DISTRIBUTIONAL AND CONSUMPTIVE WATER DEMAND IMPACTS OF DIFFERENT TYPES OF ECONOMIC GROWTH IN TWO NORTHERN AUSTRALIAN RIVER CATCHMENTS

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Distributional and Consumptive Water Demand Impacts of Different Types of Economic Growth in Two Northern Australian River Catchments

ABSTRACT: Using an extensive array of primary and secondary data, this paper constructs, and then uses water-use-input-output (WIO) models to look at the way in which different types of economic growth affect (a) the incomes and employment of Indigenous and non-Indigenous households and (b) consumptive water demand in both the Daly River (NT), and the Mitchell River (QLD) catchments of northern Australia. Expansion of a sector generally creates larger employment and income benefits for non-Indigenous than Indigenous households. Moreover, expansion of the agricultural sector is associated with significant growth in consumptive water demand – a major concern since underground water resources are limited and dry season flows often rely on underground aquifers. Those interested in *closing the* (income) *gap* between Indigenous and Non-Indigenous people without placing scarce water resources at risk may thus need to seek development options that do not solely rely upon the expansion of the water intensive agricultural sector.

KEY WORDS: Northern Australia, Economic development, Indigenous, Water Demand, Input-Output

1. INTRODUCTION

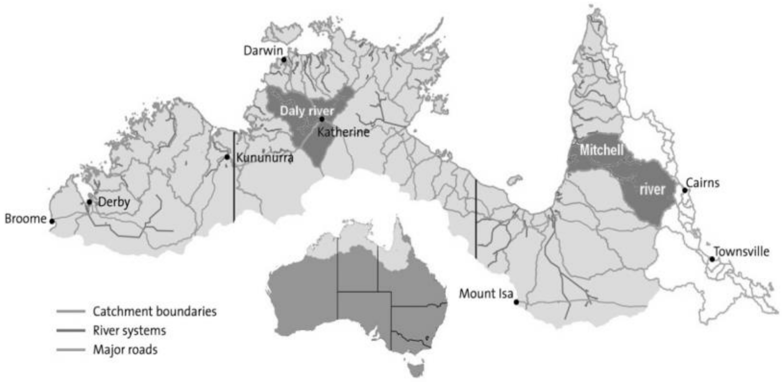
Australia is the driest inhabited continent on earth – boasting the lowest average rainfall, stream flow and run-off (Preston, 2009; State of the Environment Advisory Council, 1996). On average, only 12 percent of the nation's precipitation enters the rivers, although this varies from less than 3 percent to almost 24 percent in drier and wetter areas respectively (Australian Bureau of Statistics, 2003a). Moreover, many of the country's water resources are being used at, or have already exceeded sustainable extraction rates (Roberts *et al.*, 2006).

Northern rivers and groundwater systems are estimated to contain roughly 70 percent of Australia's fresh water resources (Land and Water Australia, 2005), and it is in these regions that the majority (65 percent) of run-off occurs (Australian State of the Environment Committee, 2006; Chartres and Williams, 2006). In comparison, the south, which comprises most of the large urban centers and agricultural activities, receives a meager 6.1 percent of the country's run-off (Chartres and Williams, 2006).

Nevertheless, very little *perennial* water exists in the north (CSIRO 2009a & b). At least part of the reason for this is because rainfall in this part of the world is both highly seasonal and highly variable. Australian river systems are the most flow variable in the world and in the North this is largely due to the fact that many areas receive no rain at all for 6-9 months each year during the winter dry (Kennard *et al*., 2010). Few northern rivers flow all year round, most are but dry, sandy creek beds for extensive periods each year, flooding – sometimes extensively – during the wet (Kennard *et al*., 2010). That Australia's largest Europeans settlements emerged where they did (i.e. predominantly in the south-east corner where perennial water exists) is not a mere accident of fate.

Nevertheless, the temporal scarcity of water has not prevented Indigenous owners from occupying lands in the North for thousands of years. Neither has it prevented more recent, European, migrants from settling in the region. Settlement has been possible at least partially because some perennial surface waters do exist (e.g. as billabongs). But that is an incomplete story: there are many underground aquifers throughout Australia which offer themselves as a viable alternative to surface water and they are often used as such (e.g. for stock, for urban irrigation, and even for human consumption). That said, many of the aquifers in Australia's north have been 'fully exploited', particularly those located in the Queensland Gulf area (Department of the Environment and Heritage, 2001). The region may be rich in some resources, but clearly not in all. Evidently, the "temporal and geographic scarcity of water [has served] as a constraint to development" (Bennett, 2005, p.1) in this part of the world.

The research presented in this paper is but one of many studies seeking to provide information to support the sustainable use, protection and management of Australia's tropical rivers. The formally defined focus area – termed the *Tropical Rivers* (TR) region (see Figure 1) – covers more than 1.3 million km^2 from the east side of Cape York in Queensland to the Kimberley in Western Australia. It includes 55 river basins, but this paper focuses on just two: the Mitchell in Queensland and the Daly in the Northern Territory (highlighted, Figure 1).



Source: Stoeckl et al., (2011).

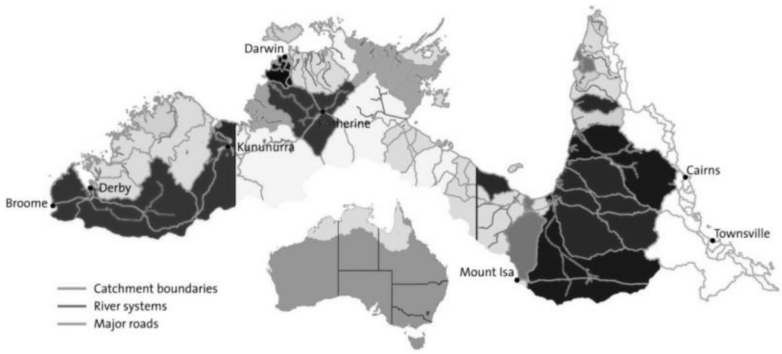
Figure 1. The Tropical Rivers region, the Daly and the Mitchell river catchments**.**

These catchments were chosen for intensive study for two key reasons. First, both were in the formative stages of water policy and planning, so a study such as this was well-timed to provide information that might assist those involved in the planning process. Second, both catchments were not as economically developed (in that residents had generally lower incomes and access to fewer economic resources) as the area in and around Darwin, but they were facing more development pressures than other catchments in the TR region (Larson and Alexandridis, 2009). Indeed, in their efforts to identify catchments that were socio-economically 'similar', Larson and Alexandridis (2009) found that:

1) The socio-economic characteristics of the Mitchell River were similar to those of the Flinders.
2) The socio-economic characteristics of the Daly were similar to those of the Flinders, the Ord and several of the northern Gulf catchments.
3) Loosely speaking, there is a development 'spectrum', with residents of the Darwin/Finiss Catchment having generally higher incomes and access to more socioeconomic resources than residents of the Mitchell (and Flinders) who in turn are relatively more 'developed' then residents of the Daly (and other 'similar'

catchments) who in turn, are more ‘developed’ than other catchments in the TR region (Figure 2).

