Australian Government

MURRAY–DARLING BASIN AUTHORITY

Identifying locations and timing of water extractions in the Barwon-Darling using remote sensing data

Australian Geoscience Data Cube pilot project

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Acknowledgement of the Traditional Owners of the Murray–Darling Basin

The Murray–Darling Basin Authority acknowledges and pays respect to the Traditional Owners, and their Nations, of the Murray–Darling Basin, who have a deep cultural, social, environmental, spiritual and economic connection to their lands and waters. The MDBA understands the need for recognition of Traditional Owner knowledge and cultural values in natural resource management associated with the Basin.

The approach of Traditional Owners to caring for the natural landscape, including water, can be expressed in the words of the Northern Basin Aboriginal Nations Board:

> …As the First Nations peoples (Traditional Owners) we are the knowledge holders, connected to Country and with the cultural authority to share our knowledge. We offer perspectives to balance and challenge other voices and viewpoints. We aspire to owning and managing water to protect our totemic obligations, to carry out our way of life, and to teach our younger generations to maintain our connections and heritage through our law and customs. When Country is happy, our spirits are happy.

Cover image: Data Cube false colour imagery data observation, Barwon River, New South Wales

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Summary

The utility of the Australian Geoscience Data Cube (AGDC) was tested to determine if the product could be used to support the Murray–Darling Basin Authority's (MDBA) policy and management decisions.

The AGDC is a data processing product developed to store and analyse large volumes of remote sensing data such as Landsat satellite imagery. The AGDC is supported by a comprehensive database from which data can be processed and extracted.

The study primarily used False Colour Imagery (FCI) data sourced from the AGDC to test if the AGDC could be used to:

- identify the location and timing of water extractions
- locate and map farm storages and observe changes to storages over time
- map and measure crop areas and observe changes to crop areas over time
- observe other on-farm activities such as irrigation applications.

A single irrigated property (the study property) located on the Barwon River was used to test the AGDC. AGDC data for the study property from March 2014 to March 2015 (the study period) was analysed. The study period included three flow events at the study property.

Location and timing of water extractions

The AGDC was effective at identifying the location and time at which extractions commenced. The accuracy of identifying when extractions commence is tied to the frequency of remote sensed imagery and whether the imagery is impacted by cloud cover. AGDC data was available at intervals of approximately 8-10 days. This has wider applications in addressing issues relating to the improved management of environmental flows. By analysing FCI data, observations can be made regarding the extent to which a flow event is extracted or remains in the river.

Location and observation of farm storages

Data sourced from the AGDC was used to effectively locate and map farm storages and observe changes to storages over time. The AGDC was most effective for assessing if a storage is completely empty (dry) or contained water. The user could determine the timing of a storage transforming from dry to wet and from wet to dry. The AGDC was found to be less effective at enabling the user to determine the volume of storage. The AGDC does not provide information on the depth of water in storage, only the wet surface area.

During the study period the farm storages observed did not undergo any significant construction works. However, the mapping technique would be a valuable tool that could be used to observe how storages change over time including the construction of new storages, or the enlargement of existing storages.

Measurement and observation of crop areas

The cropping cycle can be monitored, including the total area cropped, by analysing the AGDC data. The use of the AGDC to map and measure crop areas has broader applications that could support a range of policy and management decisions. By applying crop mapping techniques to an entire river reach across several decades, conclusions could be drawn on how land use in the reach has changed over time. This can be extended by using the mapped crop areas to derive the water use required to produce those crops. Applying the AGDC in such a way would allow the user to determine how water use in a river reach has changed over time.

Observation of on-farm activities

During the study period, on-farm activities such as ploughing and irrigation applications were observed by analysing the AGDC data. It was possible to observe irrigation events when the timing of satellite passes and irrigation applications aligned, however, the occasions at which this occurred were rare. Therefore, in terms of observing on-farm activities the AGDC has some limited applications. One application could be to analyse AGDC data for a broad timeframe to observe existing irrigation patterns and determine how irrigation trends and behaviours have changed over time.

Conclusion

The AGDC is being enhanced to provide greater pixel resolution and increased frequency of satellite observations. These enhancements will be available in 2017. There is an opportunity to further improve the AGDC by reducing the image access time from the current period of 2-3 months to just two days. A fully enhanced AGDC would be useful in supporting policy and management decisions. Some specific areas of use may include applications associated with:

- identifying extraction locations and timings such as observing flow events and addressing issues linked to the improved management of environmental flows
- mapping and observing farm storages over time such as how existing storages change and when new storages are constructed or enlarged
- identifying crop areas such as how crop areas change over time and the implications these changes have on water demand
- observing on-farm activities such as existing irrigation trends and how irrigation behaviours have changed over time.

As the AGDC continues to develop, it will become an increasingly useful resource to support MDBA policy and management decisions.

1 Introduction

The Murray–Darling Basin Authority (MDBA) is testing the utility of the Australian Geoscience Data Cube (AGDC) to support policy and management decisions.

The AGDC is a processing framework and infrastructure developed to store and analyse large volumes of earth observation, or remote sensing, data, such as Landsat satellite imagery. It includes a large database that can be queried to extract and process data into derivative products, particularly for use by non-experts in remote sensing.

This is achieved by using the ‘dice and stack’ method (depicted in Figure 1) to clip pre-processed imagery scenes into one degree tiles to form a nested grid of imagery tiles over time. Through this framework, each pixel in an imagery tile can be traced back to its original observation. By making the data consistent, accessible, relatively timely, and ready-to-use, the AGDC encourages the use of the growing catalogue of earth observations. The flexibility of the AGDC’s framework also allows other earth observation data collections to be easily added. (Australian Geoscience Data Cube, 2016)

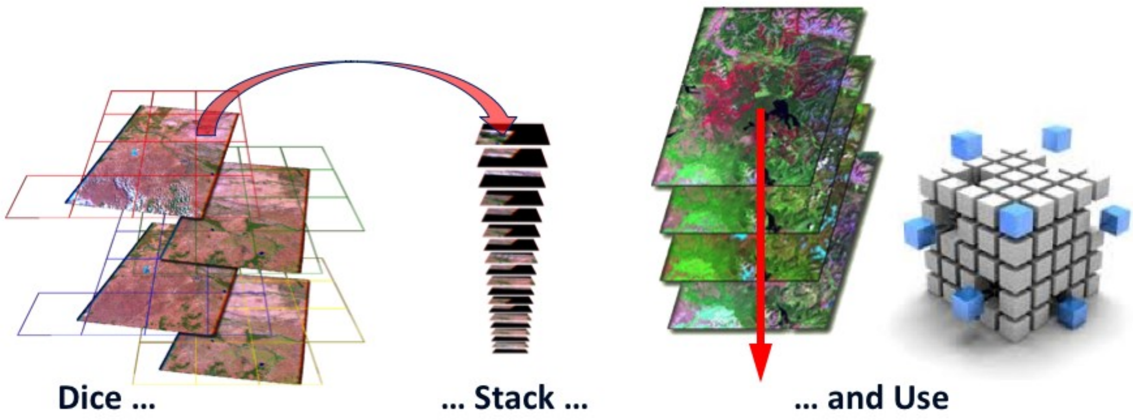

Figure 1: AGDC automated processing concept (Australian Geoscience Data Cube, 2016)

The AGDC’s dice and stack method arranges data so that the user can select and observe a particular area, referred to as a tile. The user can extract data products associated with this tile over time. Data products considered in this project include the Water Observations from Space (WOfS) and False Colour Imagery (FCI). WOfS data contains historical surface water observations derived from satellite imagery (Geoscience Australia, 2017). FCI data expresses satellite data in a range of falsified colours that the user can more readily interpret or understand (NASA Earth Observing System, 2017). Both FCI and WOfS data provides information regarding the presence of surface water in the landscape over time.

This study investigates the potential to identify the location and timing of water extractions using FCI and WOFs data contained in the AGDC.

2 Study Objective and Scope

This study tested if the AGDC can be used to:

- identify the location and timing of water extractions
- locate and map farm storages and observe changes to storages over time
- map and measure crop areas and observe changes to crop areas over time
- observe other on-farm activities such as irrigation applications.

The scope of the study was a single irrigated property (the study property) located on the Barwon River. The study was restricted to AGDC data captured from March 2014 to March 2015 inclusive (the study period). The study period included three flow events at the study property.

3 Method

The project was carried out in four stages:

- Stage 1: Property selection
- Stage 2: Data collating
- Stage 3: Data quality control
- Stage 4: Data analysis

3.1 Stage 1: Property selection

A study property was identified on the Barwon River that had irrigation, farm storages and an offtake channel. Subareas representing these key features on the study property were investigated (Figure 2). Two paddocks were selected for observation over the study period (Figure 2(A) – scale 1:25,000). The paddocks are referred to as Northern Paddock and Southern Paddock. Inset B and C in Figure 2 show two farm storages that are used to hold water during the study period. Both storages are represented at a 1:25,000 scale. Inset D is scaled at 1:12,000 and shows the point at which extractions are made from the Barwon River. Extractions are diverted through the offtake channel illustrated at Figure 2 (D).

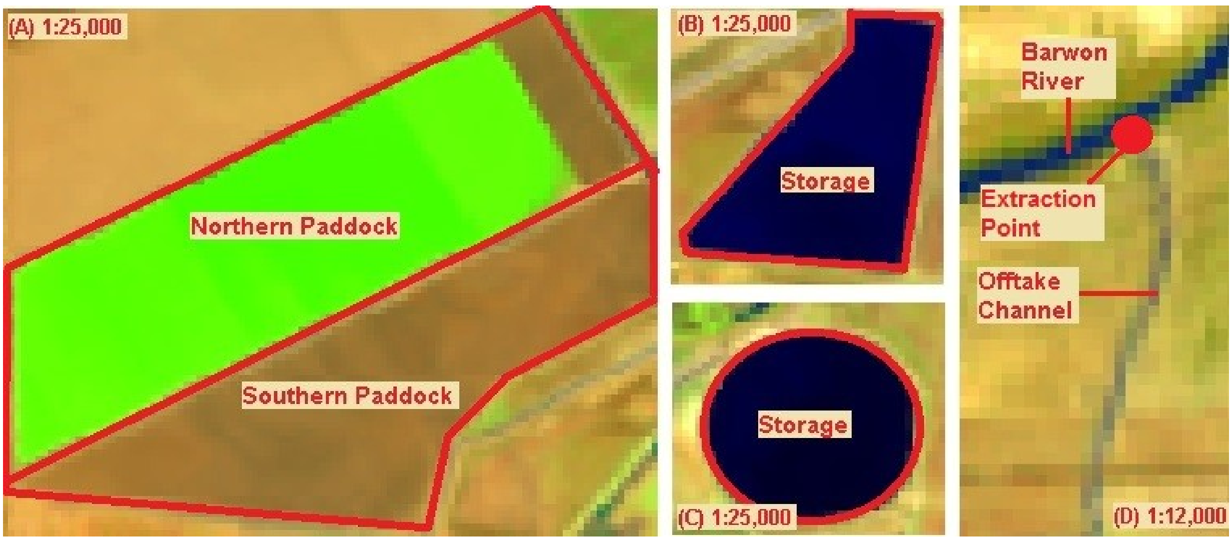

Figure 2: Key property features observed during study period

3.2 Stage 2: Data collating

Stage 2 involved the extraction of relevant tiles from the AGDC. The relevant tiles were selected by:

- using the one degree tile map to identify the tiles that cover the study property
- specifying the time period before, during and after flow events by analysing hydrographs for the Barwon River from 2014 and 2015.

