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Bureau of Meteorology

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Bureau of Meteorology
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In reply please quote

Hydraulic Fracturing Inquiry – NT Bureau of Meteorology input

Climate outlook for the Northern Territory

Below is a snapshot of the Northern Territory's future climate in relation to rainfall and temperature and its influence on our water resources.

Rainfall totals

Future projections provided by global climate models generally indicate little or no change in annual rainfall totals for the Northern Territory (figure 1) as a result of future greenhouse gas emission scenarios[1]. However, some climate models show a potential for significant changes in wet season rainfall using high emission scenarios in their assumptions, although there is *low confidence*[2] in projecting the direction of that change.

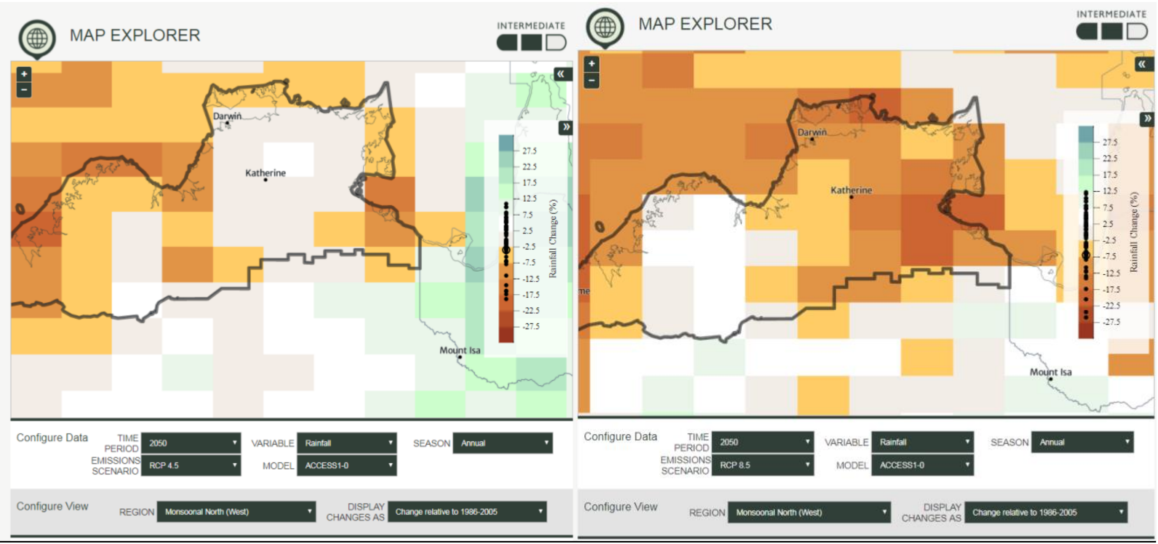


Figure 1: Projected percentage changes in annual rainfall for 2050 using ACCESS1-0 model for RCP4.5 (left) and RCP8.5 (right). In the RCP4.5 scenario, a 2.5% reduction in annual rainfall for the Monsoonal North (West) region [see appendix 1 for more information] is projected with uncertainty ranging between 12.5% increase to 20% decrease. The RCP8.5 scenario a reduction of nearly 7.5% is predicted, with a large uncertainty between 12.5% increase and 25% decrease. Source *Climate Change in Australia.*

Intensity and duration of rainfall

There is *high confidence* of a future trend toward increases in the intensity of extreme rainfall events (e.g. wettest day of the year, wettest day in 20 years). Similarly, recent historical trends in wet season rainfall across the Top End of the Northern Territory (figure 2), show a modest increase over the past 40-odd years. In contrast, a decreasing trend in rainfall in the early and late wet season (figure 3) indicates that an increasing proportion of rainfall is falling in the December to February period, effectively increasing the length of the dry season. There is considerable uncertainty around whether this trend will continue into the future.

[1] RCP: Representative Concentration Pathway – dependent on concentration of greenhouse gases used in modelling assumptions. RCP4.5 is a medium emissions scenario (roughly analogous to current-day emissions trajectory); RCP8.5 is a high-emissions scenario where CO_2 emissions are not curbed in the near future.
[2] Qualifiers used in *confidence* assessment to indicate assessed likelihood: *very high* (90-100%), *high* (66-100%), *medium* (33-66%), *low* (0-33%)

