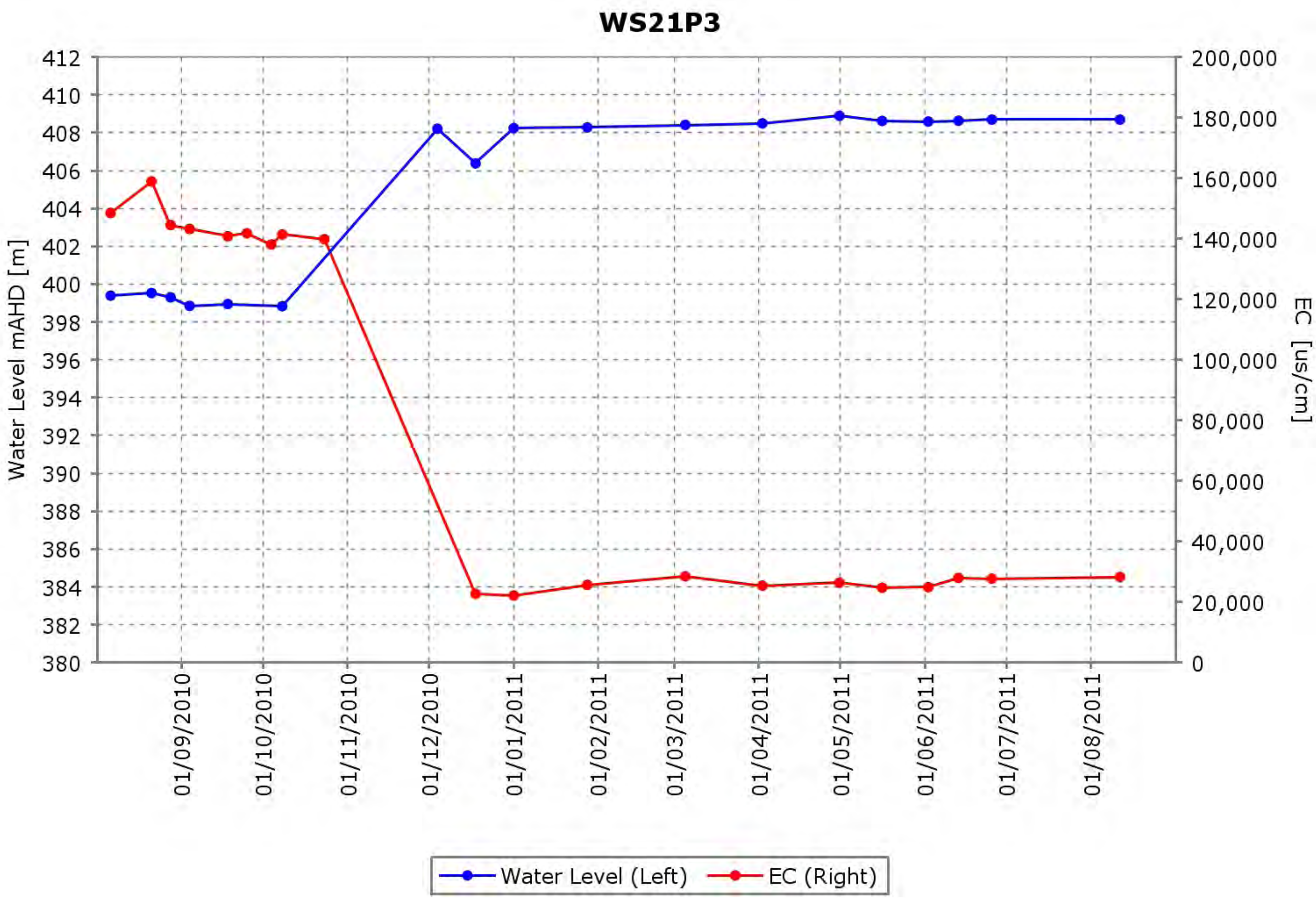

WS19P3
Water Level mAHD [m]
EC [us/cm]
415
414
413
412
411
410
409
408
407
406
405
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

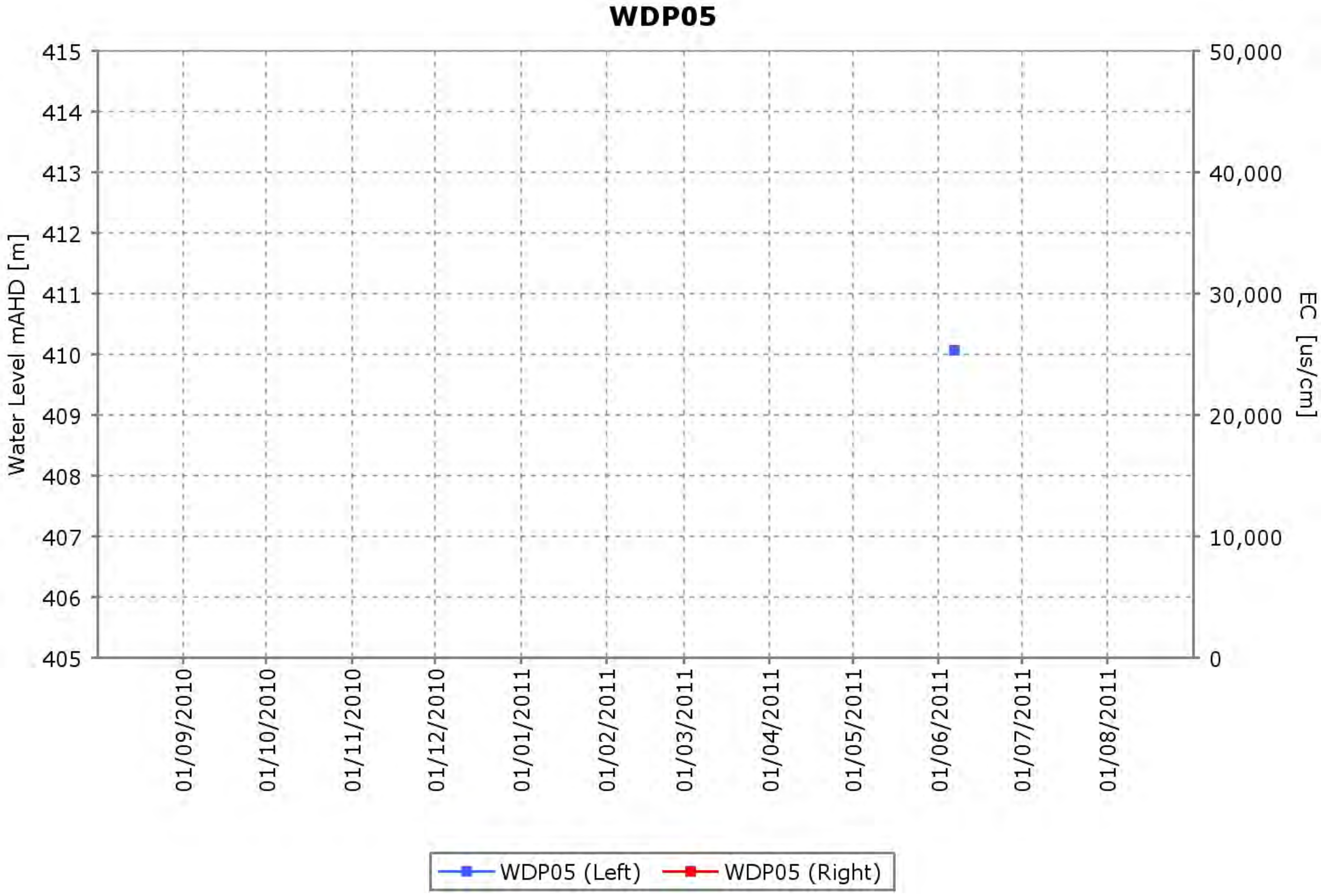

WS20P1
Water Level mAHD [m]
EC [us/cm]
415
414
413
412
411
410
409
408
407
406
405
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

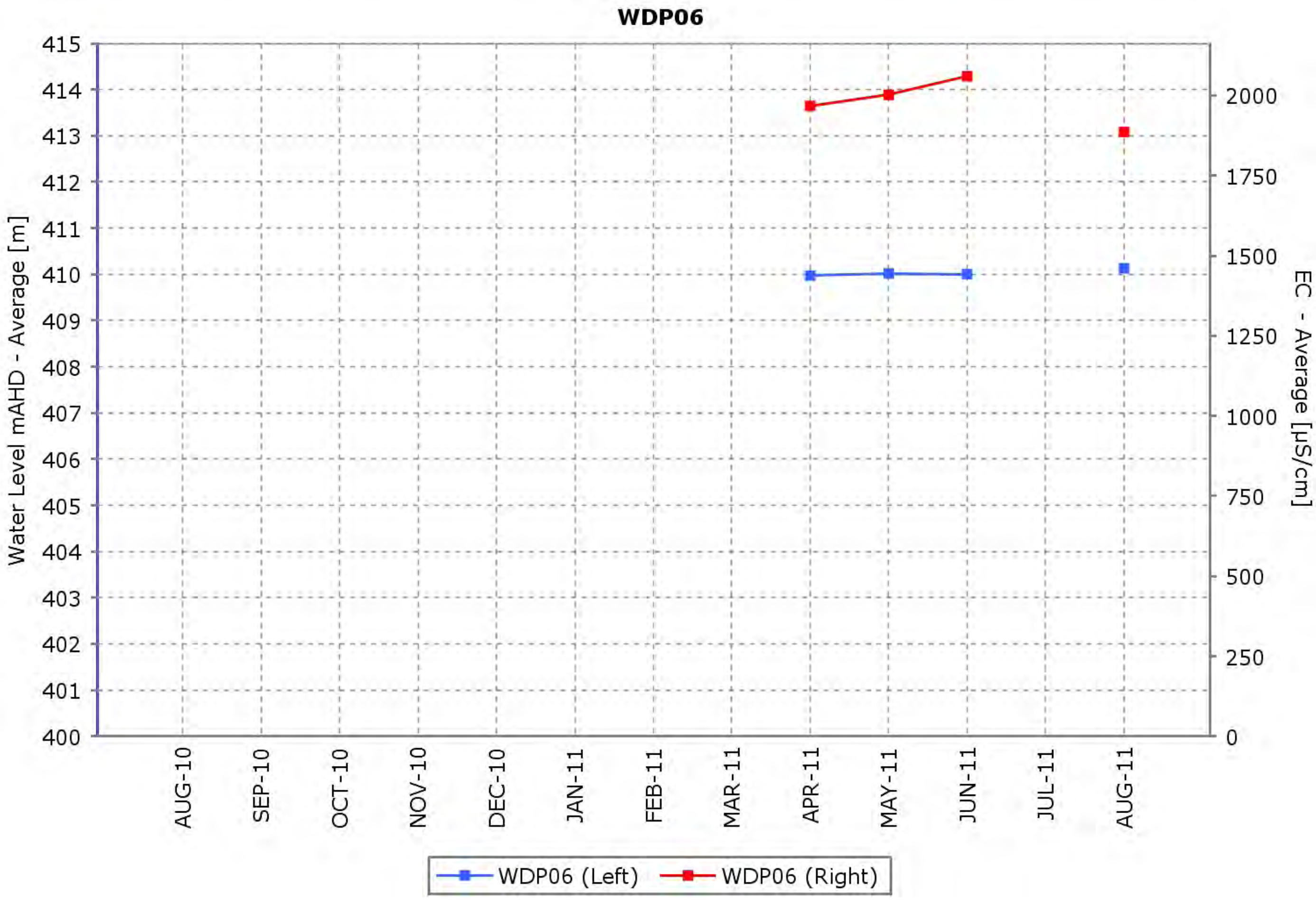

WS20P2
415
414
413
412
411
410
409
408
407
406
405
Water Level mAHD [m]
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
EC [us/cm]
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

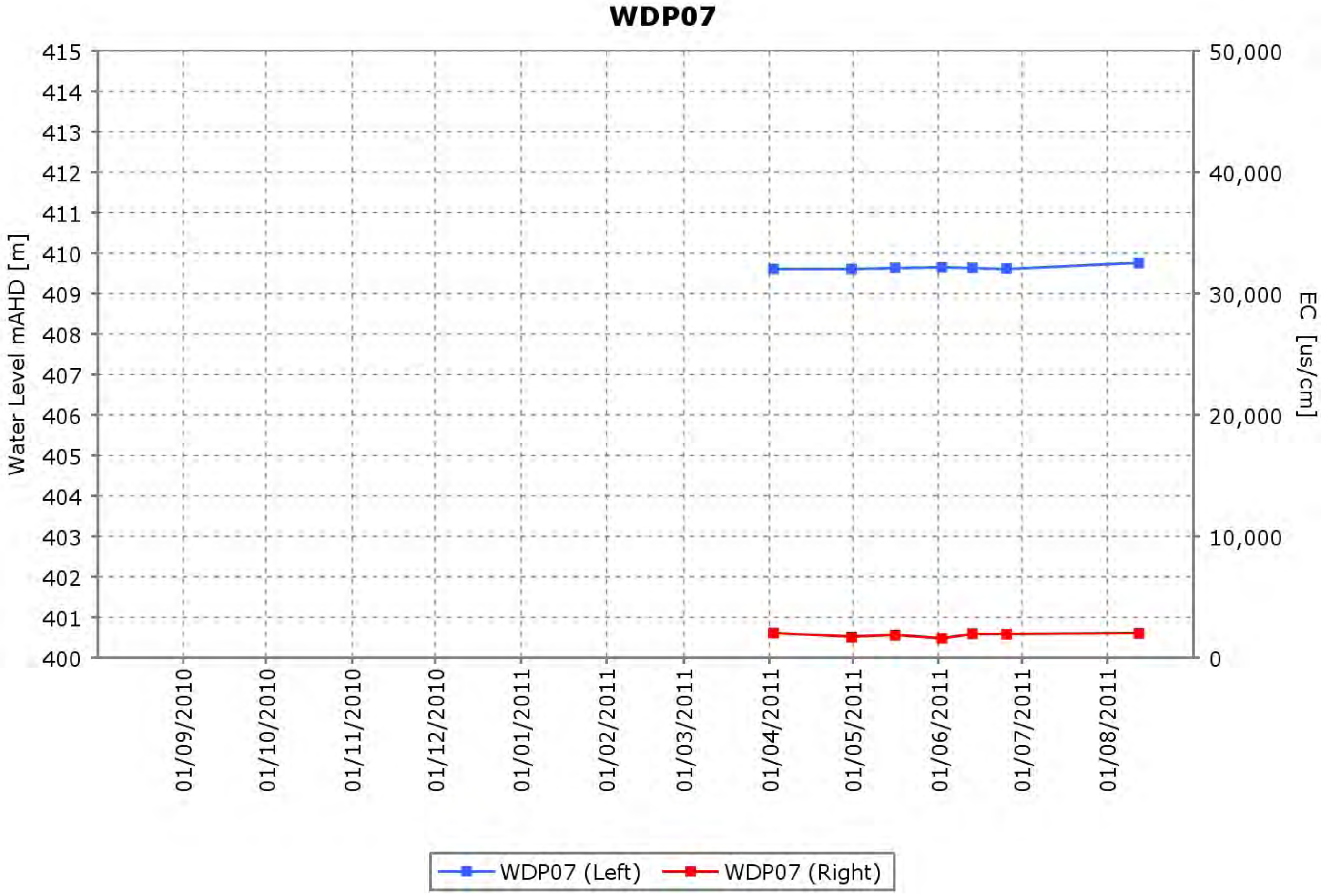

WS20P3
415
414
413
412
411
410
409
408
407
406
405
Water Level mAHD [m]
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
EC [us/cm]
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)

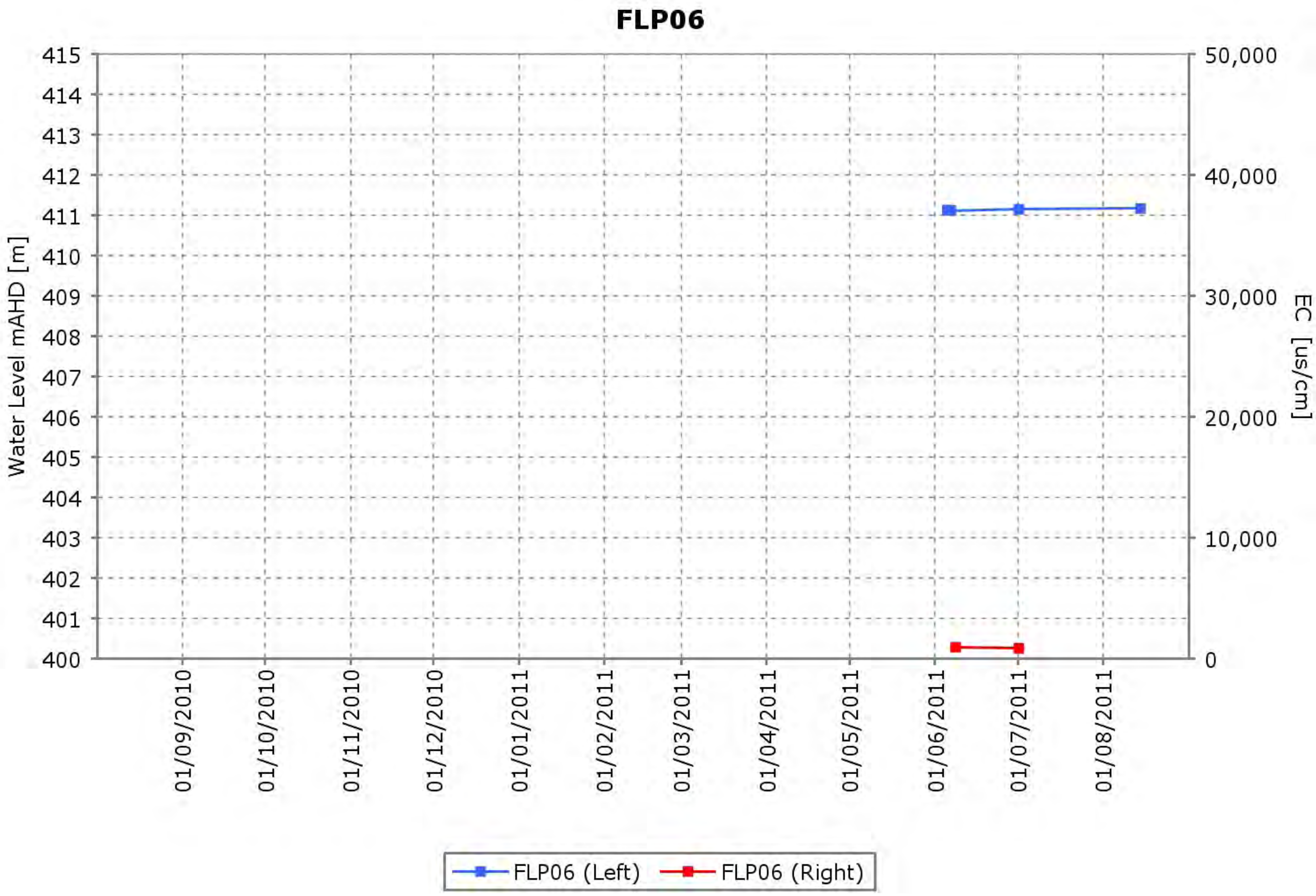

WS21P1
Water Level mAHD [m]
EC [us/cm]
410
409
408
407
406
405
404
403
402
401
400
399
398
397
396
395
394
393
392
391
390
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)


WS21P3
Water Level mAHD [m]
EC [us/cm]
412
410
408
406
404
402
400
398
396
394
392
390
388
386
384
382
380
200,000
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level (Left)
EC (Right)


WDP05
Water Level mAHD [m]
EC [us/cm]
415
414
413
412
411
410
409
408
407
406
405
50,000
40,000
30,000
20,000
10,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
WDP05 (Left)
WDP05 (Right)


WDP06
Water Level mAHD - Average [m]
EC - Average [µS/cm]
415
414
413
412
411
410
409
408
407
406
405
404
403
402
401
400
2000
1750
1500
1250
1000
750
500
250
0
AUG-10
SEP-10
OCT-10
NOV-10
DEC-10
JAN-11
FEB-11
MAR-11
APR-11
MAY-11
JUN-11
JUL-11
AUG-11
WDP06 (Left)
WDP06 (Right)

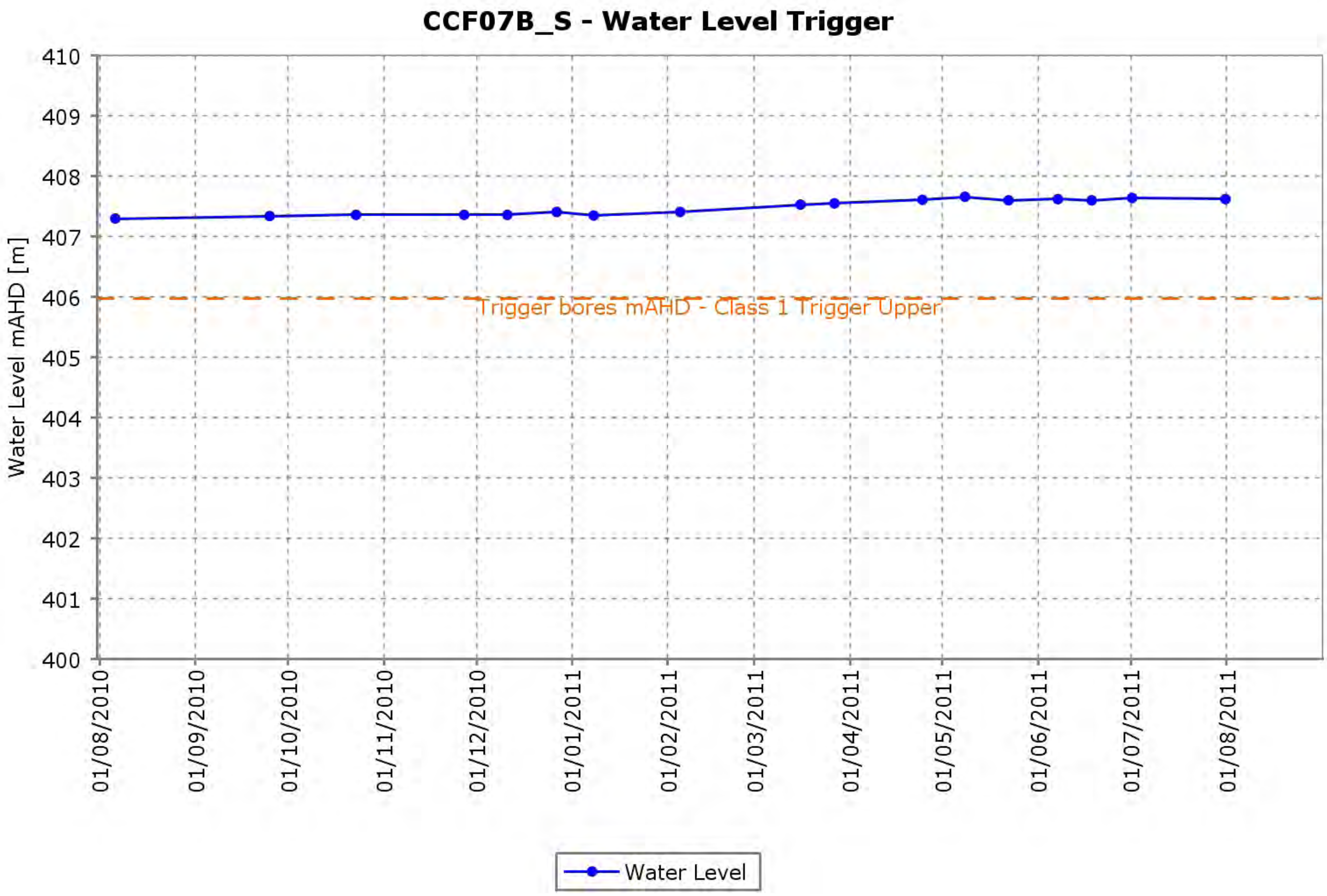

WDP07
Water Level mAHD [m]
EC [us/cm]
415
414
413
412
411
410
409
408
407
406
405
404
403
402
401
400
50,000
40,000
30,000
20,000
10,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
WDP07 (Left)
WDP07 (Right)

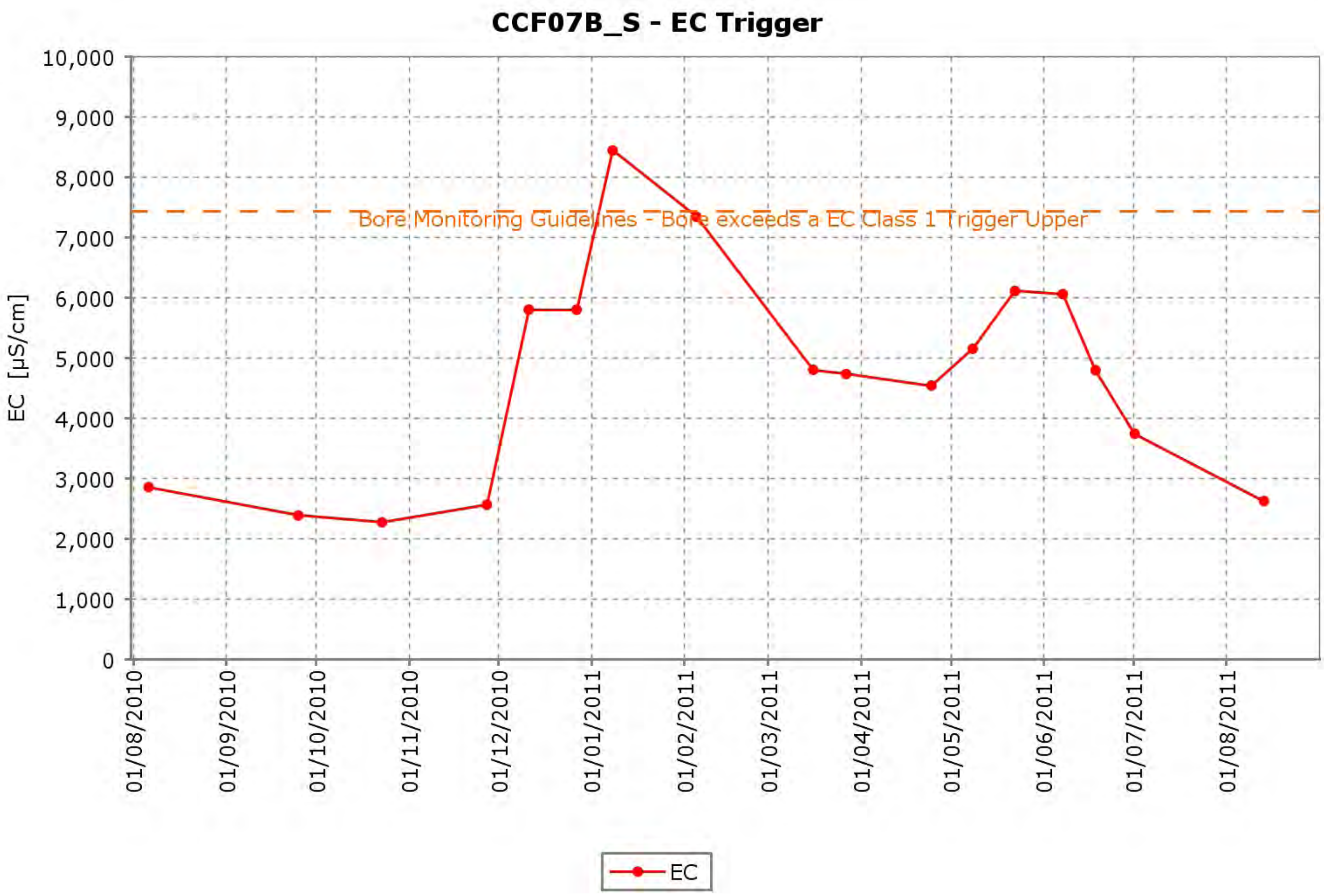

FLP06
Water Level mAHD [m]
EC [us/cm]
415
414
413
412
411
410
409
408
407
406
405
404
403
402
401
400
50,000
40,000
30,000
20,000
10,000
0
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
FLP06 (Left)
FLP06 (Right)