Initially, a MDBA project officer worked onsite at Geoscience Australia (GA) to receive training on how to extract the required imagery tiles from the AGDC. This method of information gathering proved challenging due to the degree of knowledge required to operate the AGDC. Consequently, GA officers provided the requested data to the MDBA.

FCI data tiles of the study property were collated for the study period. This timeframe saw three significant flow events pass the study property as illustrated at Figure 3.

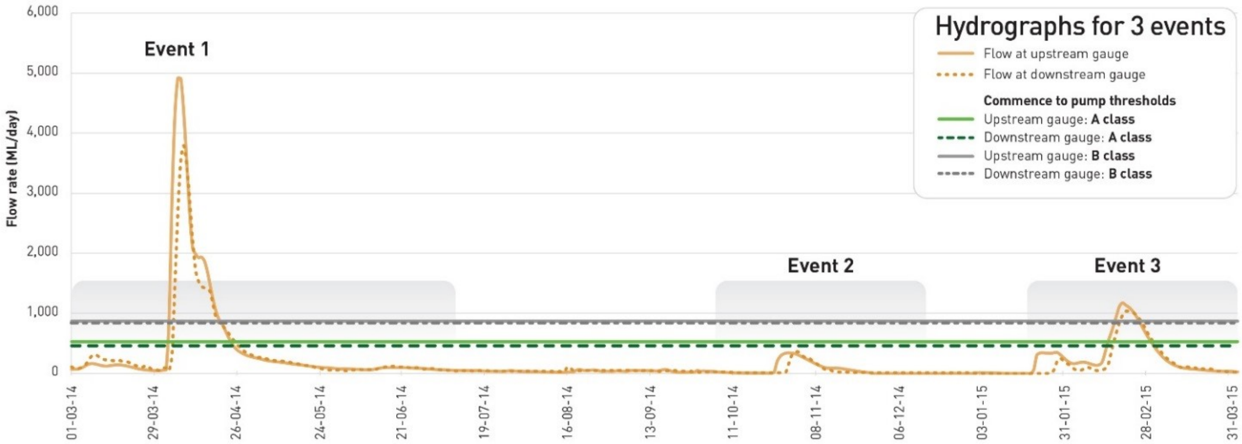

Figure 3: Hydrograph for three events (March 2014 - March 2015)

3.2.1 Pump thresholds

The hydrograph at Figure 3 shows four lines indicating commence-to-pump thresholds. Commence-to-pump lines indicate the flow rate thresholds required to be met before pumping is permitted to commence. The commence-to-pump thresholds are set out in the Water Sharing Plan (WSP) for the Barwon-Darling Unregulated and Alluvial Water Sources 2012 (NSW Government, 2016) and are as follows:

For unregulated A Class licences to be activated the following conditions must be met:

- more than 530 ML/day at the gauge upstream of the study property and more than 460 ML/day at the gauge downstream of the study property, and
- less than or equal to 870 ML/day at the gauge upstream of the property or less than or equal to 840 ML/day at the gauge downstream of the study property.

For unregulated B Class licences to be activated the following conditions must be met:

- more than 870 ML/day at the gauge upstream of the study property and more than 840 ML/day at the gauge downstream of the study property, and
- less than or equal to 6,800 ML/day at the gauge downstream of the study property.

During the study period C class licence commence-to-pump thresholds were not triggered and therefore do not appear on the hydrograph at Figure 3.

3.3 Stage 3: Data quality control

Quality control criteria were applied to the FCI data tiles. The data quality control stage eliminated data tiles where the tiles:

- did not contain adequate data to make the study property visible
- displayed > 50% cloud cover
- displayed > 50% cloud shadow
- displayed > 50% terrain shadow

Diagonal striping, as shown at Figure 4, was present in much of the FCI data extracted from the AGDC. Diagonal striping is common to data captured from Landsat 7. The diagonal striping is due to a malfunction in the satellite's scanning equipment. The striping does not affect interpretation of the imagery and so data that showed diagonal striping was not eliminated during the data quality control stage.

The data for the study period that was deemed to be of suitable quality was collated into an ArcGIS file.

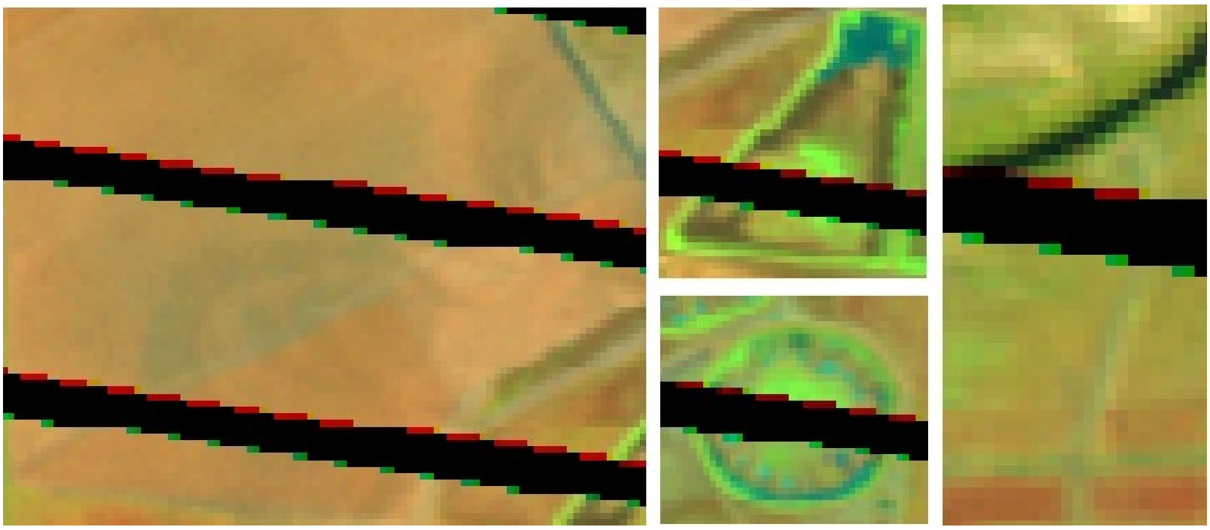

Figure 4: Example of diagonal striping

3.4 Stage 4: Data analysis

The collated data was analysed to identify key property features, including:

1) offtake channels
2) farm storages
3) irrigation paddocks.

FCI data was interpreted for each of the property features. This provided information on whether farm channels and storages were wet or dry, whether crop areas were identifiable and whether on-farm activities occurred.

3.4.1 Interpreting the False Colour Imagery data

FCI is a method of expressing remote sensing data to improve the useability of the data. To generate FCI data, satellites record the reflected and emitted brightness across the spectrum. Images can be displayed using blue, green and red light, and by combining these three wavelengths of light a colour image is generated. The colour image is referred to as a false colour image because particular colours are assigned to the data so that the user can more easily interpret that data.

To understand what the FCI colours represent, the user must know which band is used for each of the blue, green and red components of the image. Without knowledge of how each band has been changed for contrast and brightness the user is unable to interpret the FCI data accurately. In this particular study the FCI data assumes the combination of shortwave infrared (red), near infrared (green) and green (blue) wavelength bands (NASA Earth Observing System, 2017).

To interpret the data the user must understand what each of the falsified colours represent.

Water absorbs all three wavelengths and so is represented as black. Where the water is turbid the sediment reflects visible light which is represented as blue. Therefore water is shown on the blue colour scale where light blue represents water with high sediment levels through to dark blue which represents water with low sediment levels. Saturated soil also appears blue.

Exposed, bare earth generally reflects shortwave infrared light and tends to have a red colour. Much of the data observed in the study appears a red-brown colour. Therefore exposed bare earth is shown on the red-brown colour scale. Light red-brown represents exposed earth with low moisture content through to dark red-brown which represents exposed earth with high moisture content.

Since plants reflect near infrared light very strongly, vegetated areas are bright green. Where a higher density of plants is detected the brighter the green will be. Where a lower density of plants is detected the paler the green will be (NASA Earth Observing System, 2017).

The colour interpretations for the study are summarised at Table 1.

Table 1: Interpreting shortwave infrared, near infrared and green FCI data

Colour	Tone	Represents	Illustrates
Black	N/A	Clear water	Water bodies with no sediment
Blue	Dark	Water with low levels of sediment	Storages, rivers and channels
Blue	Light	Water with high levels of sediment and saturated soil	Storages, rivers and channels and Irrigation applications
Red-Brown	Dark	Exposed bare earth with high moisture content	Land without vegetation where soil has recently been ploughed
Red-Brown	Light	Exposed bare earth with low moisture content	Land without vegetation where soil is undisturbed
Green	Bright	High density vegetation	Late stage crops and other vegetation with dense canopies
Green	Pale	Low density vegetation	Early stage crops and other vegetation with sparse canopies

4 Results and Discussion

4.1 Data Analysis

4.1.1 Event 1 - April 2014

Event Observations

The data for 3 April 2014 in Figure 5 shows the storage colours ranging from bright green through to dark red-brown with intermittent blue areas. This colour combination represents closed canopy vegetation and moist soil with some water coverage. This indicates that storages are empty and that the storage beds comprise vegetation, bare moist soil and some residual water.

The Barwon River can be observed as the dark blue colour that represents water. The adjacent offtake channel is not blue, therefore, the offtake channel is dry indicating that extractions have not recently been made.

The light red-brown paddocks represent dry bare land, therefore, no irrigated crop is under production.