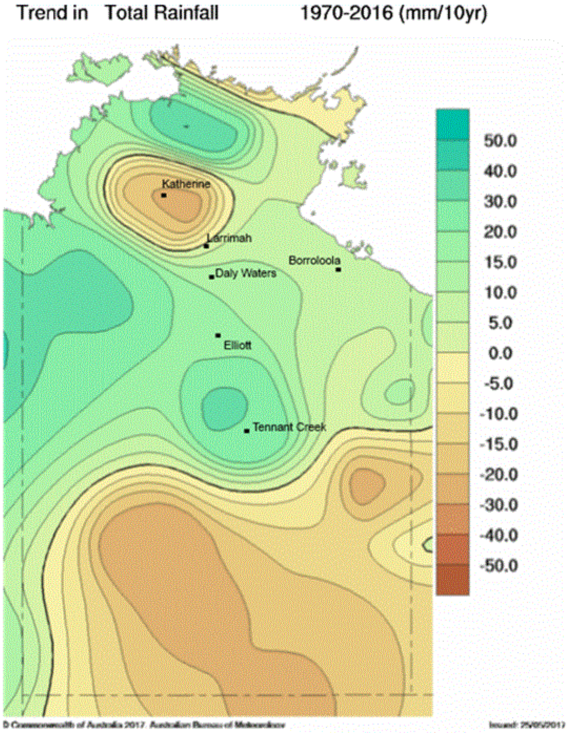


Figure 2: Annual rainfall trend (mm/10 years) for NT, 1970-2016

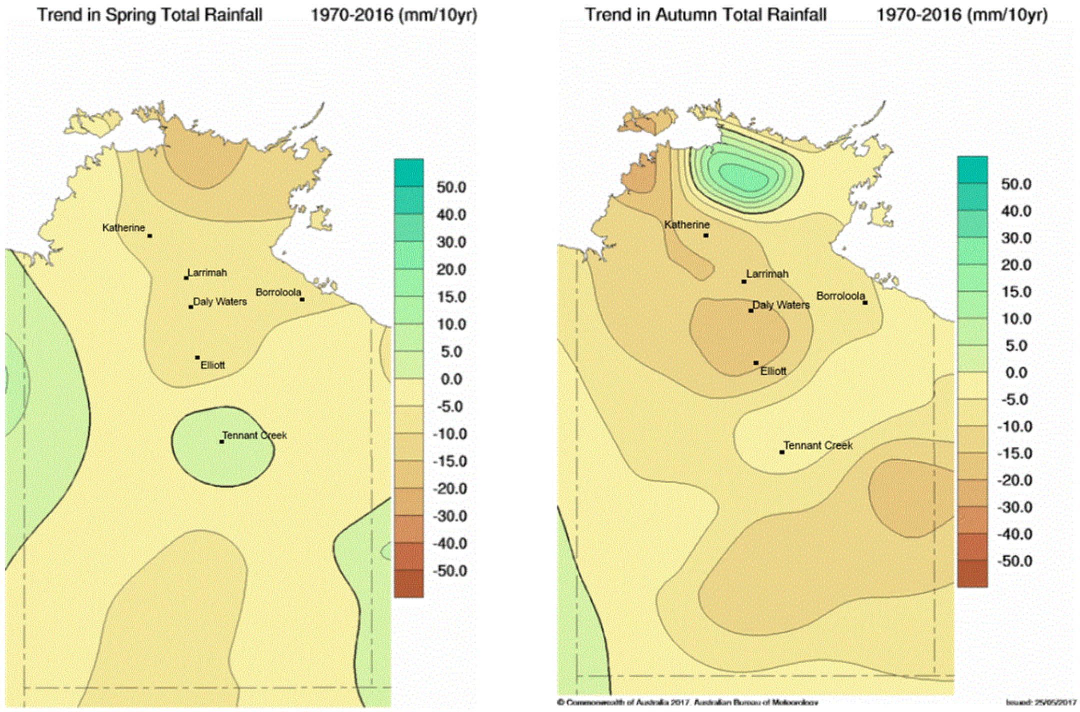


Figure 3: Rainfall trend (mm/10 years) for NT for periods September-November (left) and March-May (right), 1970-2016.
http://www.bom.gov.au/climate/change/index.shtml#tabs=Tracker&tracker=trend-maps

Based on the trend maps above, figures 2 and 3, the Beetaloo Sub-basin region has recorded an annual rainfall increase of approximately 10 mm per decade since 1970. In the September–November period a decrease of between 5 and 10 mm/decade has been observed; in the March–May period a decrease of nearly 10 mm/decade has been observed.

Temperature increases

There is *very high confidence* that warming will continue across the Northern Territory throughout the 21st century, with greater warming in inland areas than coastal areas (figure 4).