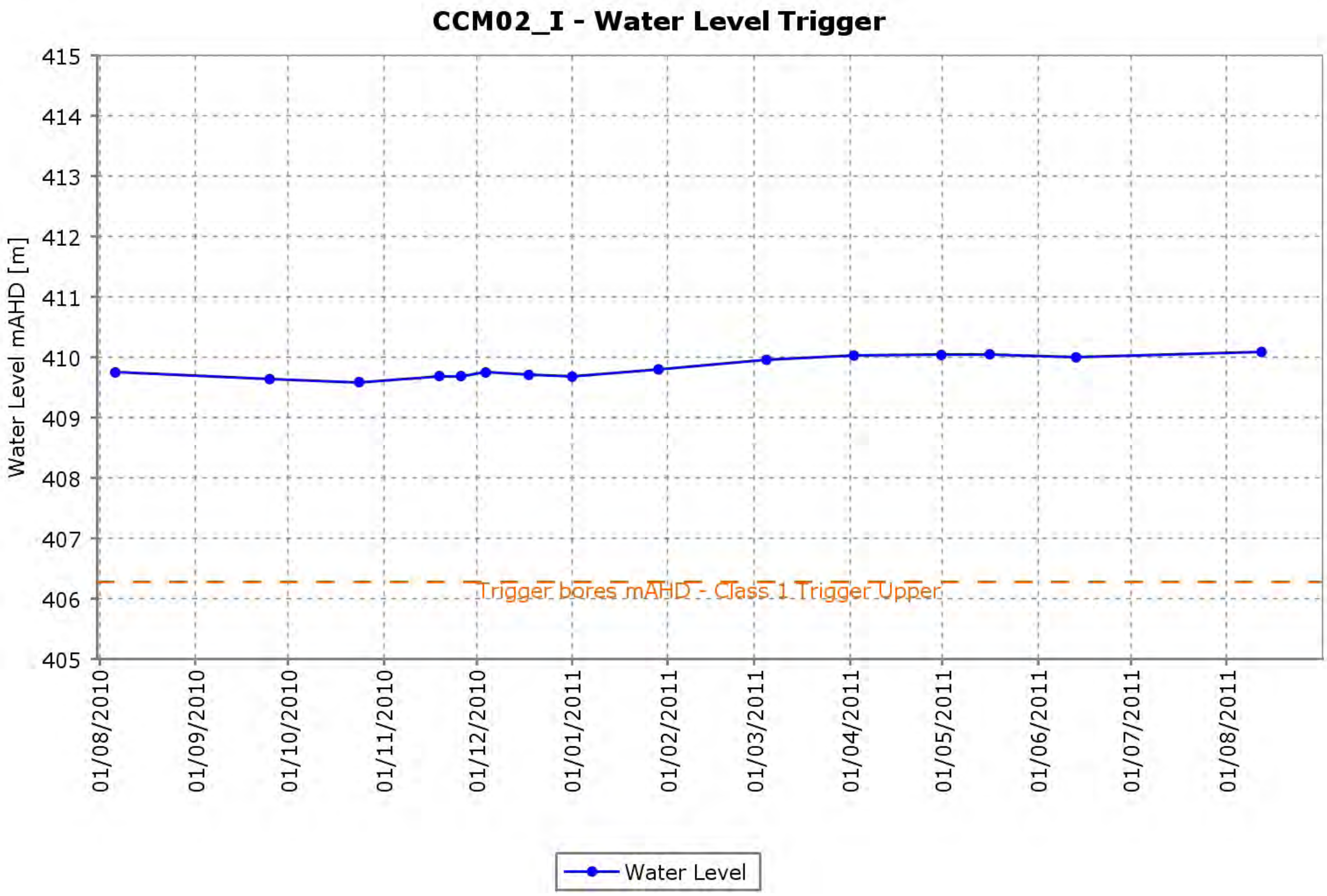
Appendix E

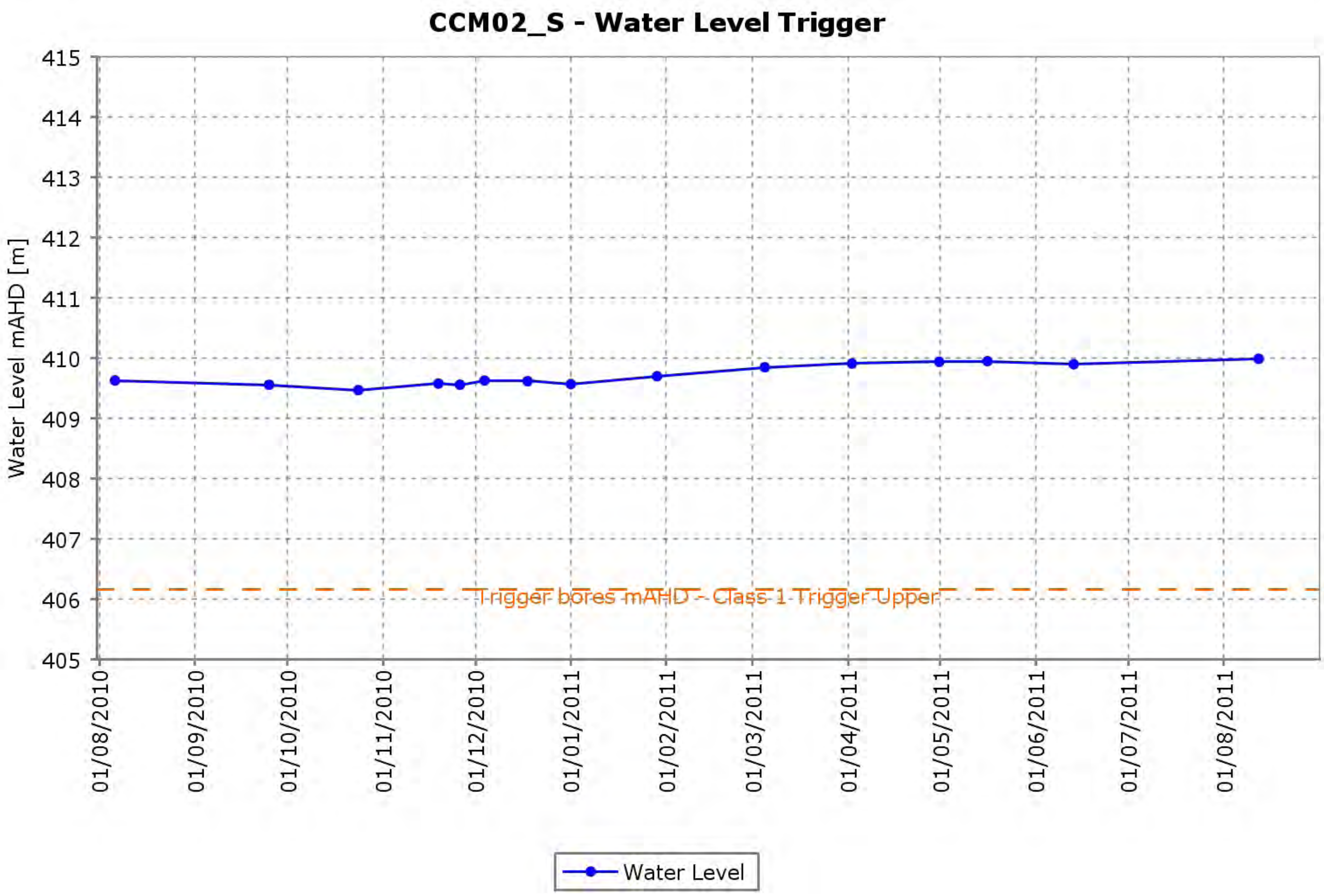
Groundwater levels and electrical conductivity for bores associated with trigger level compliance

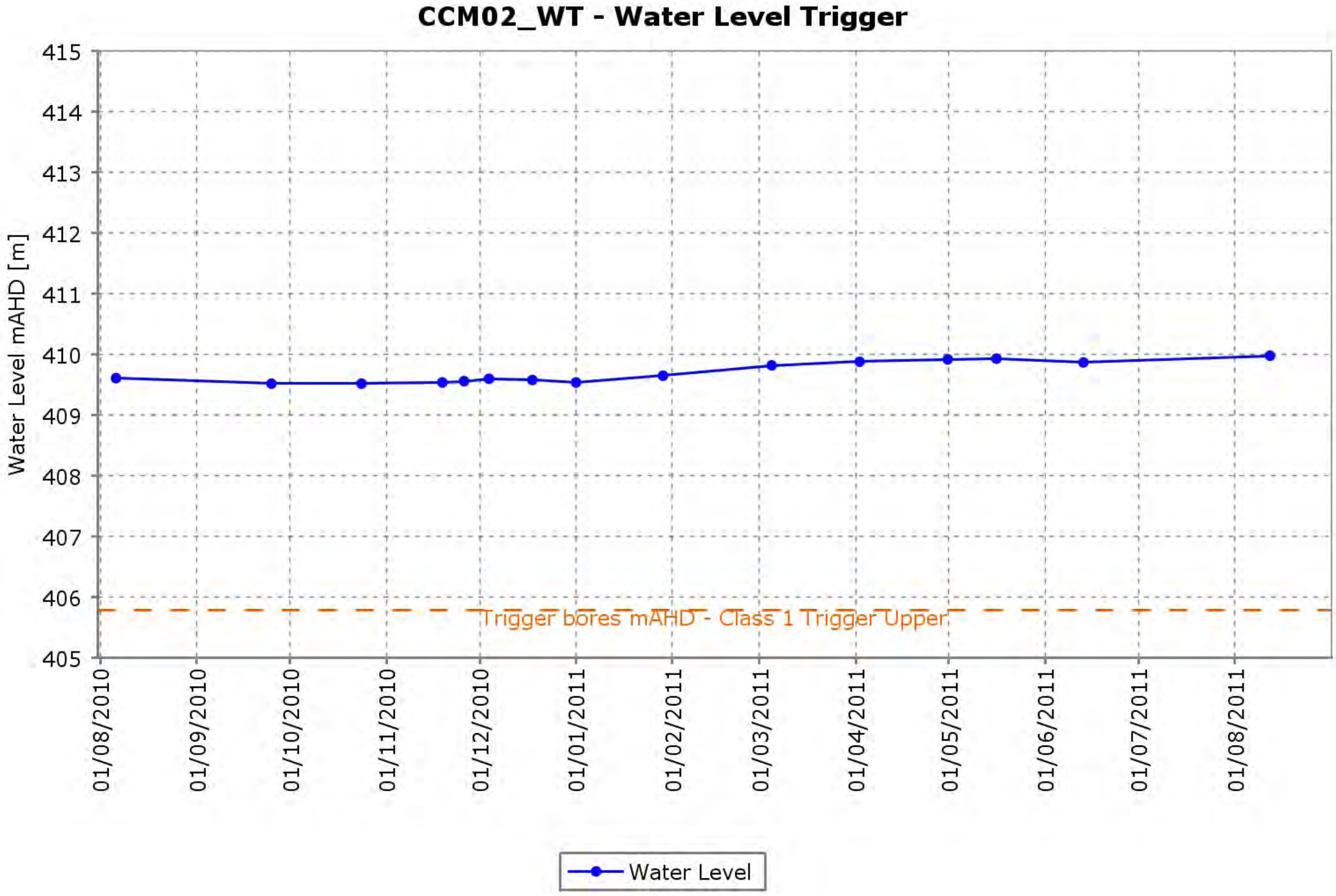
[This page has been left blank intentionally]

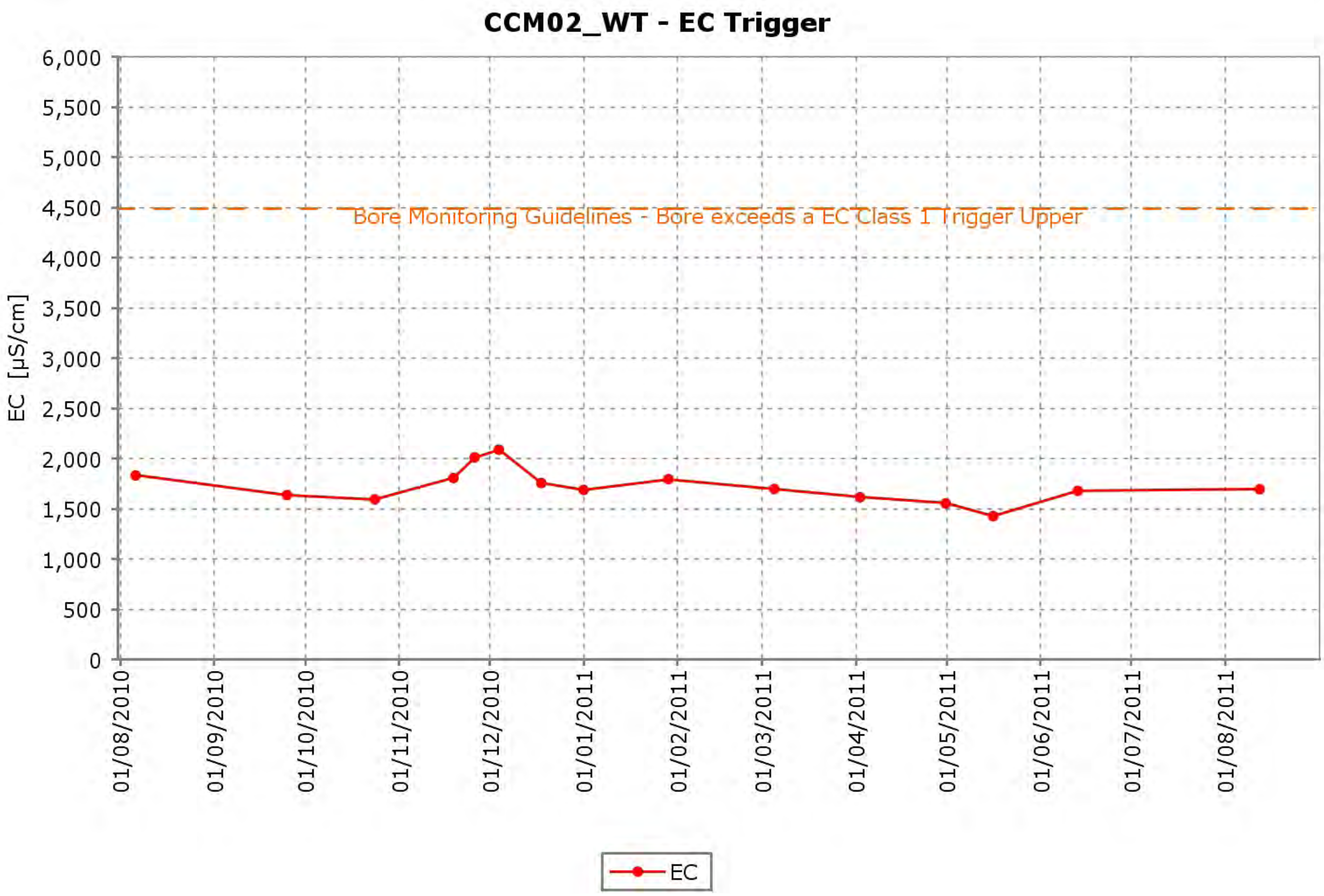

CCF07B_S - Water Level Trigger
Water Level mAHD [m]
410
409
408
407
406
405
404
403
402
401
400
Trigger bores mAHD - Class 1 Trigger Upper
01/08/2010
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level


CCF07B_S - EC Trigger
EC [µS/cm]
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Bore Monitoring Guidelines - Bore exceeds a EC Class 1 Trigger Upper
01/08/2010
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
EC

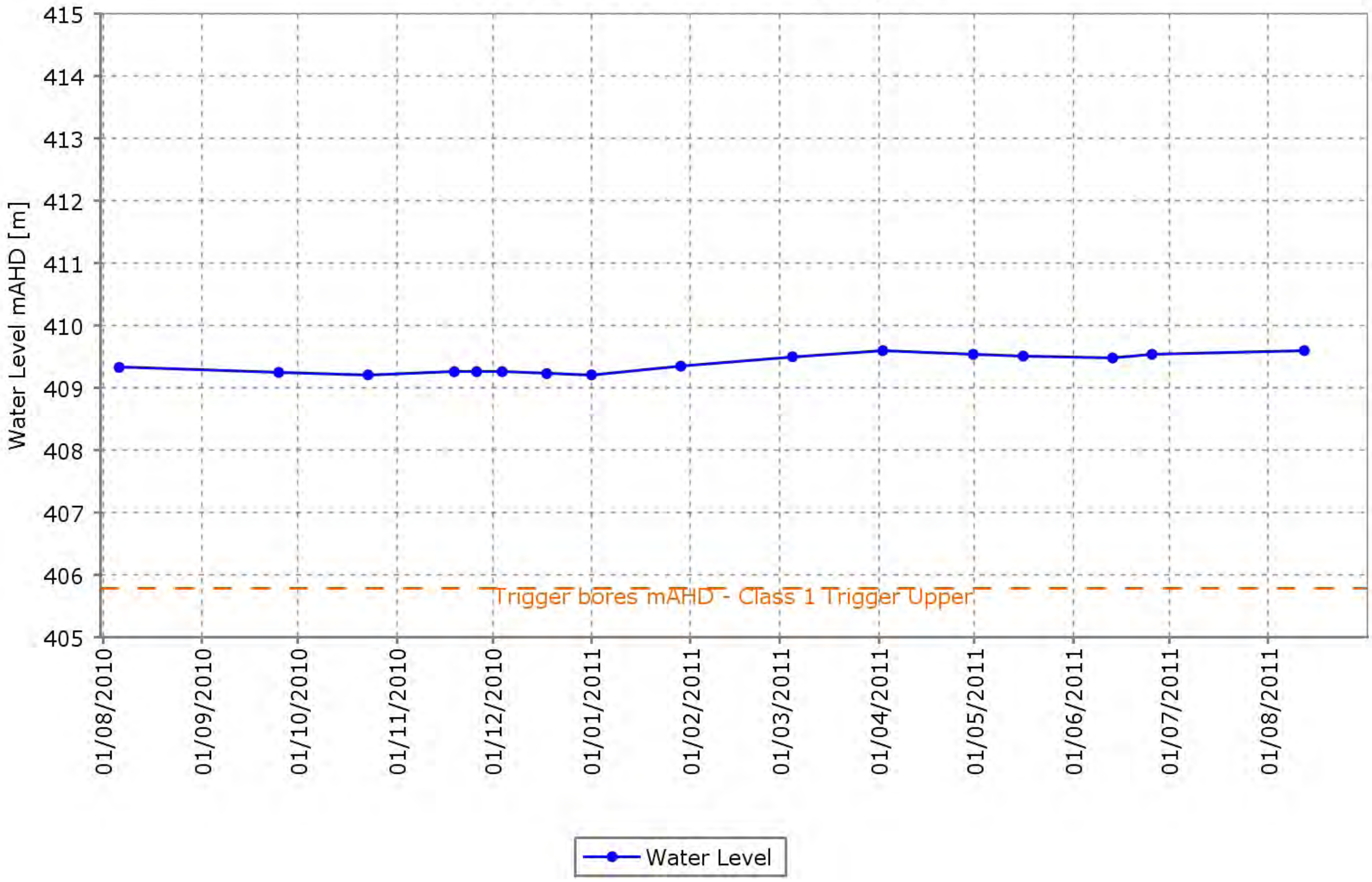

CCM02_I - Water Level Trigger
Water Level mAHD [m]
415
414
413
412
411
410
409
408
407
406
405
Trigger bores mAHD - Class 1 Trigger Upper
01/08/2010
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level


CCM02_S - Water Level Trigger
Water Level mAHD [m]
415
414
413
412
411
410
409
408
407
406
405
Trigger bores mAHD - Class 1 Trigger Upper
01/08/2010
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level

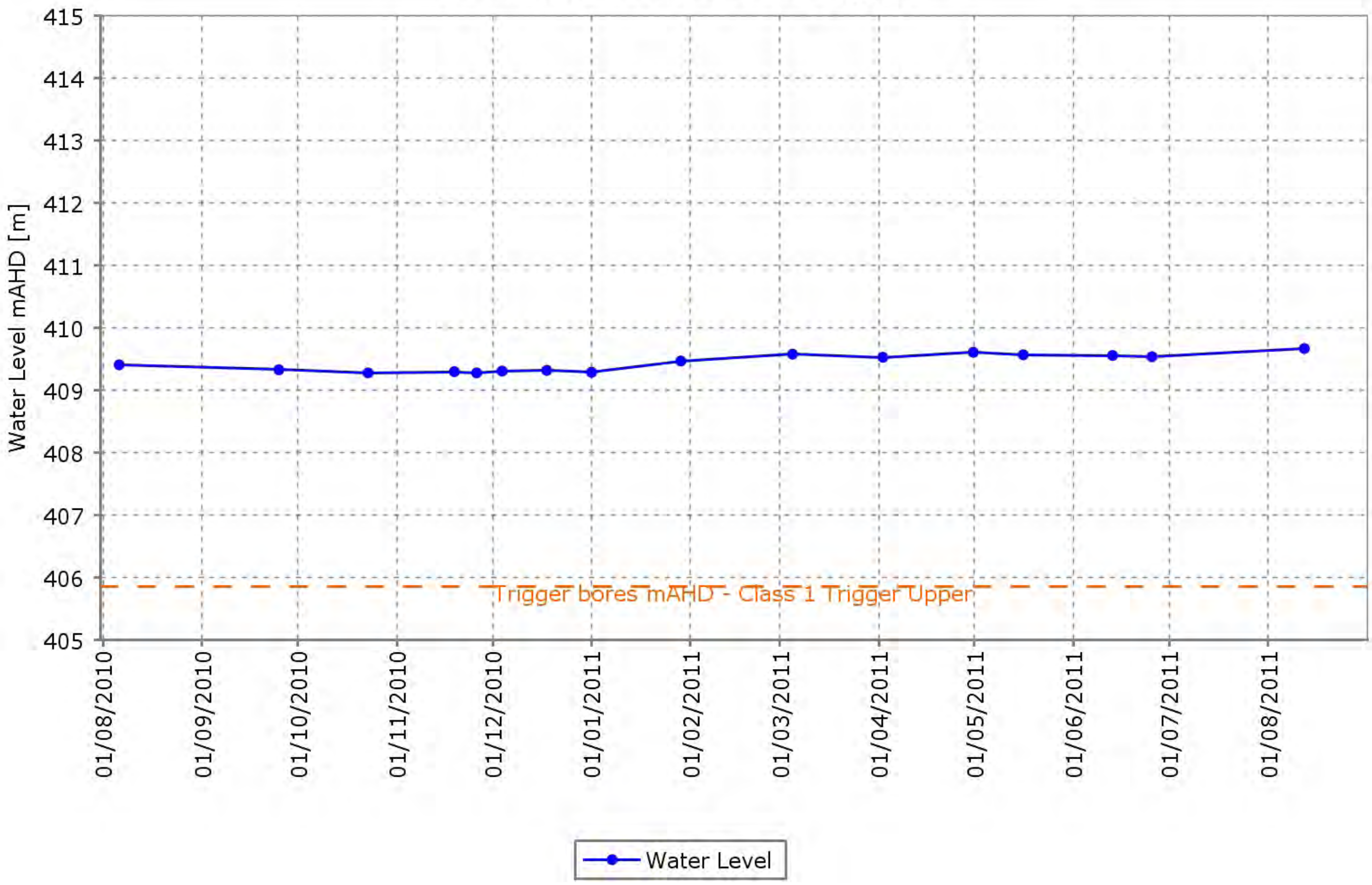

CCM02_WT - Water Level Trigger
Water Level mAHD [m]
415
414
413
412
411
410
409
408
407
406
405
Trigger bores mAHD - Class 1 Trigger Upper
01/08/2010
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level

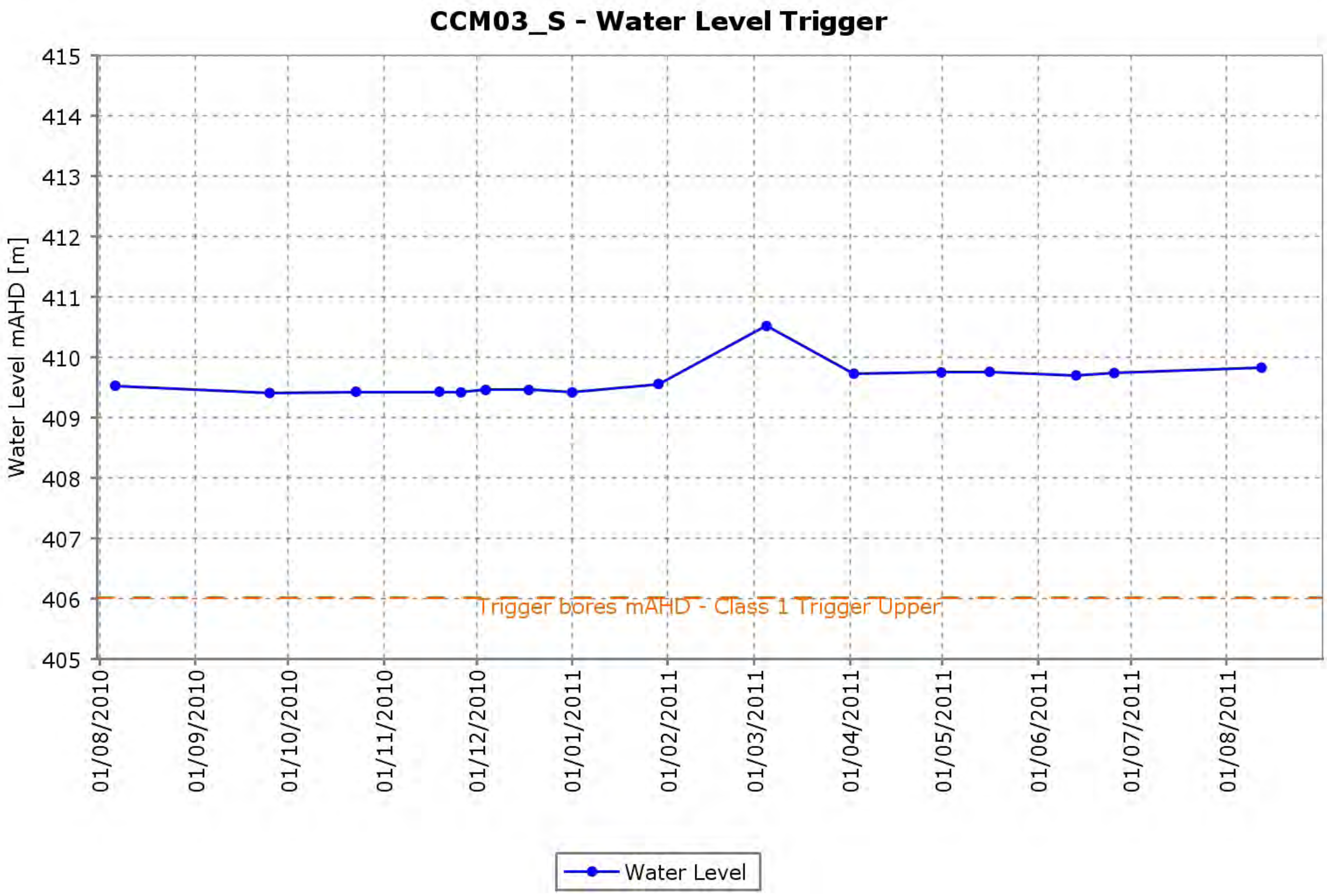

CCM02_WT - EC Trigger
EC [µS/cm]
6,000
5,500
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
Bore Monitoring Guidelines - Bore exceeds a EC Class 1 Trigger Upper
01/08/2010
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
EC