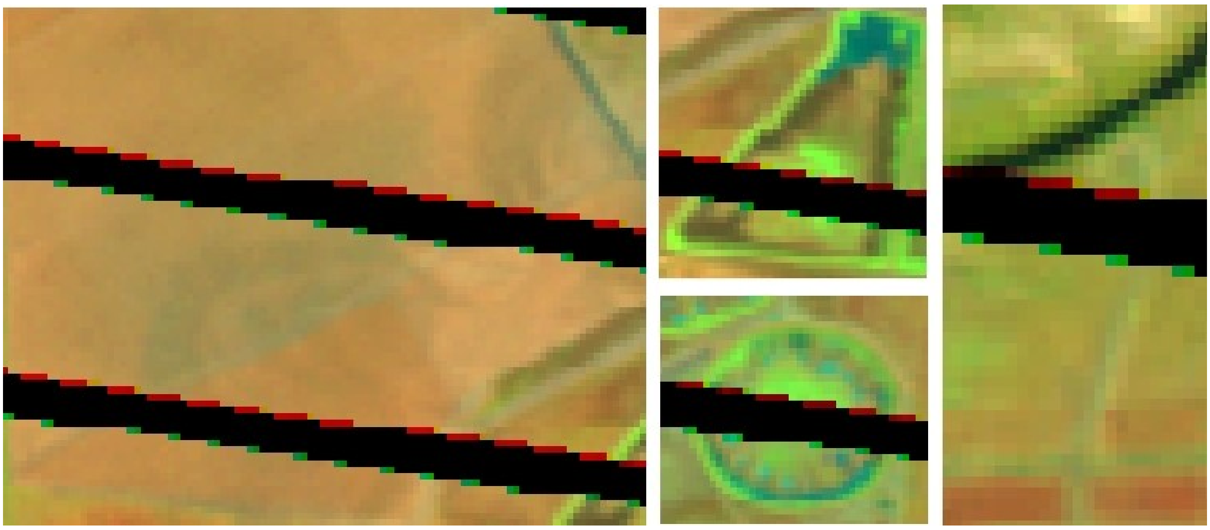

Figure 5: Data observations for 3 April 2014

The data for 11 April 2014 is partially obscured by cloud cover. In Figure 6 the white-grey patches represent clouds and the black-grey patches represent the cloud's shadows on the land. Although the data is partially obscured, several observations can be made.

The offtake channel is a light blue colour closely resembling that of the Barwon River. This indicates that the offtake channel is wet and therefore shows that extractions are either being made or have recently been made.

This observation is supported by changes in the storages. One storage is a dark blue colour indicating that the storage bed is completely covered in water. The second storage shows a predominately dark blue area with a bright green patch. This represents a storage bed partially covered in water with the exposed bed covered in vegetation. Therefore the storages contain water, reinforcing the observation that extractions have been made.

There is no significant change observed in the paddocks and therefore still no crop production.

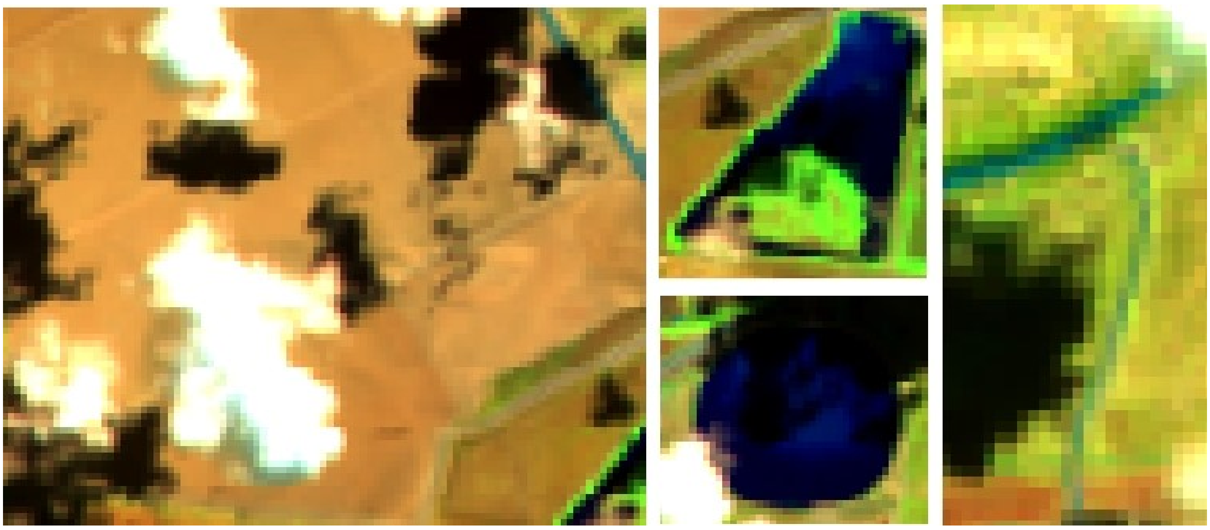

Figure 6: Data observations for 11 April 2014

The offtake channel in Figure 7 is a light blue colour similar to the Barwon River. This represents that the offtake channel is wet and therefore indicates that extractions are either being made or have recently been made.

The storages are both now completely blue. This represents water completely covering the bed of each storage and therefore indicates that the storages are holding water.

The Southern Paddock has transformed from light red-brown to dark red-brown. This represents a transformation from dry bare soil to moist bare soil in the Southern Paddock. The transformation indicates recent work such as ploughing has been carried out in the paddock.

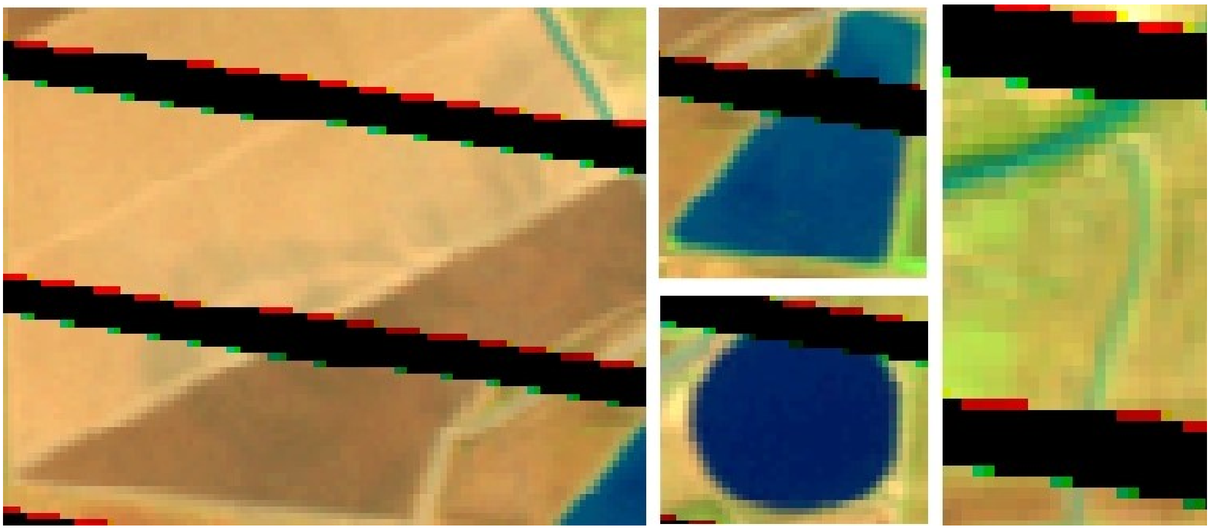

Figure 7: Data observations for 19 April 2014

The offtake channel has continuously remained blue since the 11 April observation. Figure 8 shows the final time that the offtake channel appears blue for this event.

The storages remain completely blue representing that both storages continue to hold water to the extent that the storage beds are completely submerged.

There is no notable change observed in the paddocks and still no crop production.

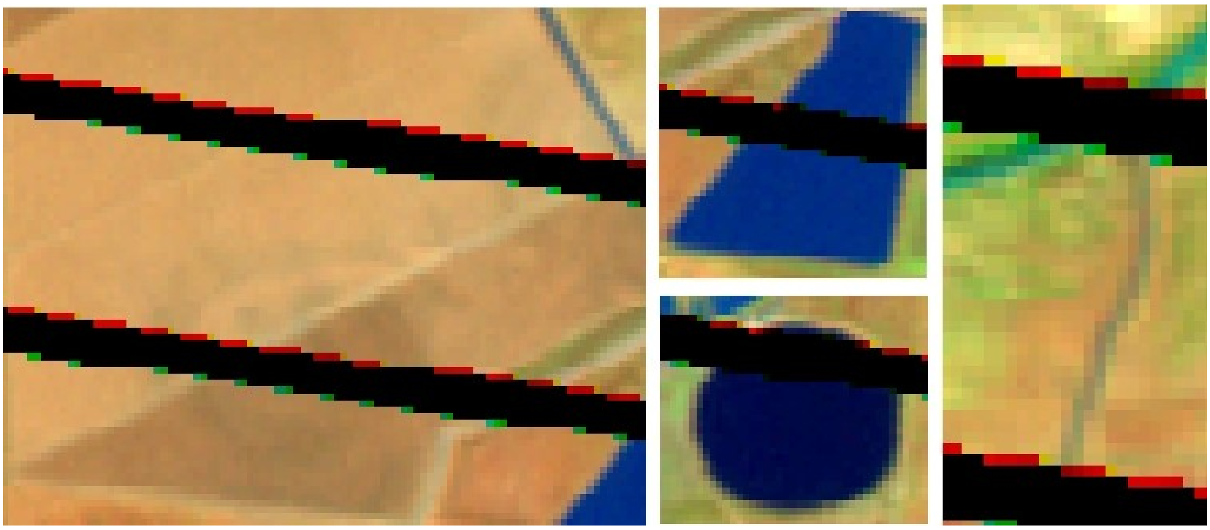

Figure 8: Data observations for 6 June 2014

The Northern Paddock in Figure 9 is light blue. This represents saturated soil and indicates an irrigation application. The western half of the Southern Paddock is dark red-brown compared to the eastern half of the paddock. The dark red-brown represents bare moist soil and indicates that the land has recently been ploughed. The light red-brown eastern end represents bare dry soil. Therefore, this area has not been ploughed.

The Barwon River appears dark blue, however, the offtake channel does not. Given that blue represents water this indicates that the channel is not wet and therefore that extractions are not being made.

The storages remain dark blue and are therefore still holding water.

