climate change in

Townsville

and potential impacts on water quality

SEA O2
SUSTAINABLE DEVELOPMENT

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About

Townsville and Thuringowa City Councils established the Creek to Coral initiative in 2003 in partnership with the Queensland Environmental Protection Agency (EPA) and supported by the Great Barrier Reef Marine Park Authority (GBRMPA). Creek to Coral (since Council amalgamation in March 2008) is now a partnership between the three levels of government (Local, State and Federal), industry and community throughout the Townsville City local government area.

The Creek to Coral initiative is a locally adapted version of the South East Queensland (SEQ) Healthy Waterways Program focusing on local environmental concerns and issues in the context of Townsville's location in the Coastal Dry Tropics adjacent to the Great Barrier Reef.

Creek to Coral is managing the Coastal Catchments Initiative project for the Black and Ross River Basins and, with the assistance of its many partners, is developing a Water Quality Improvement Plan (WQIP) for our region stretching from Crystal Creek in the north to Cape Cleveland in the south, and including Magnetic Island.

The Black Ross WQIP will identify actions to improve the quality of the water flowing from the catchments of the study area to the Great Barrier Reef. It will also identify the most appropriate and cost effective actions to improve water quality while also accounting for the potential implications of climate change on water quality.

In March 2008, Creek to Coral commissioned local sustainability consultant SEA O2 to compile a report on the potential impacts of climate change in Townsville on water quality to inform the WQIP. While collating information for the report, climate change data for capital cities and some regional cities including Cairns, was identified. However, climate models had not been run specifically for the Townsville region. Townsville is part of the Dry Tropics and has a significantly different climate regime to neighbouring regions i.e. Wet Tropics (north) and Central Queensland Coast (south), and other parts of Australia. Subsequently, Creek to Coral commissioned CSIRO to run a climate model specific to Townsville. The CSIRO report *Climate Change Projections for the Townsville Region* (prepared for Townsville City Council by Kevin Hennessy, Leanne Webb, James Ricketts and Ian Macadam) was delivered in July, 2008.

1. Introduction


An airline contrail in the lower stratosphere, one of many forms of human influence on the atmosphere.

The Earth's climate naturally exists in a state of cyclic flux. There are annual cycles i.e. seasons, and long-term indeterminate cycles demonstrated by the coming and going of ice ages. While the climate is a complex 'chaotic' system, scientists have a good grasp of the fundamentals, the extent of climatic cycles in the past, and the potential for future change.

There is evidence that earlier humans (c. 100,000 years ago and onwards) influenced the climate, through deforestation and other impacts. Later human activities such as the cultivation of rice in paddies, and more recently the burning of fossil fuels, are contributing to an accelerated variability of the climate.

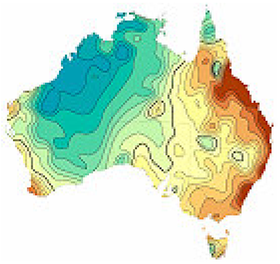
This variability occurs as a result of the increasing concentration of greenhouse gases in the atmosphere, particularly carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O). These gases absorb and re-radiate infra-red energy (heat) that would otherwise have passed out of the atmosphere into space.

As a result the atmosphere and the planet is getting warmer, hence the term ‘global warming'. The warming atmosphere and associated subtle variations in ocean and land temperatures is in turn leading to changes in the climate i.e. ‘climate change'.

Just as the distribution of carbon emissions (a generic term for all greenhouse gas emissions) is not evenly distributed around the planet, neither are the physical effects of climate change.

Understanding the impacts of climate change is a critical issue for today’s world. This is because a large body of evidence suggests that climate change could be a key factor in the demise of human civilization within this century. Understanding these changes can provide insights to avoid or, at least, mitigate the outcomes.