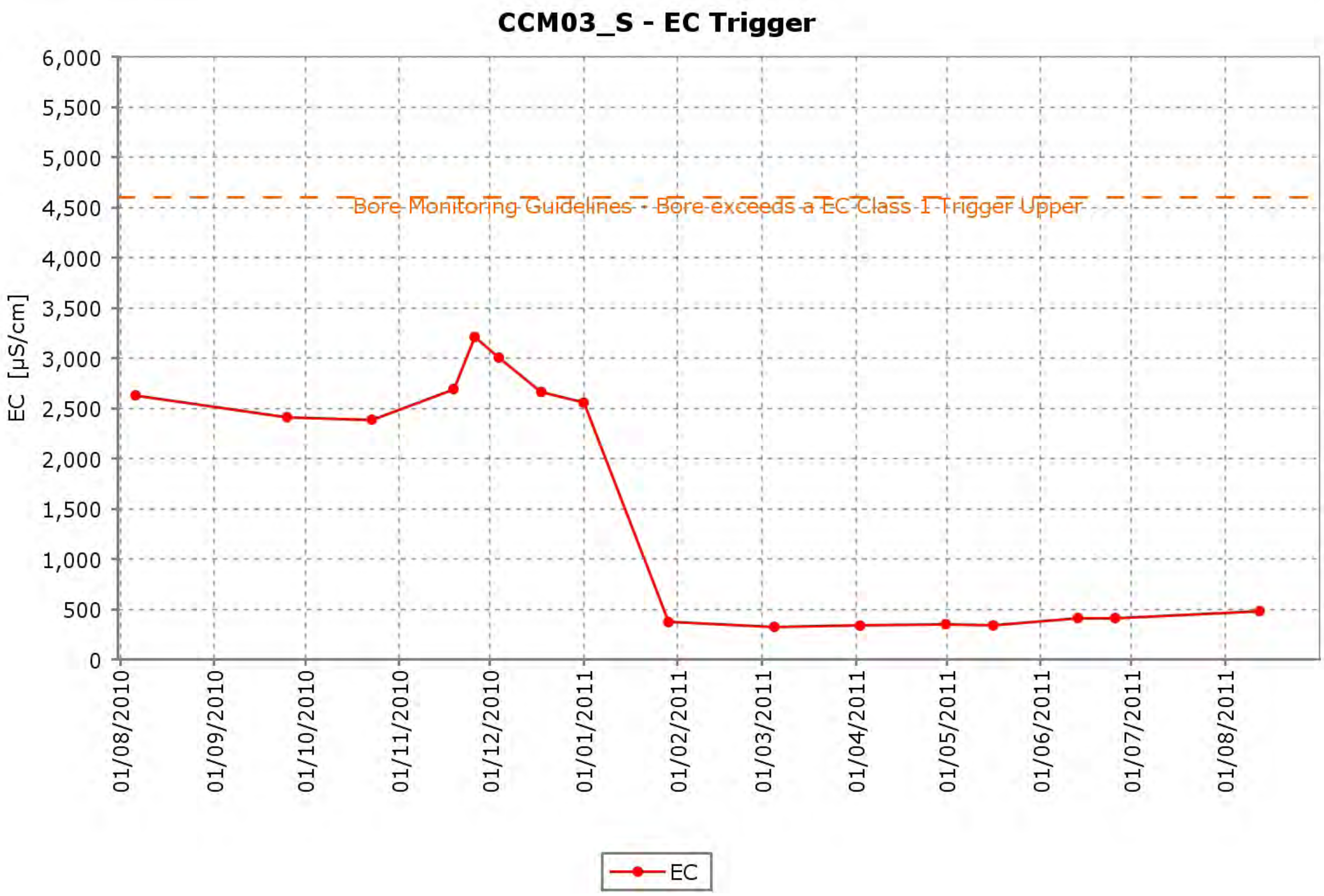
CCM03_D - Water Level Trigger

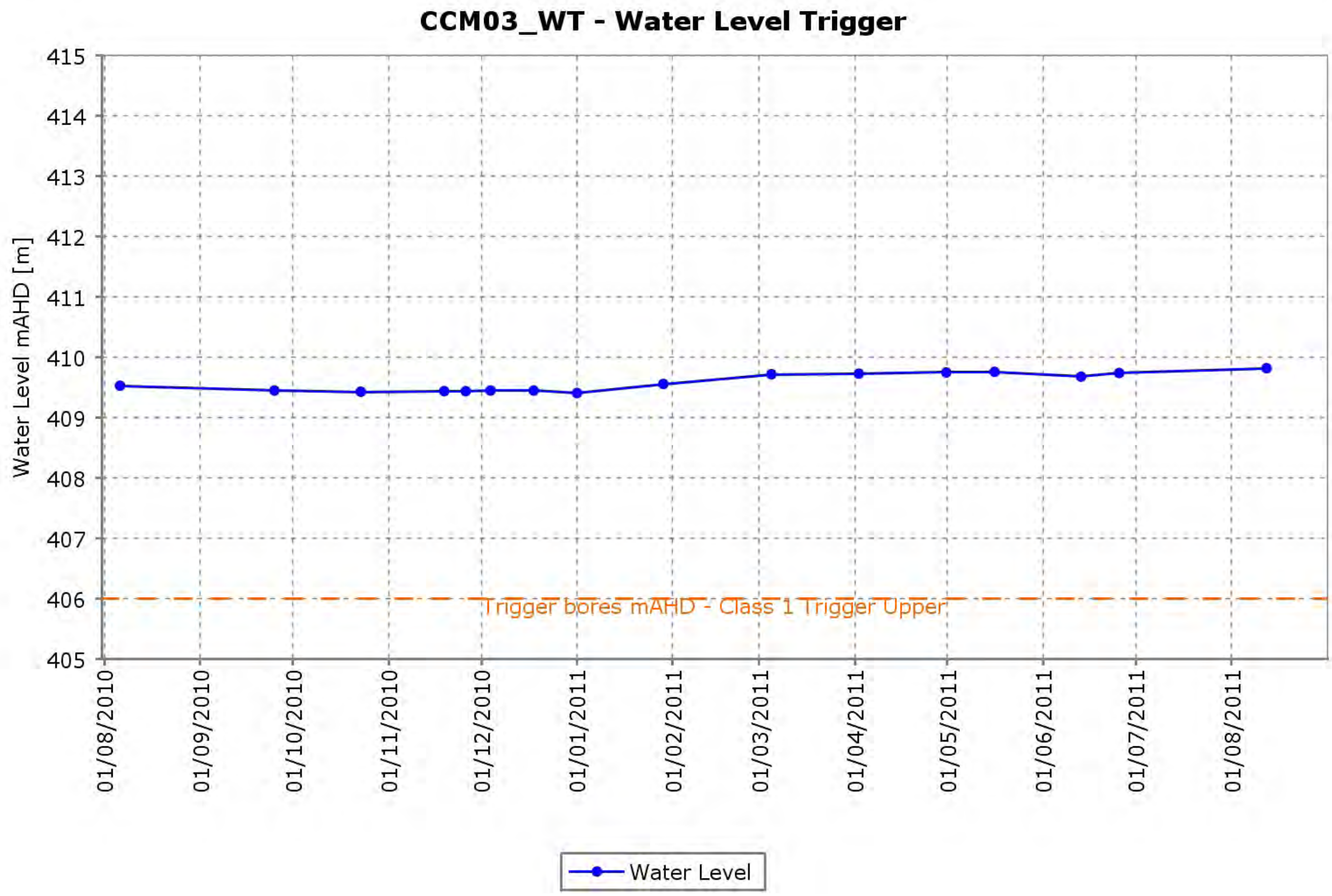


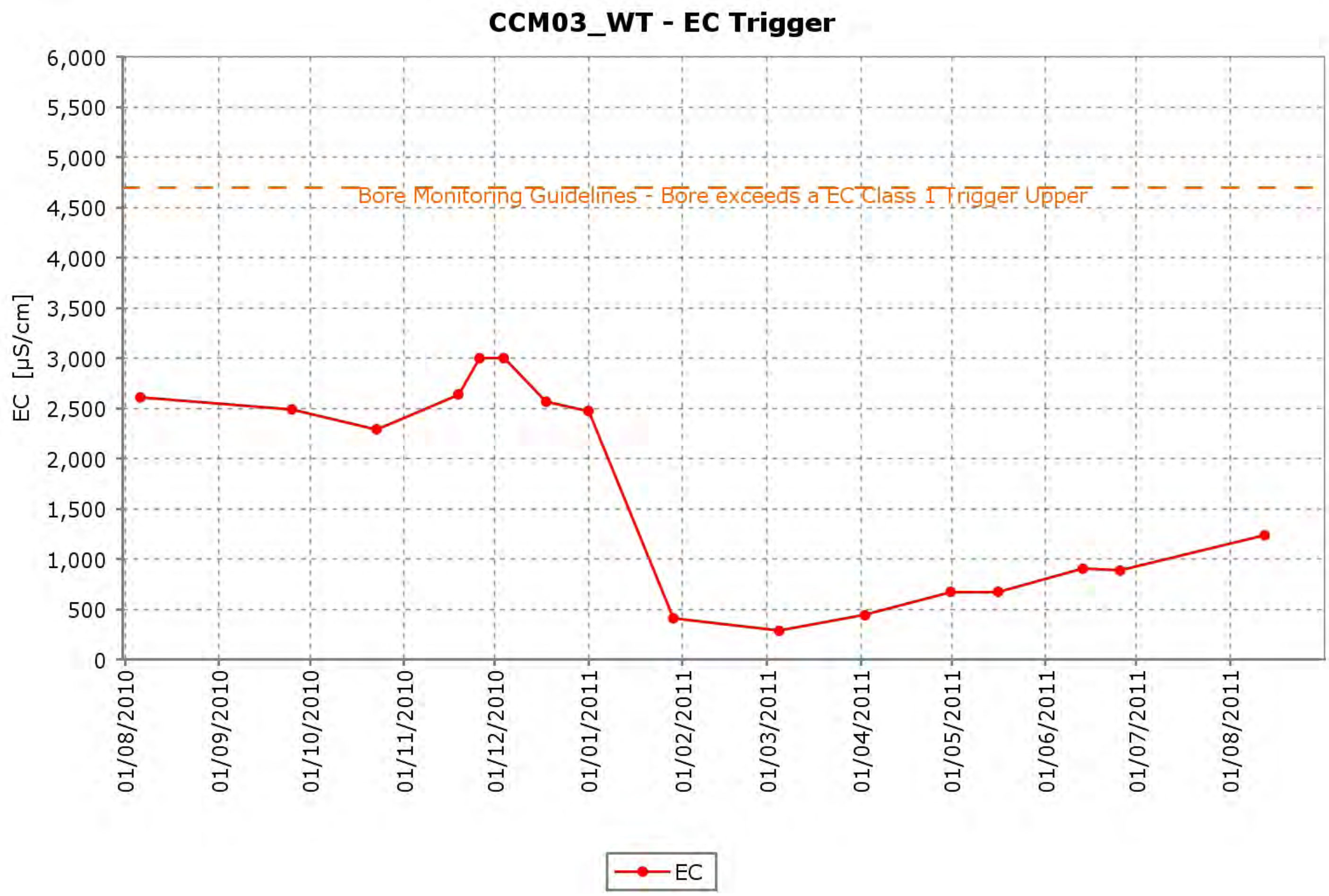
CCM03_I - Water Level Trigger

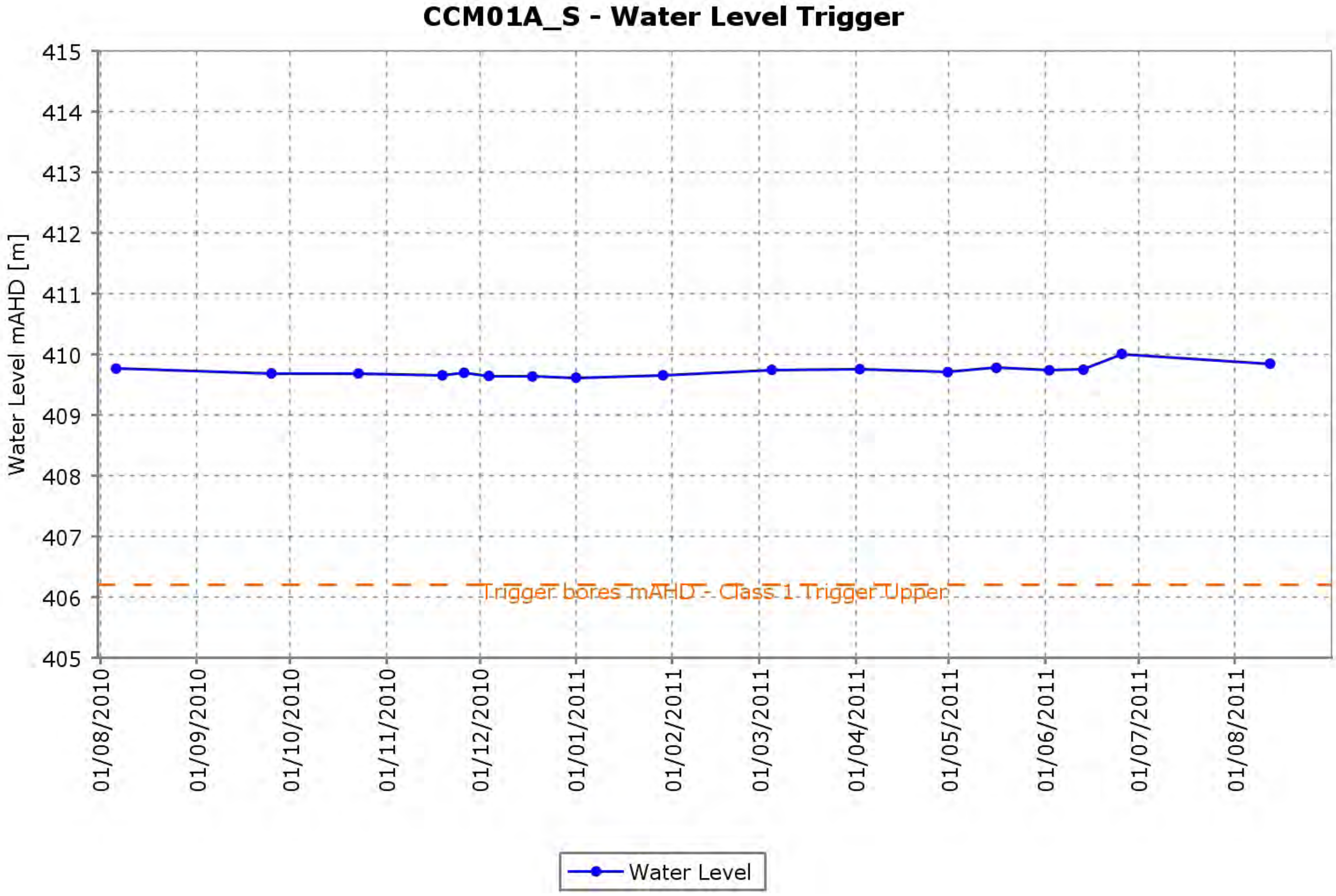


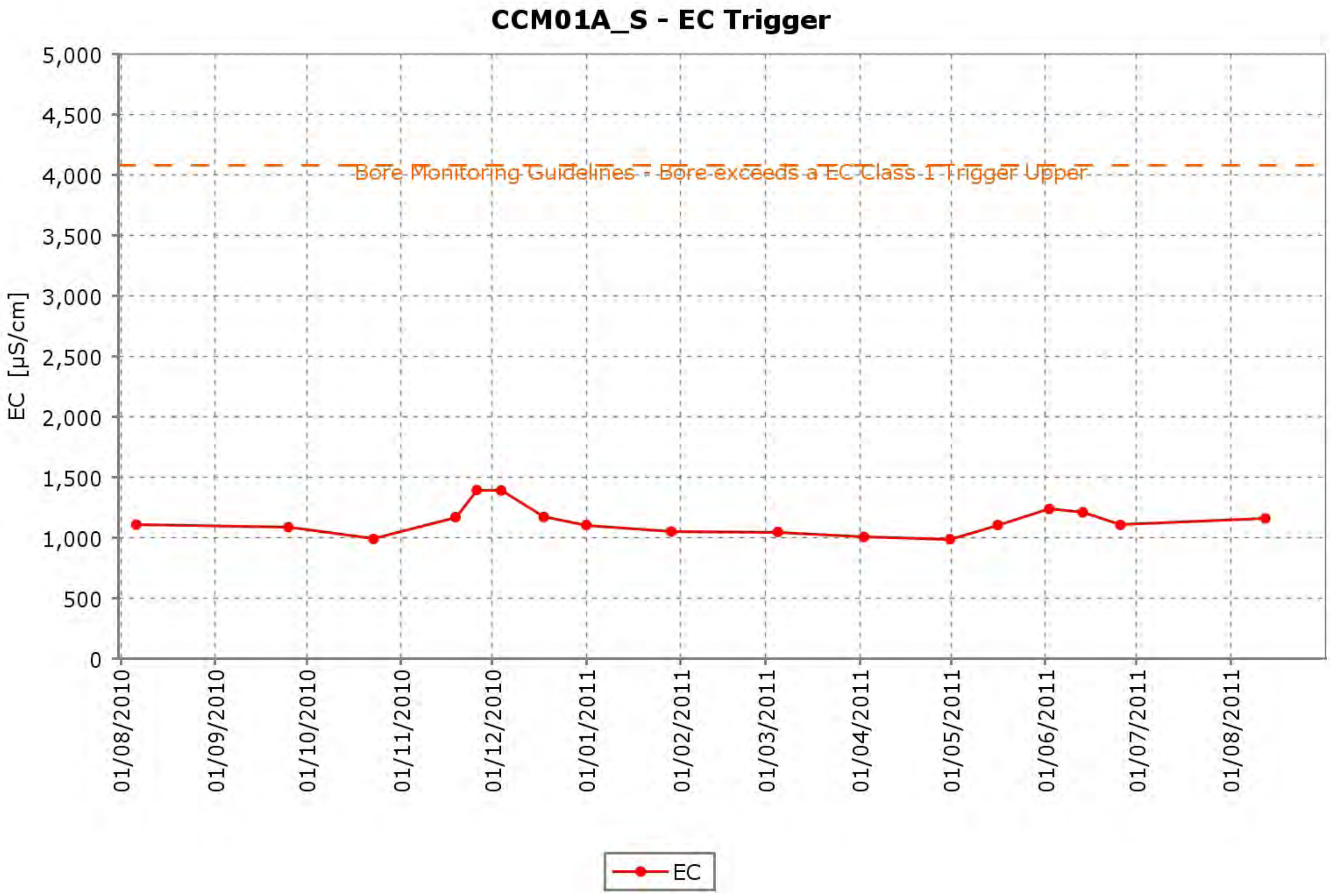

CCM03_S - Water Level Trigger
Water Level mAHD [m]
415
414
413
412
411
410
409
408
407
406
405
Trigger bores mAHD - Class 1 Trigger Upper
01/08/2010
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level

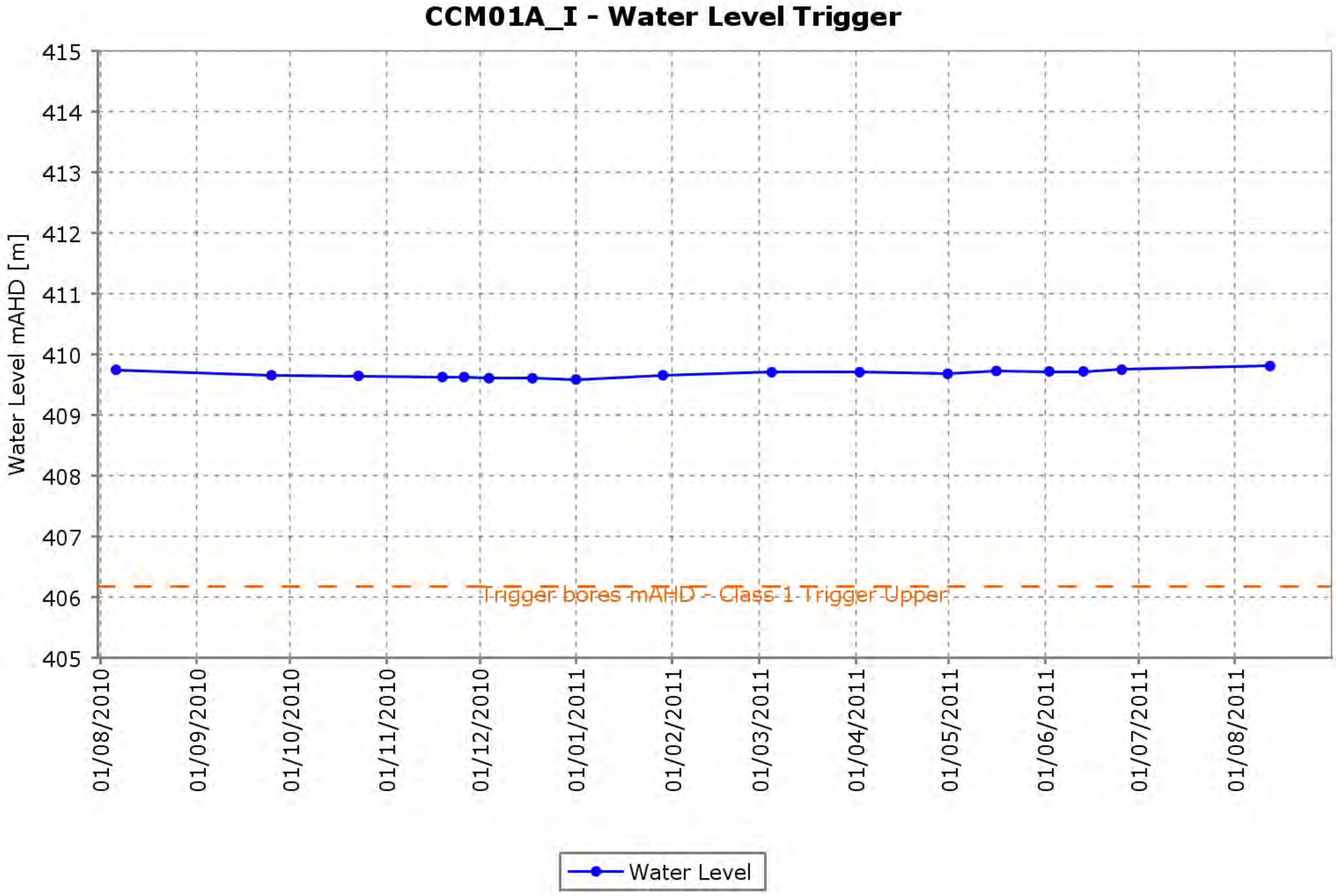

CCM03_S - EC Trigger
EC [µS/cm]
6,000
5,500
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
Bore Monitoring Guidelines - Bore exceeds a EC Class 1 Trigger Upper
01/08/2010
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
EC

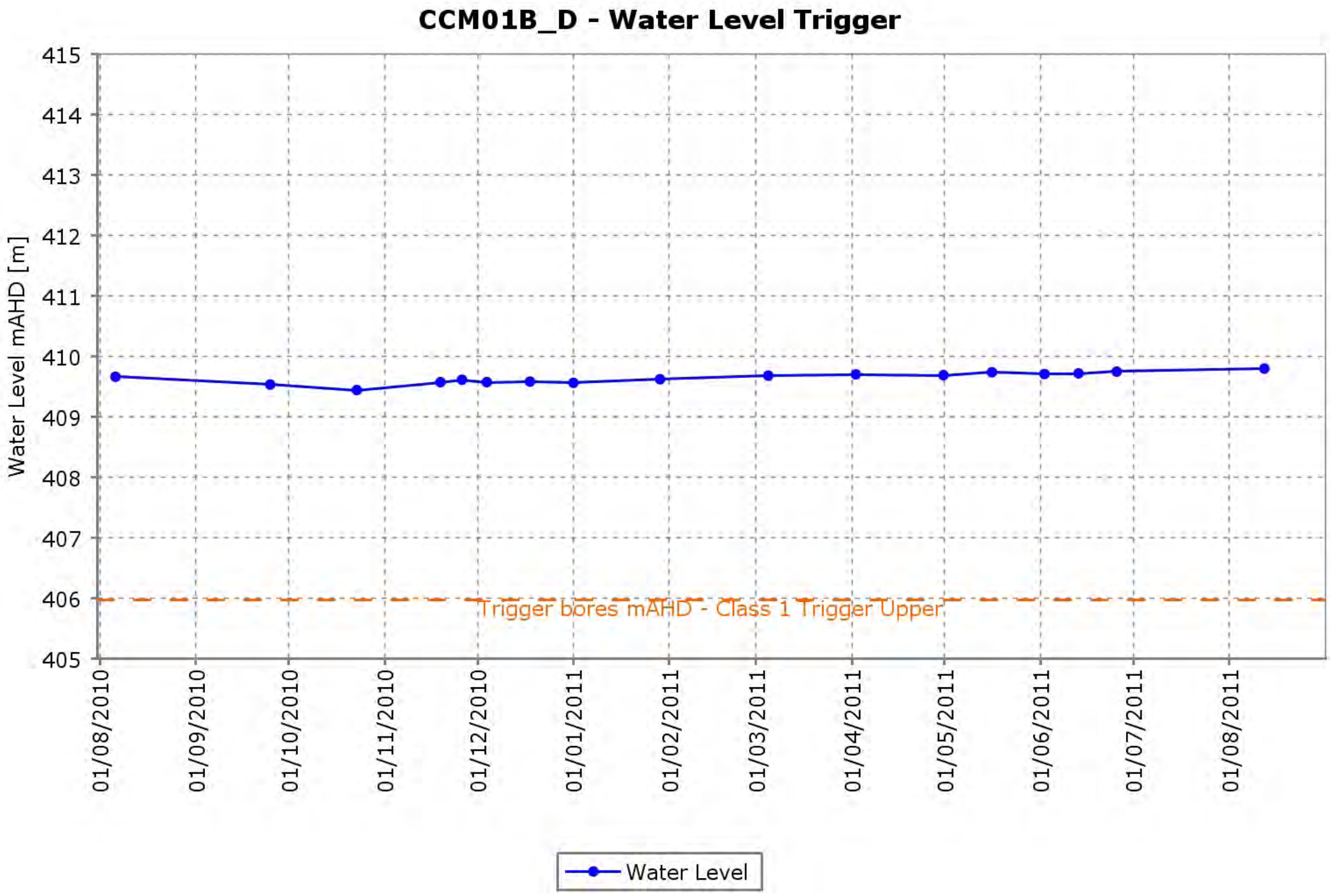

CCM03_WT - Water Level Trigger
Water Level mAHD [m]
415
414
413
412
411
410
409
408
407
406
405
Trigger bores mAHD - Class 1 Trigger Upper
01/08/2010
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level

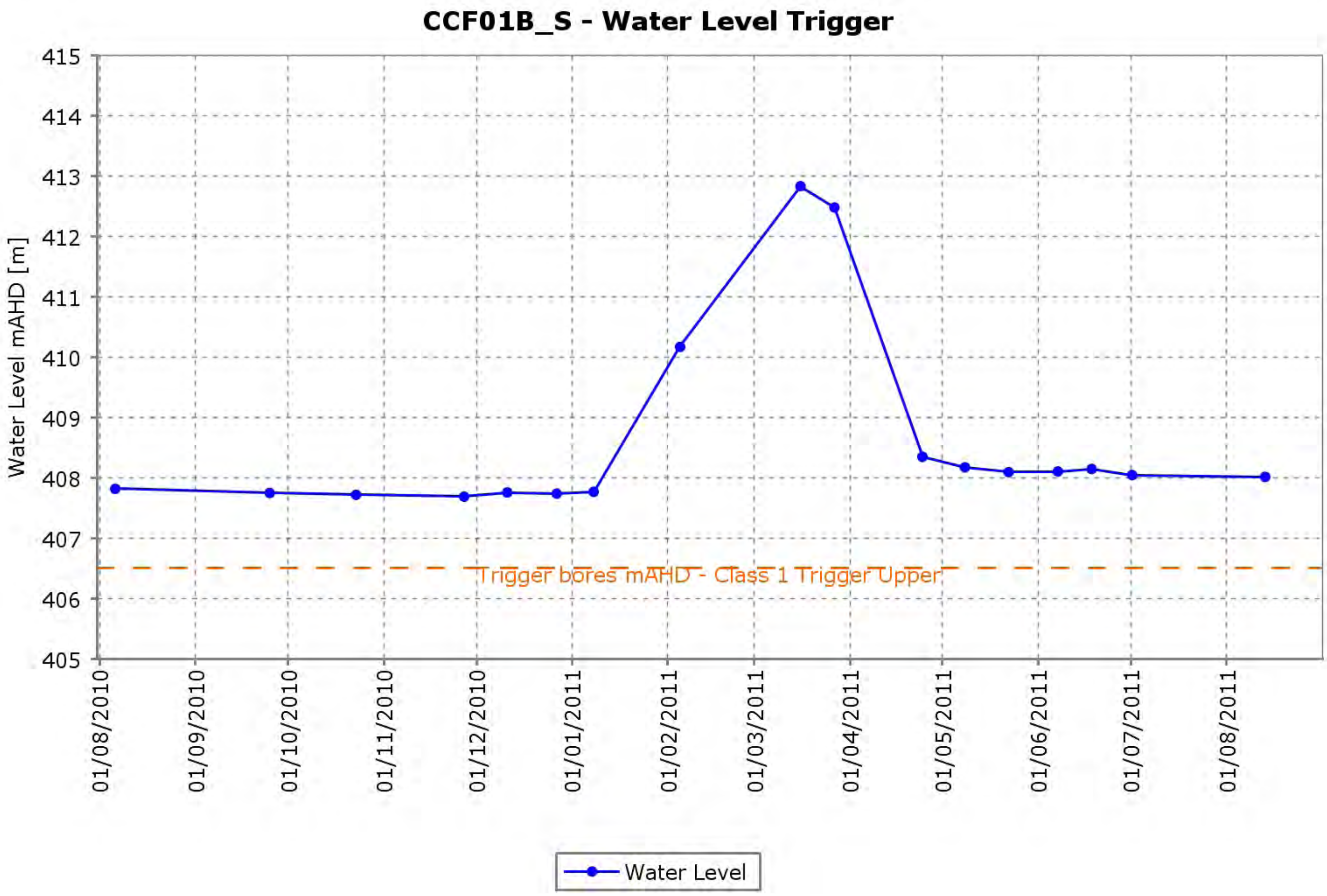

CCM03_WT - EC Trigger
EC [µS/cm]
6,000
5,500
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
Bore Monitoring Guidelines - Bore exceeds a EC Class 1 Trigger Upper
01/08/2010
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
EC

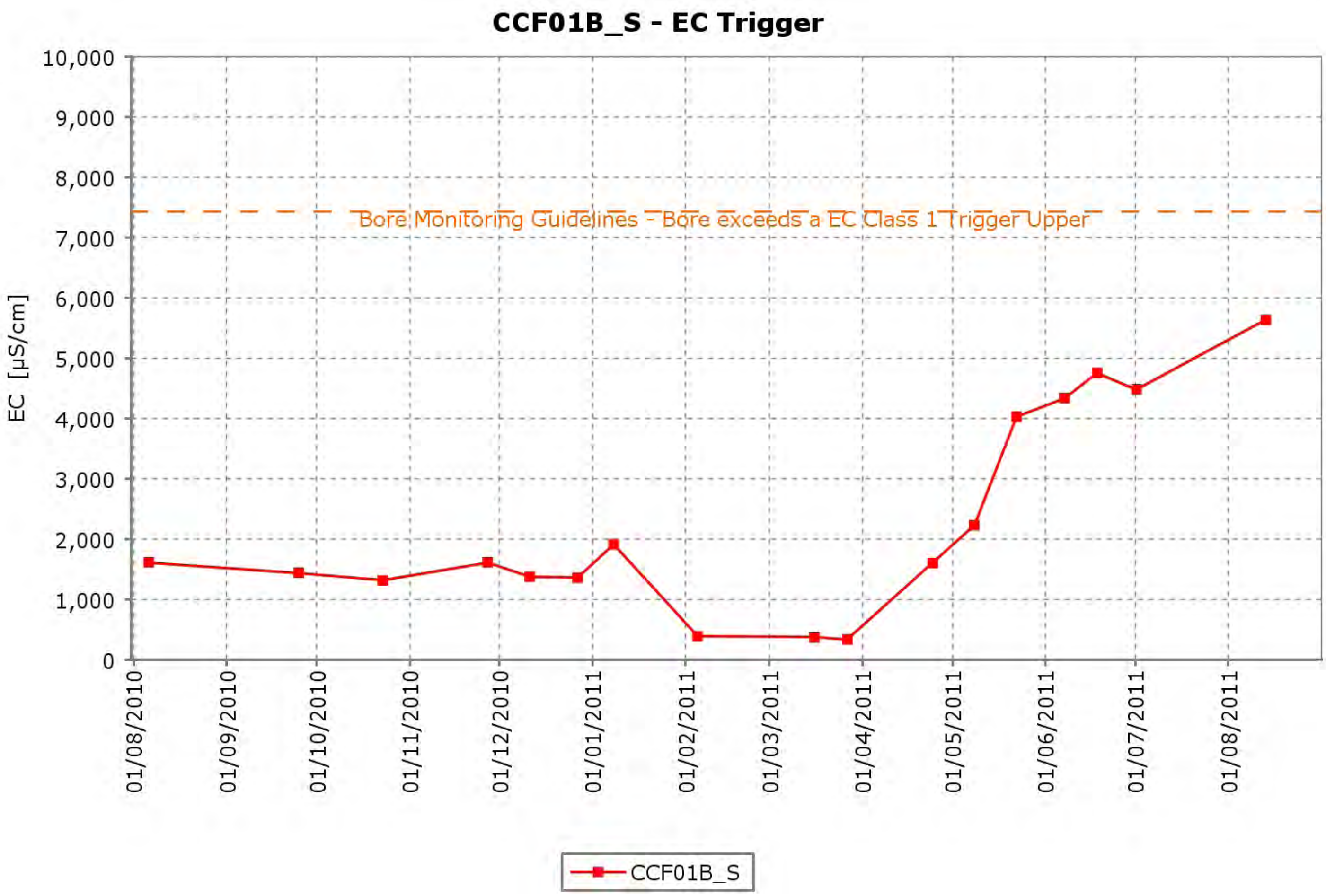

CCM01A_S - Water Level Trigger
Water Level mAHD [m]
415
414
413
412
411
410
409
408
407
406
405
Trigger bores mAHD - Class 1 Trigger Upper
01/08/2010
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level