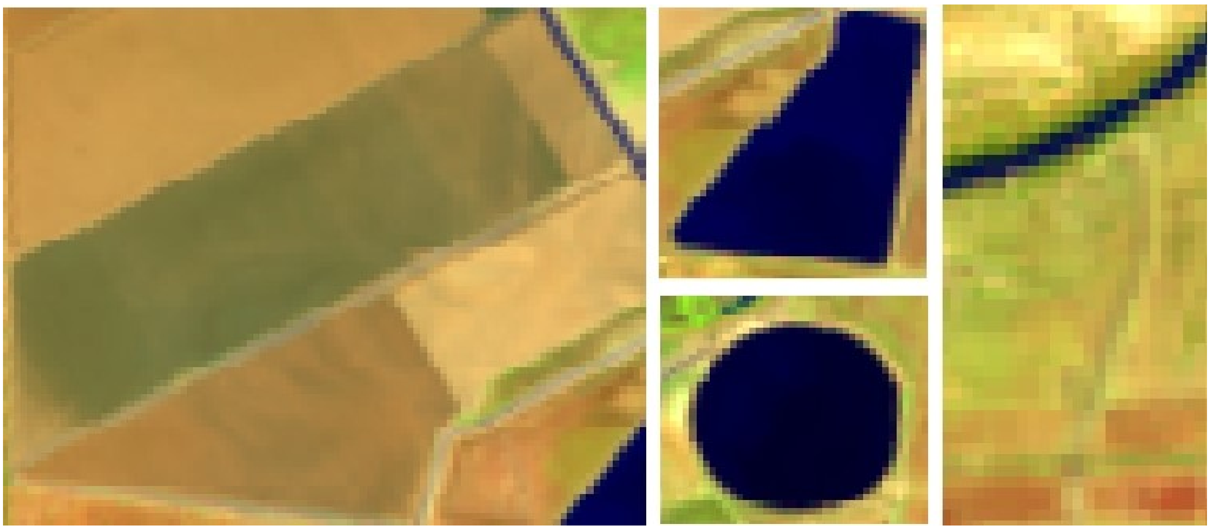

Figure 9: Data observations for 18 September 2014

Event Summary

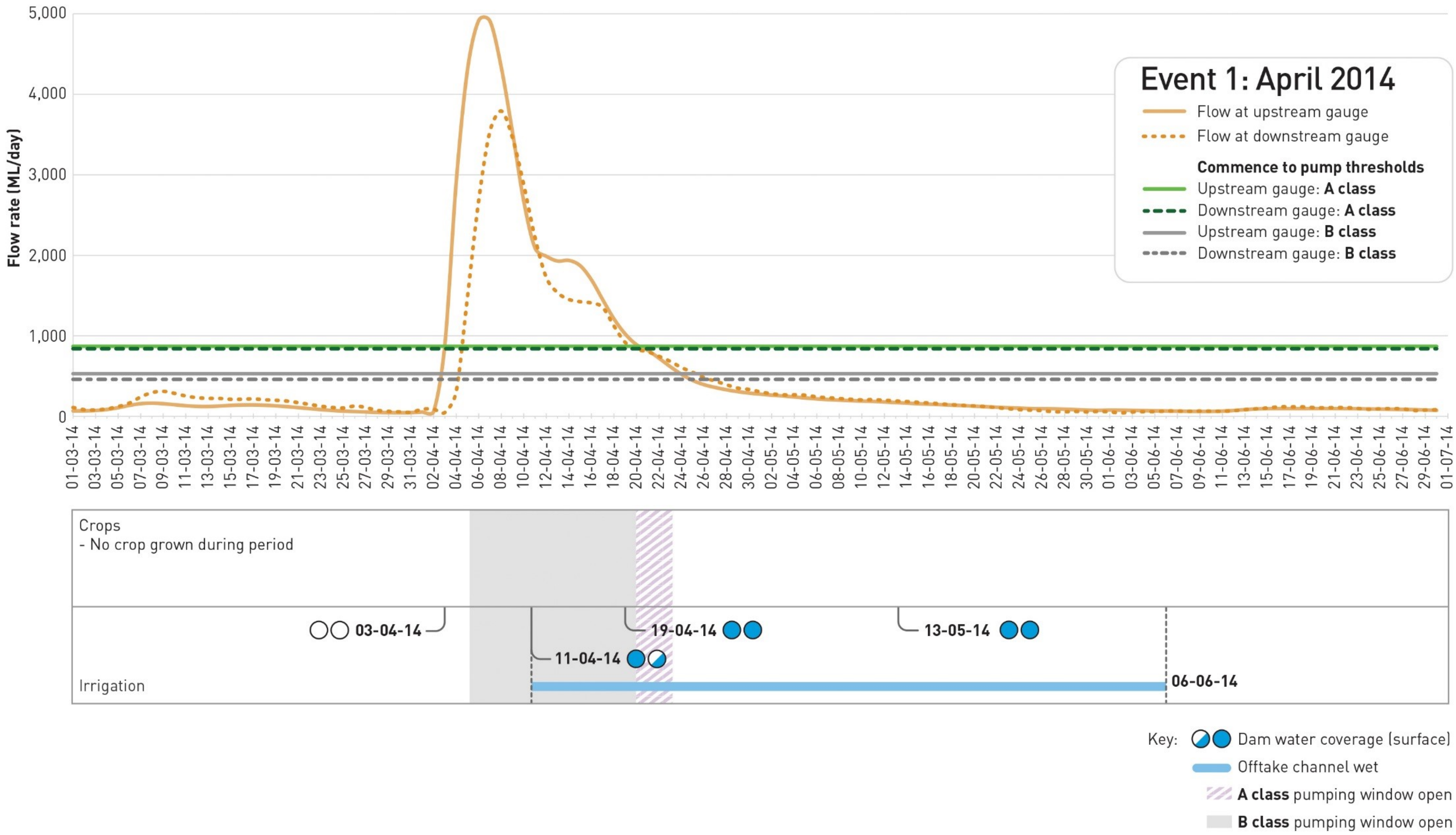

Figure 10: Hydrographic for Event 1, April 2014

Figure 10 summarises the key observations made against the hydrograph for Event 1.

At the beginning of the event, on 3 April, no significant water coverage was detected in either of the property's storages. However, data for the 11 April observation indicates that water is present in the storages. In addition, the offtake channel is also wet. This shows that extractions began to occur at the property during the week 4-11 April. Data observations showed that the offtake channel remained wet through until 6 June. This does not mean that water was extracted for this whole period as the channel would remain wet for a period after extractions ceased.

These observations can be verified using the hydrograph at Figure 10. The hydrograph shows that at the time that extractions were made, the flow had exceeded commence-to-pump thresholds for B-class licences. This means that appropriate conditions for B-class licence holders to make extractions were met.

Although there was some on-farm activity such as ploughing and irrigation application, no crops were produced on either of the paddocks during this event.

4.1.2 Event 2 - November 2014

Event Observations

Figure 11 illustrates the key property features at the beginning of the second event. The data is partially obscured by cloud cover where the black-grey patches represent the cloud's shadows on the land and the white-grey patches represent the clouds themselves.

The offtake channel is not blue, representing a dry channel and indicating that extractions have not been made.

Both storages are still completely blue. This represents full water coverage over the storages' beds and shows that the storages are holding water.

Despite the irrigation application at 18 September the Northern Paddock is still a dark brown colour which represents bare moist soil.

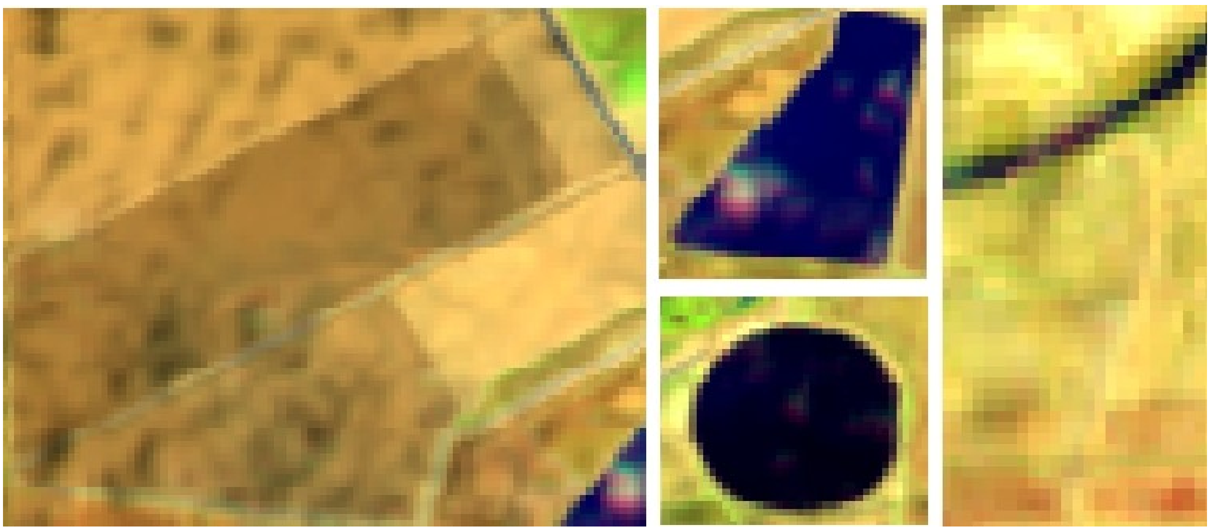

Figure 11: Data observations for 4 October 2014

The data at Figure 12 shows the Northern Paddock as pale green. Pale green represents low density vegetation. This shows the sparse canopy of an early stage crop. This observation supports the irrigation application observation made at 18 September (Figure 9).

Storages remain blue, representing water. This shows that the storages are still holding water.

Although the Barwon River is shown as a dark blue line the offtake channel is not. This represents water present in the river but not in the offtake channel. Therefore, no extractions have been made.