Climate change researchers use some of the biggest and fastest computers in the world, such as the ‘Earth Simulator' in Japan, to model future climates. Under the direction of the United Nations Intergovernmental Panel on Climate Change (IPCC), an elaborate consensus-based methodology has been developed to provide a range of estimates of the future climate. These estimates are based on ‘climate models', computer simulations of the climate that describe future climactic situations. The climate models are fed with ‘emissions scenarios', which are estimates of projected quantities of greenhouse emissions produced by society.



Climate Change in Australia demonstrated in this map.

The emissions scenarios range from an assumption that the global economy will move to a low energy path and carbon emissions will plateau and then fall, the B1 scenario. Alternatively, the global emissions will continue to rise at the current rate, a business as usual scenario referred to as the A1FI scenario.

This report seeks to inform the reader about projected climate change in the Townsville region with a focus on the potential impacts on water quality. This is achieved by first considering in more detail how climate change scenarios are developed, then reviewing the results of the climate change model that has been run by the CSIRO specifically for the Townsville region. Using these results a qualitative assessment of the potential impacts on local water quality can be made.

It should be noted that climate modeling is a very complicated process, riddled with assumptions and fraught with uncertainty. This is due in part to a lack of scientific certainties about natural systems, particularly non-linear feedback systems and the future volumes of global greenhouse gas emissions.

The best that can be said for climate models is that they represent the best information on hand at the time. Having said this, today's best information may not be as good as tomorrow's best information, so this data must be understood in the context of when it was written and all future findings since.

To illustrate this point, in the time that this report was written many new pieces of scientific evidence were announced in the world press. For example, one piece of news was UK/Finnish climate model that suggested that sea level rise may be as much as *4 times greater* than projected in the IPCC report (see Appendix 2).

The simple lesson to be drawn from this is that there is only one certainty in climate science: the climate is changing and will continue to do so.

2. Climate Models & Emission Scenarios

As considered in the introduction, climate change projections are based on climate models and emission scenarios. This chapter provides an overview of these elements. This information is provided to assist the reader to understand how climate change projection data should be used.

Climate Models
Climate models are mathematical formulae run on powerful 'super' computers. There are over 20 climate models in existence, run by organisations such as America's NASA, Australia's CSIRO, Germany's Max Planck Institute for Meteorology, and the Hadley Center in the UK.

The climate models all work in a similar manner, by dividing the atmosphere (or part of it) into cells and ascribing values to different variables. Each climate model goes about this differently, and as a result some models are more accurate at projecting climate changes in coastal areas, others in inland areas and so on.

Some more contemporary models combine large scale and micro (i.e. millimeter) scale views of how the climate changes. The fundamentals of a climate model involve the delineation of the 'model atmosphere' into square 'cells' which might be 100 – 200 kilometers along the side. Each cell is given a number of starting parameters such as average temperature, humidity, and the amount of solar energy it receives.

Over time parameters such as the total concentrations of greenhouse gases are increased. As the model is run, the cells interact with each other and the model demonstrates the state of the cells at each time interval.

Climate models undergo continual adjustment and improvement. A standard way to test the model is to run it backwards in time and compare its results to historical climate records. For an assessment of the reliability of climate models see Appendix 3.

Emissions Scenarios
A key input to the climate model is the total concentration of atmospheric greenhouse gases as described by the 'emission scenarios'. These scenarios were commissioned by the IPCC under the title the Special Report on Emissions Scenarios (SRES). The scenarios consider the total

concentration of greenhouse gases in the atmosphere based on storylines.

Storylines are qualitative assessments on the state of the global economy, in particular global gross domestic product (GDP) and population growth, both of which influence emissions volumes. The outcome of the storylines, scenarios and the climate models is a range of parameters that describe the future state of the global climate.

The emissions scenarios range from an assumption that the global economy will move to a low energy path and carbon emissions will plateau and then fall, the **B1 scenario**. Alternatively, the global emissions will continue to rise at the current rate, a business as usual scenario referred to as the **A1FI scenario**.

As the emissions scenarios were developed in the early 1990s, we now know from the measurement of atmospheric greenhouse gas concentrations and other parameters that the actual global emissions most closely match the A1FI scenario.