As such, at least some of the development issues confronting those in the Mitchell and the Daly River Catchments are likely to: (a) post-date those facing residents in and around the Darwin area; (b) mimic those faced by other socioeconomically ‘similar’ catchments; and (c) precede those in other, less developed TR catchments. Lessons learned from these case-studies were thus deemed likely to be useful in other regions today, and in the future.



Source: Larson et al. (2013).

Figure 2. Map Showing Catchments Across the TR Region Using a Spectrum of Shades.
Catchments with similar shades are socioeconomically ‘similar’. The greater the contrast in shade, the greater the socioeconomic dissimilarities.

Encompassing 53 197km^2 and 71 471km^2 respectively, the Daly and the Mitchell, are relatively unique to the North, in that both have perennial rivers – although the Daly’s dry-season flows are fed by underground aquifers whereas the Mitchell’s are sustained by relatively high rainfall in the upper reaches (an unusual facet of northern rivers), supplemented in the late dry by discharge from the Artesian basin (CSIRO, 2009a; 2009b). Importantly, both rivers experience considerable seasonal variation in river flows (Kennard *et al.*, 2010); in the Daly, dry season flows are a very small fraction of total annual flow (CSIRO, 2009a) and although the Mitchell is perennial, other main water courses within that catchment cease to flow towards the end of the dry season, or in times of drought (CSIRO, 2009b).

In terms of demographics, their relatively small populations (of approximately 10 000 in the Daly, and 5 500 in the Mitchell), comprise about 27.6 percent and 22.6 percent Indigenous persons, and Indigenous populations are growing more rapidly than non-Indigenous populations (Carson *et al.*, 2009). In the Mitchell river catchment, the two most important industries – in terms of employment and income – are agriculture and government administration/defence, each sector contributing about 27 percent of the region's jobs (Larson and Alexandridis, 2009). Ninety-five percent of land use is directed towards production from unchanged land (predominantly grazing, but the Mareeba-Dimbulah Irrigation Scheme also enables the upper catchment to be viable for agriculture, horticulture and small scale cattle fattening projects). Three percent of the Mitchell catchment has land that is still in its natural condition and almost exclusively under conservation while land under intensive use (including urban, mining, industrial) is minimal at just 0.03 percent (Mitchell River Watershed Management Group, np; Larson and Alexandridis, 2009). The predominant crops grown are sugarcane, coffee, stone-fruit and a variety of tropical fruits (Connor *et al.*, 2009). Further agricultural developments in the Mitchell catchment have been discussed for many years, and several projects to supply water to these developments have either already been implemented (e.g. the construction of Lake Tinaroo, and the diversion of water from the Baron river for agricultural developments in the upper Mitchell) or have been deemed unsuitable (e.g. potential of installing a dam at the Pinnacles which could have stored 158 000 ML) (Connor *et al.*, 2009).

The Daly river catchment is heavily dependent upon the government sector – it provides close to 48 percent of all employment (Larson and Alexandridis, 2009). Agriculture (primarily irrigated) has been identified as having much prospect for further development. However, concerns have been raised: assessments of water availability have shown that while there is room for additional growth, water availability is likely to be a limiting factor (Daly River Management Advisory Committee, 2009). Accordingly, those charged with managing water resources in those catchments will have to be cognizant of the fact that further developments will place increasing pressures on the catchments resources. Moreover, as populations rise, these pressures may intensify.

Dependence upon the government sector is common in this region. Indeed across northern Australia, three sectors which include: (i) government administration and defence; (ii) Health and (iii) Education are responsible for more than 25 percent of employment in Australia's north (Stoeckl and Stanley, 2007). Those seeking to become less dependent upon the government, rightfully, look towards developing industries that capitalize on the region's comparative advantage: namely, abundant natural resources. As such, there is much interest in fostering the growth of agricultural, mining, and tourism enterprises.

The key problem here, however, is that all of these industries use and rely on the region's water resources. Of all these industries, agriculture has been identified as having vital importance to the future economic development of the region (Connor *et al.*, 2009; Daly River Management Advisory Committee, 2009; Stoeckl *et al.*, 2011). The Northern Australia Land and Water Taskforce (2009) notes that the sector could double in size within the next 15 years. However, there has been limited research into the use of water by this, or indeed any other industry in Tropical Australia. Several studies have looked at water use and demand by households (Australian Bureau of Statistics, 2010; Loh and Coghlan, 2003; Turner *et al.*, 2005) and industries (Australian Bureau of Statistics, 2010; Economics Consulting Services, 2004; Khan *et al.*, 2010). Some studies have explored the potential for sustainable use of water in northern Australia and its tropical rivers (Northern Australia Land and Water Taskforce, 2009; Stoeckl *et al.*, 2006) and some have even briefly looked at sectoral water use (Connor *et al.*, 2009; Daly River Management Advisory Committee, 2009). However, none have examined water use by households in this region, and although the Australian Bureau of Statistics (ABS) Water Account (ABS, 2001) reports on the sectoral water use at the state level, similar information is not available at a finer geographic scale in Australia's north. As such there is very limited information about the potential 'consequences' on water resources – conceptualized, here, as potential increases in the demand for scarce water resources – of the expansion of any (or all) of these key industries.

Moreover, the northern part of Australia contains a significant number of Indigenous people (~one-third compared to just two percent nationally – Carson *et al.*, 2009); a group of people who are at a significant socio-economic disadvantage (Hunter, 1999; Banks, 2007, Australian Institute of Health and Welfare 2010). However, to the best of our knowledge, no study has compared the financial 'benefits' accruing to Indigenous and non-Indigenous people (loosely interpreted here to be those associated with employment and income) of different types economic growth with at least some of the environmental 'costs' of that growth (e.g. increases in consumptive water demand).

This paper thus seeks to at least partially fill those information gaps. Specifically, it describes the way in which an extensive array of primary and secondary data, were compiled in a manner that facilitated the construction of water-use-input-output (WIO) models for both the Daly River (NT), and the Mitchell River (QLD) catchments of northern Australia. It then presents results from several simulations that look at the way in which the expansion of different types of industries affect (a) the incomes and employment of Indigenous and non-Indigenous households and (b) consumptive water demand in each catchment. The analysis thus provides insights into some of the distributional (i.e. Indigenous versus non-Indigenous) and environmental (specifically, changes in water demand) consequences of different types of economic growth – insights which could potentially be used by a wide range of government departments, NGO's and private enterprises when attempting to assess the desirability, or otherwise, of development proposals in Northern Australia.

Following this introduction (section 1) the paper is structured as follows: section 2 describes the way in which the WIO models were built, whilst section 3 presents the results of our simulations. Section 4 offers some concluding remarks.