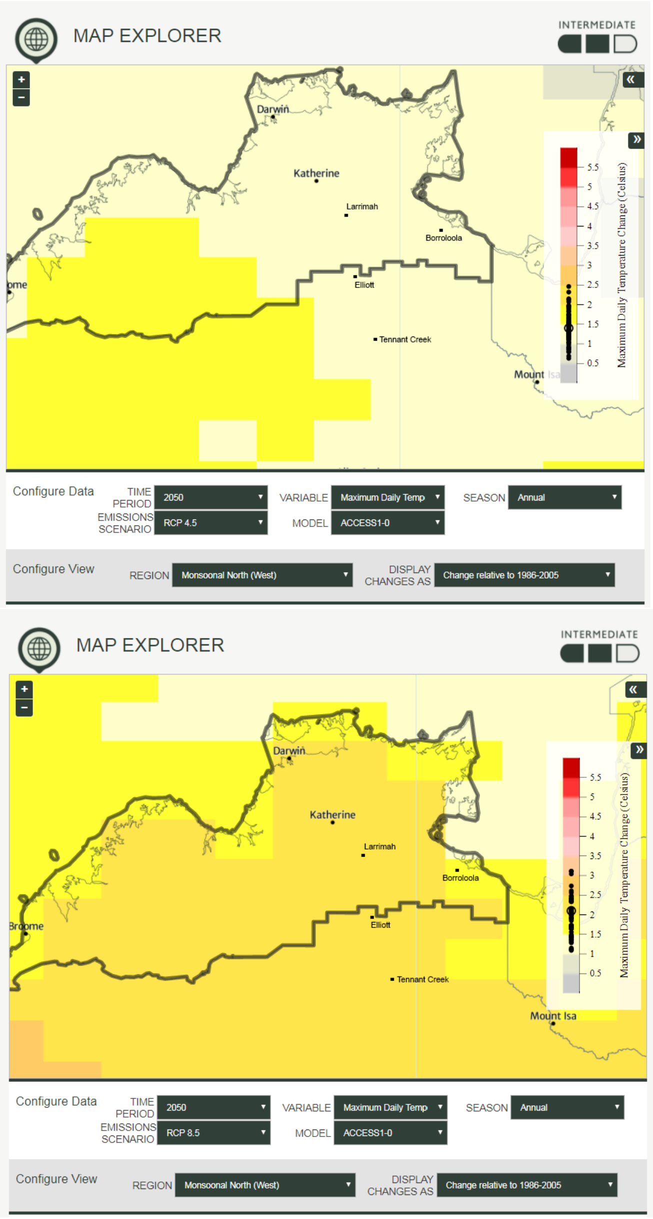


Figure 4: Projected annual mean surface temperature changes (degrees Celsius) for 2050 using ACCESS1-0 model for RCP4.5 (left) and RCP8.5 (right). In the Bettaloo Sub-basin the RCP4.5 projection indicates an increase in annual mean temperature by 2050 of 1.0-1.5 °C and 2.0-3.0 °C for the RCP8.5 emission scenario. Source *Climate Change in Australia.*

The projections in figure 4 are consistent with the observed trend for annual mean temperature increases across the Northern Territory since 1910 (figure 5).