3. National and Regional Trends

Trends for Australia
According to bodies such as the Commonwealth Scientific and Industrial Research Organisation (CSIRO), climate change is expected to have an impact on several key variables within Australia. These include increases in atmospheric and sea surface temperatures, rising sea levels and decreasing annual precipitation rates.

Changes such as these have significant implications for other climatic and environmental factors including strengthening evapo-transpiration rates, reduced soil moisture levels, extending the range and frequency of coastal flooding, increasing the intensity of tropical cyclones and raising the height of storm surges.

In this way, climate change can have severe impacts on bushfire and drought incidence, changes in vegetation, erosion and consequentially on ecosystem health and water quality.

Trends for Queensland
The impacts of climate change across Queensland closely mirror those experienced by the wider continent, particularly in terms of temperature, sea level and evapo-transpiration increases as well as the related impacts of tropical storms, flooding, drought, bushfire and erosion.

The main difference relates to the proximity of areas to the coast with inland temperatures expected to increase more strongly than in coastal areas.

4. Climate Change in Townsville

Climate Change in Townsville 2015

The CSIRO *Climate Change Projections for the Townsville Region* report (Hennessy et al 2008) details projected climate variables for the years 2030 and 2070. The requirements of the Coastal Catchments Initiative (CCI) assessment for Townsville required climate change projections for a period consistent with the planning period of the Water Quality Improvement Plan (WQIP) i.e. 2008 to 2014. For this reason, climate change projections were sought from another source. The selected source of information was the online climate change calculator called Oz Clim.

Oz Clim is an initiative of the CSIRO and provides an opportunity for the public to assess the climate on a limited number of climate change parameters using a range of climate models. It must be noted, however, that inherent uncertainties and variability of climate research mean that figures generated by Oz Clim may contain some level of error.

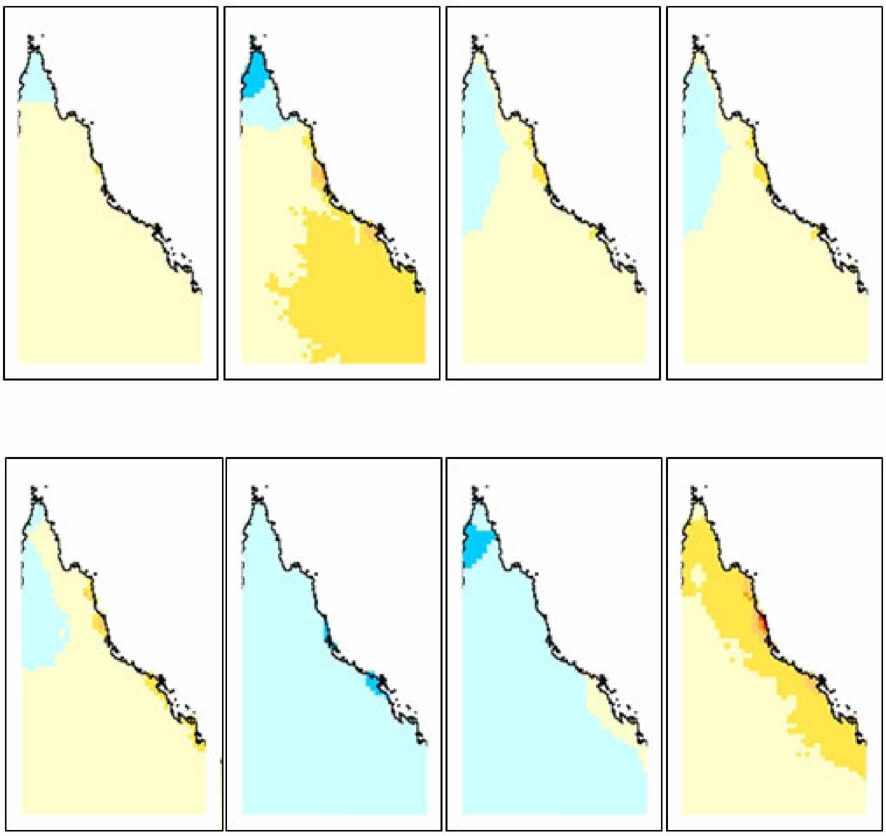
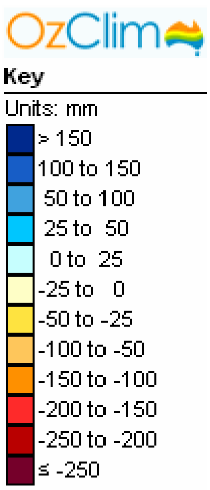