2. THE MODELS

Although Australia is host to many world-class general equilibrium models that could, theoretically at least, be extended to include water-use variables, none provide information at a fine geographic scale in the North. The economic structure of remote northern economies differs, sometimes substantially, from that of urban and/or regional centres (Stoeckl and Stanley 2007). In addition a clustering analysis undertaken by Larson and Alexandridis (2009) suggests that there are significant socio-economic differences between the Daly, the Mitchell and Darwin. So information produced from any of the currently available models that describe more urbanised economies (e.g. Darwin in the Northern Territory) is unlikely to be relevant to those living in our key focal catchments: regionally relevant models are clearly required.

One option is to build a regionally specific "Green" computable general equilibrium (CGE) model. Unfortunately it can be extremely costly, in terms of both time and money, to develop such models. For example, the ORANI-NT model (based upon ORANI – a widely used Australian model developed by Peter Dixon in the 1970s – cited in Breece *et al.*, 1994), comprised more than 7983 variables, in 3249 equations (Knapman *et al.*, 1991) and the Monash model (which used ORANI as its base) took nine years to develop. The time frame associated with this project precluded that as an option, but it did NOT rule out the option of developing an IO model. Furthermore, CGE's use IO tables *as their base*. In fact, most of the CGE models that are in existence today, started 'life' as simple IO models; they were subsequently refined and embellished upon over the course of time. It was thus decided to build an IO model, reasoning that it could be refined and/or 'embellished' in future projects, perhaps subsequently transforming it into a genuine CGE that could consider price effects, alternative technologies and other more complex issues.

Conceptualisation

IO models are based on transactions tables which describe the economic structure of an economy. Set out in matrix format, the columns of the table show how a particular industry spends its money, whilst the rows indicate where an industry sells its output. Each element x_{ij} shows how much industry *j* (the column) spends with industry *i* (the row). By adding all elements in a column, the total expenditure of a particular industry *j* can be estimated. Looked at the other way, each element of each row x_{ij} shows how much industry *i* (the row) earns from (or sells to) industry *j* (the column). By adding all the elements of a row, the total value of sales for a particular industry *i* can be estimated. By definition, total expenditure (which includes provisions for profits) equals total income (sales). Hence, for any given industry, the sum of its column equals the sum of its row.

In matrix algebra:

$$(Ax)+(f)=(x) \tag{1}$$

Where:

A is a block matrix of direct input coefficients
f is a vector of final demands
x is a vector of sectoral outputs

As such, final demand can be characterised (F) as:

$$(f) = (x) - (Ax) = (I - A)(x) \tag{2}$$

Where:

I is the identity matrix

Hence, estimates of the total change in final demands that would occur in response to a change in demand for the final output of just one sector can be generated as follows:

$$\Delta(f) = (1 - A)\Delta(x) \tag{3}$$

Which means that the total regional change in output (Δx) that occurs as a result of the change in final demand (Δf) can be calculated as:

$$\Delta(x) = (1 - A)^{-1}\Delta(f) \tag{4}$$

Where:

$(1\text{-}A)^{-1}$ is often referred to as the Leontief (inverse) matrix

However, if the results of IO analysis are to be used to draw inferences about the population in general, an assumption that each sector within the model is essentially homogenous needs to be made. There is clear evidence to suggest that this is not the case for Indigenous and Non-Indigenous communities. Indeed, as highlighted by Altman (2001), the economic structure of Indigenous communities is quite different from that of Non-Indigenous communities. As such, Indigenous and Non-Indigenous householders are not expected to have similar earning and spending behaviors. This leads to questions regarding the efficacy of models which fail to differentiate between the groups – particularly models in regions like these, where Indigenous people comprise close to 25 percent of the population.

Fortunately, there are numerous techniques for adapting traditional IO analysis to suit a variety of different circumstances, and the one which is most pertinent in this instance is Miyazawa's extended [IO] framework.

Miyazawa's model allows analysis of the structure of income distributions, by endogenising consumption demands in the standard Leontief model (Miyazawa, 1976). Conceptually, this is equivalent to the idea of 'enlarging' the matrix of technical coefficients described above, to include coefficients that describe the earning and consumption patterns of different types of households.

More formally, the model can be depicted by re-writing Equation 1:

$$\begin{pmatrix} A & C \\ V & 0 \end{pmatrix}\begin{pmatrix} x \\ y \end{pmatrix} + \begin{pmatrix} f \\ g \end{pmatrix} = \begin{pmatrix} x \\ y \end{pmatrix} \tag{5}$$

Where:

x is a vector of output

y is a vector of total income for the different household groups (Indigenous and Non-Indigenous, in this instance)

A is a block matrix of direct input coefficients

V is a matrix of value-added ratios for the different household groups

C is a corresponding matrix of consumption coefficients for the household groups

f is a vector of final demands – except for household consumption

g is a vector of exogenous income for the household groups

Solving this system yields:

$$\Delta\begin{pmatrix} x \\ y \end{pmatrix} = \begin{pmatrix} B(1+CKVB) & BCK \\ KVB & K \end{pmatrix}\Delta\begin{pmatrix} f \\ g \end{pmatrix} \tag{6}$$

Where:

B = $(I-A)^{-1}$ is the Leontief matrix

BC is a matrix of production induced by endogenous consumption

VB(= *VxB)* is a matrix of endogenous income earned from production

L = VBC is a matrix of expenditures from endogenous income

K = $(1-L)^{-1}$ is a matrix of the Miyazawa inter-relational income multipliers

Researchers involved in this project, thus used this approach, since it allowed them to explicitly consider the effect on both industry and household incomes (Indigenous and Non-Indigenous) of changes in final demand. In addition the models were populated with data collected from a variety of different sources.

First, during 2006, a large-scale survey of the purchasing and import behaviours of almost 1000 private businesses and government organisations located across Australia's far north was conducted. This information was used in the manner described by Stoeckl (2007; 2011) to construct the matrix of coefficients for each catchment.

Next, ABS census data on the sector of employment for Indigenous and non-Indigenous workers was used to supplement the matrix of coefficients - adding a *value-added matrix*. Specifically, collection districts that lay either partially, or entirely within each focal catchment were identified, and specialized tables were ordered from the ABS, detailing the number of Indigenous and non-Indigenous people employed in each sector (E_j^I and E_j^{NI}) as well as the median incomes obtained (Y_j^I and Y_j^{NI}). An estimate of the total annual income going to each household group in each sector was then generated by multiplying the number of employees, by the weekly median income, by 52, and then that information was used to calculate the share of total income going to each household type from each sector (S_j^I and S_j^{NI}). Estimates of the proportion of total sectoral income paid to Indigenous (and non-Indigenous) households in the form of wages within each industry/sector, *j*, – i.e. the elements of the value-added matrix – were then obtained by multiplying S_j^I (and S_j^{NI}) with the corresponding technical coefficient (from the preceding section).