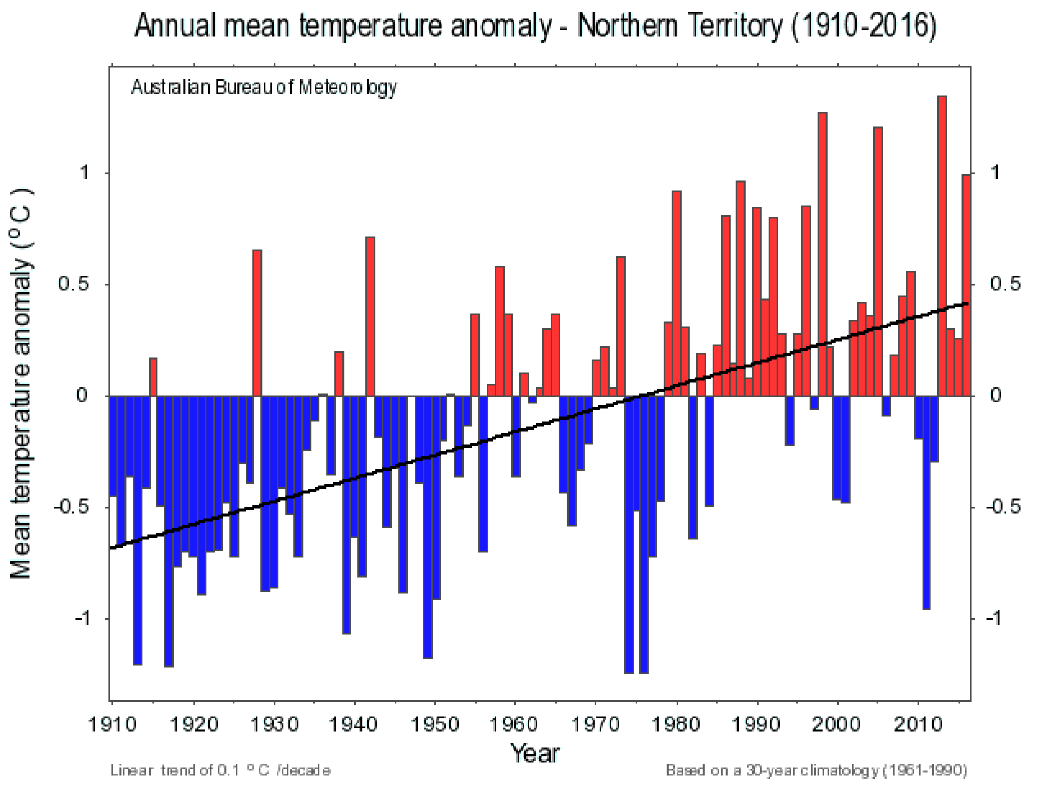


Figure 5: Annual meant temperature anomaly for Northern Territory 1910-2016 (based on 1961-1990 climatological average).
http://www.bom.gov.au/climate/change/index.shtml#tabs=Tracker&tracker=timeseries

Groundwater and recharge

Irrespective of changes to consumer demand, in a future warmer world where rainfall is likely to become increasingly variable, the availability of our water resources (both surface and groundwater) will be affected in different ways.

If future rainfall conditions remain similar to historical conditions, it follows that future runoff and groundwater recharge will also be similar to past levels. This is consistent with the findings reported in the Northern Australia Sustainable Yields Project (CSIRO, 2009). However, an increase in intensity of rainfall events during the wet season may result in an increase in runoff as large storm events can have a substantial influence on annual streamflow and surface flow volume.

The Bureau of Meteorology provides ready access to information on rainfall, runoff, evapotranspiration and deep drainage via the Australian Landscape Water Balance service (see figure 6). Daily data back to 1910 is available at a grid resolution of 5km x 5km.

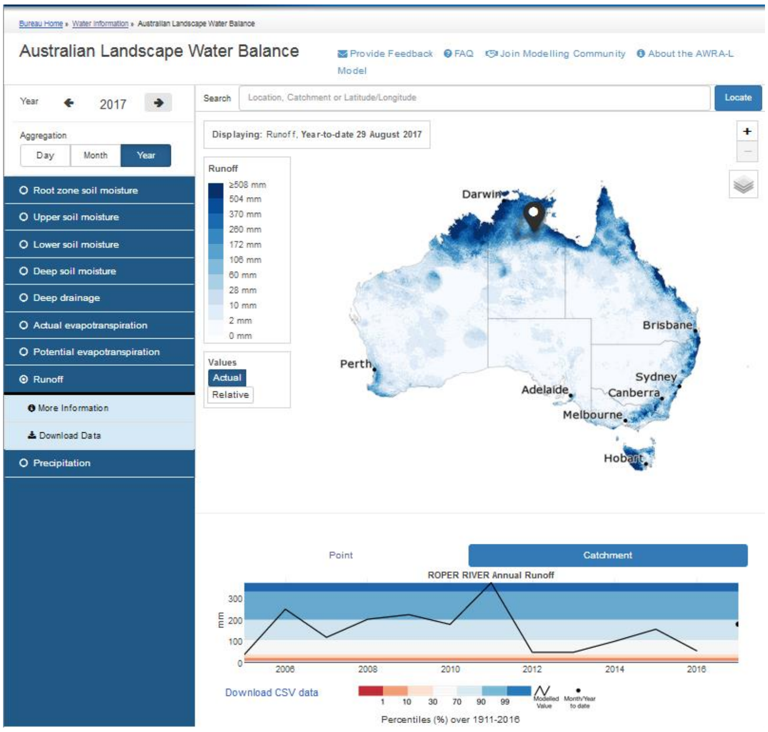


Figure 6: Graph of annual runoff for Roper River catchment, 2006-2016. http://www.bom.gov.au/water/landscape/

Evapotranspiration

Evapotranspiration, which has a strong correlation with temperature, is projected to increase, although there is only *medium confidence* in the magnitude of the change.

Increased evapotranspiration would have a lesser effect on runoff and recharge, although an increase in annual evaporation will have an effect on the available yield in surface water storages (e.g. Darwin River Dam). Increased evaporation is likely to result in an increase in water demand, particularly during the dry season. Further increases in water demand are possible if wet season rainfall occurs over a shorter time period and dry seasons become longer.

Location *(station number)*	**Rainfall (mm/yr)**	**Evaporation (mm/yr)**
Darwin *(14015)*	1722 *(1941-2017)**	2454 *(1957-2017)*
Katherine *(14903)*	1088 *(1943-2017)*	2270 *(1999-2011)*
Daly Waters *(14626)*	675 *(1939-2017)*	2960 *(1954-1970)*
Elliott *(15131)*	589 *(1949-2017)*	2743 *(1980-2010)*
Alice Springs *(15590)*	284 *(1941-2017)*	3142 *(1959-2017)*

* Period of record

Table 1: Long-term mean rainfall and evaporation

(Further explanatory notes regarding water and drainage information above are available in Appendix 3.)