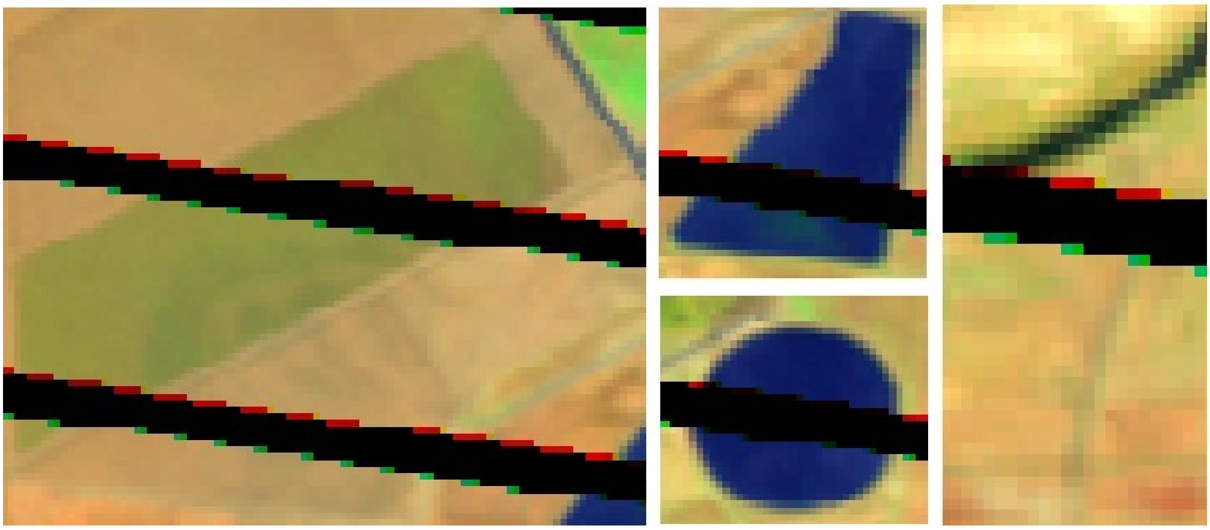

Figure 12: Data observations for 29 November 2014

Figure 13 illustrates the key property features at the end of the second event. The offtake channel does not appear blue. This represents that water is not present in the offtake channel and thus indicates that extractions have not been made.

The Northern Paddock has changed from a pale green at Figure 12 to a brighter green. The change from pale green to a brighter green represents the vegetation’s canopy becoming denser, therefore indicating that the crop is growing.

One storage remains blue, representing that the storage is still holding water. The other storage is now predominately dark red-brown. Dark red-brown represents moist bare soil thus showing the exposed bed of the second storage and indicating that the second storage no longer holds a significant volume of water.

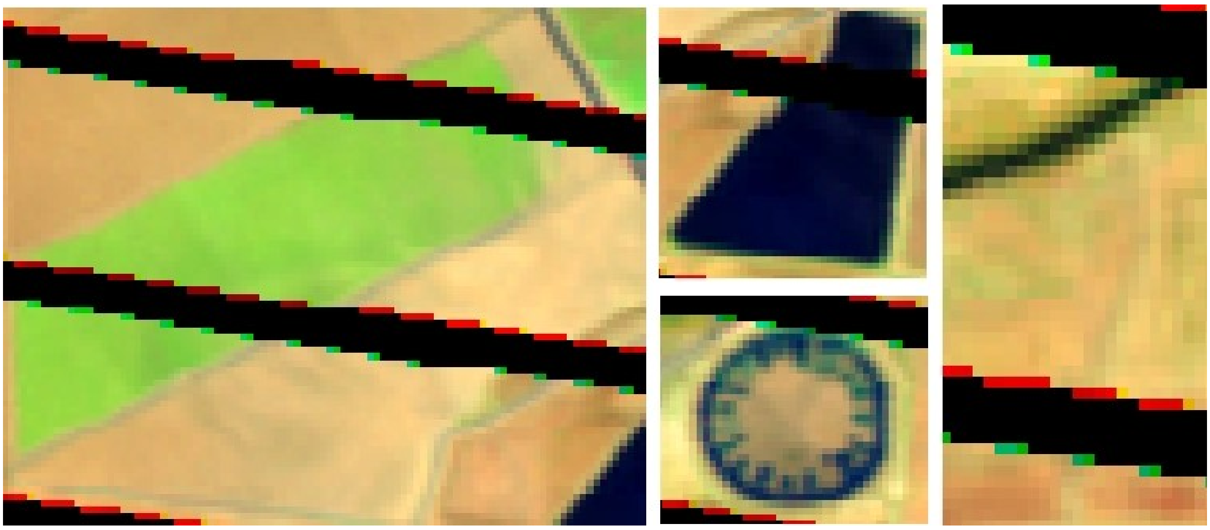

Figure 13: Data observations for 15 December 2014

Event Summary

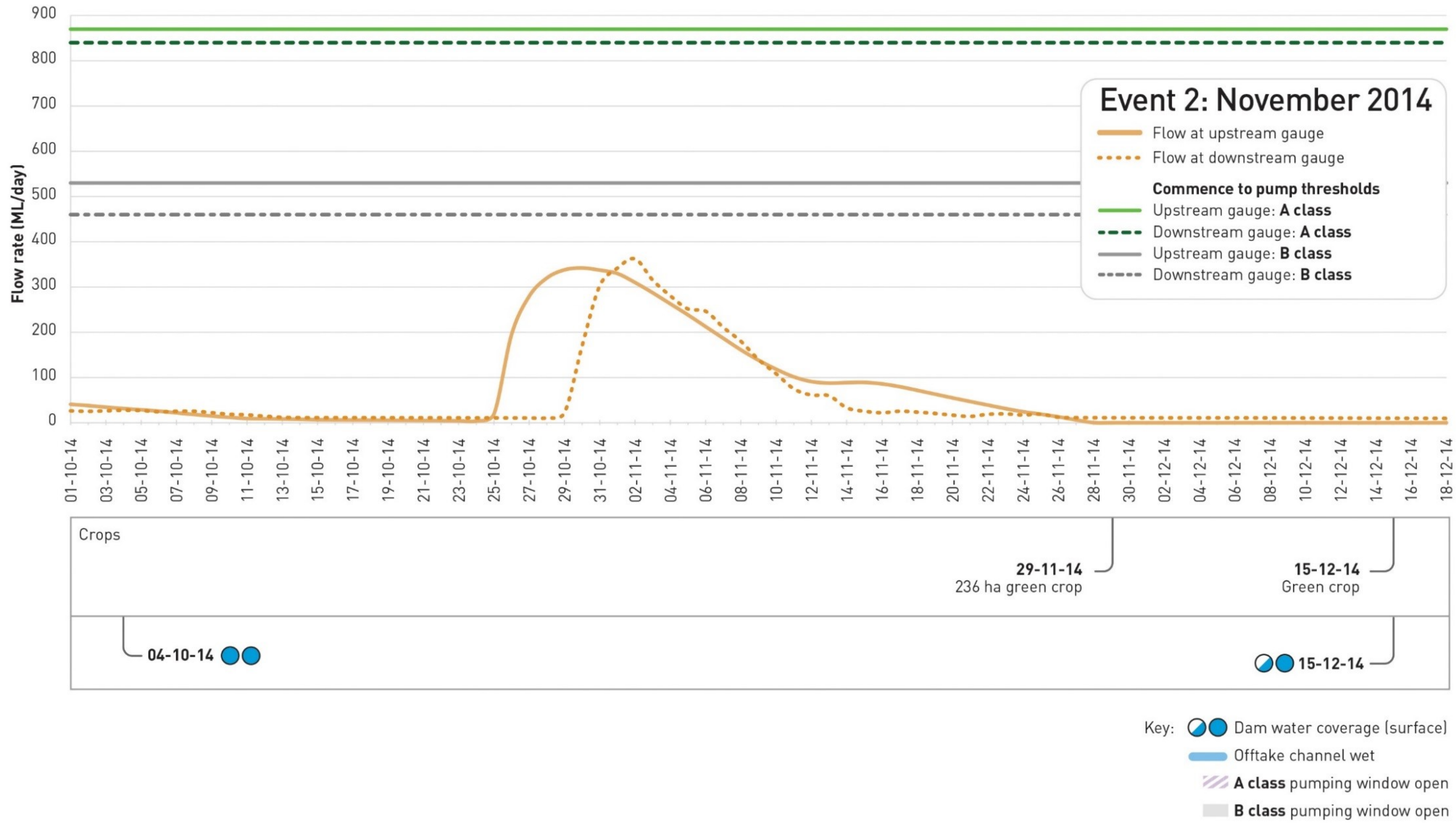

Figure 14: Hydrographic for Event 2, November 2014

Figure 14 summarises the key observations made against the hydrograph for Event 2. No extractions were made at the property during this event. This is supported by the observation that the offtake channel remains dry throughout this period. Further, at the beginning of this event both storages held water, however, by the end of the event the resources in one of the storages had been exhausted. The crop produced during this event relied on resources held in storage for irrigation alone since no extractions were made. This is reinforced by the depletion of one of the storages throughout the event.

These observations can be verified using the hydrograph at Figure 14 The hydrograph shows that flow did not exceed commence-to-pump thresholds for either A-class or B-class licences. This means that appropriate conditions were not met for licence holders to make extractions.

Although this study only conveys data for two paddocks, it is important to note that crop is produced at other sections of the property in sequence with the crop produced at the Northern Paddock. The overall crop area produced at the property during this event is approximately 236 hectares, as is noted in Figure 14.

4.1.3 Event 3 - February 2015

Event Observations

Figure 15 shows the key features at the beginning of the third event. The offtake channel is not blue, representing a dry channel and indicating that extractions have not been made.

One storage appears completely blue representing full water coverage over the storage bed. The other storage is a combination of light and dark red-browns representing bare soil with varying levels of moisture and blue around the storage periphery, indicating residual water. This indicates that only one of the two storages is holding water.

The Northern Paddock that was observed as green during Event 2, continues to brighten. This represents the crop's canopy becoming denser as the crop grows. The Southern Paddock is the light red-brown which represents bare, dry soil.