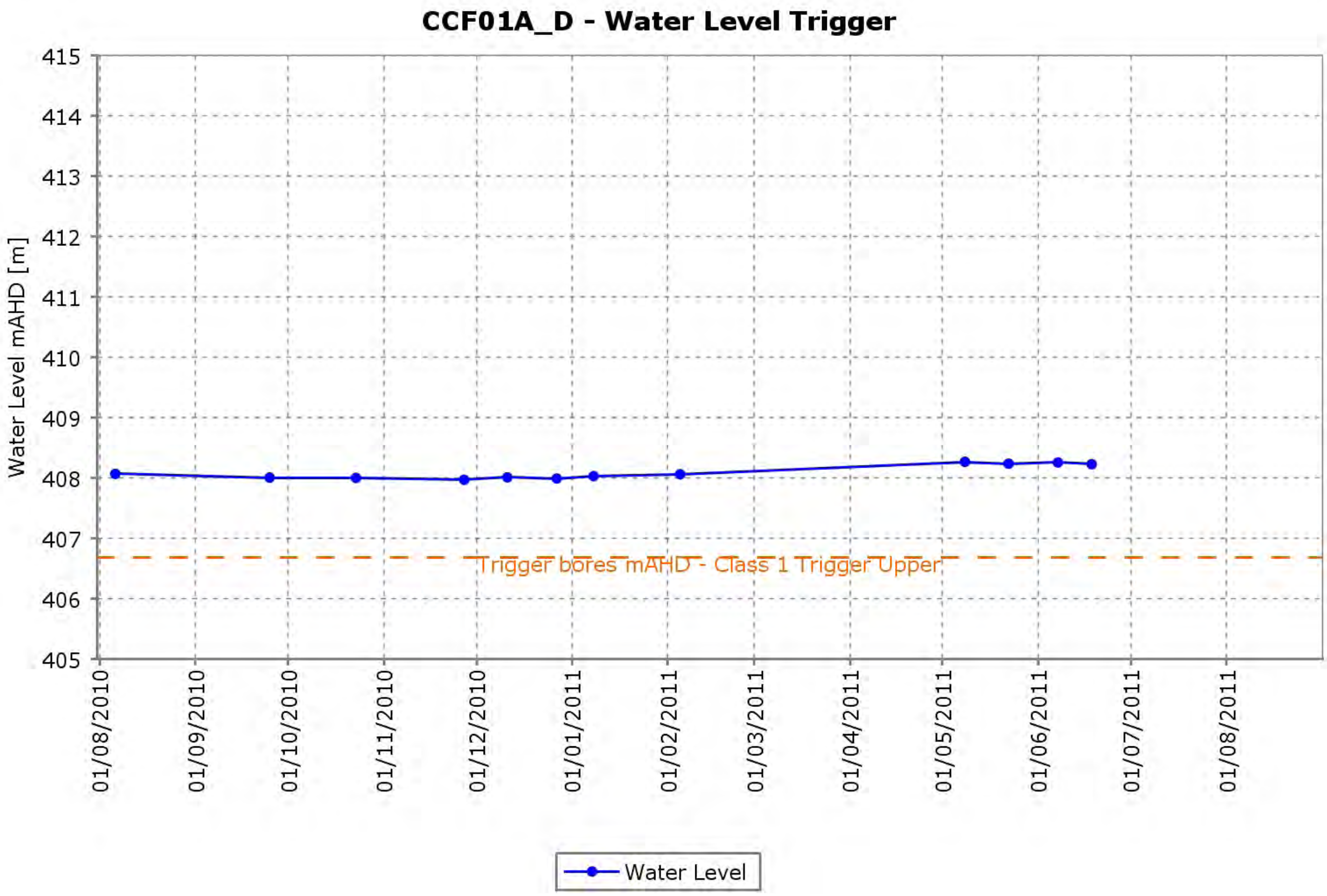

CCM01A_S - EC Trigger
EC [µS/cm]
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
Bore Monitoring Guidelines - Bore exceeds a EC Class 1 Trigger Upper
01/08/2010
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
EC

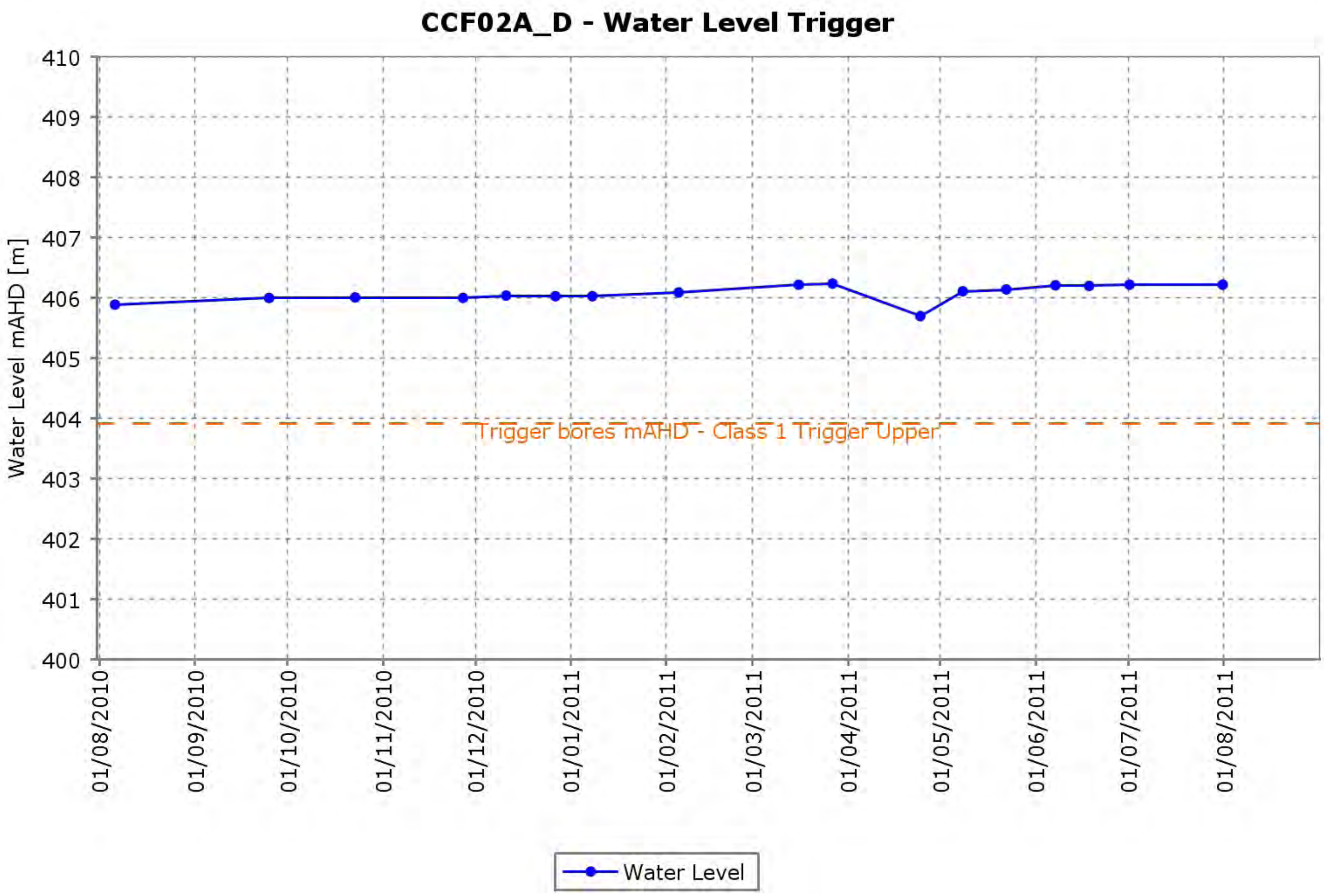

CCM01A_I - Water Level Trigger
Water Level mAHD [m]
415
414
413
412
411
410
409
408
407
406
405
Trigger bores mAHD - Class 1 Trigger Upper
01/08/2010
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level

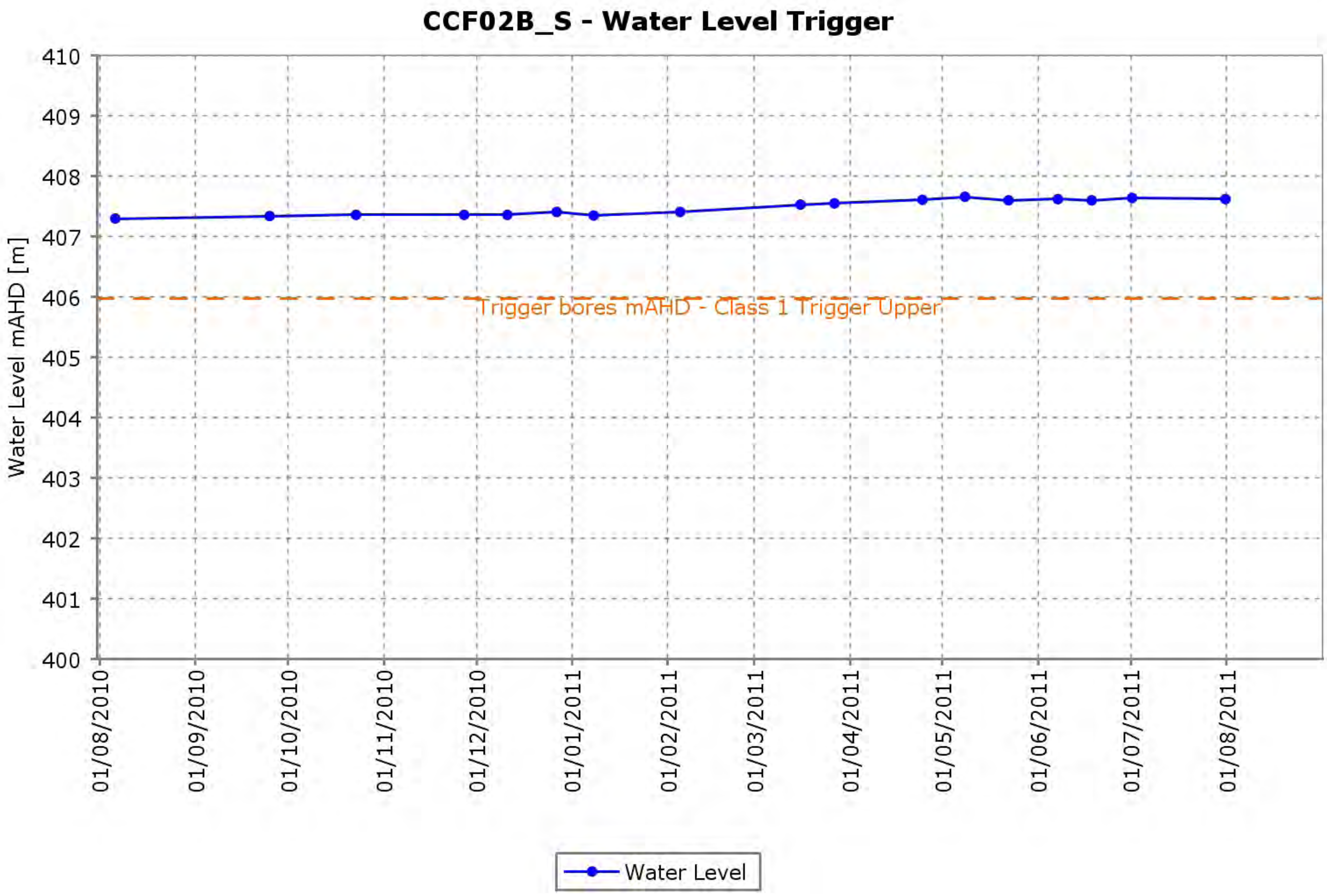

CCM01B_D - Water Level Trigger
Water Level mAHD [m]
415
414
413
412
411
410
409
408
407
406
405
Trigger bores mAHD - Class 1 Trigger Upper
01/08/2010
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level

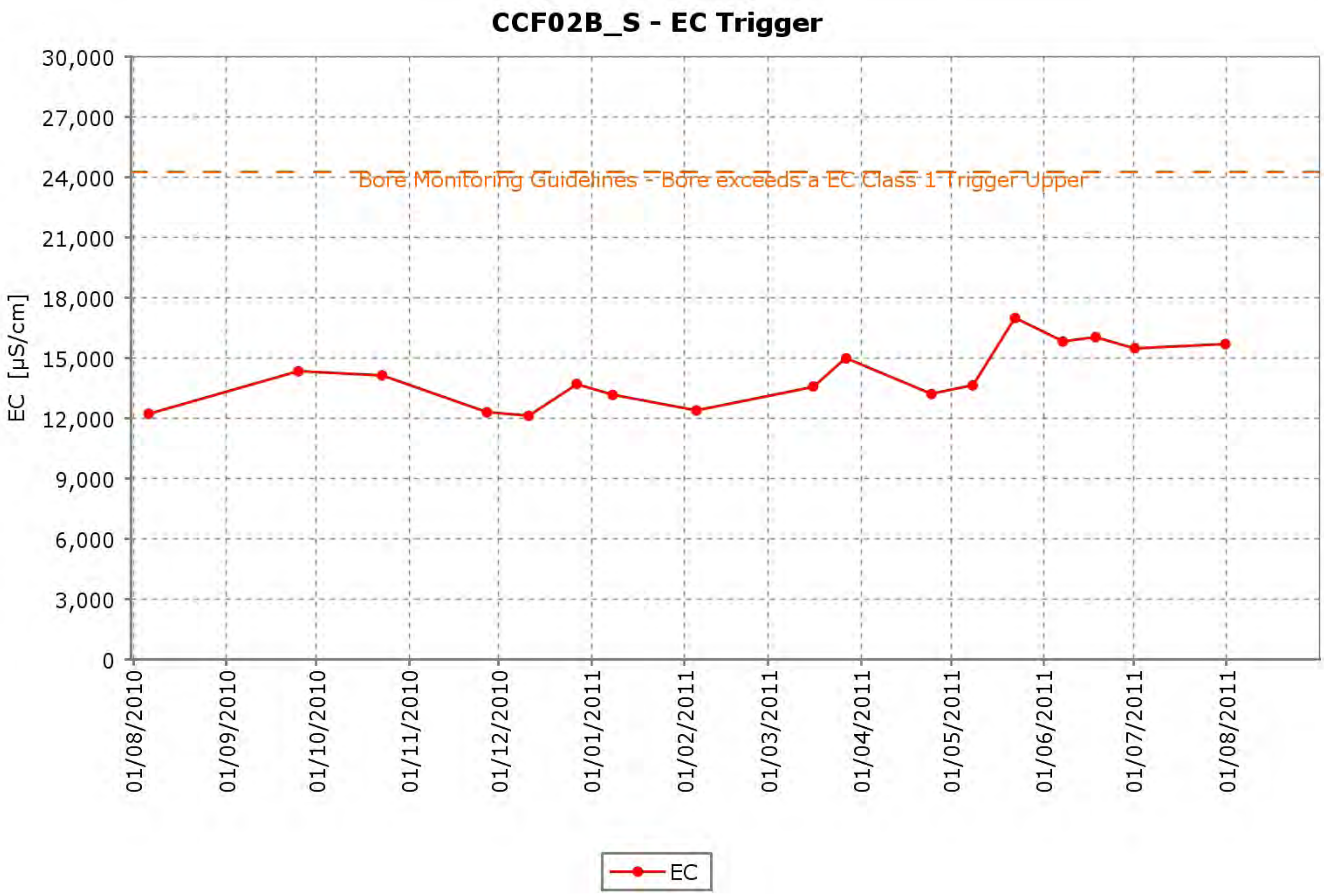

CCF01B_S - Water Level Trigger
Water Level mAHD [m]
415
414
413
412
411
410
409
408
407
406
405
Trigger bores mAHD - Class 1 Trigger Upper
01/08/2010
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level

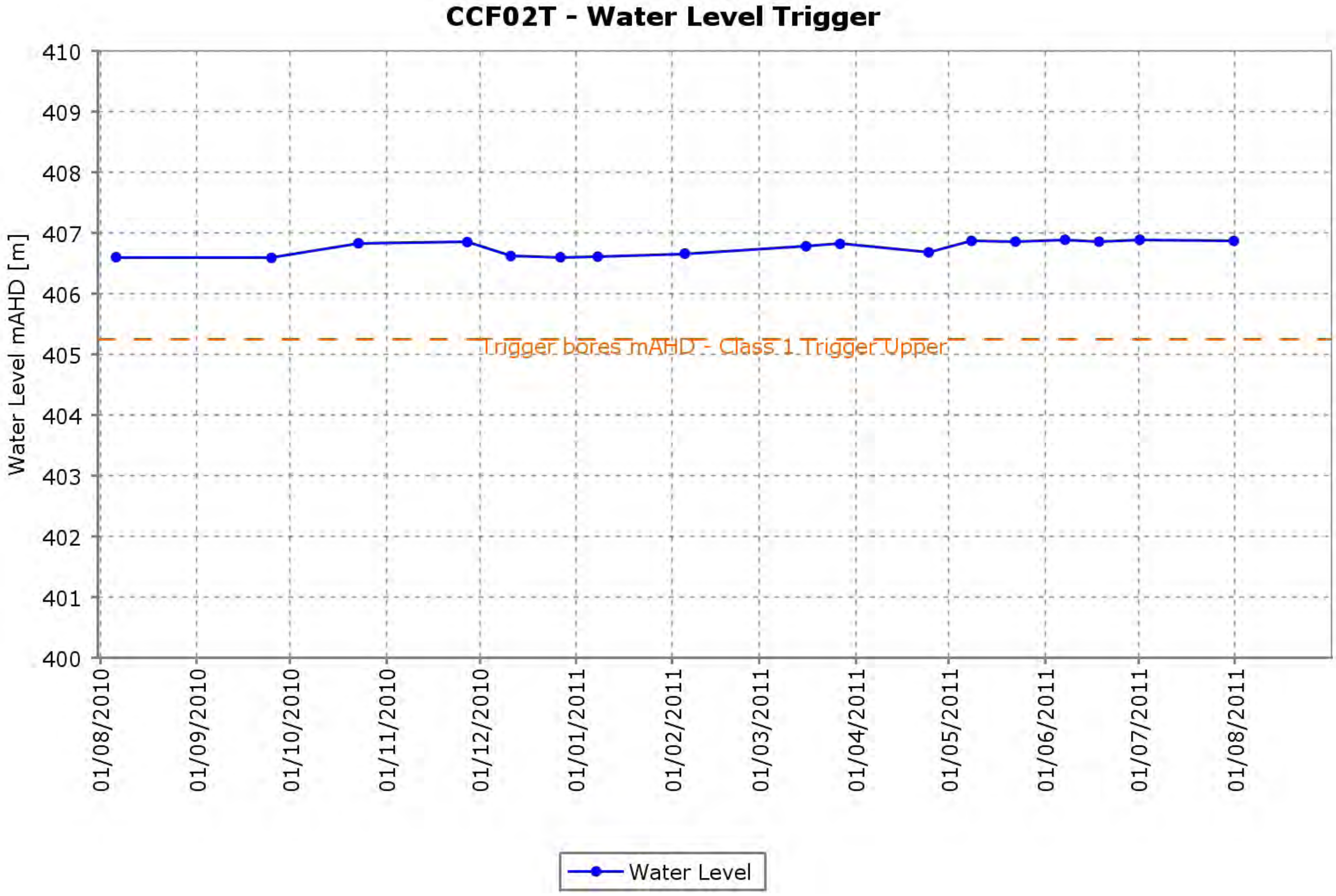

CCF01B_S - EC Trigger
EC [µS/cm]
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Bore Monitoring Guidelines - Bore exceeds a EC Class 1 Trigger Upper
01/08/2010
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
CCF01B_S

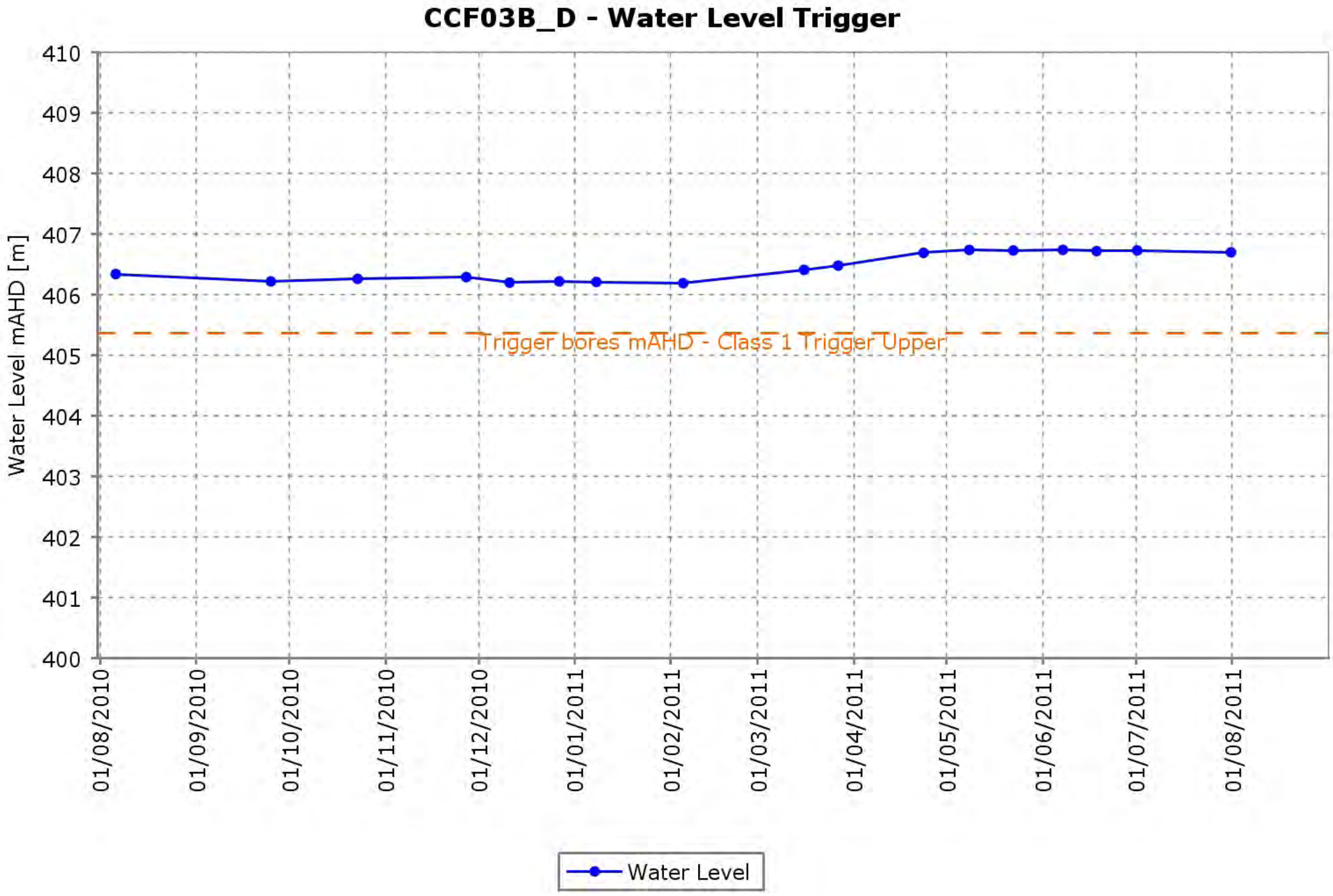

CCF01A_D - Water Level Trigger
Water Level mAHD [m]
415
414
413
412
411
410
409
408
407
406
405
Trigger bores mAHD - Class 1 Trigger Upper
01/08/2010
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level

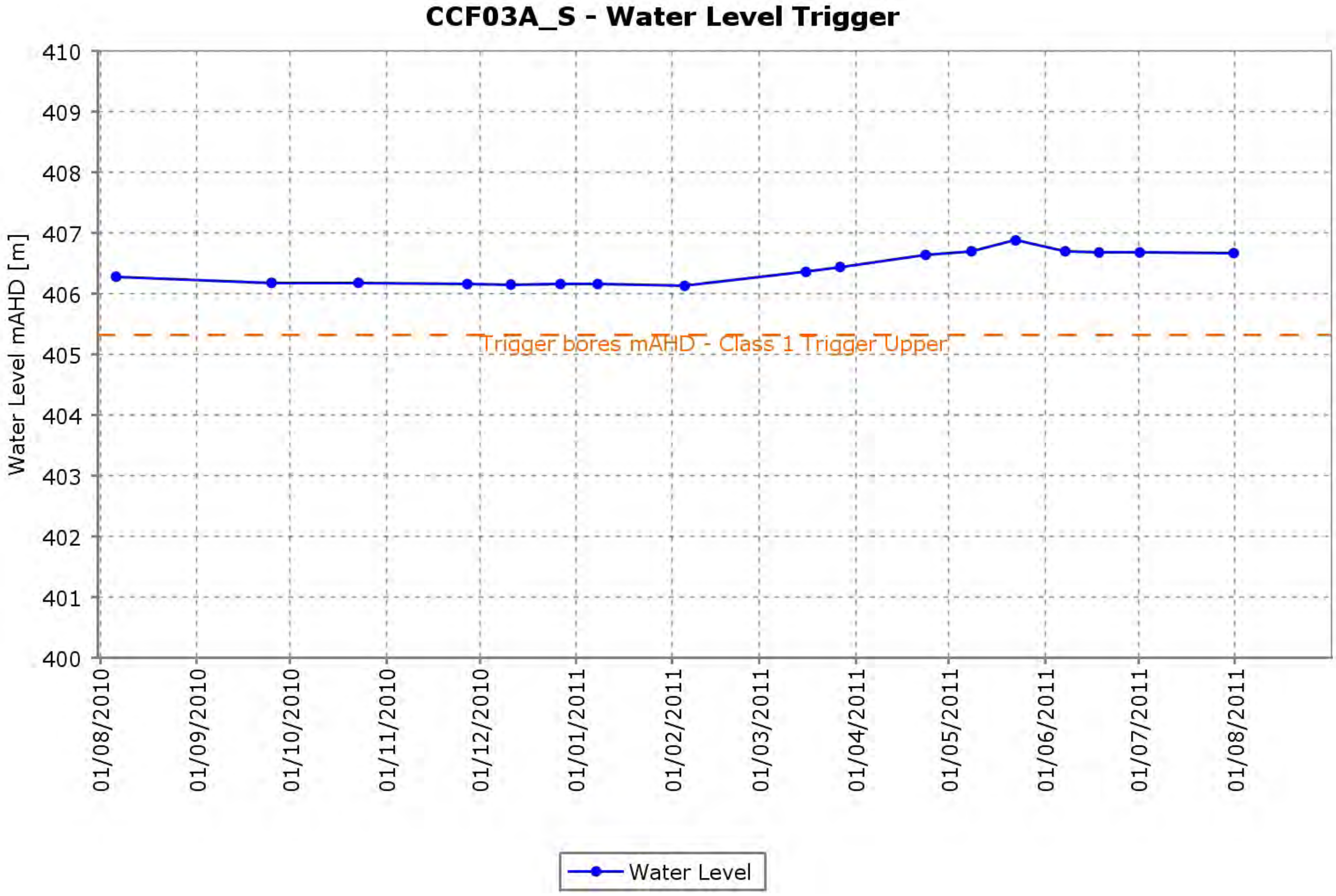

CCF02A_D - Water Level Trigger
Water Level mAHD [m]
410
409
408
407
406
405
404
403
402
401
400
Trigger bores mAHD - Class 1 Trigger Upper
01/08/2010
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level