Appendix 1

The climate projections in this report are based on the regional clusters displayed in figure 7. The Beetaloo Sub-basin spans part of the Monsoonal North (West) and northern Rangelands clusters.

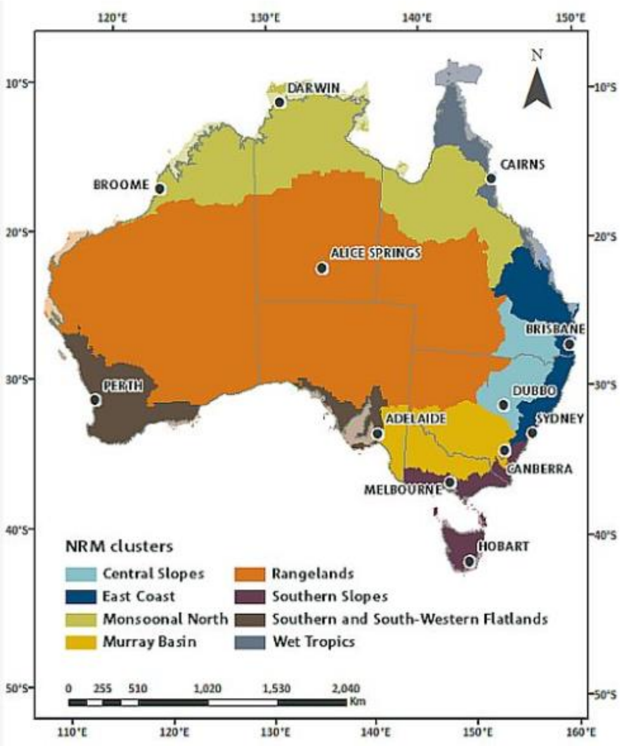


Figure 7: Map showing the regional clusters of Australia used for the climate change projections

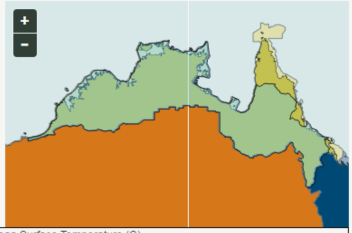
The projections in the body of this report are primarily based on output from the ACCESS1.0 climate model. For completeness, the following two tables are included. The tables include assessments by all forty-six international climate models used in the *Climate Change in Australia* projections.

MONSOONAL NORTH CLIMATE FUTURES

Go back

Change scenario: RCP 4.5

Change time period: 2050



		Annual Mean Surface Temperature (C)			
		Slightly Warmer < 0.50	Warmer 0.50 to 1.50	Hotter 1.50 to 3.00	Much Hotter > 3.00
Annual Rainfall (%)	Much Wetter > 15.00				
	Wetter 5.00 to 15.00		8 of 46 (17%)	2 of 46 (4%)	
	Little Change -5.00 to 5.00		19 of 46 (41%)	9 of 46 (20%)	
	Drier -15.00 to -5.00		3 of 46 (7%)	2 of 46 (4%)	
	Much Drier < -15.00			3 of 46 (7%)	

Consensus	Proportion of models
Not projected	No models
Very Low	< 10%
Low	10% - 33%
Moderate	33% - 66%
High	66% - 90%
Very High	> 90%

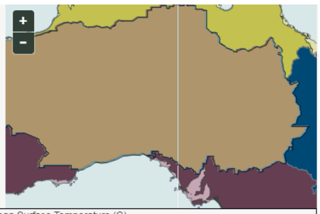
Table 2: Summary of climate model projections for annual rainfall and annual mean surface temperature for Monsoonal North cluster

RANGELANDS CLIMATE FUTURES

Go back

Change scenario: RCP 4.5

Change time period: 2050



		Annual Mean Surface Temperature (C)			
		Slightly Warmer < 0.50	Warmer 0.50 to 1.50	Hotter 1.50 to 3.00	Much Hotter > 3.00
Annual Rainfall (%)	Much Wetter > 15.00			1 of 46 (2%)	
	Wetter 5.00 to 15.00		5 of 46 (11%)	2 of 46 (4%)	
	Little Change -5.00 to 5.00		13 of 46 (28%)	9 of 46 (20%)	
	Drier -15.00 to -5.00		3 of 46 (7%)	10 of 46 (22%)	
	Much Drier < -15.00			3 of 46 (7%)	

Consensus	Proportion of models
Not projected	No models
Very Low	< 10%
Low	10% - 33%
Moderate	33% - 66%
High	66% - 90%
Very High	> 90%

Table 3: Summary of climate model projections for annual rainfall and annual mean surface temperature for Rangelands cluster

Bureau weather stations within the Beetaloo Sub-basin:

1. Daly Waters (16.26°S, 133.38°E): 1939-present (http://www.bom.gov.au/climate/averages/tables/cw_014626_All.shtml)
2. Elliott (17.56°S, 133.54°E): 1949-present (http://www.bom.gov.au/climate/averages/tables/cw_015131_All.shtml)

Appendix 2

The Landsat image below (figure 8) indicates surface water was detected on the Barkly Tableland in the southern portion of the Beetaloo Sub-basin in around 5–20% of observations. Landsat images are taken regularly throughout the year (every 16 days), so the imagery suggests surface water generally exists in the area for approximately 2 weeks to 2 months of the year, likely during periods of the wet season (December–April). The image below is derived from the Landsat satellite archive which spans the period from 1987 to present, captured at a resolution of 25 m x 25 m.

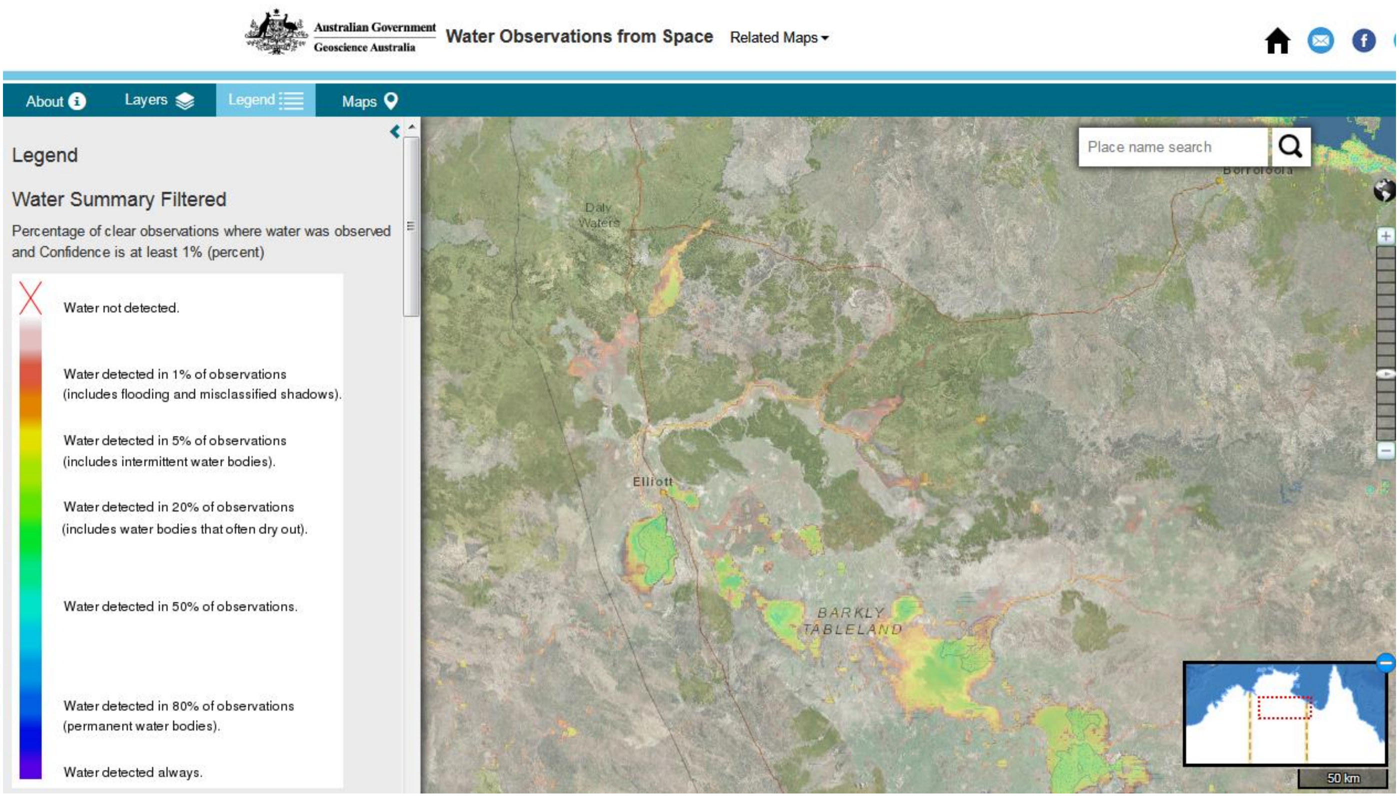


Figure 8: Satellite observations of surface water in the Beetaloo Sub-basin region. http://www.ga.gov.au/interactive-maps/#/theme/water/map/wofs. Courtesy of *Geoscience Australia*.