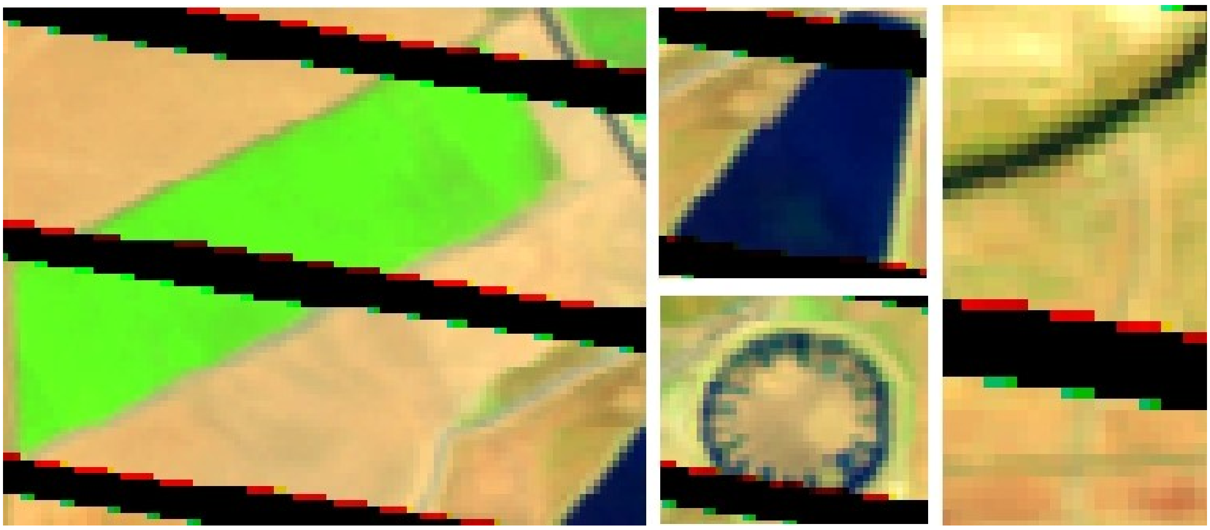

Figure 15: Data observations for 31 December 2014

The offtake channel does not appear blue in Figure 16, this represents a dry channel and indicates that extractions have not been made.

The storage which held water at 31 December 2014 is no longer completely blue. This represents that the storage bed is no longer fully submerged and that the volume of storage has decreased. The second storage comprises green, red-brown and blue patches. This combination represents vegetation, soil and patches of water and indicates that the storage remains empty.

No significant change is observed in either the Northern or Southern Paddocks.

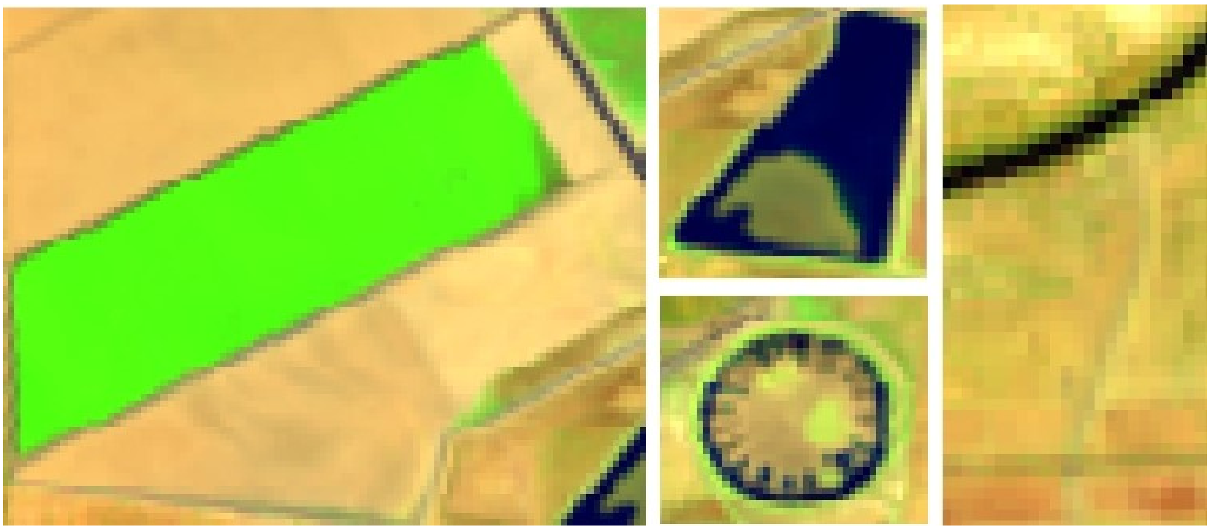

Figure 16: Data observations for 8 January 2015

The Barwon River at Figure 17 is a dark blue line, however, the adjacent offtake channel is not. This represents that water is not present in the offtake channel and indicates that extractions have not recently been made.

Both storages are observed as a combination of green and red-brown with blue patches around the perimeter of the storages (Figure 18). This represents vegetation, soil and pools of water. It indicates that the beds of both storages are now visible and shows that one storage is empty while the other storage holds only a very small volume of water.

The Northern Paddock appears unchanged from the previous observation. The Southern Paddock is now a dark red-brown. This represents bare, moist soil and indicates that work has recently been carried out on the Southern Paddock.

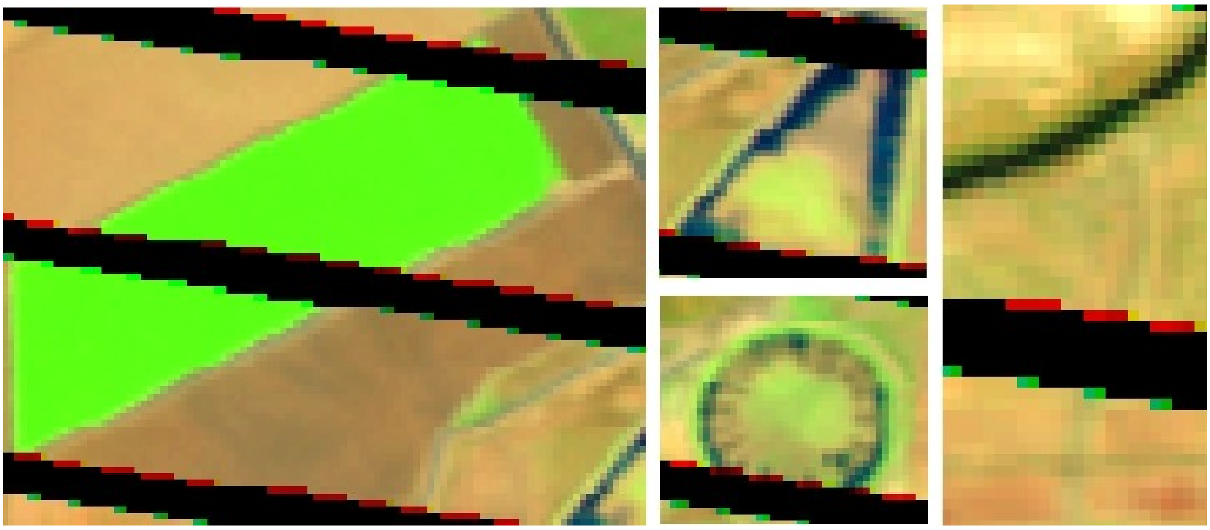

Figure 17: Data observations for 1 February 2015

The offtake channel appears as a dark blue line in Figure 18. Blue represents water and indicates the offtake channel is wet and extractions have been made.

Both storages are observed as a combination of green, red-brown and blue patches. This represents the storage beds which are composed of vegetation, soil and residual water. Neither storage is observed as holding any significant volume of water.

No significant changes are observed in either of the paddocks.

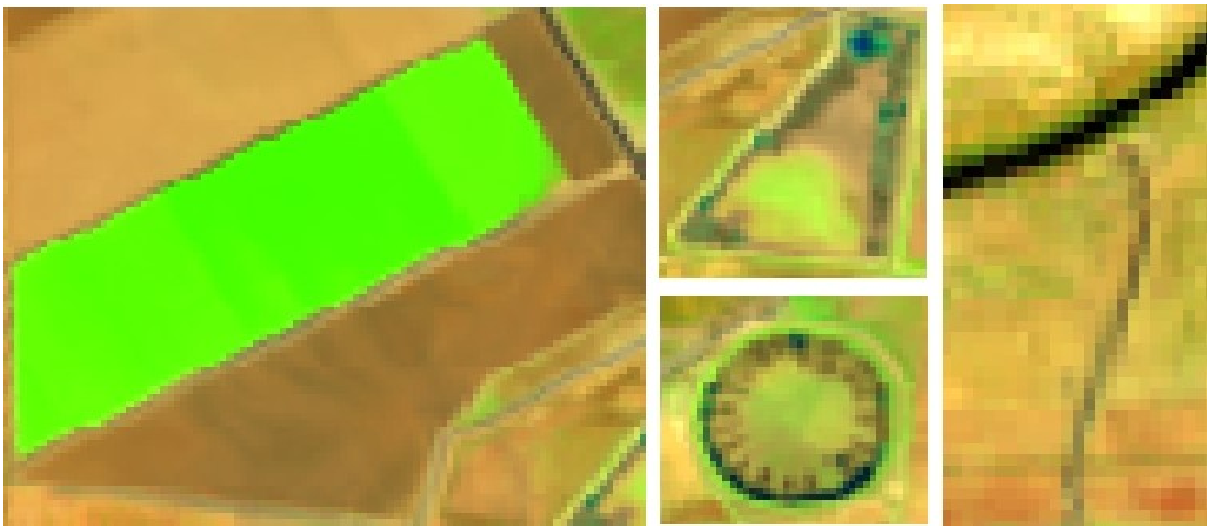

Figure 18: Data observations for 9 February 2015

The data at Figure 19 is partially obscured by cloud cover, however, a series of observations can still be made.

The offtake channel remains a dark blue line similar to the Barwon River. The blue represents water and indicates that the offtake channel remains wet.

Both storages remain empty with shades of green and red-brown representing the vegetation and bare soil of the storage beds.

There are no observed changes in either the Northern or Southern Paddocks.

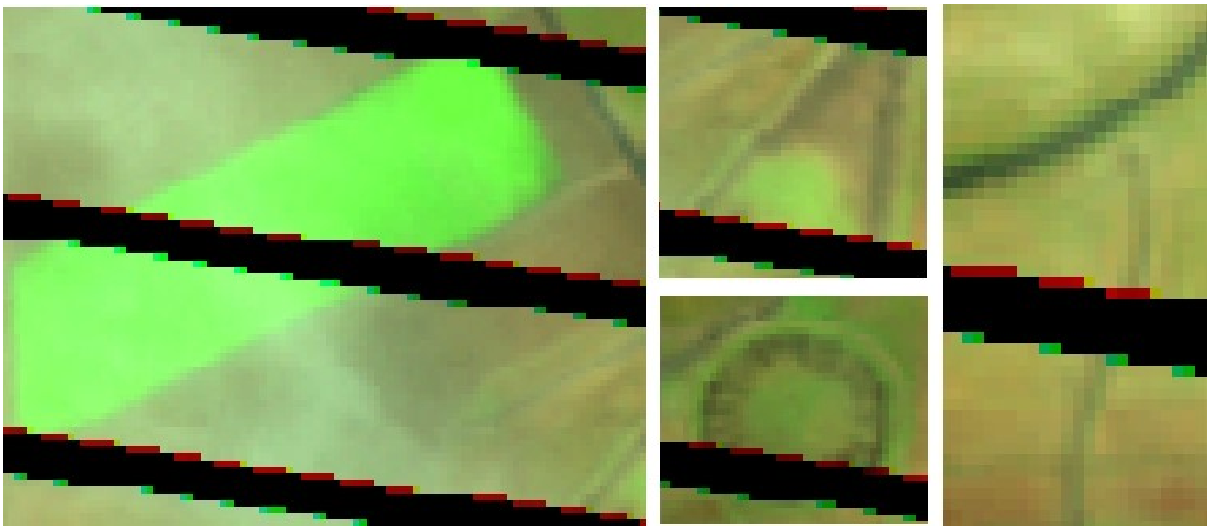

Figure 19: Data observations for 17 February 2015

At Figure 20, the Barwon River is shown as a thick blue line, however, the adjacent offtake channel is no longer blue. This represents that water is no longer present in the offtake channel and indicates that extractions have not recently been made.