Figure 1. Changes in precipitation for Northern Queensland by 2015 using eight different models. From top left to bottom right: CSIRO MK3.0, GFDL-CM2.1, ECHAM5/MPI-OM, IAP FGOALS-g1.0, MRI-CGCM2.3.2, MIUB KMA ECHO-G, NCAR CCSM3, UKMO-HadGEM1.



For the year 2015, the closest year to the WQIP cut off date of 2014, the only climate parameters that are available from Oz Clim are average temperature and precipitation.

Projected changes in precipitation to 2015 for the Townsville region typically (75% of the models) show a reduction to the annual average rainfall of between 0mm and 50mm. Two of the models (MIUB KMA ECHO-G and NCAR CCSM3) show an increase of 0mm to 25mm (see Figure 1).

It should be noted that little difference in projections would be expected between models and between emissions scenarios until approximately 2030 due to the long lasting nature of greenhouse gases already present in the atmosphere. This is true for a range of variables, including the temperature and precipitation projections for 2015 generated by the Oz Clim software.

Climate Change in Townsville 2030 & 2070

This chapter provides a summary of the climate change modeling report for Townsville written by the CSIRO.

The CSIRO report *Climate Change Projections for the Townsville Region* (a report prepared for Townsville City Council by Kevin Hennessy, Leanne Webb, James Ricketts and Ian Macadam) was delivered in July, 2008.

As sea level was not modeled in the CSIRO *Climate Change Projections for the Townsville Region* report, additional data is made available from alternative sources.

The CSIRO climate change projections are presented as 10^{th}, 50^{th} and 90^{th} percentile units, reflecting the uncertainty inherent in global climate modeling. While the 10^{th} and 90^{th} percentiles give an indication of the range of uncertainty contained in the projections, the 50^{th} percentile, or central estimate, can be taken as the best estimate.

Thus for the purposes of uniformity and to ensure best estimates only the 50^{th} percentile values are focused on by this study.

The climate change projections for Townsville in the years 2030 and 2070 are shown for the following features:

- Mean Temperature
- Number of Days over 35ºC
- Precipitation
- Potential Evapo-transpiration
- Wind Speed
- Relative Humidity
- Fire Risk
- Solar Radiation
- Sea Surface Temperature and Sea Level Rise

Mean Temperature

Rises in temperature are measured relative to the average value recorded over the period 1980-1999, often denoted simply as 1990 levels.

Projections for 2030

Mean temperature is projected to rise by 2030. Based on data generated by the IPCC emissions scenario A1B, annual average temperatures in the Townsville area will be 0.8ºC warmer by 2030 than 1990 levels. This increase is expected to be consistent across all seasons.

Mean Temperature (°C)

Percentile	2030	2070
10th	0.6	1.9
50th	**0.8**	**2.7**
90th	1.2	3.7

Rises in temperature are measured relative to 1990 levels.

Projections for 2070

By 2070, annual average temperatures based on the A1FI scenario are projected to have risen 2.7ºC above the 1990 levels. This rise is uniform for all seasons except spring when projections are an increase of 2.6ºC above 1990 levels.

Number of Days over 35ºC

Changes for the number of days above 35ºC are measured relative to the average figure during the period 1971-2000.

The current average number of days over 35°C is 4 per annum.

Projections for 2030
This is expected to rise to 7 days per annum by 2030.