Finally, during 2009, a large-scale survey of the purchasing and import behaviours of households in the Mitchell and Daly River Catchments was conducted, so that a matrix of consumption coefficients could be added to the other matrices. The 318 mail-out surveys received from residents of the Mitchell River Catchment provided information about the expenditure patterns of 775 people, covering approximately 18 percent of the population of non-Indigenous people and almost 31 percent of all Indigenous people in that catchment. In the Daly River, information was collected from 219 householders, covering approximately 6.42 percent and 8.70 percent, respectively, of the non-Indigenous and Indigenous population in this catchment (NB: our estimates for Indigenous people are likely to overstate the true representativeness of the sample since ABS

Census counts tend to underestimate the actual number of Indigenous residents There are significant problems with the quality of data relating to Indigenous people (Australian Human Rights Commission, 2008). For a good discussion of these issues, see http://www.hreoc.gov.au/social_justice/statistics/index.html).

Incorporating Water Use

The ABS publishes data on the national and state-wide water use of sectors within the economy (which, for the most part, coincide with the ANZSIC sectors + the Household sector). These data clearly show that some sectors – for example the Agricultural sector – are higher 'consumers' of water than other sectors, say Retail, or Household. However, these figures do not give a complete story. To see why, note that some households use water to grow their own fruit and vegetables. But many household do not – instead choosing to purchase their fruit and vegetables from a store. While these households are not *direct* consumers of water for vegetable gardens, they are, nonetheless, *indirect* consumers of water for this purpose. So if only the *direct* uses of water (like those reported in the ABS accounts) are considered, some important pieces of information will be omitted. Fortunately, IO models allow both these types of water uses (direct and indirect) to be taken into account.

As noted above, Equation 6 can be used to calculate the total regional change in output (and household incomes) that occurs as a result of the change in final demand. In a similar vein, it is possible to calculate both the direct and the indirect changes to water demand (ΔW) that are likely to occur in response to a change in final demand by multiplying the TOTAL change in regional output by a vector that describes sectoral (direct) water use (w):

$$\Delta \mathrm{W} = \mathrm{w}' \Delta \begin{pmatrix} x \\ y \end{pmatrix} = w' \begin{pmatrix} B(1+CKVB) & BCK \\ KVB & K \end{pmatrix} \Delta \begin{pmatrix} f \\ g \end{pmatrix} \qquad (7)$$

Where:

w is a vector of direct sectoral water use requirements (w′ is the transpose of w),

W is a vector of total sectoral water use requirements

There is clear guidance on methods for incorporating water-use into input-output (IO) models (e.g. Kondo, 2005; O'Doherty and Tol, 2007). Guan and Hubacek (2008), for example, provide a very good framework for considering both water consumption and water availability within an IO model and, closer to home, Lenzen and Foran (2001) have published an IO analysis of Australian water usage. However, there is no regionally specific information available on the water use of different industries and households for the catchments considered here. Thus for this project, water use coefficients had to be estimated 'from scratch'. This was carried out differently for households and industry, as described below.

The water-use IO (WIO) model requires data on the water use per $ of output for each sector. Thus it was decided that estimates of these coefficients would be generated by dividing ABS estimates of total water consumption per industry within Queensland and the Northern Territory, by the associated Gross value added (GVA) for each sector (see Table 1). For consistency (i.e. to match water use data), we used 2000-01 estimates of GVA for these calculations.

Table 1. Litres of Water Consumed Per $GVA – by Sector and State (2001).

Sector	Queensland	Northern Territory
Agriculture	664.52	185.20
Mining	15.54	3.90
Electricity	111.18	54.28
Construction	0.13	0.07
Retail	1.60	3.54
Accommodation	2.76	1.63
Transport	1.89	3.50
Finance	0.86	0.59
Government	1.73	9.14
Culture	21.55	6.32

Source: author calculations using ABS data.

Evidently, water use per dollar of income varies greatly by industry sector. There are also differences across states – an observation that is likely to be at least partially attributable to different climatic and rainfall conditions and also partially attributable to differences in agricultural practices since different types of agriculture have vastly different water-use requirements (see, for example, Lenzen and Foran 2001). As such, it is clear that it cannot simply be assumed that the water-use coefficients which apply to Queensland as a whole will apply to the Mitchell, nor that those which apply to the Northern Territory as a whole will apply to the Daly. For quite legitimate reasons, water use coefficients will vary over time, and in response to a wide range of external drivers such as climate, policy, and technology. Therefore when conducting simulations, the state-wide water-use vectors from Table 1 were chosen to define a 'plausible' *minimum* and *maximum* water-use coefficient for each sector, within each catchment. In most cases, the *minimum* water-use coefficient was that of the Northern Territory estimates, the three exceptions being for the Retail, Transport and government sectors. These, same, *minimum* and *maximum* coefficients were used in both WIO models.

Household water use data was collected in conjunction with the household expenditure data in the 2009 survey described above. When collecting data, the researchers involved in this study were cognizant of the fact that few respondents would be able to provide precise information about the water used by their household each year (particularly those without water meters). So a series of questions was designed to elicit information about the extent to which various water-using appliances were used, as illustrated in Figure 3.

What type of washing machine do you have? ***Please tick appropriate box. If you do not have a washing machine, but use a Laundromat instead, then please tell us about the type of washing machine at the Laundromat***

☐ We do not have a washing machine – and wash our clothes by hand. ***(Please go to question 9)***

☐ Twin Tub ☐ Front Loader ☐ Top Loader

How many times per week does your household use a washing machine? ***Please tick appropriate box. If you do your washing at a Laundromat, please tell us how many times you use a washing machine at the Laundromat***

☐ We rarely use a washing machine (or do not have one)

☐ Once a week ☐ 4 times a week ☐ 7 times a week (approx once a day)

☐ Twice a week ☐ 5 times a week ☐ 14 times a week (approx twice a day)

☐ 3 times a week ☐ 6 times a week ☐ More than 3 times a day

Source: the Authors

Figure 3. Excerpt from the Questionnaire.

This information was combined with information about the average water used by a range of different appliances compiled from the Melbourne's Household Water Use Calculator, Water Wise and Brisbane Water (Melbourne City Council, 2003; Waterwise Brisbane, 2008) to generate an estimate of total household water consumption. For example, if the respondent indicated that their washing machine was a front-loader and that they did approximately 3 loads of washing each week, then researchers were able to conclude that the household used approximately 300 litres per week of water for washing (3 x 100 litres). This information was combined with other information about the number of people living in the house and the type (and use) of other appliances to generate an estimate of the total water used per household per week inside the home. Consequently, estimates of inside water use, are a function of (a) the number of householders; (b) the number of water-saving appliances; and (c) the use of water and water-saving appliances.

Householders were also asked about their water usage outside the home which differentiated between wet season and dry season use, and responses to this question were then combined with information about internal water use to generate an estimate of the total quantity of water used per week by each household during the wet and the dry season.