There are no significant changes observed in either of the storages or paddocks as compared to the 17 February.

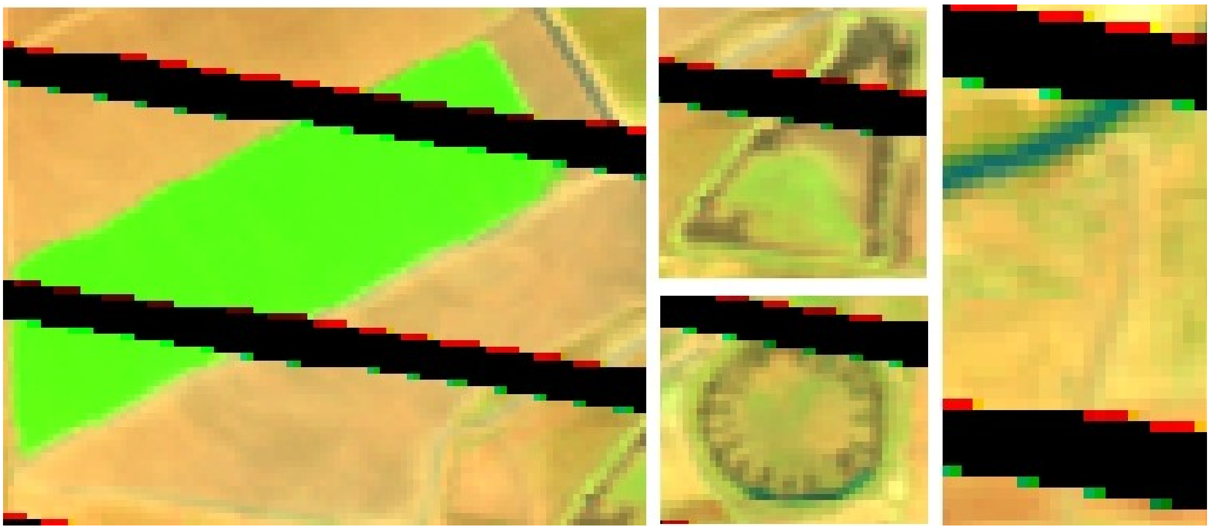

Figure 20: Data observations for 5 March 2015

The final observations for Event 3 are at Figure 21. At the end of the event, on 13 March, the offtake channel does not appear blue. This represents that the offtake channel is not wet and indicates that extractions have not been made.

Both storages are observed as a combination of green and red-brown patches. This represents bare soil with intermittent vegetated areas. Therefore, no water is held in storage.

The Northern Paddock is observed as bright green which represents a crop with a dense canopy. The Southern Paddock is a light red-brown which represents bare, dry soil.

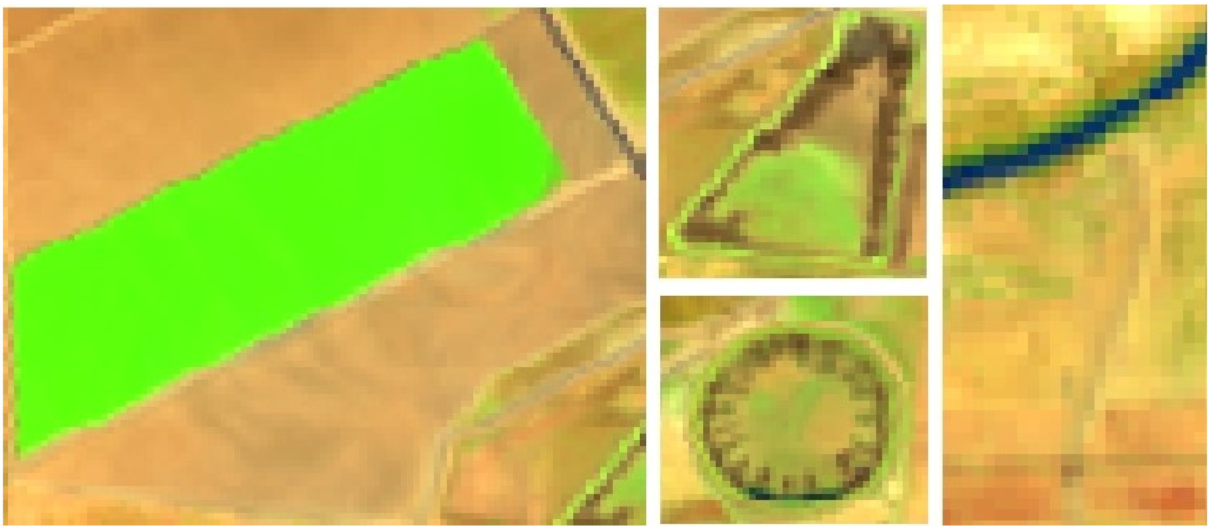

Figure 21: Data observations for 13 March 2015

Event Summary

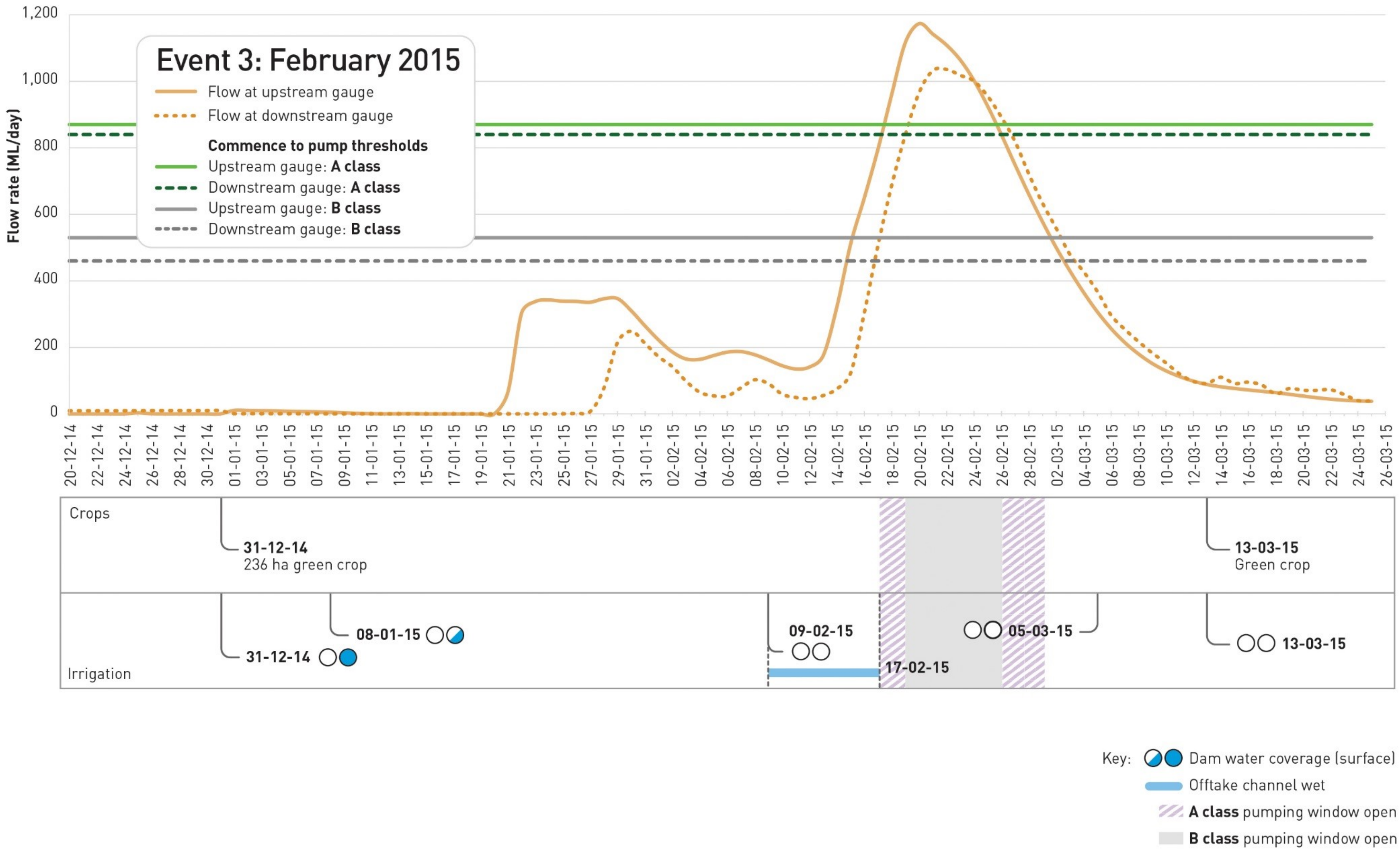

Figure 22: Hydrographic for Event 3, February 2015

Figure 22 summarises the key observations made against the hydrograph for Event 3. Data for the 9 February observation shows the first time that the offtake channel is observed as wet during Event 3. The most recent data prior to 9 February is captured at 1 February. Data for the 1 February observation confirms the offtake channel as dry. Therefore, extractions commenced between 1-9 February 2015.

At the outset of Event 3, on 31 December 2014, one of the two storages is observed as holding water. By 1 February 2015 only a very small volume is held in one of the storages. By 9 February neither storage holds any significant volume of water. Both storages remain dry for the remainder of the event.

A crop occupies the Northern Paddock for the entirety of Event 3 and is a portion of the overall 236 hectare crop produced across the whole of the property. No crop is produced on the Southern Paddock during this event.

The sequence and combination of observations make sense when each of the property's features are analysed in context. Specifically, to produce the crop observed at the Northern Paddock irrigation is required. Initially, irrigation needs are met from the full storage. When the resources in the storage are exhausted at around 1 February, irrigation needs are required to be met from another source. To meet those needs Barwon River extractions commence between 1-9 February. The data shows that those extractions are not used to fill the storages and therefore indicates that the water was delivered directly to paddocks.