Projections for 2070
By 2070, it is anticipated that there will be 38 days over 35°C per annum.

Days over 35°C

Percentile	2030	2070
10th	6	18
50th	**7**	**38**
90th	9	86

Changes for the number of days above 35ºC are measured relative to the average value during the period 1971-2000.

Precipitation

Projections for changes in precipitation are measured as percentile differences from 1990 levels.

Projections for 2030
By 2030, projections using the A1B emissions scenario show that annual precipitation in the Townsville area is expected to fluctuate throughout the year. While the annual average projection is expected to be 2.3% lower than 1990 levels, winter projections are for a weaker decrease of 1.2% lower than 1990 levels. Strongest variation is seen during spring when decreases in precipitation lie at 5.8% lower than 1990 levels.

Precipitation (%)

Percentile	2030	2070
10th	-9.8	-31.6
50th	**-2.3**	**-7.5**
90th	5.7	18.4

Projections for changes in precipitation are measured as percentile differences from 1990 levels.

Projections for 2070
Decreases in precipitation are also expected by 2070. For the A1FI scenario, this drop in precipitation lies at approximately 7.5% less annual precipitation than 1990 levels. As with projections for 2030, projections for 2070 fluctuate throughout the year with winter showing the weakest decreases (4% lower than 1990 levels) and spring showing the strongest (18.8% lower than 1990 levels).

Potential Evapo-transpiration

Changes in potential evapo-transpiration are expressed as percentile differences from 1990 levels.

Projections for 2030
Based on data generated by the A1B emissions scenario, annual potential evapo-transpiration rates for 2030 are expected to rise by 3.3% from their 1990 base levels. Projections vary throughout the year, ranging from 2.8% of 1990 levels in spring to 3.9% of 1990 levels in autumn.

Potential Evapotranspiration (%)

Percentile	2030	2070
10th	2.1	6.9
50th	**3.3**	**10.7**
90th	4.9	15.8

Changes in potential evapo-transpiration are expressed as percentile differences from 1990 levels.

Projections for 2070
For 2070 projections, using the A1FI emissions scenario, annual potential evapo-transpiration increases by 10.7% of 1990 levels. The estimate for spring lies marginally lower at 9% while the autumn and winter months increase by 12.5% and 12.2% of 1990 levels respectively.

Wind Speed

Changes in wind speed are expressed as percentile differences from 1990 levels.

Projections for 2030
By 2030, average wind speed in the Townsville area is expected to increase 1.3% above 1990 levels. These projections are generated using the A1B emissions scenario and range across seasons from 0.7% in autumn to 2% in spring.

Wind Speed (%)

Percentile	2030	2070
10th	0.1	0.3
50th	**1.3**	**4.3**
90th	2.9	9.4

Changes in wind speed are expressed as percentile differences from 1990 levels.

Projections for 2070
The A1FI emissions scenario estimates that by 2070 wind speeds will rise annually by 4.3% of 1990 levels. As with projections for 2030, seasonal fluctuations see projections vary between 2.3% in autumn and 6.3% in spring.

Relative Humidity

Changes in relative humidity are expressed as percentile differences from 1990 levels.

Projections for 2030
The A1B emissions scenario show little change in annual average relative humidity from 1990 levels. Relative humidity during summer is projected to decrease by 0.2% from 1990 levels while winter projections increase by 0.1% of 1990 levels.

Relative Humidity (%)

Percentile	2030	2070
10th	-0.4	-1.4
50th	**0**	**0**
90th	0.4	1.2

Changes in relative humidity are expressed as percentile differences from 1990 levels.

Projections for 2070
The A1FI emissions scenario for 2070 does not project annual average relative humidity to change from 1990 levels. However seasonal projections vary a little, with a decrease of 0.7% of 1990 levels during summer and an increase of 0.2% in winter.

Fire Risk

Projections of fire risk are unavailable for the Townsville region, with the closest relative analogy being Rockhampton. Projections are only available for 2020 and 2050. Changes in the risk of fire are expressed as percentile differences from average 1974-2007 levels.