Appendix 3

Supplementary information: response to questions from NT Hydraulic Fracturing Taskforce

a) *We see the term deep drainage is defined as the volume of water that moves below vegetation root zones which may or may not enter the saturated zone and become recharge to the groundwater system by the Australian Water Information System. Could you please advise how deep drainage is calculated?*

The definition of deep drainage they quoted comes from the Australian Water Information dictionary and is slightly different to the conceptualisation of deep drainage in the AWRA-L (Australian Water Resources Assessment Landscape model). The water balance stores and fluxes presented on the Australian Landscape Water Balance website are estimated according to AWRA-L (see figure 9 below). Deep drainage is an estimate of the water that drains from the bottom of the model's deep soil layer (6 m) into the groundwater store. Soil drainage and moisture dynamics are based on water balance considerations for each layer, and unsaturated downward movement of water under gravity only. There is assumed to be no lateral drainage from the deep soil layer. Drainage from each layer is subject to limits imposed by water availability and hydraulic conductivity. Deep Drainage generally describes diffuse groundwater recharge.

For further details of the model and how deep drainage is calculated please see About the AWRA-L Model on the webpage (http://www.bom.gov.au/water/landscape/) and section 2.1 of the model description report Frost, A. J., Ramchurn, A., and Smith, A. 2016b. The Bureau's Operational AWRA Landscape (AWRA-L) Model. Bureau of Meteorology Technical Report.

b) *Please advise if any assumptions can be made regarding if and when deep drainage equates to recharge of the aquifer?*

The AWRA-L model assumes that the groundwater store is an unconfined aquifer directly below the soil stores and that deep drainage reaches the saturated zone in the groundwater store in the day immediately after it leaves the deep soil store.

If a region is strongly affected by limestone or other sorts of confined aquifers, this assumption will be incorrect.

c) *In relation to the cumulative deep drainage maps available on-line (see low res version in figure 9, below), please confirm if the white areas within Beetaloo are drainage lines and the big white area below Elliott is Lakes Woods.*

Figure 9: Example of model output from AWRA-L model (http://www.bom.gov.au/water/landscape/)

Based on a comparison between the supplied image (figure 9) and a Google maps satellite image, it can be confirmed that the white area south of Elliott referred to in the question is Lake Woods, and the white areas are most likely drainage lines/floodplains.

Regarding the 'white areas', i.e. depictions of lake and drainage areas, in the current version of the AWRA-L model water surfaces are not simulated: all areas are assumed to be land areas. The reason they stand out like this is because of the model using the underlying geology/soil data as an input.

In the current model version, deep drainage is approximately = 0 for these areas. We don't explicitly model them as water surfaces, but something in the soil/geological spatial input data (e.g. hydraulic conductivity) sets these areas aside from the surrounding countryside which makes them stand out in the deep drainage results. Unfortunately, this low deep drainage value is probably an unreasonable estimate. While the AWRA-L model performs well for soil moisture, evapotranspiration and runoff, estimates of deep drainage are less reliable. As a result, it is better to use the AWRA-L estimates as guidance for the relative differences in deep drainage spatially only (i.e. lower in one area than another). The absolute values mightn't be reliable, particularly in this region. This is an issue the model developers are aware of and are trying to address with the next version of the model which, it is hoped, will be released in the next 1-2 years. Another improvement expected in an upcoming model version will be specific interpretation of water bodies as water bodies.

d) Could you provide an interpretation of the image at figure 8 (as an example) of how surface water exists in the semi-arid regions of Beetaloo in the wet (and dry?) season.

Reply from BoM Groundwater Unit:

To the north of the Beetaloo Sub-basin, near Katherine, the limestone aquifers fill up during the wet season and drain through the dry season, keeping water in the rivers year round; it is highly likely that a similar process is happening here. Beetaloo is on the same regional limestone aquifer as Katherine.

In support of this, the Groundwater Dependent Ecosystem (GDE) atlas (see http://www.bom.gov.au/water/groundwater/gde/) assesses the Newcastle Creek (which flows through Beetaloo) as a potential GDE. Most of its length is ranked as 'low potential', but some short sections near Beetaloo are ranked as 'high potential', based on a national assessment. This means it is very likely that the creek is receiving groundwater baseflow near Beetaloo, which may keep the creek flowing regardless of the rainfall.

References

CSIRO and Bureau of Meteorology 2015, Climate Change in Australia Information for Australia's Natural Resource Management Regions: Technical Report, CSIRO and Bureau of Meteorology, Australia. https://www.climatechangeinaustralia.gov.au/en/

CSIRO 2009, Summary of reports to the Australian Government from the CSIRO Northern Australia Sustainable Yields Project

Appendix 4

Satellite images showing variation in surface water occurrence between 1 October 2015 (late Dry season) and 3 January 2016 (following extreme monsoonal rains).