Table 2 shows data on household water consumption in the Mitchell and Daly catchments. It is in the order of 200-260 litres per person per day during the wet season (with most water consumption for internal household use). In the dry season, this increases to between 370 and 790 litres per person – the extra consumption largely due to the extra water used outside the house (in the garden, for the swimming pool, etc). These estimates seem ‘plausible’ in so much as our lower, wet-season estimates roughly accord with household water consumption figures from the ABS’s Water Accounts for Australia’s south east – where rainfall has a more even temporal dispersion than Australia’s north and may entice fewer householders to use significant quantities of water outside (e.g. Victorian water consumption was approximately 220 litres per person per day in 2001). Our upper estimates of household water consumption relate to the dry season in a hot climate (the Daly) and exceed the ABS’s estimates of the average estimate of household water consumption in the Northern Territory (420 litres per person per day). This is not surprising, since the ABS’s figures are a ‘whole of year’ estimate; it would be expected that dry-season consumption exceed that of the wet season.

Table 2. Average Litres of Water Used Per Person Per Day – by Catchment and Indigenous Status.

	Daly River Catchment		Mitchell River Catchment	
Type of use	**Indigenous**	**non-Indigenous**	**Indigenous**	**non-Indigenous**
General Water Use	20.00	20.00	20.00	20.00
Wash Water Use	24.49	32.65	29.93	33.31
Dishwater Use	11.46	14.67	16.12	18.74
Shower Water Use	104.90	68.96	133.82	62.87
Toilet Water Use	50.63	50.61	50.16	48.43
Leaking Toilet Water Use	27.50	14.26	13.29	19.90
Leaking Taps Water Use	84.78	125.17	93.00	118.61
Bath Water Use	3.99	4.10	3.87	1.59
Total Inside Water Use	152.53	183.11	215.49	165.11
Outside water use during the dry	285.33	604.07	156.59	393.55
Outside water use during the wet	51.01	75.94	9.23	66.39
Total daily water use during the dry	**437.86**	**786.05**	**372.08**	**558.10**
Total daily water use during the wet	**203.54**	**259.05**	**224.72**	**230.94**

Source: survey data collected by authors

Interestingly, in the Mitchell River Catchment daily inside water use is higher in Indigenous households than in non-Indigenous households and most of the ‘excess’ is attributable to the use of water for showers. One possible explanation for this difference can be found in the qualitative information collected during interviews: Indigenous householders generally earn much less than non-Indigenous householders (quantifiably verifiable) and are thus not wealthy enough to pay large electricity bills – instead some choose to shower many times a day during the hot summer months as a way of keeping cool (in lieu of air-conditioning).

Recognising that household water demand is every bit as likely to vary across a range of factors as industry water demand, researchers used data from Table 2 to generate a range of per-person water consumption estimates:

Minimum annual water consumption = (Total daily water use during the wet) * 365

Maximum annual water consumption = (Total daily water use during the dry) * 365

Dividing these minimum and maximum estimates of household water consumption by per-person income, thus allowed researchers to estimate *minimum* and *maximum* water-use coefficients for each individual. This information was then grouped by Indigeneity, and averaged, to generate appropriate lower and upper bound estimates of household water-use coefficients for use in the WIO model – in line with the *minimum* and *maximum* estimates derived for industry.

Allowing for Employment

Just as it is possible to define a vector of direct sectoral water-use requirements from which the total water requirements of a change in final demand can be calculated, so too is it possible to do this for employment. Specifically, it is possible to define a direct vector of sectoral employment requirements (e) which can be used to estimate the total change in employment (ΔE) likely to arise in response to change in final demand:

$$\Delta E = e' \Delta\begin{pmatrix} x \\ y \end{pmatrix} = e'\begin{pmatrix} B(1+CKVB) & BCK \\ KVB & K \end{pmatrix}\Delta\begin{pmatrix} f \\ g \end{pmatrix} \tag{8}$$

Where:

e is a vector of direct sectoral employment requirements, (e′ is the transpose of e),

E is a vector of total sectoral employment requirements

This general approach was used here, although researchers distinguished between Indigenous and Non-Indigenous employment, thus working with a matrix of employment requirements, rather than a vector (as is done with water).

When populating the vector with data, state-wide data was used to generate an estimate of the average number of employees per dollar earned within each sector for each state (specifically, they divided the total number of employees within each sector by each sector's GVA) – since both employment and GVA data was not available at the catchment level. These estimates were then converted into estimates of the number of Indigenous and Non-Indigenous employees per dollar of output using data supplied by the ABS to apportion the total number of employees per \$M of GVA across household types. For example, the number of Indigenous employees per dollar of GVA in the Agricultural sector in the Daly was calculated as:

$$\frac{\text{No of Indigenous employees working in the Agricultural sector}}{\text{Total no of employees working in the Agricultural sector}} \times \text{Employees per \$ GVA in the NT}$$

To ensure that employment and GVA data all related to the same period, 2006 output data were used. .

A Preliminary Caution about the Interpretation of Results

When IO tables are used to estimate the impact of an increase in demand in one sector, it is implicitly assumed that the extra revenues received by that sector will be distributed according to the current, observed (average) expenditure patterns.

From the perspective of a householder, using observed expenditure patterns to predict changes in expenditure that may result from changes in income is tantamount to assuming that the marginal propensity to consume (MPC) is equal to the average propensity to consume (APC). Ceteris paribus, if consumption (C) is a linear function of income (Y), comprised of both an autonomous (CA) and an induced component that increases with income (CI), then the higher is the MPC and/or the smaller is CA relative to Y, the closer will the APC be to the MPC, and the more 'palatable' will be the assumptions underlying IO analysis.

From the perspective of businesses, this is equivalent to assuming that inputs are always used in fixed proportions (i.e. Leontief technologies) and that production technologies are constant across time. IO analysis also assumes (even if only implicitly) that prices are constant. Conceptually, it is as if these 'limitations' mean that IO models provide information about the maximum, likely, outward shift of a demand curve. IO analysis is unable to allow for the fact that subsequent changes in price and/or production methods may 'erode' some of that initial impact with the economy. In other words, IO models are demand-driven. Without supply-side information (like that collected for full-scale CGE models), 'a supply curve' cannot be added to the model, so IO cannot be used to make accurate predictions about the 'final' impact of a change on either prices or quantity. Although some argue that these limitations mean that IO analysis is more suited to short-term analysis than to long-term analysis, such an interpretation is not strictly correct. As clearly argued by Wilting et al., (2004), valid long-term projections can still be produced with IO, providing that (a) exogenous changes (the development 'scenarios') are being modeled, and (b) a reference base is used – e.g. comparing the likely change in incomes after 2006 from growth scenario *A* with the changes from scenario *B*.

3. SIMULATION RESULTS

Establishing a Base-Line

The first step of the modeling exercise required researchers to establish a starting-point (or base year) for key variables. In all cases, this was assumed to be 2006, since that is the year during which most of the data that populate these models were collected.

The 2006 ABS census data referred to above were used to estimate total employment in each industry/sector for each catchment (differentiated by Indigeneity). In each sector, estimates of income (GVA) were generated by multiplying ABS state-level estimates of $GVA per employee by ABS census estimates of the number of employees within that sector in that catchment (also differentiated by Indigeneity). Survey data were used to estimate baseline aggregate household income (household income = average per-person income x estimated resident population). We did this because the ABS income data only provided information about the income which householders earn from industry, and may, therefore, have omitted income from other sources.