Projections for 2020
When the rate of global warming is low, fire risk for 2020 rises by 5% of 1974-2007 levels. When the rate of global warming is high, fire risk for 2020 rises by 30% of 1974-2007 levels.

Fire Risk (%)

Global Warming Scenario	2020	2050
Low	5	5
High	**30**	**140**

Changes in fire risk are expressed as percentile differences from average 1974-2007 levels.

Projections for 2050
When the rate of global warming is low, fire risk for 2050 rises 5% of 1974-2007 levels. When the rate of global warming is high, fire risk for 2050 rises by 140% of 1974-2007 levels.

Solar Radiation

Solar radiation is calculated as percentile deviations from the 1990 base levels.

Projections for 2030

By 2030, projections using the A1B emissions scenario show little change in in the Townsville area. Annual solar radiation is expected to increase by 0.1% of 1990 levels by 2030. This projection is relatively constant across the seasons.

Solar Radiation (%)

Percentile	2030	2070
10th	-1.1	-3.7
50th	0.1	0.2
90th	1.3	4.1

Changes in solar radiation are expressed as percentile differences from 1990 levels.

Projections for 2070

Small increases in solar radiation are also expected by 2070. Under the A1FI scenario, annual solar radiation is projected to increase by 0.2% of 1990 levels, with seasonal variation ranging from 0.8% of 1990 levels during the summer months to a decrease of -0.1% of 1990 levels in winter.

Sea Surface Temperature

Projections of changes of sea surface temperature near Townsville are measured relative to 1990 levels.

Projections for 2030

The A1B emissions scenario for 2030 projects that sea surface temperature near Townsville will rise by an average of 0.76°C.

Sea Surface Temperature (°C)

Percentile	2030	2070
10th	0.45	1.46
50th	**0.76**	**2.17**
90th	0.96	3.1

Changes in sea surface temperature are expressed as differences from 1990 levels.

Projections for 2070

For 2070, the A1FI emissions scenario projects that sea surface temperature near Townsville will rise by an average of 2.17°C.

Impacts on Sea Level

Note: While trends in sea level were discussed in the 2007 IPCC climate report as well as in the 2008 CSIRO *Climate Change Projections in the Townsville Region* report, **sea level has not been modeled for the Townsville area**. The most recent historical records for the area come from sources such as the Australian Institute of Marine Science (AIMS).

Data for sea level rise in Australia are sourced from the CSIRO *Climate Change Projections in the Townsville Region* report.

Sea surface temperature changes trigger widespread oceanic thermal expansion, melting of glaciers and the breakdown of large ice sheets, all of which powered annual global sea level rises of 1-2mm throughout the twentieth century (Lough 2007).

Sea Level Rise (m) (Australia)

Range	2030	2070
Low	0.13	0.32
High	**0.20**	**0.56**

Changes in sea level are expressed as height in metres above current Australian sea levels.

However, since the introduction of high-technology satellites in 1993 to track changes, recent global sea levels have been found at accelerated levels of 3mm per year (IPCC 2007). These estimates put the global sea level rise throughout the 21st century at approximately 18-59cm, with the potential to be 10-20cm greater with the melting of glacial masses (IPCC 2007).

Further, recent research taking into account the ever accelerating melting of large-mass ice sheets has generated substantially greater sea level rise estimates of between approximately 80 and 150cm by 2100, suggesting the IPCC estimates may be too conservative and enhancing concerns about impacts on coastal ecosystems and waterways (Black 2008).

For Australia, the CSIRO Climate Change in Townsville Report prepared by Hennessy *et al* (2008) projected sea level rises in 2030 to be between 13 and 20cm above current levels depending on the rate of global warming. For 2070, these projections were between 32 and 56cm above current sea levels. On a more regional scale, sea level records measured between September 1991 and May 2006 at Cape Ferguson, near Townsville, showed an annual increase of 2.9mm per year, higher than the national average of 1.2mm per year (Lough 2007).