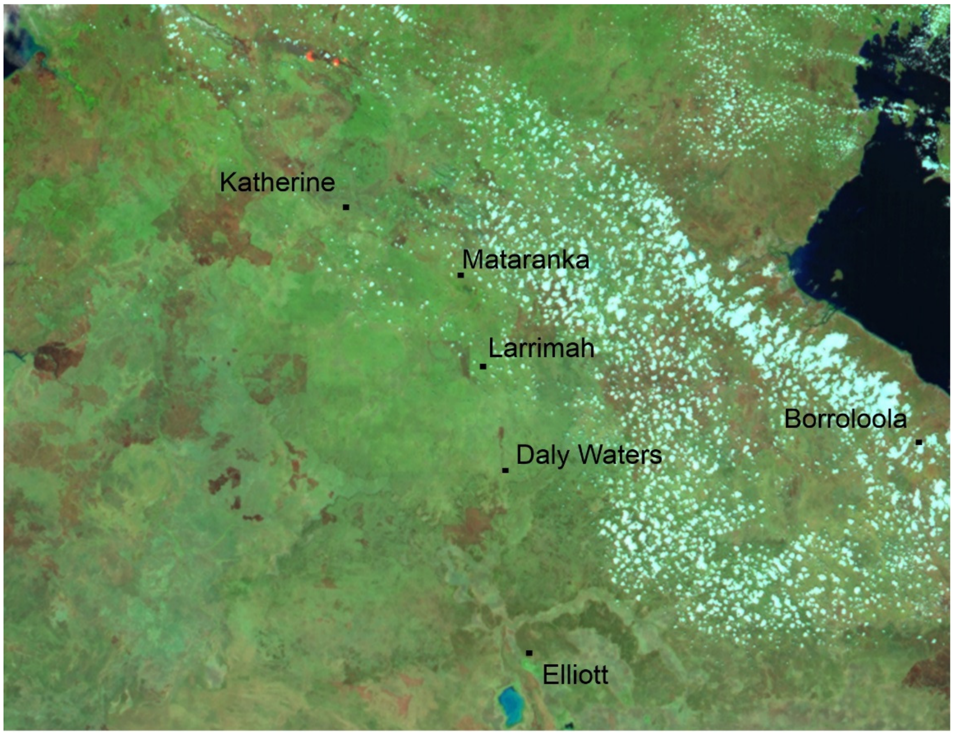


Plate 1: Satellite imagery 1 October 2015

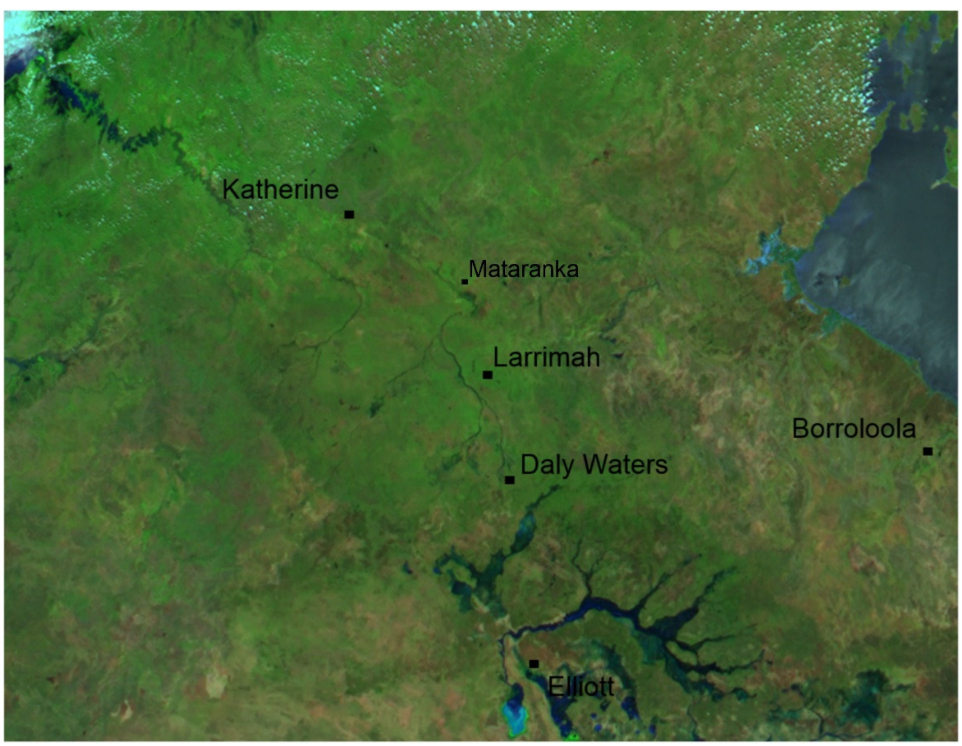


Plate 2: Satellite imagery 3 January 2016