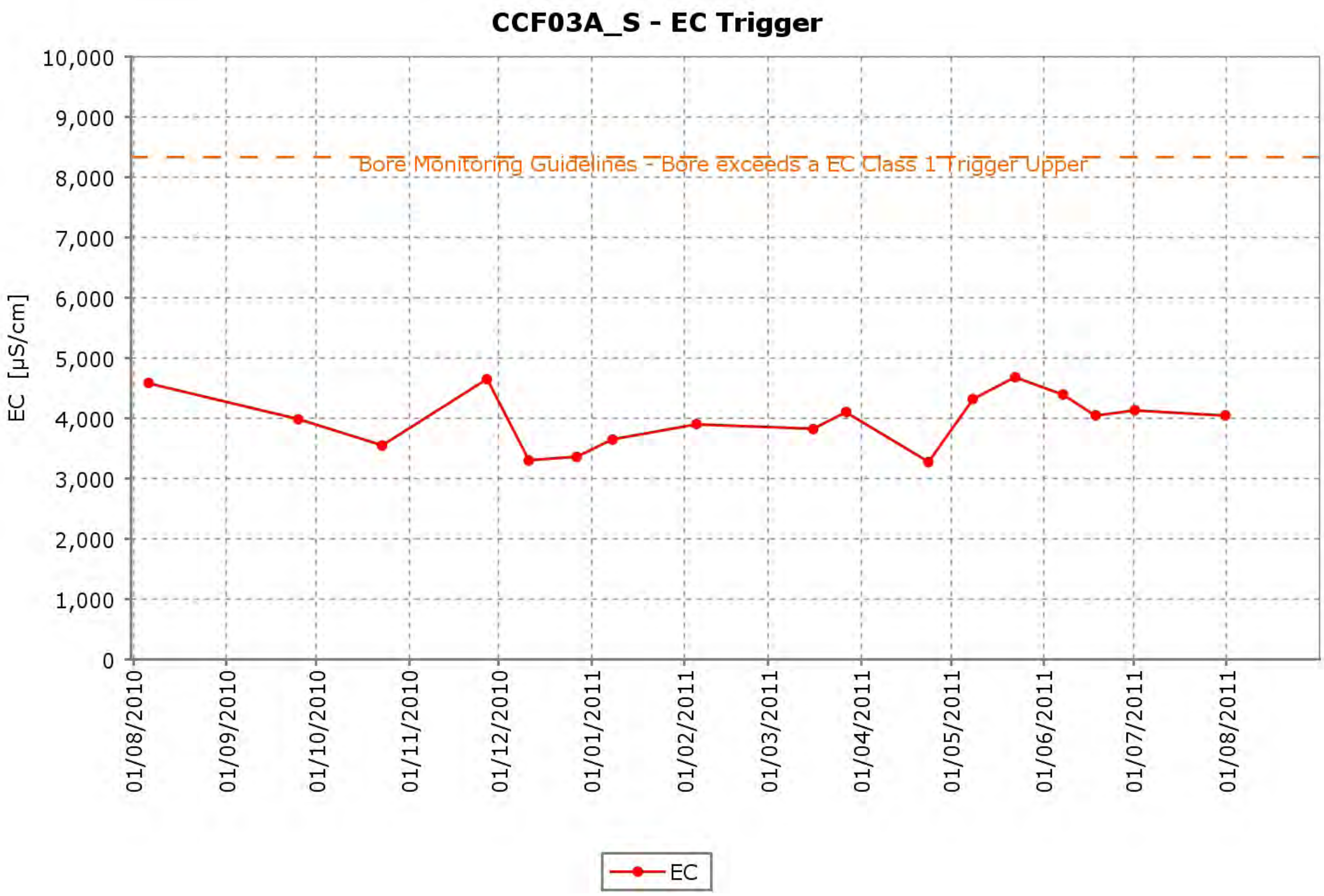

CCF02B_S - Water Level Trigger
Water Level mAHD [m]
410
409
408
407
406
405
404
403
402
401
400
Trigger bores mAHD - Class 1 Trigger Upper
01/08/2010
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level


CCF02B_S - EC Trigger
EC [µS/cm]
30,000
27,000
24,000
21,000
18,000
15,000
12,000
9,000
6,000
3,000
0
Bore Monitoring Guidelines - Bore exceeds a EC Class 1 Trigger Upper
01/08/2010
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
EC


CCF02T - Water Level Trigger
Water Level mAHD [m]
410
409
408
407
406
405
404
403
402
401
400
Trigger bores mAHD - Class 1 Trigger Upper
01/08/2010
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level


CCF03B_D - Water Level Trigger
Water Level mAHD [m]
410
409
408
407
406
405
404
403
402
401
400
Trigger bores mAHD - Class 1 Trigger Upper
01/08/2010
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level


CCF03A_S - Water Level Trigger
Water Level mAHD [m]
410
409
408
407
406
405
404
403
402
401
400
Trigger bores mAHD - Class 1 Trigger Upper
01/08/2010
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
Water Level


CCF03A_S - EC Trigger
EC [µS/cm]
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Bore Monitoring Guidelines - Bore exceeds a EC Class 1 Trigger Upper
01/08/2010
01/09/2010
01/10/2010
01/11/2010
01/12/2010
01/01/2011
01/02/2011
01/03/2011
01/04/2011
01/05/2011
01/06/2011
01/07/2011
01/08/2011
EC

[This page has been left blank intentionally]

Appendix D.

Mulga Health Monitoring Parameters

This page has been left blank intentionally

Mulga Health Monitoring (from Mulga Monitoring Guidelines 45-GU-EN-0001) is based on an indicative 2 Ha survey area to allow sufficient sample trees. The number of mature Mulga for the whole sample plot should be recorded, including their relative position, to allow individual plants to be monitored over time. The Mulga visual condition rating is adapted from Souter *et al*. (2010).

Fortescue recognises that there is currently no broadly accepted methodology for Mulga condition measurement in Western Australia. The Souter *et al*. (2010) method was developed for riparian Eucalypts, and components of this method considered to be relevant for Mulga condition measurement have been selected based on current knowledge and assumptions regarding Mulga responses to environmental stress factors. The method will be subject to an ongoing process of review, and updated where appropriate based on new scientific knowledge.

Table A1: Mulga Health Monitoring Parameters

Plant Dimensions			
Number of mature Mulga	Number recorded including position		Crown estimate
Dimensions	Height		
Age Class	Definition		
Mature	Plants > 2 m tall, and with ascending branches present, no phyllodes in ‘clusters’.		
Juvenile	Plants between 0.5 to 2 m tall; may have phyllodes in ‘clusters’ at ends of branches; usually demonstrating a horizontal branching habit; and with possibly some ascending branches present.		
Re-sprout	Any tree or juvenile looking plant that has obvious growth from epicormic buds or the base of the stem (within 30 cm of the trunk)		
Seedling	Any plant that is less than 0.2 m tall		
Mulga Visual Condition Assessment			
Score	Health Ranking	Health rating/description	
Canopy health score			
0		Dead	No phyllodes on canopy and branches ends dry and brittle when snapped (indicating no xylem flow). Bark exfoliating or flaking off.
1	Highly stresses	Pronounced shrivelling (greater 20%) of buds or shoot tips. If total phyllode loss, then branch ends not dry and brittle when snapped. Evidence of epicormic or advantageous resprouting from branchlets.	
2	Slightly stressed	Largely full canopy cover, some phyllodes may appear desiccated with brown/yellow hues, less than 20% shrivelling of buds or shoot tips	
3	Alive	Full canopy of healthy, green phyllodes present.	
New tip growth scores (growth from new shoots and branch tips)			
1	Absent	Effect not visible	
2	Scarce	Effect is present within the crown but not readily visible	

3	Common	Effect clearly visible throughout the assessable crown
4	Prolific	Effect dominates the appearance of the assessable crown
Reproduction scores (combined relative abundance of fruit and pods)		
1	Absent	Effect not visible
2	Scarce	Effect is present within the crown but not readily visible
3	Common	Effect clearly visible throughout the assessable crown
4	Prolific	Effect dominates the appearance of the assessable crown

Where appropriate for the range of potential impacts on vegetation, the following additional information should be considered for inclusion in monitoring programs:

- Presence of insect damage and/or pathogens;
- Dust cover on plant canopy; and
- Any evidence of fire.

Appendix E.

Leaf Water Potential Measurement Data Sheet

This page has been left blank intentionally

Astron Environmental Services - Groundwater Dependent Ecosystems/Riparian Vegetation Monitoring									
Leaf water potentials			Monitoring Program: FMG Christmas Creek GDE Survey					Trip No: 1	
Site No:		Date:		Predawn	Site No:		Date:		Midday
Time:		Collected by:			Time:		Collected by:		
Tree No.	1	2	3	4	Tree No.	1	2	3	4
1					1				
2					2				
3					3				
4					4				
5					5				
6					6				
7					7				
8					8				
9					9				
10					10				
Comments:					Comments:				
Site No:		Date:		Predawn	Site No:		Date:		Midday
Time:		Collected by:			Time:		Collected by:		
Tree No.	1	2	3	4	Tree No.	1	2	3	4
1					1				
2					2				
3					3				
4					4				
5					5				
6					6				
7					7				
8					8				
9					9				
10					10				
Comments:					Comments:				

Site No:		Date:		Predawn
Time:		Collected by:		
Tree No.	1	2	3	4
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
Comments:				

Site No:		Date:		Midday
Time:		Collected by:		
Tree No.	1	2	3	4
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
Comments:				

Site No:		Date:		Predawn
Time:		Collected by:		
Tree No.	1	2	3	4
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
Comments:				

Site No:		Date:		Midday
Time:		Collected by:		
Tree No.	1	2	3	4
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
Comments:				

Appendix F.

Baseline Vegetation Data Report

This page has been left blank intentionally

Christmas Creek
Vegetation Health Monitoring and Management Program
Baseline Report

October 2011

Prepared for
Fortescue Metals Group Limited

Astron Environmental Services
129 Royal Street
East Perth WA 6004
Phone: (08) 9421 9600
Fax: (08) 9421 9699
Email: perth@astron.com.au

Report Reference: 12306-11SRV1RevA_111104

Christmas Creek
Vegetation Health Monitoring and Management Program – Baseline Report

Prepared for
Fortescue Metals Group Limited

Job Number: 12306-11

Reference: 12306-11SRV1Rev0_111114

Revision Status

Rev	Date	Description	Author(s)	Reviewer
A	04/11/2011	Draft Issued for Client Review	L. Britt	M. Garkaklis
0	14/11/2011	Final Issued for Information	L. Britt	M. Garkaklis

Approval

Rev	Date	Issued to	Authorised by	
			Name	Signature
0	14/11/2011	FMG – B. Von Perger	Mark Garkaklis	[signature]

Abbreviations

Abbreviation	Definition
FMGL	Fortescue Metals Group Limited
GDE	Groundwater Dependent Ecosystem
CC	Christmas Creek
MS	Ministerial Statement
FMGL	Fortescue Metals Group Limited
GDE	Groundwater Dependent Ecosystem
CC	Christmas Creek
MS	Ministerial Statement
FMGL	Fortescue Metals Group Limited
PFC	Projected Foliar Cover (%)
VHMP	Vegetation Health Monitoring Program
VPD	Vapour Pressure Deficit
Ψpd	Leaf water potential

Glossary

Epicormic growth refers to growth of shoots from dormant buds that are activated following damage (e.g. fire) or stress (e.g. severe drought). Epicormic growth is a commonly observed in many eucalypts.

Groundwater Dependent Ecosystems are ecosystems that require access to groundwater to maintain their biological composition, ecological processes and ecosystem services (Murray et al. 2003; Sinclair Knight-Merz 2007a; Walker and Salt 2006).

Leaf Water Potential (Ψ_w) is the sum of the osmotic potential and the hydrostatic pressure in the leaf (Lambers *et al*. 1998). Pre-dawn leaf water potential (Ψ_{pd}) provides information on the soil water potential in the zone where roots are extracting water. Lower water potentials (i.e. more negative water potentials) equate to increased water stress and vice versa.

Phreatophytes are plants that draw water from the saturated zone in order to maintain vigour and function (Sinclair Knight-Merz 2007b). Obligate phreatophytes are fully dependent on groundwater, while facultative phreatophytes are not, using groundwater when it is available or, in the case of deep or saline sources of groundwater, when no other water source is available.

Pressure Chamber is an instrument that measures the water potential of an excised leaf or shoot by applying a known pressure (Turner 1988).

Stomata are structures on the surface of the leaf that act as pores to enable the exchange of gases.

Transpiration is the process by which water absorbed by the plant evaporates from the leaf through stomata (Lambers *et a*l. 1998).

Vapour Pressure Deficit (KPa) is the difference in vapour pressure or moisture in the air and the moisture content of the atmosphere at which saturation is reached under current atmospheric conditions (Lambers *et al.* 1998). In general, as VPD increases, water stress in plants increases due to increased rates of transpiration.

Executive Summary

In August 2011, Ministerial approval was granted to allow for an increase in the dewatering rate at Christmas Creek, located 110 km north of Newman, Western Australia, to 50 gigalitres per annum and injection of surplus water into the groundwater aquifers. As a condition of the approval Fortescue Metals Group Ltd (Fortescue) was required to develop and implement the Christmas Creek Vegetation Health and Monitoring Management Plan (VHMMP). This plan was completed by Astron Environmental Services (Astron) on behalf of Fortescue and in close consultation with the Western Australian Department of Environment and Conservation (DEC). The plan was submitted for approval to the Department of Sustainability, Environment, Water, Population and Communities. The objective of the plan is to quantify the water status and health of keystone species and impact on habitat characteristics located in or near areas potentially effected by dewatering or reinjection activities. Astron was engaged to undertake baseline survey to establish monitoring sites as part of the VHMMP.

The establishment of the Christmas Creek Vegetation Health Monitoring and Management Program commenced in August 2011 when field work was carried out to install the required monitoring sites and collect baseline data before the anticipated increase in dewatering rate commenced. As a result, eight sites containing keystone species were installed in or near dewatering and reinjection zones for ecophysiology (water status) assessment. At Christmas Creek the keystone species identified which may be impacted due to an increase in dewatering (drawdown of the watertable) is Coolibah (*Eucalyptus victrix*). Reinjection of surplus water may affect the keystone species Mulga (*Acacia aneura* species complex). Within each of these eight monitoring sites three 20 m transects were installed to capture baseline data regarding habitat characteristics. Additionally a further nine 20 m transects were installed in Samphire communities located near the southern boundary of the western reinjection zone. In reinjection related monitoring sites, soil samples were collected for the purpose of moisture content analysis.

The main findings in the baseline data captured were,

- There are significant differences in Leaf Water Potential between some Mulga sites
- There are significant differences in PFC between some Mulga sites
- There are no significant differences in Leaf Water Potential or PFC in dewatering sites.
- Most transects representing habitat characteristics in the dewatering and reinjection monitoring sites are statistically similar with the exception of two.
- Soil moisture content measured from samples collected at Mulga sites was generally low percentage. The mean percentage moisture per site ranged from 4 ± 0.41%w/w to 7.33 % ± 0.88 %w/w.
- Samphire community transects show individual plants in the reference transects are denser and smaller while those in the reference transect appear to be more spare with larger canopies

The baseline sampling program has established 33 transects across eight sites. Vegetation species and cover was measured at all transects. Within Coolibah and Mulga monitoring sites a total of 80 trees had baseline water status measurements taken and 240 trees had visual health assessments. The baseline sampling will allow tests of significant change in vegetation health parameters to be tested and satisfies the design outlined within the Christmas Creek VHMMP.

Table of Contents

List of Figures

List of Tables

List of Appendices

This page has been left blank intentionally.

1 Introduction

1.1 Project Background

Fortescue Metals Group Pty Ltd (Fortescue) is developing the Pilbara Iron Ore and Infrastructure Project, which involves a series of iron ore mines in the Pilbara region of Western Australia. Included in the Pilbara Iron Ore and Infrastructure Project are the Chichester Operations, which have two operating iron ore mines, Cloudbreak and Christmas Creek. The Christmas Creek mine is located approximately 110 km north of Newman, in the central Pilbara region (Figure 1).

Continued mining at Christmas Creek requires dewatering to access ore below the watertable. Fortescue therefore submitted a proposal (the Christmas Creek Water Management Scheme Project (the Project)) to the Environmental Protection Authority (EPA) to allow for an increase in the dewatering rate at Christmas Creek to 50 gigalitres per annum and injection of surplus water into the groundwater aquifers. The Project was assessed under Section 38 of the *Environmental Protection Act 1986* at the level of 'Assessment on Proponent Information' (API) (EPA 2011). In August 2011, the Project was approved by the Minister for Environment under Ministerial Statement 871 (MS 871).

The EPA determined during its assessment of the Project that Fortescue should manage groundwater to ensure significant vegetation communities are not adversely impacted. Condition 8 of MS 871 therefore requires Fortescue to prepare a Vegetation Health Monitoring and Management Plan (VHMMP) for the Project.

The relevant parts of Condition 8 state:

8-1 The proponent (Fortescue) shall manage groundwater abstraction and disposal (dewatering and injection) for the Project in a manner that ensures:

1. There is no adverse impact on native vegetation communities attributable to the project outside the predicted impact areas[1]: and
2. Within the proposed impact areas there is no mortality of keystone plant species or significant changes in habitat characteristics attributable to the Project.

8-2 Prior to the reinjection of surplus water and in consultation with the Department of Environment and Conservation (DEC), the proponent shall prepare a Vegetation Health Monitoring and Management Plan for the project area to the requirements of the Chief Executive Officer (CEO) of the Office of the Office of the Environmental Protection Authority (OEPA) to verify and ensure that the requirements of Condition 8-1 shall be met.

[1] The *predicted/proposed impact areas* are defined in Schedule 2 of MS 871 and are provided in Figures 1 & 2

8-3 The plan shall include the following:

1. Identification of keystone species and habitat characteristics and limits of acceptable change in health and/or condition of these to be used as a basis for monitoring;
2. Locations for predicted impacts and reference monitoring sites (outside the predicted impact areas) for baseline and ongoing monitoring, with sites selected based on scientific rationale and to the satisfaction of the DEC;
3. Results of the baseline monitoring for vegetation health, species composition and habitat characteristics at both the predicted impact and reference monitoring sites and groundwater levels and groundwater quality at agreed sites in proximity to the vegetation monitoring sites;
4. Specifications for the monitoring program for vegetation health, species composition and habitat characteristics, including trigger levels for additional management actions to prevent further impacts and ensure compliance with 8-1; and
5. Specific management and contingency actions beyond reporting or initiating assessment.

8-4 The monitoring is to be carried out according to a method and schedule determined prior to the injection of surplus water to the satisfaction of the CEO OEPA, and is to be carried out until such a time as the CEO OEPA determines from the DEC that monitoring may cease.

The Project was also assessed under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), with the Federal Minister for the Environment approving the Project subject to several conditions. One of these conditions requires that an appropriately qualified expert prepare a Vegetation Health Monitoring and Management Plan (Condition 5 of the EPBC Act approval (EPBC2010/5706) for the Project to the satisfaction of the Federal Minister for the Environment. This task has been completed and has been approved by the Western Australian Department of Environment and Conservation (DEC) and Australian Department of Sustainability, Environment, Water, Population and Communities (Astron 2011).

The Vegetation Health Monitoring and Management Plan (VHMMP) uses the framework recommended by the International Union for the Conservation of Nature and Natural Resources (the IUCN) to assist in developing and implementing the key issues with respect to vegetation health and condition management targets, monitoring designs and reporting requirements (Hockings *et al.* 2006). The IUCN framework allows the application of the Pressure-State-Response model for adaptive environmental management through a systematic process that avoids the haphazard application of monitoring programs. Using the IUCN framework, the VHMMP defines the project management areas and the roles and responsibilities of Fortescue personnel implementing the plan. The VHMMP also provides environmental context and identifies the current area of keystone species and habitat characteristics within vegetation communities that may be impacted by groundwater drawdown or groundwater rise (Astron 2011). It is these keystone species and habitats that are the focus of this baseline monitoring report.

1.2 Keystone species and habitats

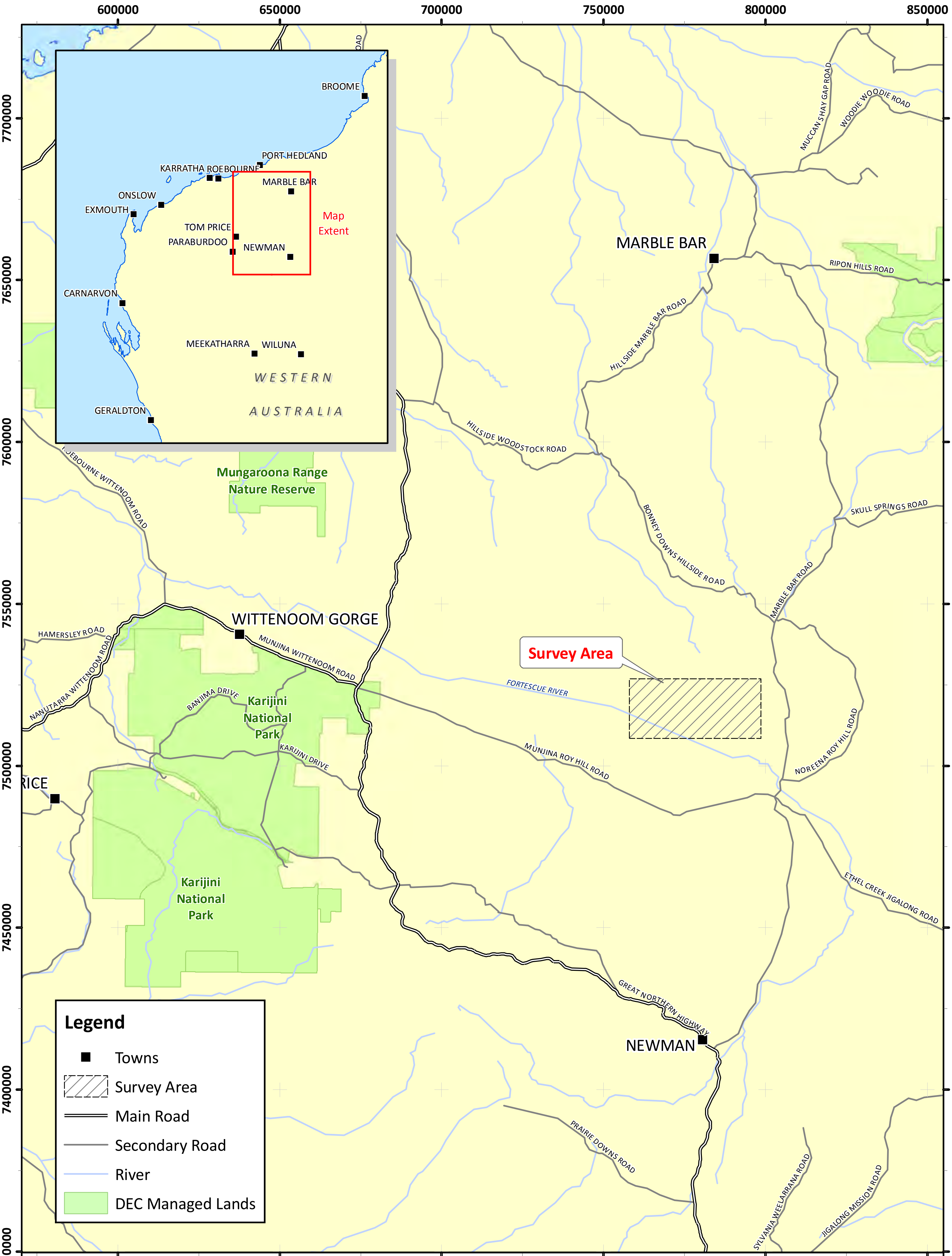
Keystone plant species identified in the VHMMP are those species occurring in vegetation communities that provide high ecosystem service value to the community, or are species within communities of high conservation value of which little precise knowledge regarding ecosystem function is know (Astron 2011). For the VHMMP, the following keystone plant species are identified:

- Mulga (*Acacia aneura species complex*) – Low open forest to woodland;
- River Red-gum (*Eucalyptus camaldulensis*) – Riparian woodland to open woodland;
- Coolibah (*Eucalyptus victrix*) – Riparian woodland to open woodland; and
- Samphire communities (*Tecticornia* species and other major shrubs such as *Muellerolimon salicorniace*um).

Other vegetation communities considered regionally important, e.g. low woodland dominated by Snakewood (*Acacia xiphophylla*) are not significantly represented within the Project area. Hummock grassland dominated by *Triodia basedowii* is extensive in the northern portions of the drawdown impact area (Figure 2), but is considered unlikely to be susceptible to drawdown impacts (Astron 2011). The baseline depth to watertable where this vegetation type occurs is >20m (Fortescue 2011a).

1.3 This report

This document is a baseline report addressing Condition 8.1 of MS 871. Field works were conducted between 15th-19th August 2011 and 1st-5th September 2011. The objective of the field survey, data analysis and report was to provide a measure of the current state of the keystone species and habitats at a number of permanently marked monitoring sites. These sites will form the basis of the vegetation health monitoring. The broad monitoring hypothesis is that measurements of ecological parameters within keystone vegetation habitat or keystone species at potential impact sites (drawdown impact area or mounding impact areas), do not, over time, alter significantly beyond the natural variation of reference sites.



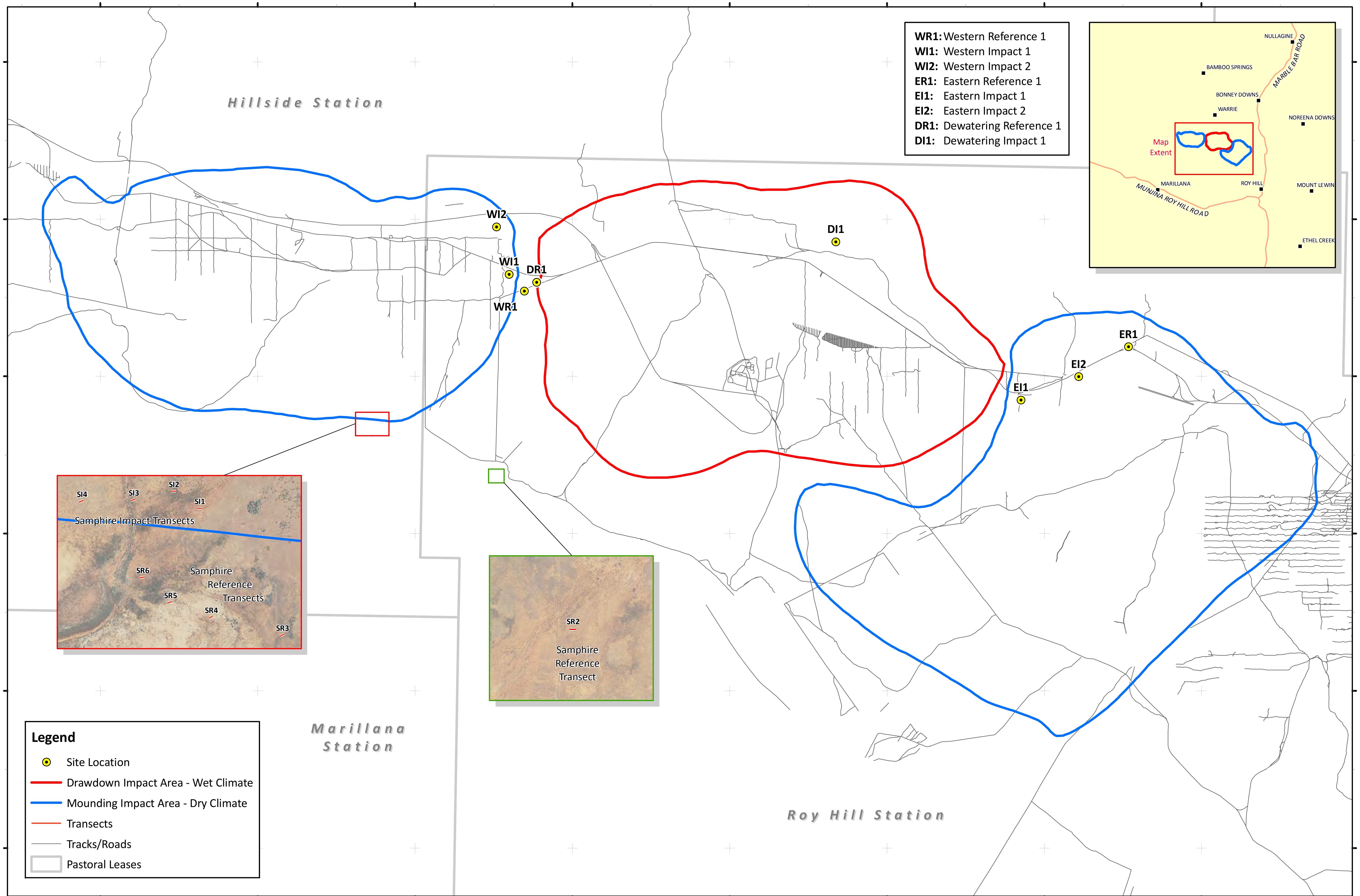
Fortescue Metals Group

Christmas Creek Vegetation Health Monitoring

Figure 1: Location of the Christmas Creek Survey Area

astron environmental services

Author: L. Britt	Date: 21-09-2011	Datum: GDA 1994 - Projection: MGA Zone 50 Scale: 1:1,500,000 (A4)
Drawn: C. Dyde	Ref: 12306-11FMV1RevA_110921_Fig1	0 10 20 30 40 50 Kilometres N



Fortescue Metals Group

Christmas Creek Vegetation Health Monitoring

Figure 2: Overview Map of the Survey Area

Datum: GDA 1994 - Projection: MGA Zone 50 - Scale: 1:110,000 (A3)

0 2 4 6 8 10 Kilometers

N

astron environmental services

Author: L. Britt | Drawn: C. Dyde | Date: 21-10-2011 | Figure Ref: 12306-11FMV1RevA_111021_Fig2

This page has been left blank intentionally.

2 Methodology

2.1 Project Location

Fortescue Metals Group Pty Ltd (Fortescue) is developing the Pilbara Iron Ore and Infrastructure Project, which involves a series of iron ore mines in the Pilbara region of Western Australia. Included in the Pilbara Iron Ore and Infrastructure Project are the Chichester Operations, which have two operating iron ore mines, Cloudbreak and Christmas Creek. The Christmas Creek mine is located approximately 110 km north of Newman, in the central Pilbara region (Figure 1).