5. Potential Impacts of Climate Change on Water Quality

Climate Change Impacts on Water Quality

As with the overall impacts of global warming on climate change the exact impacts of climate change on water quality are uncertain. The anticipated effects on water quality associated with projected changes in Townsville's climate have the potential to follow a number of different pathways depending on the type and range of climatic variation.

It has been possible to identify a range of factors associated with climate change, which could impact water quality. Quantifying the water quality impacts with any level of certainty will, however, require further research.

Key drivers for changes to water quality associated with climate change are primarily indirect, with the possible exception of a direct increase in the temperature of water bodies due to increases in average temperatures and extreme daily temperatures i.e. number of days with temperatures over 35 degrees Celcius.

Indirect impacts of climate change on water quality include:

- Increased temperature of water bodies;
- Changes to vegetation condition and/or coverage altering the levels of erosion;
- Changes to soil condition affecting vegetation growth and soil cohesion;
- Changes to fire regimes affecting vegetation cover and surface soil condition;
- Land use change from a less intensive to a more intensive use, with higher levels of pollutant run-off.

Water Quality Pollutants

The principle water quality pollutants being considered in the Black Ross Water Quality Improvement Plan (WQIP) are nutrients (Nitrogen and Phosphorus) and sediment. Water quality is negatively impacted when the concentration and/or load of nutrients and sediment is increased above guideline levels. Guideline levels are those considered to be optimum for the maintenance of ecosystem health of water bodies.

Sources of Pollutants

There are background levels of nutrients and sediment in water-bodies, which are a natural consequence of weathering and erosion and the movement of organic and mineral material to water-bodies through rainfall run-off and wind action. At times natural climatic variations may result in the transport of relatively large loads of nutrients and sediment to water-bodies e.g. drought and associated impacts such as fire and a reduction in vegetation cover, followed by a cyclone and/or an extended period of heavy rain.

Climate Change-Water Quality Linkages
As the majority of impacts of climate change on water quality are indirect it is important to understand the linkages between the two. Some of the interactions are relatively complex and even have the potential to result in an improvement in water quality. The Climate Change-Water Quality linkages we have identified are summarised below.

Increased Temperatures
The main driver of water quality impacts is considered to be the projected increase in average temperatures (up 2.7°C by 2070). There are five identified pathways by which increased temperature is likely to impact on water quality:

- Altered fire regimes;
- Increased temperature of water bodies;
- Changes to soil condition;
- Cyclonic conditions;
- Changes to vegetation.

Increased temperatures are anticipated to alter vegetation patterns by creating conditions favorable to certain species. These changes might include an increase in the expansion of grassland at the expense of forest, and the expansion of dry forest at the expense of wet forests.

Also, increased temperatures are likely to increase days at which vegetation suffers thermal stress, particularly in the height of summer when some communities might be on the edge already.

The two main implications associated with changes to vegetation are related to:

- The potential for increased run-off i.e. there is more run-off from grasslands than from mature forests
- Reduced groundcover leading to increased soil exposure and greater potential for erosion.

Altered fire regimes
Increased temperature, and associated increase in potential evaporation (10.7%) along with a reduction in rainfall (-7.5%) will increase the number of fire weather days, leading to an increased number and intensity of bush fires.

Fire is capable of altering vegetation patterns at the landscape scale over time as well as creating disturbed conditions in the short term. The disturbance can promote the growth of fire tolerant species and pioneering plants such as exotic weeds in the short to medium term. If there is storm activity before the ground cover has a chance to re-establish then there is a high likelihood of increased erosion as well as the transportation of the ash from the fire to waterways.

Increased temperature of water bodies
Increased air temperature will increase the temperature of water bodies themselves, which along with other factors could result in increased risk of algal blooms and oxygen depletion.

Increases in evaporation could also reduce volumes in water and flows in water bodies, thus increasing the concentration of nutrients and suspended sediments. Any reduction of shade from riparian vegetation as a result of altered vegetation communities and their structure, or through impacts of fire, also has the potential to increase the temperature of water-bodies.