These observations can be verified using the hydrograph at Figure 22. The hydrograph shows that at the time that water appears in the channel, 9-17 February, flows were present in the river.

4.2 Key Findings

4.2.1 Location and timing of extractions

FCI data from the AGDC was analysed to test the usefulness of the AGDC in identifying the location and timing at which extractions were made.

The AGDC is effective at identifying the location and time at which extractions commenced to a window of approximately 8-10 days. To determine the date at which extractions commenced, FCI data was analysed by identifying the date that the offtake channel first appears as blue during an event. This represents the first known date at which the offtake channel is wet during an event. FCI data for the closest available date prior to the offtake channel being observed as blue was then identified. By finding the last time that the offtake channel appears dry and the first time that the offtake channel appears wet, a window for when extractions commenced could be identified.

Factors including intervals between satellite passes and data quality issues were found to be the most significant limitations on narrowing the observation window. Data is available from two satellites, Landsat 7 and Landsat 8, passing over every 16 days and approximately eight days apart from each other. Between 4-6 images are captured per month, due to the satellites' overlapping pathways. Cloud cover and inadequate data can render the images useless, resulting in extended periods between suitable images being captured. The frequency of satellite images is expected to improve over the next 12 months as data from a new satellite, the Sentinel 2, become available. Sentinel 2 data will be captured every five days and have an improved pixel resolution of 10 m^2, compared to the current 25 m^2 pixel resolution of Landsat 7 and Landsat 8. Sentinel 2 is operating in addition to the Landsat satellites, meaning that future data will be captured at more regular intervals and be a combination of both 10 m^2 and 25 m^2 pixel resolution.

Using the AGDC to identify the location and timing of extractions could prove useful in supporting policy and management decisions. Identifying extraction details can be applied to address issues relating to the improved management of environmental flows. By analysing FCI data for an environmental flow event in a particular river reach, observations can be made regarding the extent to which a flow is extracted or remains in the river.

4.2.2 Location and observation of farm storages

FCI data from the AGDC was analysed to establish the usefulness of the AGDC in locating and mapping farm storages. The AGDC was also tested to determine the extent to which it can be used to observe when farm storages are wet or dry.

During Stage 1 of the study, FCI data from the AGDC was used to shortlist study properties. This process involved inspecting FCI data to locate farm storages and identify those properties that store water for irrigation purposes. This proved to be an effective method and by locating farm storages an initial shortlist of four potential study properties was compiled.

Throughout Stage 4 of the study, FCI data from the AGDC was analysed and a series of observations of the key property features were made. As part of this process two of the property’s storages were mapped for the period between March 2014 and March 2015. During the study period neither of the mapped storages were subject to any significant construction works. However, the mapping technique would be a valuable tool that could be used to observe how storages change over time including the construction of new storages.

One change that was observed throughout the study was the two storages transforming from dry to wet and wet to dry. The FCI data was very effective at illustrating when the storages were holding water and this application proved to be a strength of the AGDC.

The AGDC is less effective at enabling the user to determine the volume of water held in storage. The AGDC data allows the user to view the wet surface area of a storage, but not the depth of water in the storage. If the storage walls were a gradual slope the user could expect rising and falling water levels to translate to a change in the storage surface area. However, in reality, most storages are constructed with relatively steep walls and therefore it is generally not possible to observe a change in a storage's surface area using FCI data. This means that it is difficult to use the AGDC to determine the degree to which a storage is filled. Rather, the FCI is most effective when used to establish whether or not a storage is completely empty (dry) or even partially filled (wet).

4.2.3 Measurement and observation of crop areas

FCI data from the AGDC was analysed to establish the usefulness of the AGDC in mapping and measuring crop areas and observing changes to crops over time.

Analysing FCI data is a useful way to observe vegetation. Different shades of green represent the vegetation’s canopy density. This enables the user to monitor the crop cycle and measure the total area cropped. During Event 2, FCI data shows a crop emerge from bare soil and begin to develop a crop canopy. The crop observations pass into Event 3 where the same crop continues to develop as represented by the increasingly brighter green in the FCI data.

Using ArcGIS, the crop area was measured to find that approximately 236 hectares of crop was produced across the study property during the study period. Of the total 236 hectare crop, approximately 147 hectares of the crop was grown in the Northern Paddock.

The use of the AGDC to map and measure crop areas has broader applications that could support policy and management decisions. The scope of this study is restricted to analysing a single property over a 13 month period. However, the techniques used in this study can be applied at a wider scale. By compiling FCI data for an entire river reach across several decades, conclusions can be drawn on how land use in the reach has changed over time. This can be extended by using the mapped crop areas to derive the water use required to produce those crops. Therefore by compiling information regarding changes to crop areas over time, information regarding how water use in a river reach has changed over time can be determined.

4.2.4 Observation of on-farm activities

FCI data from the AGDC was analysed to establish the usefulness of the AGDC in observing on-farm activities such as irrigation applications.

During the study period on-farm activities were observed by analysing the FCI data. On-farm work, such as ploughing, can be observed when a paddock transforms from bare, dry soil to bare, moist soil. This occurs due to the moist subsurface material being exposed to the surface through the action of ploughing.

It was also possible to identify the date at which irrigation applications were made. The FCI data shows an application was made at 18 September 2014 (Figure 9). Although additional irrigation applications would have been required to produce the crops observed during the study period, the AGDC was unable to identify each of the dates at which irrigation occurs. This is due to the data interval limitation of the AGDC whereby satellite passes and data quality issues mean that there is often several days between data capture. Due to irrigation applications taking place over a relatively small window the chance of a satellite pass aligning with an irrigation application is relatively small. However, where these events do align, the FCI data can effectively be used for observing irrigation applications.

In terms of observing on-farm activities the AGDC has some limited applications that could be useful to support policy and management decisions. By analysing the AGDC data to observe on-farm activities the AGDC has some capacity to identify dates at which irrigation applications occur. This may allow broader application of the AGDC to observe existing irrigation patterns and determine how irrigation trends and behaviours have changed over time.

4.2.5 AGDC Limitations

There is currently a 2–3 month delay (latency) between the satellite observations and the data being made available through the AGDC. GA has advised that the latency could be reduced to 2-3 days (predictive) and seven days (authoritative) if the AGDC receives further development to enhance its data correction processing capabilities (e.g. atmospheric correction).

The study initially used AGDC's WOfS and FCI data. Both data types are able to detect surface water, however, the AGDC applies a classification algorithm to the WOfS data, which expresses a pixel as either wet or dry, rather than expressing grades of "wetness". GA has advised that this is a conservative classification, where the entire pixel must be detected as wet otherwise the data expresses the pixel as dry. As such, the WOfS data underestimates water detections as illustrated in Figure 23. In the WOfS data at Figure 23 water is represented as the blue hatching. The WOfS data shows a series of intermittent blue patches that represent a sequence of disconnected pools of water in the river bed. However, FCI data for the same day at Figure 23 shows a continuous blue line representing a wet and well connected river bed. In the case of the WOfS data at Figure 23 the conservative WOfS classification system means that pixels are represented as dry given that they are detected as being not completely wet. In this case, factors such as a narrow river channel and overhanging vegetation are likely to have combined to mean that the WOfS data shows the river bed as dry. The FCI data that indicates greater volumes of water present in the river channel is supported by gauge data showing an approximate flow rate of 45 ML/d is present in the river reach on 16 July 2014 (NSW Office of Water, 2016).

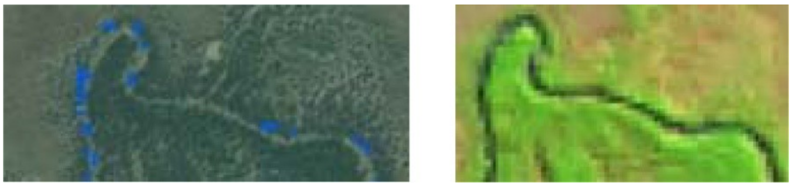

Figure 23: Example of WOfS (L) and FCI (R) data for July 16 2014

A similar outcome was reached when using WOfS data to detect water in irrigation channels. This issue is illustrated in the comparison of WOfS and FCI data shown at Figure 24. The limitation in the WOfS data meant that FCI data became the preferred AGDC data used in the study.

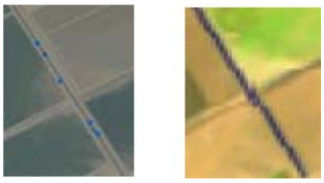

Figure 24: Example of WOfS (L) and FCI (R) data for September 18 2014

A further limitation of the AGDC is that it cannot be used to estimate farm storage volumes. AGDC data could be improved by including storage dimensions to assist the user in estimating storage volumes. Storage dimensions could be captured using LiDAR to observe storage profiles. Providing farm storage volumes in the AGDC data would improve capabilities for estimating extraction volumes.

5 Conclusion

The study analysed AGDC data for a single irrigated property located on the Barwon River from March 2014 to March 2015 inclusive. The study period included three flow events at the study property.

By analysing the AGDC data a series of observations were made in relation to the study objectives:

- the locations and timings at which extractions were made were identifiable using the AGDC to observe whether farm channels and storages were wet or dry
- the AGDC alone cannot determine the volumes of farm storages, however, it does allow the user to locate, map and observe storages at regular intervals over time. This feature of the AGDC was useful when applied to observe storages transforming from dry to wet throughout the study period
- crop areas were identifiable using AGDC data
- on-farm activities such as irrigation applications and ploughing could be identified using AGDC data

The study tested the utility of the AGDC to support policy and management decisions. The AGDC is being enhanced by greater pixel resolution and increased frequency of satellite observations, available in 2017. There is an opportunity to further improve the AGDC by reducing the image access time from the current period of 2-3 months to just two days. The inclusion of LiDAR captured storage dimensions would be a further improvement to the AGDC and provide storage volume estimation capabilities.

A fully enhanced AGDC would be useful in supporting policy and management decisions. Some specific areas of use may include applications associated with:

- identifying extraction locations and timings such as observing flow events and addressing issues linked to the improved management of environmental flows
- mapping and observing farm storages over time such as how existing storages change and when new storages are constructed
- identifying crop areas such as how crop areas change over time and the implications these changes have on water demand
- observing on-farm activities such as existing irrigation trends and how irrigation behaviours have changed over time.

As the AGDC continues to develop it will become an increasingly useful resource to support policy and management decisions.

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