2.1.1 Climate

The climate of the Pilbara is classified as arid tropical with two distinct seasons: a hot wet summer (October – April) and a mild dry winter (May – September) (Maunsell 2006a). Rainfall can occur throughout the year, but most rain is due to monsoonal low pressure systems and tropical cyclones in the summer season. During the winter season, mild cold fronts influence rainfall patterns across the region.

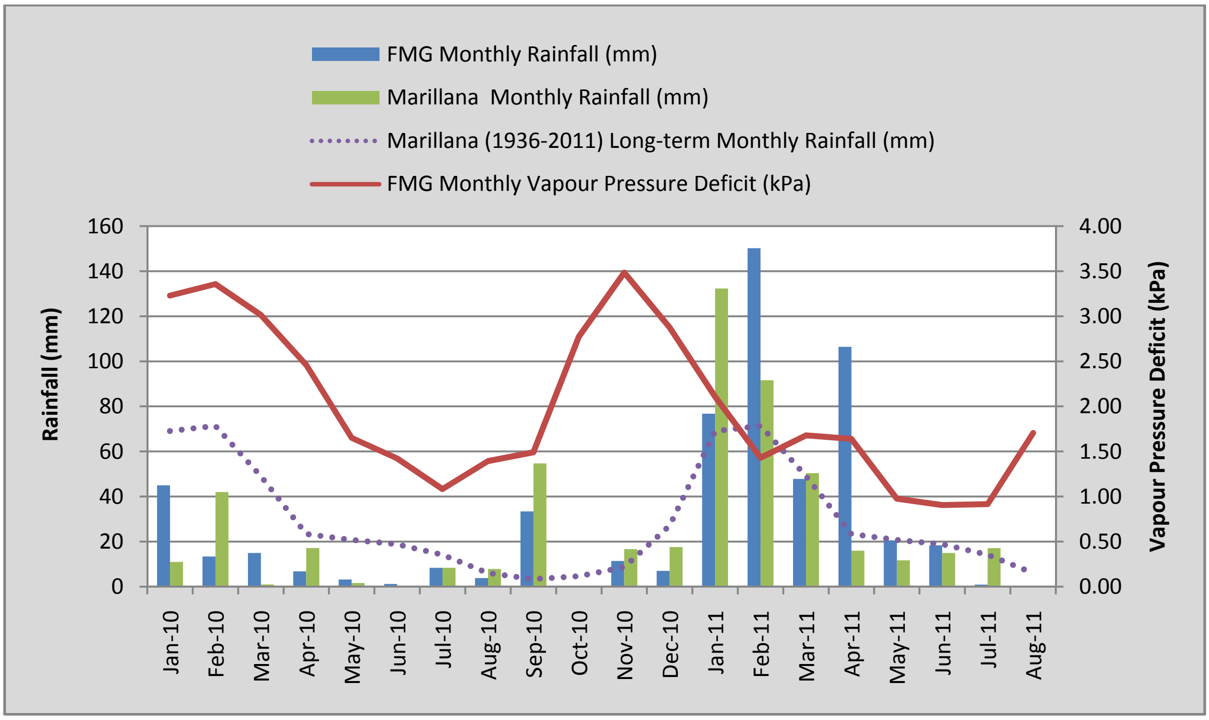


Figure 3: Mean monthly rainfall (mm) sourced from Cloudbreak Weather Station and Marillana Weather Station. Long term (1936 – 2011) mean monthly rainfall is shown from Marillana Station. Monthly Vapour Pressure Deficit (kPa) is sourced from Cloudbreak Weather Station. Note: Data captured at Cloudbreak is invalidated prior to July 2011.

2.1.2 Landform

The Pilbara region has been surveyed by the Western Australian Department of Agriculture and Food (DAFWA), for the purposes of land classification, mapping and resource evaluation. The region consists of 102 land systems; distinguished on the basis of topography, geology, soils and vegetation (Van Vreeswyk *et al.* 2004). The Project area coincides with the Jamindie, Turee, Cowra and Marsh land systems. Further detail of land systems occurring in the project area are outlined in VHMMP (Astron 2011).

2.1.3 Groundwater – Primary Pressure

Change in groundwater depth (drawdown and mounding) due to Project dewatering or re-injection is the Primary pressure that may impact groundwater sensitive vegetation. Groundwater monitoring bore locations provided by FMGL show some bores could be located within the vicinity of some vegetation monitoring site; however, this was not found to be consistent with all sites. A broad statement can be made regarding the depth to water directly below monitoring sites. Groundwater depths gauged monthly (mean monthly depth used where gauging more frequent) from bores considered the 'nearest' to monitoring sites showed a depth to water ranged of 16.04 mbgl to 30.06 mbgl. The highest levels (approximately 16-17 mbgl) in the water table appear to be near the western reinjection area while water table levels associated with the eastern reinjection monitoring sites are approximately 8 m lower. The lowest ground water level, 30.06 mbgl recorded at Charlton Bore is the closet to DI1 monitoring site. The areas bounding where changes in groundwater are predicted to occur are provided in Figure 2.

2.1.4 Vegetation

Vegetation descriptions at Christmas Creek are provided in the VHMMP (Astron 2011). The Project area is located on the northern edge of the Fortescue Marsh, which contains the Fortescue Marsh Priority 1 PEC. A brief description of the keystone vegetation communities that are the focus of vegetation monitoring is provided below.

2.1.4.1 Mulga Vegetation Communities

The Mulga communities of the Project area range from low woodland, low open forest to mixed *Acacia* scrub. These are generally dominated by members of the Mulga species complex; however other prominent species include *Acacia xipholphylla*, *A. pruinocarpa* and *A. tetragonophylla*. Groundwater monitoring associated with the Fortescue bore network indicates that the baseline depth to watertable ranges from approximately 3 to >15 m where these communities occur (Fortescue 2011b).

Habitat and plant / community health characteristics targeted for Mulga vegetation monitoring are:

- Density and cover of dominant *Acacia* species;
- Life histories of dominant *Acacia* species (fruiting seeding and recruitment);
- Cover of species in perennial understorey measured between sites; and
- Indicative health of dominant *Acacia* species measured by physiological water status and soil moisture measurements between sites.
- The potential for incorporating additional parameters into the monitoring program, such as ant community structure, is being further investigated by Fortescue.

2.1.4.2 Facultative (Partially) Phreatophytic Vegetation

Within the Project area River Red Gums (*Eucalyptus camaldulensis*) and Coolibah (*E. victrix*) mapping indicted these species being restricted to major drainage lines, where they grow as open woodland. River Red Gums and Coolibahs are considered to be facultative phreatophytes, which are species that can utilise groundwater opportunistically at times when water availability is limited (ENV Australia 2010). However, during on-ground surveys for phreatophytic vegetation monitoring sites, only Coolibah open woodlands along drainage lines were found. Therefore all phreatophytic monitoring was targeted towards this keystone species. A brief description of Coolibah is provided below.

Coolibah is a spreading tree to 12 m and is considered a facultative phreatophyte as it occurs low in the landscape, most commonly on the floodplains along watercourses. It has a spreading, heavily lateralized root system with major laterals appearing to act as tap roots in some cases, with small secondary laterals and secondary sinker roots also common (Grigg *et al*. 2008). In a Western Australian Department of Water study of two sites on the de Grey and Fortescue Rivers, the 5-year absolute water level range tolerated by Coolibah was 1.6 m (inundation) and -7.5 m (depth to groundwater) (Loomes 2010). However, the length of time experienced at these levels was not discussed.

Habitat and plant / community health characteristics targeted for Coolibah vegetation monitoring are:

- Water status (pre-dawn water potential);
- Density of trees;
- Canopy health; and
- Recruitment.

2.1.4.3 Samphire vegetation

The samphire communities of the Project area are largely comprised of Low Halophytic shrubland of *Tecticornia auriculata*, *T. indica* subsp. *leiostachya, T. halocnemoides* subsp. *tenuis* with patches of *Frankenia* species. Areas of *Muellerolimon salicorniaceum* and *T. indica* subsp. *bidens* shrubland are mapped in Mounding impact area 1 to a lesser extent.

Typically the watertable is several (2 to 5) metres deep near the marsh fringe and shallower towards the centre of the marsh. Samphire species zonation in the project area is considered to reflect the variable edaphic and water quality conditions; and varying tolerance to stressors of drought, salinity and waterlogging between the dominant species.

Habitat and plant / community health characteristics targeted for Coolibah vegetation monitoring are:

- Distribution of plant species (reference labelling is used as an interim in the baseline monitoring as identifiable plant material was not available); and
- Plant health.

2.1.5 Weed density and abundance – Secondary Pressure

A number of weed species have been identified from botanical surveys of the Project area (ENV Australia 2010). Weeds have the potential to alter keystone species habitat are baseline measurements of weed presence and density is required as part of the current monitoring program (S. Van Leeuwin, DEC, Pers. Comm.).

The baseline spatial distribution and densities of weed species was recorded. Weed record points were taken at monitoring sites to capture weed species, life stage and abundance data in a systematic grid survey. The spatial distribution of weed occurrences located by weed record point grids is provided in Appendix Figures 1 to 8.

The occurrence of weed species was also quantified within line intercept transects.

2.1.6 Grazing Impact – Secondary Pressure

Grazing by introduced cattle has the potential to alter keystone species habitat are baseline measurements of grazing pressure is required as part of the current monitoring program (S. Van Leeuwin, DEC, Pers. Comm.). Grazing impacts on monitoring sites were quantified by recording counts of cow pats and the presence cattle tracks. Monitoring sites generally recorded both measures indicating cattle activity is widespread across the site and was recorded within drawdown, mounding and reference sites.

2.2 Design of Monitoring Program

Monitoring potential impact of keystone species required the installation of reference and impact sites. Impact sites are at the dewatering zone, where drawdown is predicted to occur and may have an effect on phreatophytic vegetation, and two reinjection zones, where groundwater mounding is predicted occur. The mounding may have an effect on Mulga and Samphire communities.

The selection of sample sites within impact and reference areas was designed to:

- Contain the vegetation communities of interest. For example, the occurrence of Coolibah open woodland that was accessible was scattered. Extensive searches failed to locate other phreatophytic species, in particular *Eucalyptus camaldulensis*. Therefore Coolibah is the only potentially phreatophytic community that occurs in the impact area. Similarly, on-ground survey for Samphire communities, conducted over two separate reconnaissance trips, only identified suitable sample sites on the very southern boundary of the western reinjection (mounding) zone. Samphire communities did not occur further northward within the mounding impact zone.
- Align as closely as possible to groundwater bores. This is to provide a measure of actual, rather than inferred, groundwater change. The location of monitoring bores is provided in Appendix Figures 1 to 3 and Figures 6 to 8.
- Allow safe access. The sample sites are within two kilometres walking distance from a vehicle track.
- Allow measurement of the baseline state of vegetation within drawdown or mounding zones for three keystone communities:
    - Potentially phreatophytic Coolibah communities in drawdown zones;
    - Mulga vegetation with root systems that may be affected by mounding; and
    - Samphire communities that may be affected by mounding.

To satisfy Ministerial conditions for the project, the sample design required:

- Sample areas (Sites) for phreatophytic vegetation. Nested within these Sites are permanently marked visual health monitoring sample trees, ecophysiological (water status) monitoring tress, 20 m understorey monitoring transects and weed record points. The spatial location of phreatophytic sampling trees, transects and weed record points is provided in Appendix Figures 4 to 5.
- Sample areas (Sites) for Mulga vegetation. Nested within these Sites are permanently marked visual health assessment Mulga trees, ecophysiology (water status) monitoring

trees, understorey monitoring transects and weed record points (Appendix Figures 1 to 3 and 6 m to 8).

- Sample line-intercept transects within Samphire vegetation communities. The transects measure intersections of each individual plant (Samphire or other species, plant height and tip die-off. The locations of Samphire monitoring transects, which are within approximately a 3 km by 3 km area, are provided in Figure 2. Weed record points survey did not identify any weed species in the vicinity of these transects at the time of baseline survey.

For Phreatophytic and Mulga monitoring, the area of each site is approximately 1 to 2 Ha and includes 30 permanent sampling trees from the keystone species within each area of interest. Qualitative measures of tree condition (n = 30) were taken at each site. For the reinjection sites the keystone species is Mulga and dewatering sites is the facultative phreatophytic species Coolibah (Table 1). Quantitative measures at each monitoring site on keystone species included leaf water potential status (n=10) and projected foliar cover (n=10).

Monitoring potential impact in habitat characteristics required installation of three 20 m line intercept transects, at each reference and impact site (Figures 2 to 10). Transects at reinjection sites were installed in an east/west direction for representative vegetation coverage. Transects installed at the dewatering sites were installed perpendicular to the adjacent creek bed. Samphire communities habitat characteristics were also monitored with 20 m transects (five reference and four impact) on the southern boundary of the western reinjection zone (Figure 2).

Table 1: Monitoring sites with keystone species are listed. Their potential impact if applicable is shown. Locations of monitoring sites are depicted in (Figure 2 to 10)

Monitoring Site	Abbreviation	Treatment	Keystone Species	Potential Impact	No. Sample Trees	No. of Transects	No. of Soil Bores
Western Reference 1	WR1	Reference	Mulga	n/a	30	3	3
Western Impact 1	WI1	Impact	Mulga	mounding	30	3	3
Western Impact 2	WI2	Impact	Mulga	mounding	30	3	6
Eastern Reference 1	ER1	Reference	Mulga	n/a	30	3	4
Eastern Impact 1	EI1	Impact	Mulga	mounding	30	3	4
Eastern Impact 2	EI2	Impact	Mulga	mounding	30	3	4
Dewatering Reference 1	DR1	Reference	Coolibah	n/a	30	3	n/a
Dewatering Impact 1	DI1	Impact	Coolibah	drawdown	30	3	n/a

2.3 Predawn (Ψ_{pd}) and Midday Leaf (Ψ_{md}) Water Potential

At each monitoring site containing the target keystone phreatophytic or Mulga species, four excised shoots (2 – 10 leaves) were sampled from the canopy of each sample tree at all sites an hour before dawn and again at midday on the same day. Shoots were immediately placed in a sealed plastic bag and kept chilled in an esky until water potential (Ψ) was measured using a pressure chamber (Model 1000, PMS Instrument Company, Oregon, USA), usually within one hour (O'Grady *et al*. 2002; Sinclair Knight-Merz 2007b).

2.4 Projected Foliar Cover

Projected Foliar Cover (PFC) was measured underneath each of the 10 sample trees at all sites by digital photography. Canopy photographs of the trees were taken between 7.00am – 10.00am and

2.00pm – 5.00pm to reduce glare which can cause canopy density to be underestimated. A 12 mega pixel digital camera was mounted, levelled and pointed skyward on a tripod that was placed above the permanent marker (star picket) under the canopy. Each photograph was analysed with Adobe Photoshop Elements 7.0 using the method developed by MacFarlane *et al*. (2007a; 2007b). This measure of PFC includes stems and leaves. Due to the biased selection of a suitable monitoring point under a tree canopy, comparisons of absolute values for PFC are meaningless: only trends between time periods are informative.

2.5 Qualitative Visual Health Assessment

2.5.1 Mulga Communities

All sample trees (30 per site) at each reinjection reference and impact site were allocated a Grimes health score according to Eldridge *et al*. (1993) method.

2.5.2 Facultative (Partially) Phreatophytic Vegetation

All sample trees (30 per site) were visually assessed using a method developed by Souter *et al.,* (2009) to monitor the health of phreatophytic vegetation. The assessment method is based on a conceptual model of the symptoms of decline due to water stress and indicators of recovery as conditions improve. The method incorporates the following aspects of tree health:

- Crown growth;
- Crown density;
- Epicormic growth;
- Epicormic state;
- Reproduction;
- Crown tip growth;
- Leaf die off;
- Leaf damage;
- Mistletoe; and
- Bark form.

Crown condition ratings was based on a scale from 0 to 9 which will be assigned to the stages of tree decline and recovery as displayed as combinations of crown extent and density classes in Souter *et al*. (2010). A rating of 0 corresponds to a tree with no leaves and 9 corresponding to a tree where the crown is foliated to its maximum extent and the foliage is at maximum density. A score of 5 represents a tree with moderate extent and moderate density.

Determination of crown condition trajectory was also based on the system of Souter *et al*. (2009; 2010). Scores for recovery attributes (epicormic growth, reproduction and crown growth) and decline attributes (leaf die off, leaf damage and mistletoe abundance) were totalled, with scores ranging from 0 (effect absent) to 3 (effect dominates appearance of tree) given for each attribute (Souter *et al.* 2009). In addition, one point will be added to decline attributes total when the tree had cracked bark and one point was deducted from the recovery attributes total when epicormic growth (if present) was inactive. A declining trajectory was assigned to trees where the decline total exceeded the recovery total by more than one point, and vice versa for a recovery trajectory. Where the difference was one point or less, the trajectory was determined as stable.

2.6 Habitat Characteristics

A measure of habitat characteristic was captured using replicate 20 m line intercept transects in all dewatering and reinjection (drawdown and mounding respectively) monitoring sites, and within Samphire communities. Within each transect line, observations for species present (overstorey and understorey), canopy cover and health category.

Samphire species identification requires collection and examination of the fruiting material for each plant. The phenology of fruiting in Samphires can be episodic and collection of fruits suitable for identification of different species that are morphologically similar is required (S. Van Leeuwin, DEC, Pers. Comm.). This material was not available on the Samphire plants at the time of baseline survey. Therefore, in consultation with DEC, each individual plant intersected along the transect was numbered as a reference to its position. Species identification will be undertaken when fruiting material is available for each marked plant. Samphire communities were monitored by measurement of each plants cover, plant height and a health score based on percentage of tip browning (D. Huxtable, Pers. Comm.). Health scores are provided in table 2.

Table 2: Health score table associated with Samphire communities only. Each individual plant is allocated a score based on percent of tip browning observed.

Score	Category	Percentage of Tip Browning
1	Poor	75% - 100 %
2	Moderate	25% - 75%
3	Healthy	0% - 25%

2.7 Soil Moisture

Soil samples collected for gravimetric moisture analysis were obtained from manually augering soil bores within monitoring sites located near reinjection related zones. Soil bore locations were selected to gain a representative coverage of each six sites. Each soil sample was sealed in an air-tight sample jar and sealed with electrical tape. Samples were kept chilled after collection and during transport to Perth for analysis at a National Association of Testing Authorities (NATA) accredited laboratory.

2.8 Statistical Analysis

Data collected during baseline field work were tested using Shapiro-Wilk tests to determine if the data were normally distributed. Homogeneity of variance was tested by Levene's test. If the data were normally distributed then a set of parametric tests was adopted, otherwise non-parametric tests were applied (Zar 2009).

The parametric statistical tests used to analyse the leaf water potential and tree health assessments were the *k-sample* analysis of variance (Bartlett's test) and the two sampled t-test (Student's t-test) categories with a control. The non-parametric statistical tests; Kruskal-Wallis test and Mann-Whitney U test, were used when the assumptions for parametric tests could not be met. All tests were conducted within a 95% confidence interval using XLSTAT (version 2009.3).

Classification and ordination techniques were employed to illustrate and compare the multivariate data collected along transects and allow an assessment of the replication for each treatment. The purpose of these analyses were to indicate groupings of transects according to similarity in species composition and cover. Prior to undertaking these analyses, transformation of data and the calculation of a similarity (resemblance) matrix between transects is required. In this current study, the Bray Curtis metric was used to generate the resemblance matrix (Clarke and Gorley, 2006). Data transformations in multivariate analyses allow for a better comparison of floristics by down-weighting the influence of high cover scores in a transect for a particular species (Clarke and Green, 1988). In the analyses undertaken for this report, the square-root transformation was used. All multivariate analyses were carried out in PRIMER V 6 (Clarke and Gorley; Plymouth Marine Laboratory 2006). Firstly, a dendrogram was produced using the classification procedure with Group Averaging specified. Next, an ordination plot was produced using non metric Multidimensional Scaling (MDS) with contours of similarity from the classification analysis overlaid on the plot. Finally, where appropriate, a permutation test known as Analysis of Similarity (ANOSIM) was performed to determine if reference transects were different from potential impact transects. Significance was assessed as to whether $p < 0.01$. For the data pertaining to reinjection sites, a two-way crossed ANOSIM model was used with a treatment factor (reference and potential impact sites) and a location factor (eastern or western stand). ANOSIM results were not reported for the comparison of potential impact and reference sites in the drawdown area because only 10 permutations were possible: too few to provide sufficient power or reliability (Clarke and Gorley 2006). However, with repeat measures over the continuation of the monitoring program, additional statistical power will be achieved.

3 Results

3.1 Mulga Communities

3.1.1 Leaf Water Potential

In August 2011, the mean Ψ_{pd} measured at reinjection related monitoring sites on keystone species Mulga, during a predawn sampling event ranged between -3.29 ± 0.22 Mpa to -6.83 ± 0.75 Mpa. At a midday sampling event on the same day, the mean Ψ_{md} measured ranged between -5.19 Mpa ± 0.31 Mpa to -7.82 Mpa ± 0.22 Mpa (Figure 4). The average increase of water potential between sites from the predawn sampling period to the midday sampling period was approximately 1.0 Mpa to 2.0 Mpa.

A non parametric analysis of mean water potential values indicates a significant difference between some reinjection monitoring sites as shown in Table 3.

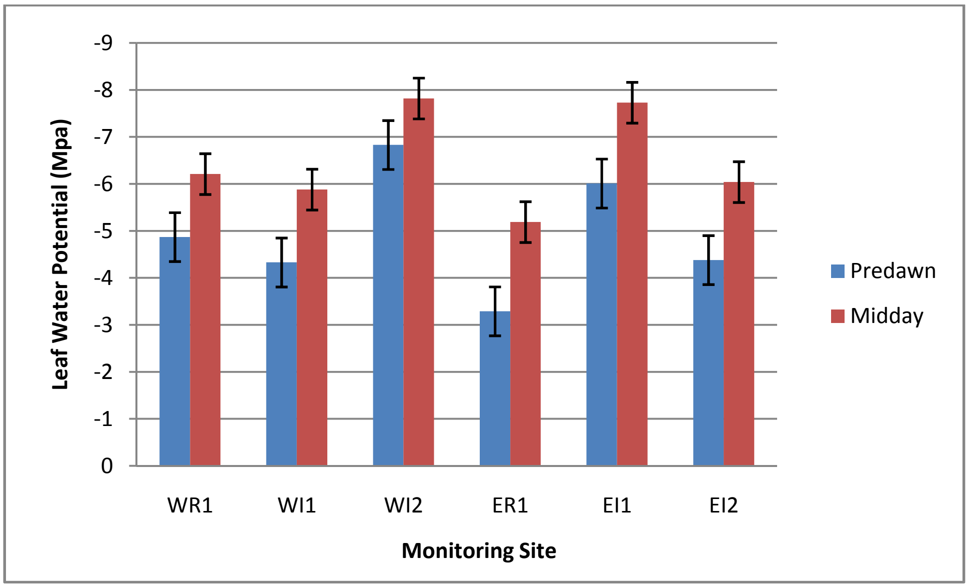


Figure 4: Averaged predawn and midday leaf water potential measurements for Mulga for each reinjection related monitoring site. Error bars represent the calculated standard error for each site.

Table 3: Significance test results (P) for differences between mean Mulga leaf water potential for all trees in reference and impact reinjection sites at Christmas Creek in August 2011. a) Results (P) for predawn leaf water potential. b) Results (P) for midday predawn leaf water potential. P was calculated with T tests using 95% confidence intervals. Significant differences are denoted in bold.

a) Predawn (P) values						b) Midday (P) values					
	WI1	**WI2**	**ER1**	**EI1**	**EI2**		**WI1**	**WI2**	**ER1**	**EI1**	**EI2**
WR1	0.796	**0.009**	**0.013**	0.063	0.353	**WR1**	0.684	**0.007**	**0.028**	**0.03**	0.811
WI1		**0.005**	0.156	**0.043**	0.631	**WI1**		**0.007**	0.271	**0.029**	0.971
WI2			**0.001**	0.123	**0.003**	**WI2**			**0.011**	0.971	**0.003**
ER1				**0.003**	**0.013**	**ER1**				**0.007**	0.086
EI1					**0.015**	**EI1**					**0.022**

3.1.2 Projected Foliar Cover

The mean PFC percentage at each reinjection site of keystone species Mulga ranged between 27.6% ± 4.2% and 62.1% ± 3.1%. Analysis of mean PFC percent shows a significant difference between sites within the reinjection zone (Table 4). EI1 has notably lower PFC percentage with an overall site mean of 27.6% compared with all other reinjection zone sites.

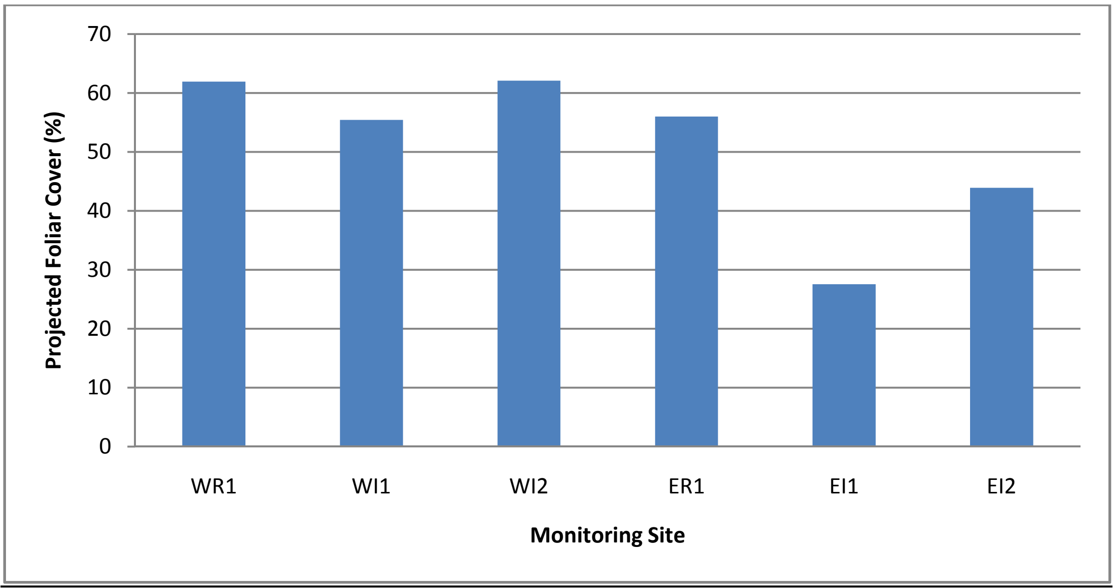


Figure 5: Mean projected foliar cover percentage for Mulga at reinjection related sites.

Table 4: Significance test results (P) for differences between mean Mulga mean projected foliar cover for all trees in reference and impact reinjection sites at Christmas Creek in August 2011. P was calculated with non parametric Kruskal-Wallis Test using 95% confidence intervals. Significant differences are denoted in bold.

Projected Foliar Cover % (P) values					
	WI1	**WI2**	**ER1**	**EI1**	**EI2**
WR1	0.19	0.971	0.19	**<0.00001**	**0.029**
WI1		0.19	0.853	**<0.00001**	0.165
WI2			0.143	**<0.00001**	**0.043**
ER1				0	0.19
EI1					**0.019**

3.1.3 Qualitative Visual Health Assessments

The Grimes scores allocated to sample trees within each the Mulga community recorded a range of 2 (poor health) to 9 (excellent health) within monitoring sites. The mean Grimes scores per site ranged from 5.67 ± 0.13 to 6.01 ± 0.25 (Figure 6).

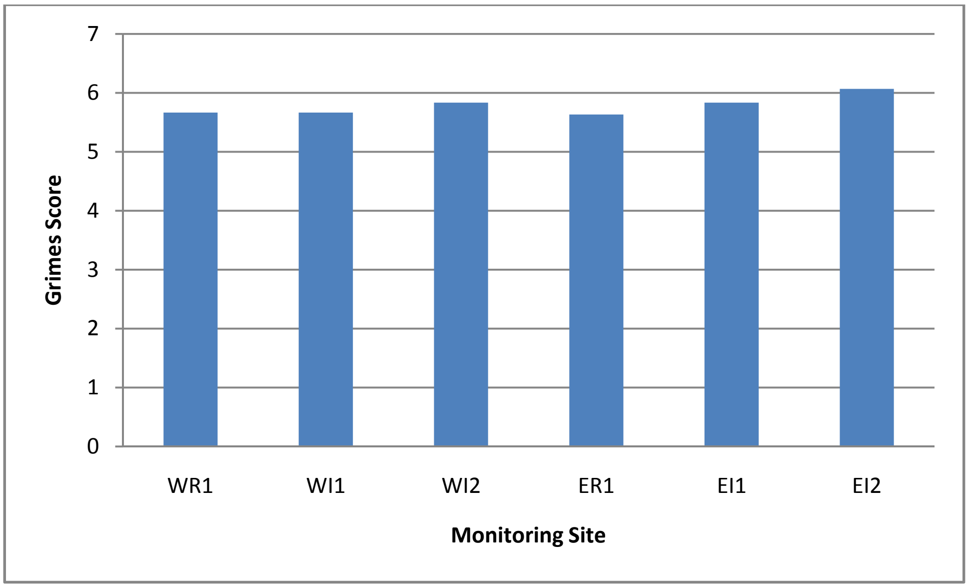


Figure 6: Results of the qualitative visual health assessment with mean grimes scores (0-9) shown for each site within Mulga communities.