Changes to soil condition
Increased evaporation, reduced rainfall, higher air temperatures and the marginal increase in wind speed, will result in a reduction in soil moisture. This can lead to increased quantities of airborne soil particles through erosion caused by wind. This can subsequently increase both turbidity and nutrient levels in water bodies. If climate change factors lead to appreciably reduced soil condition then the above ground production rate of plant material can also be affected. This could again lead to reduced groundcover and an increase in erosion potential.

Additionally if there is less soil biological activity then there is less organic material and by products that help bind the soil and again the potential for greater erosion and transport of sediment and nutrients to waterways.

Cyclonic conditions
While there is unlikely to be any increase in the number of cyclone days, severe cyclones may occur more often. Increased cyclone intensity will increase the potential for erosion and sedimentation. This might be further exacerbated by drier conditions and fires ahead of the cyclone creating greater opportunity for erosion.

Furthermore, increased storm tide height associated with sea level rise and increased cyclone severity are likely to lead to salt water intrusion further upstream as well as increased risk of erosion.

Land use changes
While difficult to quantify it is considered that one of the greatest impacts to water quality from climate change may result from land-use changes, particularly the potential increase in cultivated land in the region. This will of course be dependent on the suitability of soils, their location and a variety of interrelated social and economic issues i.e. the price of land.

This is considered a likely scenario as a result of the impacts of climate change in other parts of Australia. As drought continues to affect southern and inland areas currently under cultivation, land in northern Australia (and Queensland) may increasingly be sought after to help feed Australia.

Any increase in population and expansion of the urban footprint in north Queensland coastal areas resulting from the movement of people from less productive inland areas also has the potential to increase water quality impacts.

6. Conclusion

Climate modeling offers the best information to date that helps understand the future climate. While climate modeling relies on the fastest computers in the world, the legitimacy of the results is a function of the quality of the model and the accuracy of the input data.

The results summarised here are indicative of what the future might hold. However, this information should be read in context with the inherent limitation on climate modeling and the subsequent improvements in scientific understanding of the climate that are being discovered daily. This also relates to the projected impacts on water quality in the Townsville region.

What we can conclude from the short-term projections about climate change in Townsville is that there will be no significant direct or indirect impacts on water quality during the term of the Water Quality Improvement Plan (WQIP). This conclusion is based on the fact that there will only be minor climatic variations, which will not have major impacts on the distribution or structure of vegetation through direct association i.e. reduced rainfall and increased temperatures, or through indirect means e.g. increased fire weather. Therefore the main factor impacting water quality i.e. erosion and sedimentation, is unlikely to increase.

In the longer term there is greater likelihood of climate change impacting water quality as the variations in climatic factors increases. While we can make the linkages between climatic variability and potential water quality impacts we cannot state precisely that a certain increase or decrease in a climatic variable will lead to a corresponding increase or decrease in water quality.

While it would be relatively complex to do the most effective predictor tool for the impact of climate change on water quality is probably via the construction of an appropriate (numerical) model. This would require assumptions based on the relation between climatic factors and environmental factors such as vegetation extent and groundcover, fire, erosion, runoff, drought, evapotranspiration and soil condition, and the environmental factors and water quality. There would also be some more direct relationships between climatic factors and water quality e.g. water temperature and oxygen levels, which would need to be factored in. Climate change projection scenarios would then become the variable input to determine environmental changes and the subsequent cascade to water quality impacts.

The information presented on the topic of climate change impacts on water quality in this report is necessarily qualitative at present as the measurable impacts of climate change on water quality are not currently available. Research organisations are working on the subject, especially with regard to impacts on biodiversity and such studies may assist us to fine tune the assumptions and add quantitative measures to them in the future.

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Appendix 1: CSIRO Report

Appendix 2: Forecast for big sea level rise

SEA O2

SUSTAINABLE DEVELOPMENT

Appendix 3: How Reliable are Climate Models

SEA O2
SUSTAINABLE DEVELOPMENT