The upper and lower-bound industry water use coefficients were multiplied by estimates of GVA during 2006 to generate upper and lower-bound estimates of the total amount of water consumed by each industry/sector within each catchment. For householders, upper and lower bound estimates of total annual water use were generated by multiplying daily dry-season (upper-bound) and daily wet-season (lower-bound) estimates of per-person water use (see Table 6) by 365 and by estimates of the total population for each household type (i.e. Indigenous and non-Indigenous). These estimates are presented in Table 3.

Table 3. Estimated Total Water Consumption by Sector and by Catchment (ML, 2006).

Sector	Daly River Catchment		Mitchell River Catchment	
	Lower bound	**Upper bound**	**Lower bound**	**Upper bound**
Agriculture	7 794 223	27 966 140	15 145	25 619
Mining	381 239	1 518 556	14 680 611	52 674 915
Electricity	168 394	344 933	1158	2239
Construction	2296	4441	44 783	152 651
Retail	54 282	120 261	258 951	530 429
Accommodation	17 507	29 616	12 350	17 996
Transport	45 110	83 766	106 316	561 417
Finance	27 361	39 867	163 742	652 220
Government	261 983	1 383 447	38 382	85 036
Culture	65 325	222 671	25 339	47 053
Indigenous Households	205 046	441 090	101 544	168 132
Non-Indigenous Households	684 566	2 077 216	359 257	868 197
Total	**9 707 332**	**34 232 004**	**15 807 578**	**55 785 904**

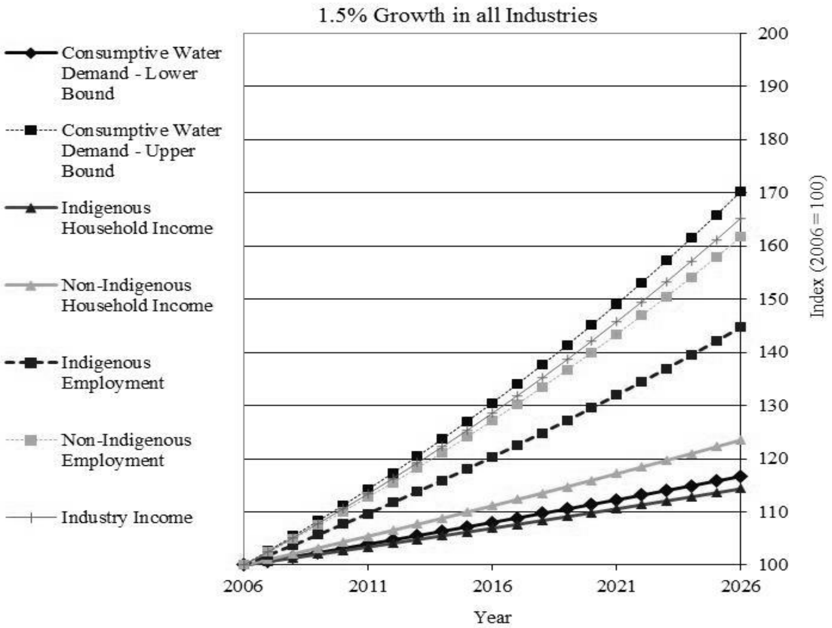
Source: author calculations using ABS data.

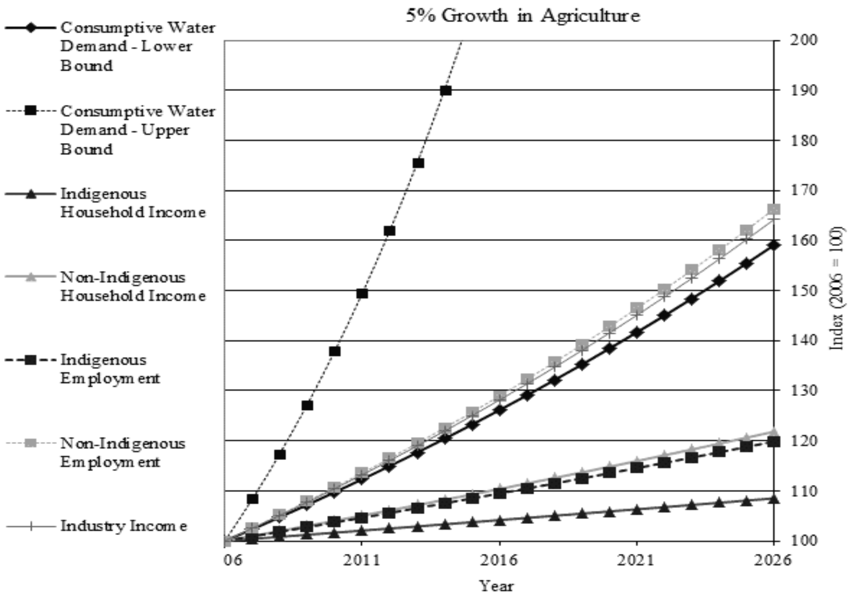
The Department of Natural Resources, Environment, Arts and Sport (2009, p.13) reports that in 2006/07 an estimated 1 085 ML of water was used from the Tindall Aquifer for 'public water supply'; an additional 12 456 GL was used for agriculture (including Horticulture), with 1 195 GL used for industry, and 1 128GL used for rural stock and domestic purposes. At close to 16GL in total, this is higher than our lower bound estimates of water use (9.7GL) and just under one-half of our upper bound estimates of water use (34.2GL) for the entire Daly Catchment during 2006. As such, it seems that the actual quantity of water used in this catchment during 2006 is likely to be between the upper and lower bound estimates presented here. Evidently, the figures presented in Table 3 may not be 'precise', but they are, at least 'plausible'. Baseline water consumption was thus taken as the mid-point of water use from Table 3 – amounting to a total (across all industry and household sectors) of 22GL and 36GL per annum in the Daly and the Mitchell, respectively.

The Growth Scenarios

The 2009-10 budget forecasted economic growth of approximately 1.5 percent over the 2010-11 financial year (Commonwealth of Australia, 2009). So in the first instance, a 1.5 percent growth scenario across all industries was performed. This was followed by other scenarios investigating a 5 percent growth in agriculture, mining and tourism respectively – the three main industries thought to offer prospects for development. The 5% growth rate was chosen because it is in line with the Northern Australia Land and Water Taskforce's (2009) observations that Agricultural production could double within the next 15 years. The models were used to calculate results for one year, and then extrapolated for the next 20 years.