3.1.4 Soil Moisture

Soil samples were collected from the six monitoring sites relating to reinjection zones. A total of between 3 and 6 samples were taken at each site, from depths between 0.45 m and 0.75 m and analysed for percentage moisture. The mean percentage moisture per site ranged from 4 %w/w ± 0.41%w/w at site ER1 to 7.33 %w/w ± 0.88 %w/w at site WI1 (Figure 7). Refer to appendices for laboratory results of the 24 samples submitted for analysis.

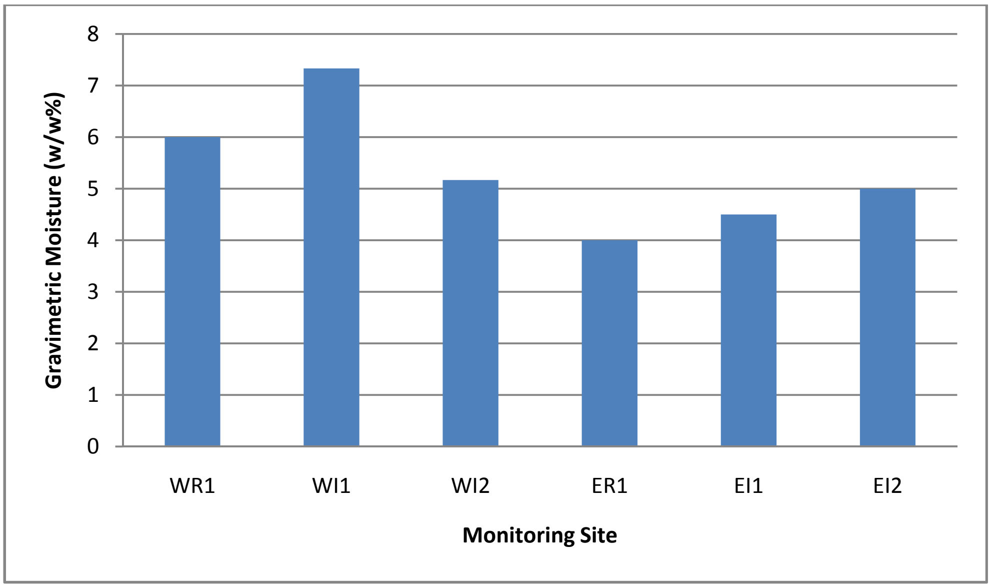


Figure 7: The mean gravimetric %w/w soil moisture per site by gravimetric soil sampled from each monitoring site related to reinjection activities.

3.2 Facultative (Partially) Phreatophytic Vegetation

3.2.1 Leaf Water Potential

In August 2011, the mean Ψ_{pd} measured at the dewatering related sites on keystone species Coolibah at a predawn sampling event were, -1.02 Mpa ± 0.04 Mpa (DR1) and -0.87 Mpa ± 0.02 Mpa (DI1). At a midday sampling event on the same day, the mean Ψ_{md} measured was -2.76 Mpa ± 0.07 Mpa (DR1) and -2.69 Mpa ± 0.09 Mpa (DI1). The difference in mean Ψ_{pd} between the predawn sampling event and the midday sampling event was -1.74 Mpa and -1.82 Mpa respectively. A parametric analysis of mean water potential show there is not enough evidence to suggest any significant difference between dewatering related sites in either the predawn sampling event ($p=0.160$) or midday sampling event ($p=0.297$).

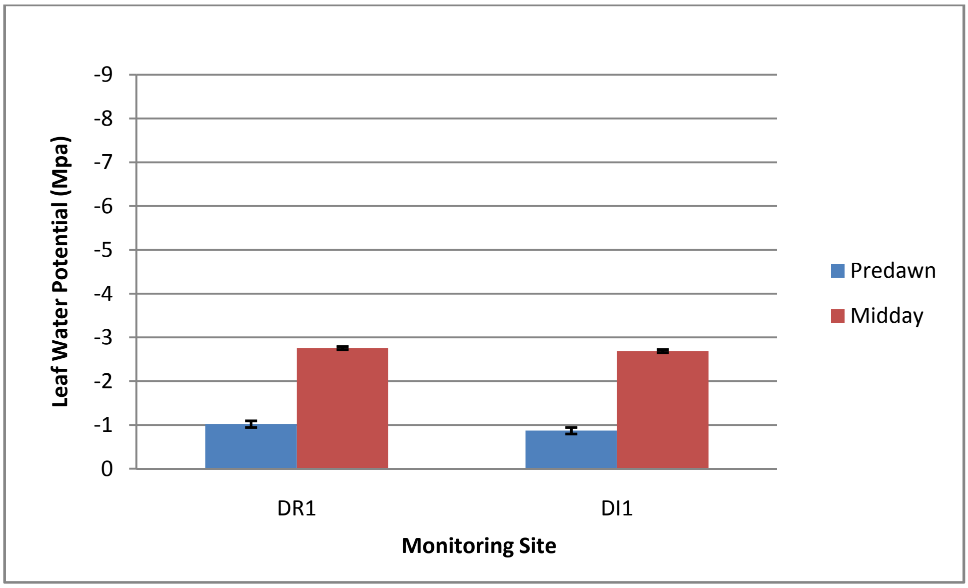


Figure 8: Averaged predawn and midday leaf water potential measurements for Coolibah for each dewatering related monitoring site. Error bars represent the calculated standard error for each site.

3.2.2 Projected Foliar Cover

The mean PFC percentage at each dewatering site of keystone species Coolibah were not statistically different ($p=0.519$). Mean PFC percentages for DR1 and DI1 were 60.1% ± 3.9% and 61.7% ± 3.1% respectively.

3.2.3 Qualitative Visual Health Assessments

There was no significant difference in the visual health assessment scores in phreatophytic communities ($p=0.342$). The mean health scores for DR1 and DI1 were 5.9 and 5.4 respectively.

Net trajectory results for DR1 and DI1 indicate most sample trees at these sites are in a stable condition. Trajectory decline does occur at both sites (see Figure 9).

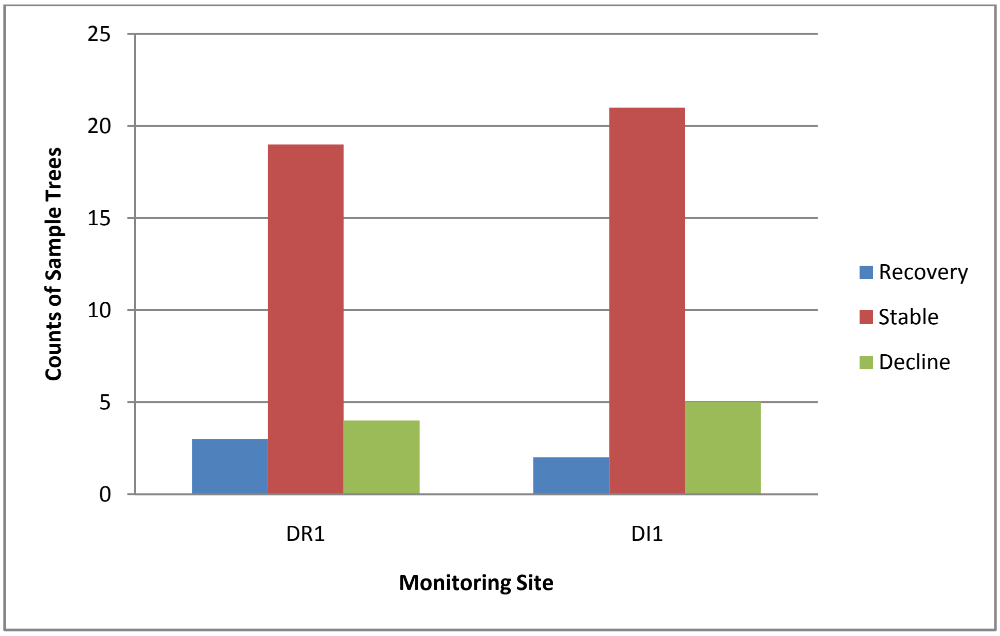


Figure 9: Tree visual assessment scores based on Souter *et al.* (2009) that details the Mean for Canopy Score and the Net Trajectory Score (Stable, Recovery or Decline) for each site for August 2011.

3.3 Habitat Characteristics

3.3.1 Mulga and Facultative Phreatophytic Communities

The ordination plot of transect composition and cover for the reinjection sites indicated two transects that were distinctly different from one another and all other transects (Figure 10). These were WI1-1 and ER1-1. This may be attributed to a difference in species richness and/or there total coverage of particular species within the transect. The reference sites and the potential impact sites and the Eastern and Western transects appeared to be located in separate sections of the ordination space. However, there was no distinct clustering of these features. Further, ANOSIM results did not indicate a significant difference between reference and potential impact sites (Global R = 0.241, p = 0.071, permutations = 999) nor between the eastern and western stands (Global R = 0.234, p = 0.017, permutations = 999).

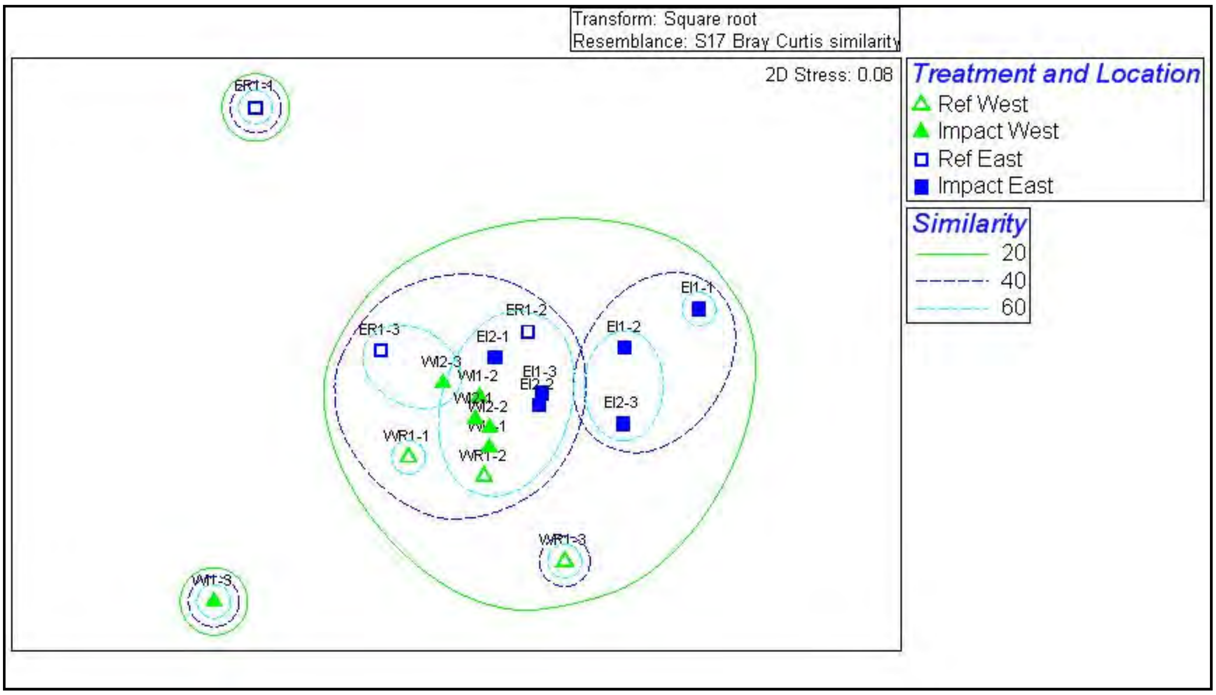


Figure 10: Multidimensional Scaling plot representing cover by species data for transects established in potential impact and reference areas in relation to reinjection of groundwater. The eastern and western stands are also distinguished. Contours of similarity (%) were derived from classification analysis.

For the drawdown area and associated reference sites, there was some clustering of the reference transects with DR1-2 and DR1-3 showing some degree of similarity (Figure 11). However, as DR1-1 was located between the potential impact transects in ordination space, there is broad level of similarity among reference and potential impact sites and a high level (40 to 60%) similarity within treatment.

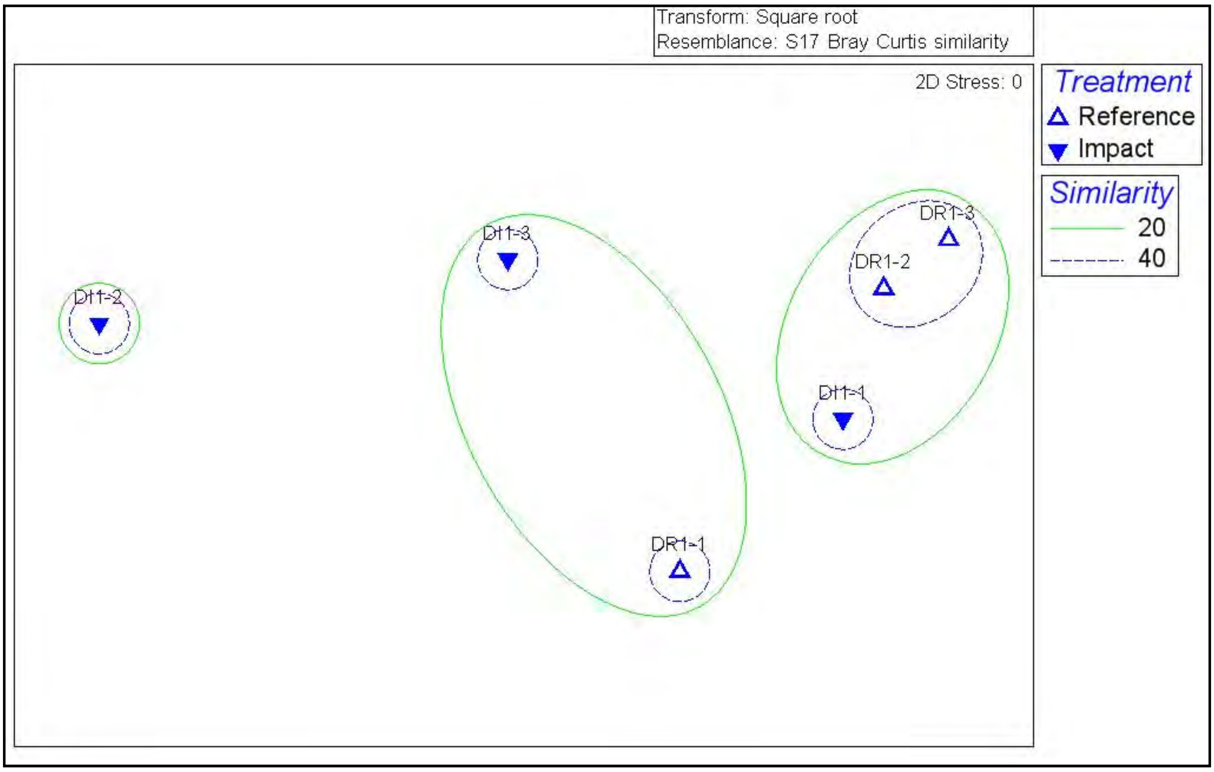


Figure 11: Multidimensional Scaling plot representing cover by species data for transects established in potential impact and reference areas in relation to groundwater drawdown. Contours of similarity (%) were derived from classification analysis.

3.3.2 Samphire Communities

The total percentage of cover within reference and impact transects ranged from 16.8 ± 0.24 % (SR2) to 54.5 ± 0.38 % (SI3). There is a highly significant difference between total percentage Samphire cover between reference and impact transects (p=<0.0001). Within treatments, there is not enough evidence to suggest a significant difference in total percentage Samphire cover among impact site transects (p=0.0804), however a significant difference was observed among reference site transects (p=0.0078). Pairwise analysis indicates this difference among reference site transects isolates transect SR6 as significantly different to all other transects in this treatment (See Table 5 for P values).

Table 5: Total Canopy Cover (%) P values for each Reference Site 20 m transect. Significant results are denoted in bold.

Total Canopy Cover (%) P values				
	SR3	**SR4**	**SR5**	**SR6**
SR2	0.856	0.8439	0.5113	0.08482
SR3		0.7978	0.6227	**<0.001**
SR4			0.5056	**0.007**
SR5				**0.01**

The reference transects indicate higher counts of individual plants with lower mean total cover than of individual plants in impact transects (See Table 6). Mean health scores, measured by tip die-off for individual plants, indicate that impact site transects scores were higher than the reference transects. The reference transects scores ranged from a mean of approximately 1.1 (tip die-off in

75%-100% of stems counted) to approximately 2.9 (tip die-off in about 10% of stems). Within impact transects, tip die-off ranged from approximately 1.7 (tip die-off in the range 25%-50% of stems counted), to 2.6 (tip die-off in about 25% of stems counted).

Table 6: Mean number of individual Samphire plants for each treatment. Mean total cover (%) for each treatment.

Mean No. of Individuals		**Mean Total Cover (%)**	
Reference Transects	28.8 ± 4.2	**Reference Transects**	28.09
Impact Transects	15.3 ± 3.6	**Impact Transects**	37.96

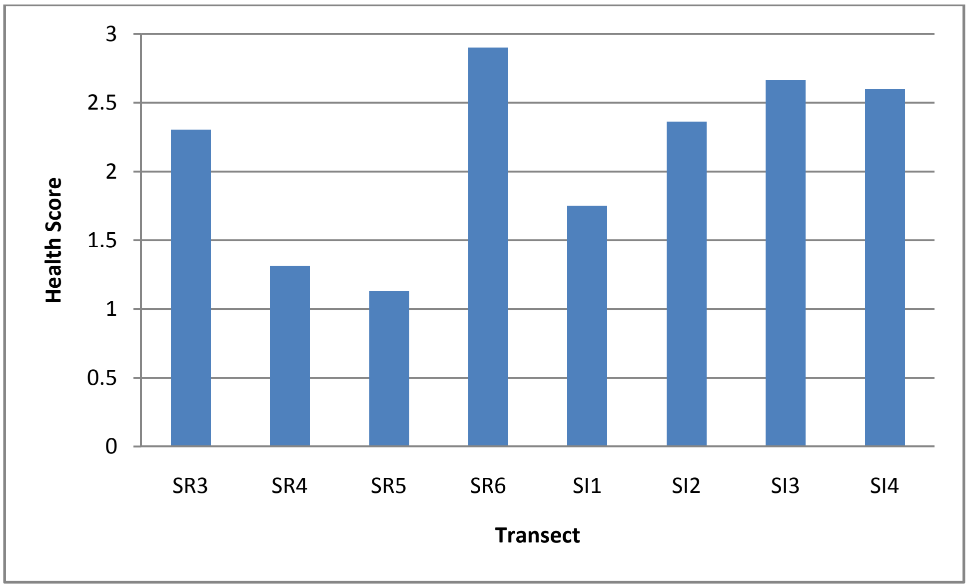


Figure 12: Mean health score for each Samphire community transect. Transect SR2 is excluded from this figure as health scoring system presented here was implemented during Trip 2 (Sept-11). See Table 2 for health score categories.

4 Discussion

Baseline monitoring has been established at sites within drawdown, mounding and reference areas to provide the current state of a range of physiological (water status), vegetation and tree health parameters. Leaf water potential, tree health data and vegetation cover data are well matched between impact and reference trees and transects for (potentially) phreatophytic tree assessments of Coolibah.

Some variation in water status between Mulga sites at reference and impact areas was detected. However, the baseline measurements have established the degree of difference in these measures between treatment. The objective of the monitoring program is to detect, in a design nested by site and time (Zar 2009), if adverse changes in water status of Mulga trees occurs within mounding impact transects in comparison to the reference. This may be indicated if in 'repeat-measures' a statistically significant rise in the midday water potential was measured in impact transects in comparison to reference. This would suggest that Mulga trees will be transpiring more because they have access to the rising groundwater. The absolute difference between the current water status measured in reference and impact sites is not of concern. They simply reflect the natural variation in water status for Mulga (determined by soil and soil moisture characteristics). The monitoring program is designed to detect trends, which requires repeat measures from the established baseline.

Soils show low percentage moisture which is associated with these soil types in the Pilbara region. However, this data should be considered with caution as samples have been collected at a seasonally dry time of year.

Within Samphire communities, the number of individual plants and mean total cover in reference transects indicates in this area the distribution of plants is more dense (than impact sites) and contains smaller plants than those in the impact transects. In impact transects, a smaller number of individual plants was recorded with higher total mean cover indicating the plants in this area more sparsely distributed but have larger canopies than reference transects. Health scores suggest the larger plants found in the impact area are less likely to have higher percentages of tip browning compared with the reference sites where the smaller plants showed some individuals with a higher percentage of tip browning.

Secondary pressures that can affect vegetation condition of keystone species were measured. Weeds and cattle activity are present at most sites, however weed records close to the Samphire transects were nil. The future impact by cattle is more likely to be on understorey species than on established keystone species. While each pressure's intensity varies between sites, it is likely at this stage their impact on keystone species is minimal however, continued monitoring of weeds and quantification of cattle visitation is recommended as the impact from these will have a direct impact on habitat characteristic.

Additional observational tasks were also completed in the baseline monitoring. No 'Yintas' were observed within the areas visited during this survey.

5 Conclusions

A repeat in soil moisture sampling may be required to measure the water content of the soil immediately after the wet season (December – February) to understand differences in moisture due to seasonal influences or effects of mounding due to reinjection.

Baseline monitoring sites have been established following the procedures outline in the VHMMP and consistent with the Ministerial Conditions for the project. The aim of repeat measures is to detect significant changes from the baseline measures in a nested design. That is, changes in impact areas (if any) that are significantly different from changes in reference areas. This will be formally tested in a Before-After-Controlled-Impact (BACI) design after the next monitoring trip.

In addition, repeated measurements will allow non-parametric Control Charts to be calculated after 3 measurements (Anderson and Thompson 2004). This will allow an interpretation of trends in data over time and will add to the significance testing that is the outcome of standard BACI monitoring.

6 References

Anderson, M.J. and Thompson, A.A. (2004). Multivariate control charts for ecological and environmental monitoring. Ecological Applications 14: 1921-1935.

Astron Environmental Services (2011) Christmas Creek Water Management Scheme, Vegetation Health Monitoring and Management Plan. Unpublished report by Astron Environmental Services for Fortescue Metals Group Ltd.

Bureau of Meteorology (2010b) Monthly climate statistics Wittenoom station (005026). Available from: http://www.bom.gov.au/climate/averages/tables/cw 005026.shtml. Accessed 20th March 2011.

Clarke K.R. and Gorely (2006). *Primer E- Tutorial and Reference Manual*. Primer-E Ltd. Plymouth.

Duff G. A., Myers B. A., Williams R. J., Eamus D., O'Grady A. and Fordyce I. R. (1997) Seasonal patterns in soil moisture, vapour pressure deficit, tree canopy cover and pre-dawn water potential in a Northern Australian Savanna. *Australian Journal of Botany* 45, 211-224.

Eldridge S. R., Thorburn P. J. and McEwan K. L. (1993) *Health and structure of Eucalyptus communities on Chowilla and Monoman Islands of the River Murray floodplain South Australia.* CSIRO Division of Water Resources, Adelaide.

Grimes R. F. (1978) *Crown assessment of natural spotted gum (Eucalyptus maculata), ironbark (Eucalyptus fibrosa, Eucalyptus drepanophylla) forest*. Technical paper 7 Dept. of Forestry, Brisbane

Hockings, M., Stolton, S., Leverington, F., Dudley, N. and Courrau, J. (2006) Evaluating Effectiveness. A framework for assessing management effectiveness of protected areas. 2nd edition. IUCN (The World Conservation Union), Gland, Switzerland and Cambridge U.K.

MacFarlane C., Arndt S. K., Livesley S., Edgar C., White D., Adams M. and Eamus D. (2007a) Estimation of leaf area index in eucalypt forest with vertical foliage using cover and fullframe fisheye photography. *Forest Ecology and Management* 242, 756-763.

MacFarlane C., Hoffman M., Eamus D., Kerp N., Higginson S., McMurtrie R. and Adams M. (2007b) Estimation of leaf area index in eucalypt forest using digital photography. *Agricultural and Forest Meteorology* 143, 176-188.

McDowell N., Pockman W. T., Allen C. D., Breshears D. D., Cobb N., Kolb T., Plaut J., Sperry J., West A., Williams D. G. and Yepez E. A. (2008) Mechanisms of plant survival and mortality during drought: why do some plants survive while others succumb to drought? *New Phytologist* 178, 719-739.

Minister for the Environment; Science (2009) *Ministerial Statement 679*. Available from http://epa.wa.gov.au/EPADOCLIB/000679.PDF. Accessed 30 March 2011.

Maunsell Australia Pty Ltd (2006a*). 'Pit Drawdown and Vegetation Monitoring Plan – Iron Ore Mine and Downstream Processing, Cape Preston, Western Australia'*. Unpublished Report prepared for Mineralogy Pty Ltd.

Murray B., Zeppel M., Hose G. and Eamus D. (2003) Groundwater dependant ecosystmes in Australia: It's more than just water for rivers. *Ecological Management and Restoration* 4, 110-113.

O'Grady A. P., Eamus D., Cook P., Lamontagne S., Kelley G. and Hutley L. (2002) *Tree water use and sources of transpired water in riparian vegetation along the Daly River Northern Territory.* Commonwealth of Australia.

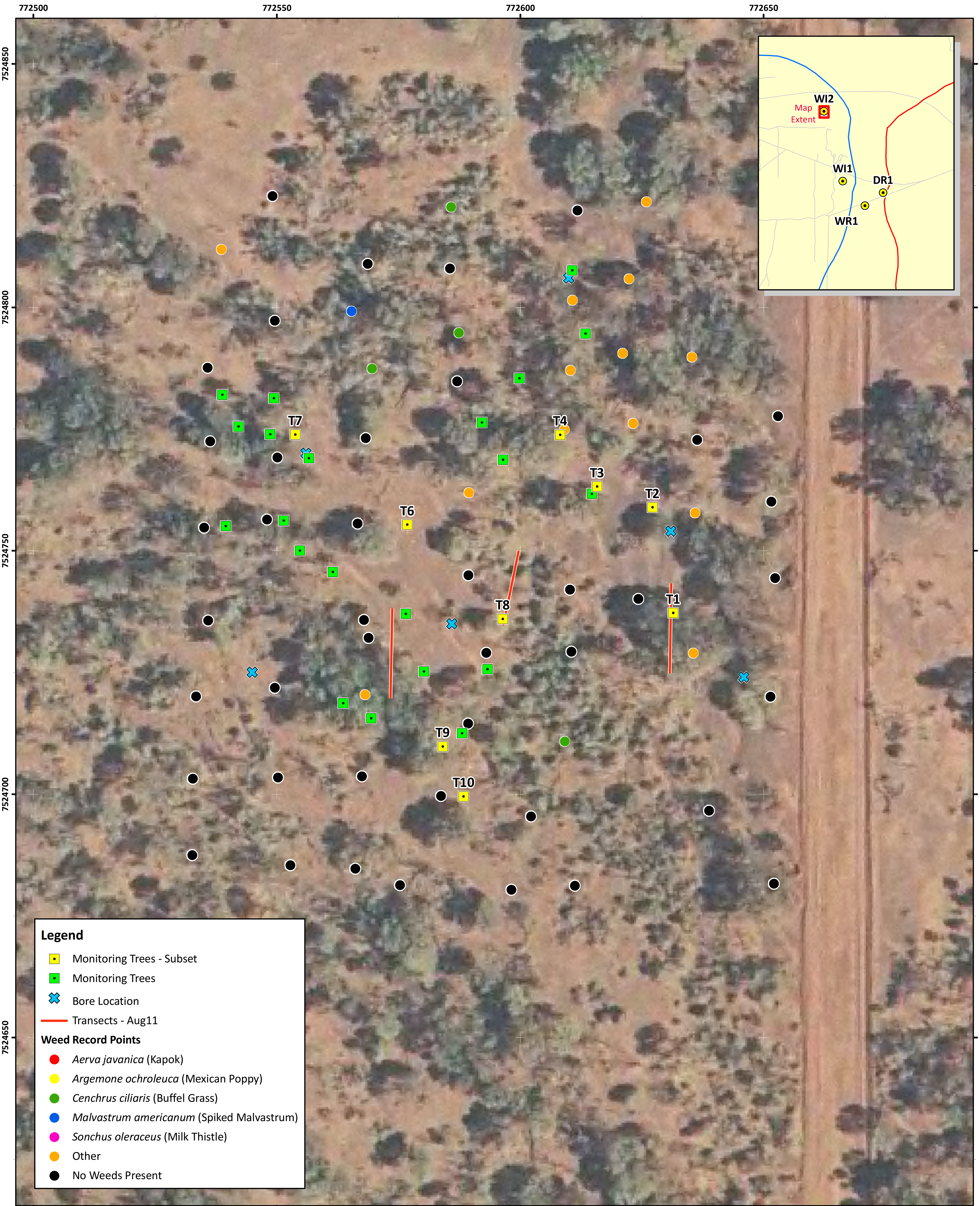
Souter N., Watts R., White M., George A. and McNicol K. (2009) *Method manual for the visual assessment of lower River Murray floodplain trees River Red Gum (Eucalyptus camaldulensis).* DWLBC Report 2009/25. Department of Water Land and Biodiversity Conservation Adelaide.

Turner N. C. (1988) Measurement of plant water status by the pressure chamber technique. *Irrigation Science* 9, 289-308.

Webb C. P. (2010) *Bureau of Meteorology Reference Transpiration Calculations*. Climate Services Centre. Queensland.

Appendix A: Baseline Figures

This page has been left blank intentionally

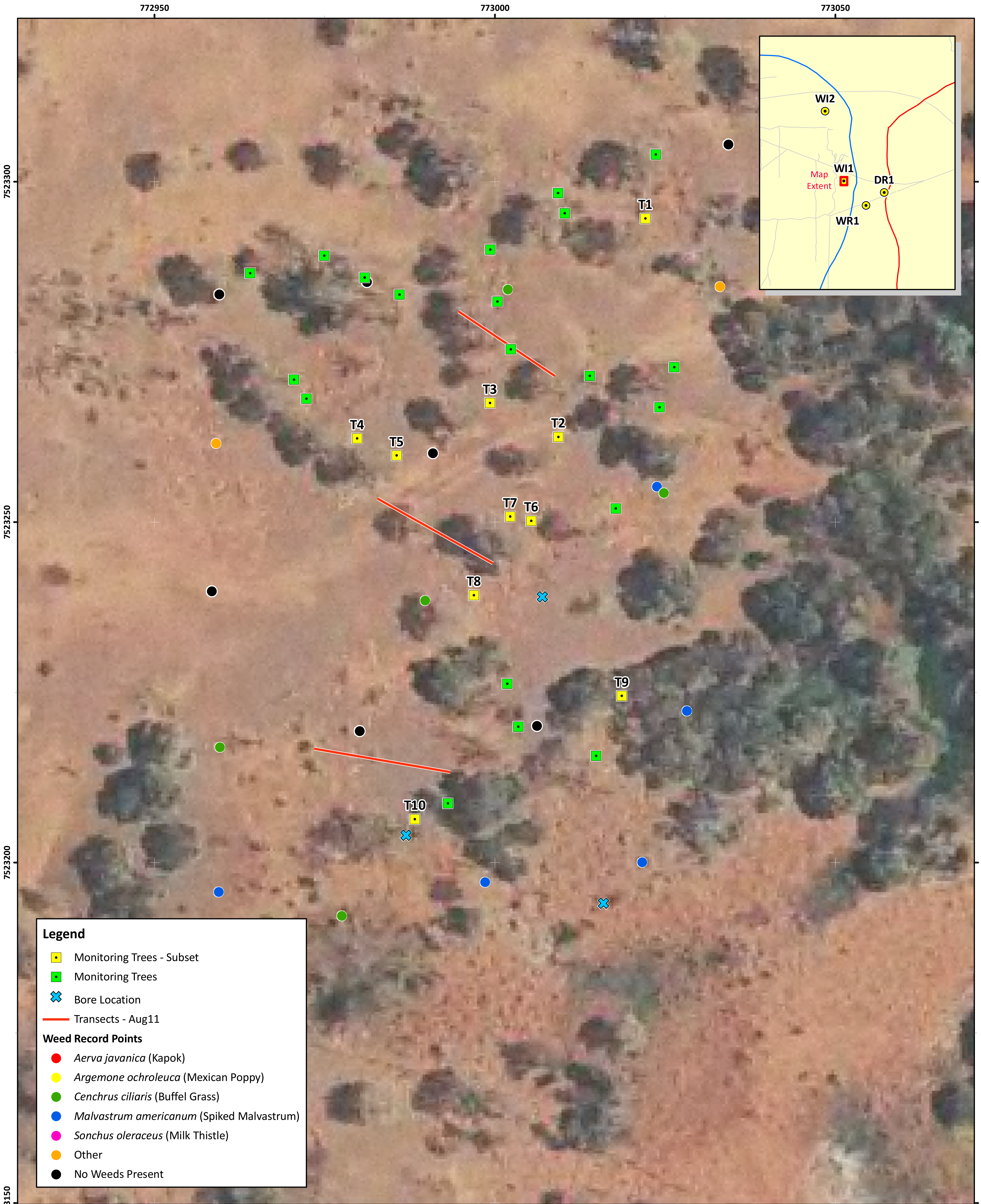


Fortescue Metals Group
Christmas Creek Vegetation Health Monitoring

Appendix Figure 1: WI2 - Western Impact 2: Weed Record Points

astron environmental services

Author: L. Britt	Date: 21-10-2011	Datum: GDA 1994 - Projection: MGA Zone 50 - Scale: 1:700 (A3)
Drawn: C. Dyde	Figure Ref: 12306-11FMV1RevA_111021_Fig3	0 10 20 30 40 50 Metres N



Fortescue Metals Group
Christmas Creek Vegetation Health Monitoring

Appendix Figure 2: WI1 - Western Impact 1: Weed Record Points

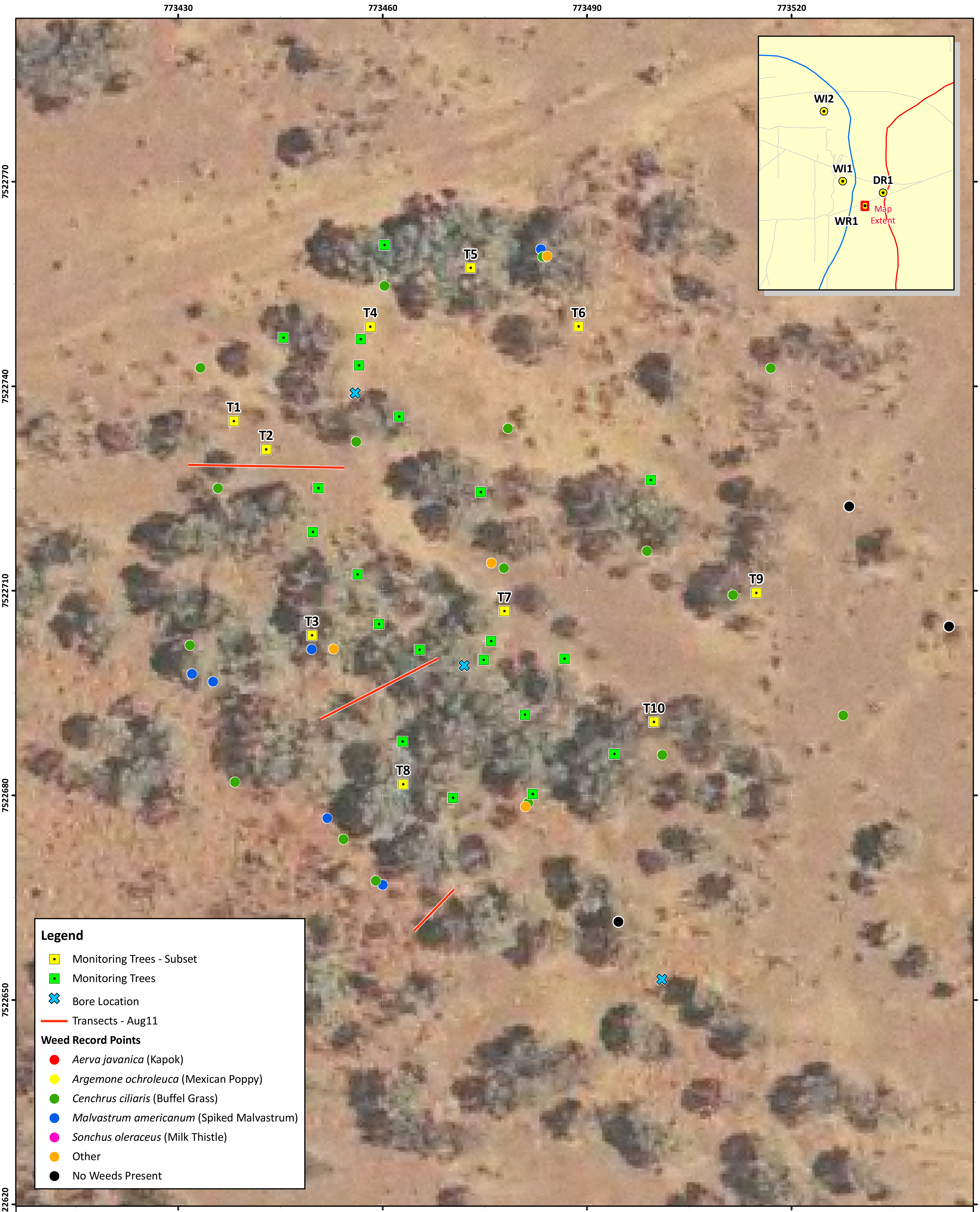
astron environmental services

Author: L. Britt	Date: 21-10-2011
Drawn: C. Dyde	Figure Ref: 12306-11FMV1RevA_111021_Fig4

Datum: GDA 1994 - Projection: MGA Zone 50 - Scale: 1:500 (A3)

Metres 0 10 20 30

N

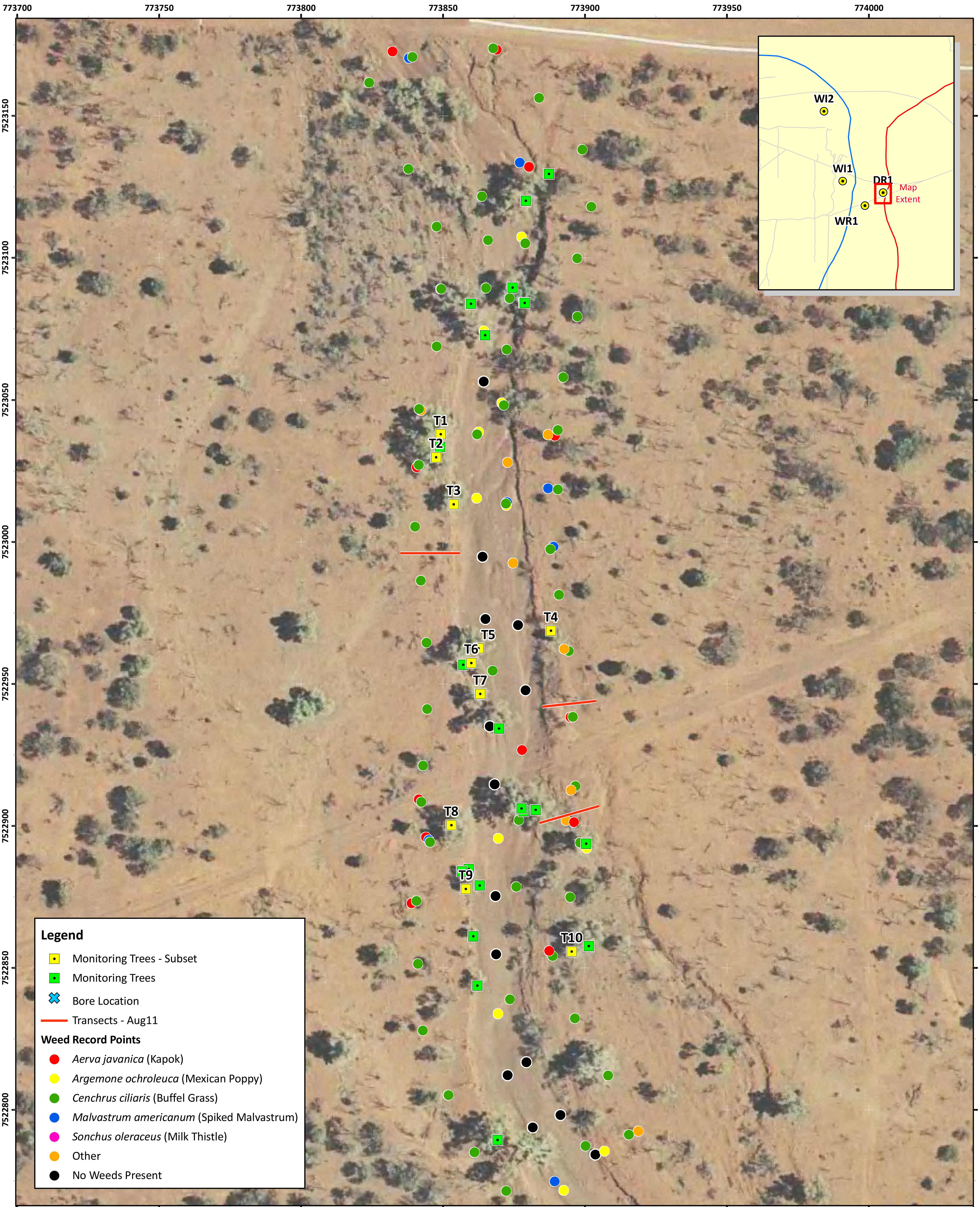


Fortescue Metals Group
Christmas Creek Vegetation Health Monitoring

Appendix Figure 3: WR1 - Western Reference 1: Weed Record Points

astron environmental services

Author: L. Britt	Date: 25-10-2011	Datum: GDA 1994 - Projection: MGA Zone 50 - Scale: 1:500 (A3)
Drawn: C. Dyde	Figure Ref: 12306-11FMV1RevA_111025_Fig5	0 10 20 30 Metres N



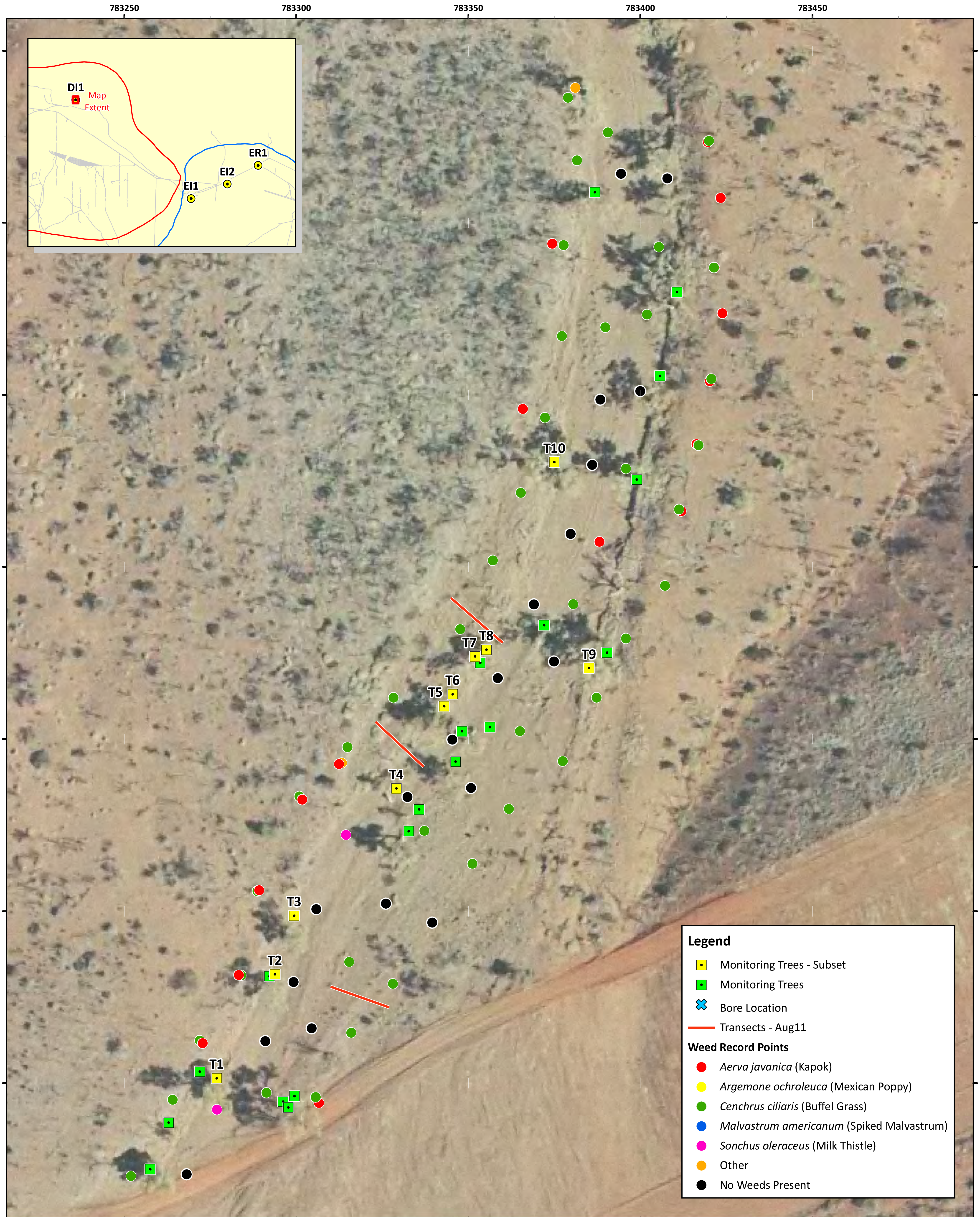
Fortescue Metals Group
Christmas Creek Vegetation Health Monitoring

Appendix Figure 4: DR1 - Dewatering Reference 1: Weed Record Points

astron environmental services

Author: L. Britt	Date: 25-10-2011	Datum: GDA 1994 - Projection: MGA Zone 50 - Scale: 1:1,200 (A3)
Drawn: C. Dyde	Figure Ref: 12306-11FMV1RevA_111025_Fig6	0 20 40 60 80 100 Metres

N



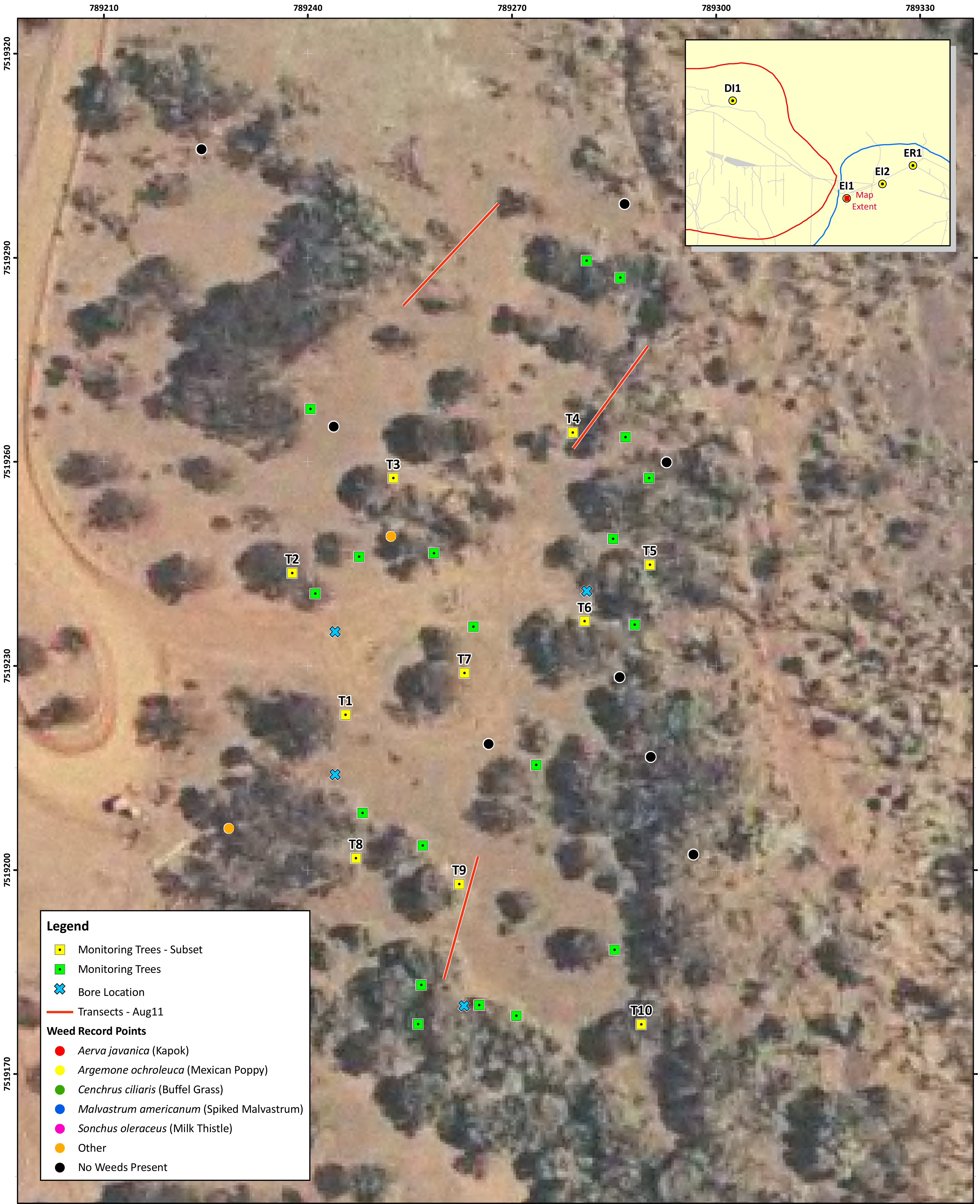
Fortescue Metals Group

Christmas Creek Vegetation Health Monitoring

Appendix Figure 5: DI1 - Dewatering Impact 1: Weed Record Points

astron environmental services

Author: L. Britt	Date: 25-10-2011	Datum: GDA 1994 - Projection: MGA Zone 50 - Scale: 1:1,000 (A3)
Drawn: C. Dyde	Figure Ref: 12306-11FMV1RevA_111025_Fig7	0 10 20 30 40 50 Metres N

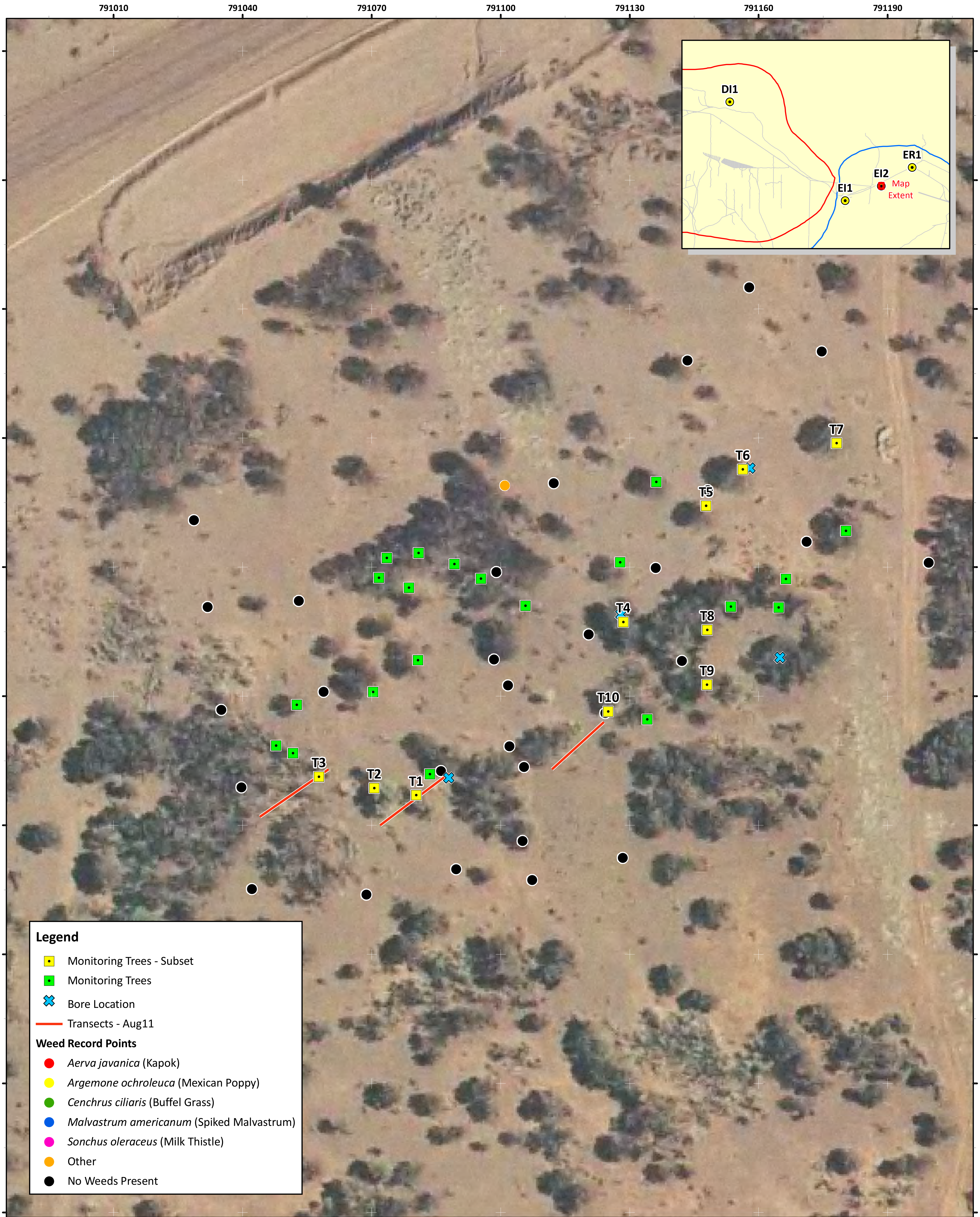


Fortescue Metals Group
Christmas Creek Vegetation Health Monitoring

Appendix Figure 6: EI1 - Eastern Impact 1: Weed Record Points

astron environmental services

Author: L. Britt	Date: 25-10-2011	Datum: GDA 1994 - Projection: MGA Zone 50 - Scale: 1:500 (A3)
Drawn: C. Dyde	Figure Ref: 12306-11FMV1RevA_111025_Fig8	0 10 20 30 Metres N

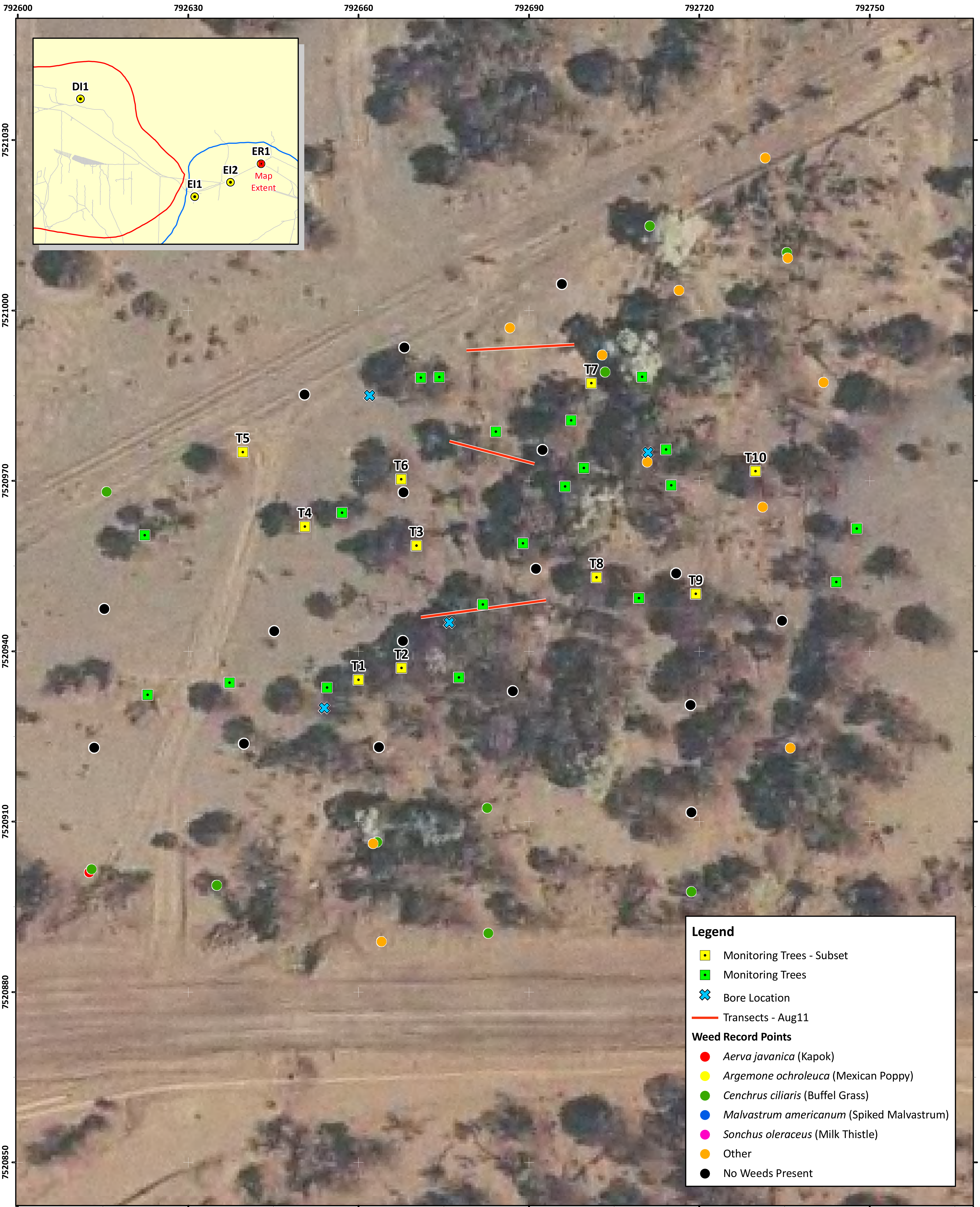


Fortescue Metals Group
Christmas Creek Vegetation Health Monitoring

Appendix Figure 7: EI2 - Eastern Impact 2: Weed Record Points

astron environmental services

Author: L. Britt	Date: 25-10-2011	Datum: GDA 1994 - Projection: MGA Zone 50 - Scale: 1:800 (A3)
Drawn: C. Dyde	Figure Ref: 12306-11FMV1RevA_111025_Fig9	0 10 20 30 40 50 Metres N



Fortescue Metals Group
Christmas Creek Vegetation Health Monitoring

Appendix Figure 8: ER1 - Eastern Reference 1: Weed Record Points

astron environmental services

Author: L. Britt	Date: 25-10-2011
Drawn: C. Dyde	Figure Ref: 12306-11FMV1RevA_111025_Fig10

Datum: GDA 1994 - Projection: MGA Zone 50 - Scale: 1:600 (A3)

0 10 20 30 40 50 Metres

N