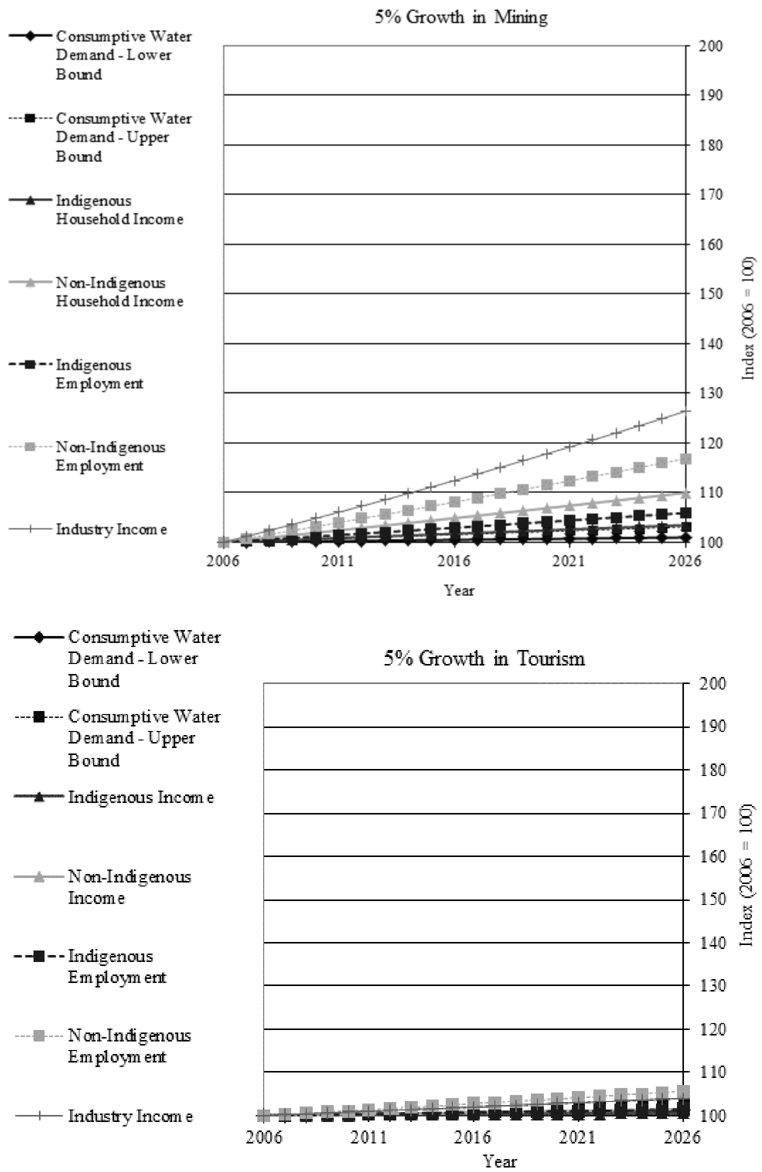
Figure 3 and Figure 4 depict the potential impact of each of the respective growth scenarios in each of the catchments. In each chart there are separate lines showing the projected growth in Indigenous and Non-Indigenous incomes and employment from the base year (2006). Each chart also shows the projected increase in water demand – although there are two 'water demand' lines on each chart: one derived from the low water use coefficients, and one from the high water use coefficients. These lines can thus be loosely interpreted as showing a range of water demand estimates – that range dependent upon the water-using habits of each community. From these charts, several observations can be made:





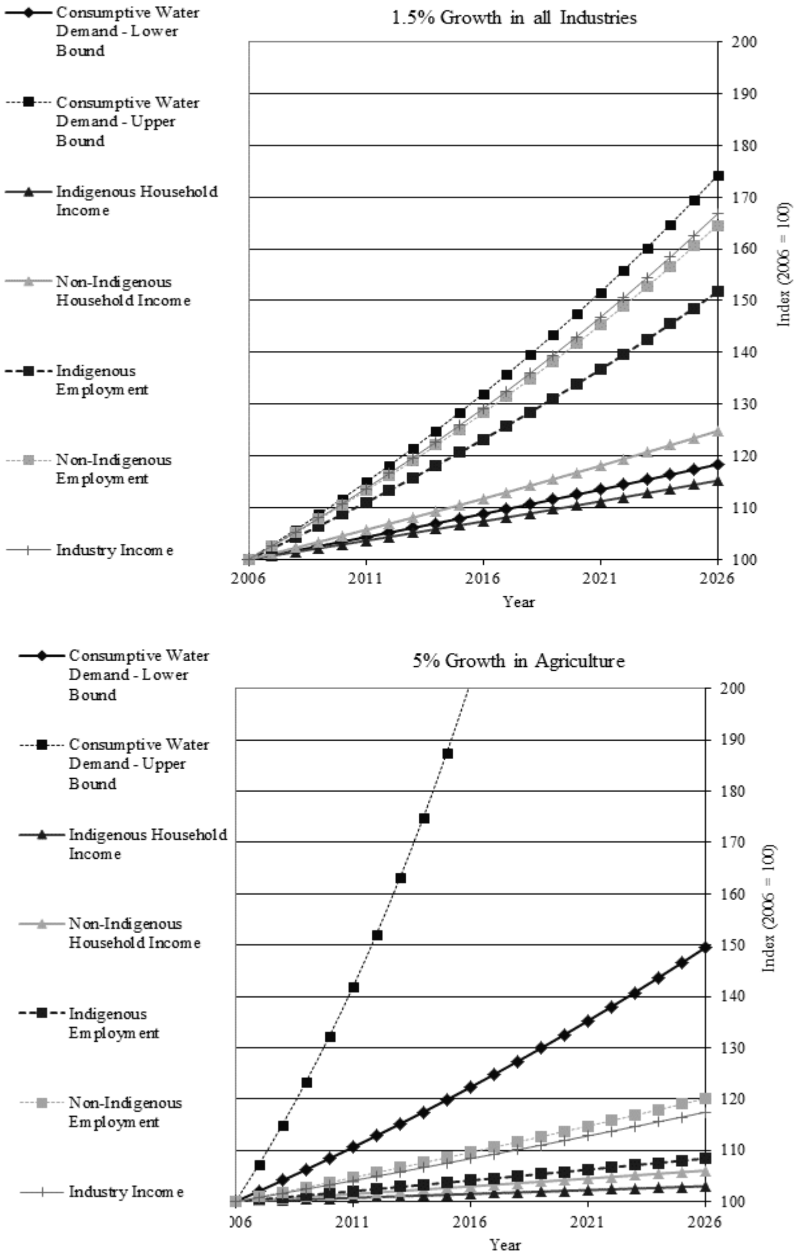
Source: the Authors

Figure 4a. Growth Scenarios in the Mitchell River.



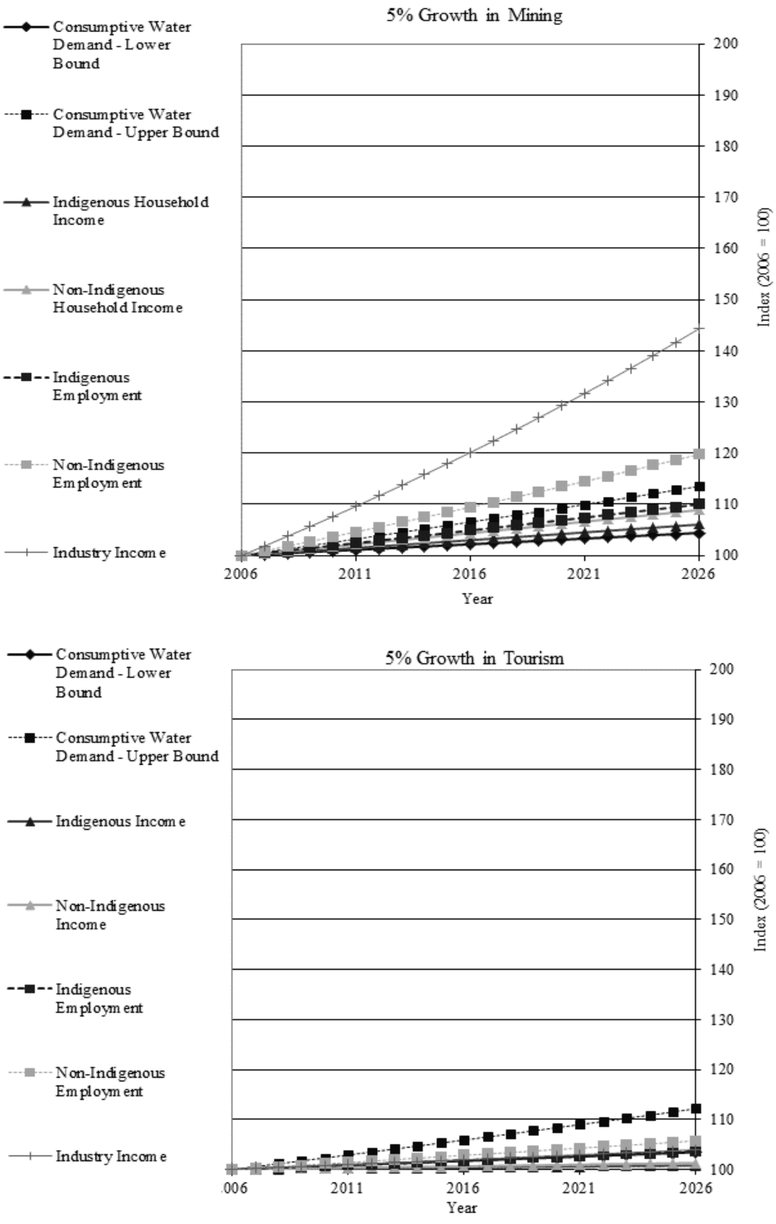
Source: the Authors.

Figure 4b. Growth Scenarios in the Mitchell River.



Source: the Authors.

Figure 5a. Growth Scenarios in the Daly River.



Source: the Authors.

Figure 5b. Growth Scenarios in the Daly River.

(a) 1.5 percent growth per annum across all industries

The 'balanced' growth scenario (of 1.5 percent per annum across all industries) significantly out-performed all other scenarios for employment and income in the Daly. It was one of the top two generators of income and employment in the Mitchell (alongside the 5 percent growth in agriculture scenario). Within 20 years, this scenario increased industry income and non-Indigenous employment to levels that were close to 1.6 times greater than in 2006. Indigenous employment outcomes were more modest – rising to between 1.4 and 1.5 times the 2006 levels. This balanced growth scenario was also associated with moderate increases in consumptive water demand – rising to between 1.2 and 1.7 times 2006 levels depending upon whether lower or upper bound estimates were used.

(b) 5 percent growth in agriculture

In the Mitchell River, growth in the agricultural sector generated substantial increases in business/industry incomes and in non-Indigenous employment. Outcomes for Indigenous people were much more modest. If growth in agriculture is achieved using water-efficient techniques ('mimicked' here, with the lower-bound water use coefficients), then in 2026, our models predict that consumptive water demand would be just 1.6 times greater than 2006 levels; but consumptive water demand could be more than double 2006 levels in less than a decade if higher water-use coefficients prevail.

Income and employment outcomes associated with the agricultural scenario were more modest in the Daly than in the Mitchell, but pressures on consumptive water demand were similar in both catchments. Outcomes for Indigenous people (incomes and employment) were also very modest in both regions – rising by less than 10 percent, in total, over a 20 year period.

(c) 5 percent growth in Tourism

The tourism scenario delivered the smallest 'returns' to income and employment for both Indigenous and non-Indigenous households, in both catchments. This is a consequence of the fact that tourism currently makes a relatively small contribution to these economies (just 3 and 2.3 percent of the Mitchell and Daly River's GVA, respectively). Consequently, 5 percent growth in tourism represents a very small increase in economic activity (5 percent of 3 percent).

(d) 5 percent growth in Mining

The mining scenario delivered marginally better household income and employment outcomes to both Indigenous and non-Indigenous households than did the tourism scenario, but the returns were still quite small. In contrast, the associated increases in industry output/incomes were relatively good and even out-performed those of the agricultural scenario in the Daly River. The predicted increases in consumptive water demand were similar for the mining and tourism scenarios. However, care must be taken when interpreting data relating to the Mining and Manufacturing sector: as noted by the NLAW taskforce (2009, p 23) "mining and resource projects are generally excluded from water resource accounting, exact water use estimates for this industry are not readily available". Consequently, the estimates presented here may understate – perhaps substantially –consumptive water demand in the mining sector.

4. CONCLUDING COMMENTS

Some of the significant water problems confronting those in the south of Australia have served to increase development pressures on those in the North, perhaps at least partially because the region is perceived to be relatively water abundant. Not only is that perception incorrect (taking into account the fact that few of Australia's Tropical rivers are perennial), but it is possible that water may serve to constrain development in this region in the not-too-distant future.

Our research clearly highlights that in both the Mitchell and the Daly river catchments – like elsewhere in Australia – it is the agricultural sector that uses most water. Moreover, our simulations indicate that if agriculture were to grow at 5 percent per annum (i.e. if the sector were to double in 15 years), and if the water use coefficients that applied in Queensland during 2001 were to prevail, then total consumptive water demand would double in less than 10 years in both the Daly and the Mitchell River Catchments. This is clearly of concern because consumptive water demand cannot grow indefinitely: sooner or later water will 'run out'.

CSIRO (2009b) notes that in the Mitchell, current average water uses amount to less than 1% of total annual flows. But without storage, total annual flows are not the relevant factor to consider; it is the availability of water during the dry season that serves as the binding constraint. This has been recognized as a significant issue in the Daly (CSIRO, 2009a), and *may* also affect parts of the Mitchell (although in this region there are significant knowledge gaps surrounding groundwater storages and recharge options – as noted by CSIRO, 2009b). Evidently, unless more efficient ways of using water are adopted, dry-season flows may soon start to constrain development in some northern regions. Our simulations serve to highlight the importance of water-saving technologies and research, particularly in the agricultural sector.

Moreover, our scenarios also highlight the fact that development does not benefit all equally. Our simulations clearly show that most forms of development serve to generate larger absolute increases in incomes and employment for non-Indigenous people than for Indigenous people. As such these types of development will widen, rather than 'close' the 'gap' (unless there are changes to the underlying structure of these economies).

Evidently, development in northern Australia does not just involve potential tradeoffs between income and environment (water); equity issues abound.

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