Informed adaptation to a changed climate state

Is south-western Australia a national canary?

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Abstract: South-western Australia experienced as sudden decrease in winter rainfall and an associated decrease in stream-flows and groundwater recharge in the mid 70s. This has strongly affected water supplies and related ecosystems and is of growing concern in other sectors.

Research has not yet been able to determine the physical cause of this switch of climate state but has concluded that, most-likely, both natural (multi-decadal) variability and the enhanced greenhouse effect have contributed. Whilst scientific debate on the cause of change continues, resource managers have needed to form judgements, respond to the observed realities, and adjust their climate baselines and their plans. The history of Perth's water supply since the mid-80s graphically illustrates the need, uncertainty, cost, and societal flow-on associated with such adaptation.

The observed climate shift, analogous to projections for a rainfall decline across southern Australia in future decades, have led to the suggestion that the region is a national 'canary'. However, it would seem more appropriate to view south-western Australia as a field laboratory for the nation. This paper discusses the regional experience, the way in which the State has constructed climate research under the Indian Ocean Climate Initiative, and its role in support of adaptation under the State Greenhouse Strategy.

Keywords: Climate change; Decadal variability; Water; Adaptation; Partnership; Regional program

1. INTRODUCTION

1.1. Post 70s Climate Experience

In the mid 70s south-western Australia, known for its reliable climate, experienced an abrupt change of climate state. A sudden decrease in winter rainfall (Fig.1) and an associated decrease in stream-flows (Fig. 2) and groundwater recharge have impacted severely on water supplies and related ecosystems. The shift is characterised by a complete absence of 'wet' winters which normally replenish reservoirs, superficial aquifers and wetlands after they have been drawn down by drier seasons.

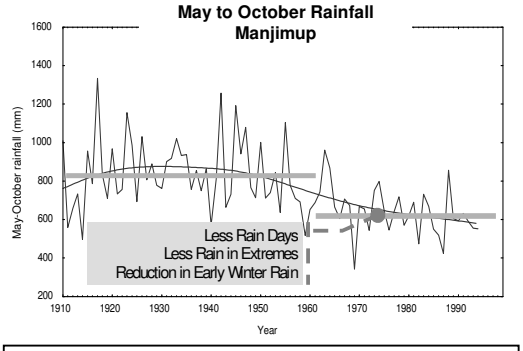

Figure 1. Change in May-Oct Rainfall at Manjimup

Rainfall decrease in this period has been in the order of 10% to 15%, but has been as great as 20% for some observation points (Fig. 3). In Perth's water catchments average stream-flows of the last quarter century are approximately 50% below those of the earlier part of the century (Fig. 2).

A disturbing feature of this decrease is that it imitates, to a degree, the increase in atmospheric pressures and the decrease in rainfall projected, for decades hence, in these latitudes due to global warming. However, regional research has also indicated that multi-decadal, non-linear shifts of this scale might be natural in this region.

Research has not yet been able to determine the physical origins of this switch of climate state but has quantitatively related the rainfall decrease to large scale changes in atmospheric circulation (IOCIP, 2002, 2001). This research has noted a likely association with changes in global circulation widely recognised to have taken place in the mid 70s. For these reasons, and also because the shift is manifest offshore at least as far west as Rottnest Island, local effects relating to land-clearing or air pollution are considered to have been, at most, secondary influences. The studies have concluded that, most-likely, both natural (multi-decadal) variability and the enhanced greenhouse effect have contributed, but

recognise that, if the latter effect is a part contributor, the total decrease experienced is of a scale only anticipated decades hence by most climate modelling (IOCIP, 2002). An associated concern of decision-makers however, is that, even if the current shift is a temporary phenomenon of multi-decadal variability, any hope of completely switching back to past regimes is clouded by the projected scenarios from global warming.

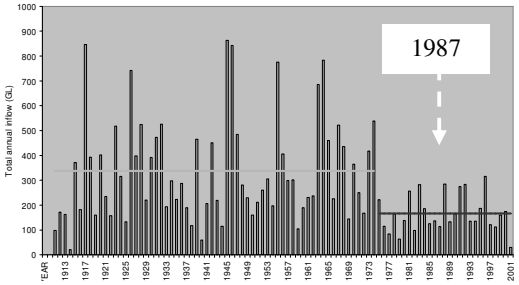

Figure 2. Inflows to Perth reservoirs 1911-2001.

The rainfall decrease has occurred mostly in early winter with less rain days and less rain on extreme days and with some (lesser) increase in spring. There has also been some smaller increase (in absolute terms) to the north-east (Fig. 3) and this has led to the hypothesis that the change may be associated with a displacement of the influence of *'north west cloud bands'* which tend to interact with frontal activity in early winter (IOCIP 2002).

The region has also experienced a warming trend in the last 50 years corresponding broadly to the national and global trend. The warming was stronger in autumn and winter than in spring and summer, and was stronger at night than in the day.

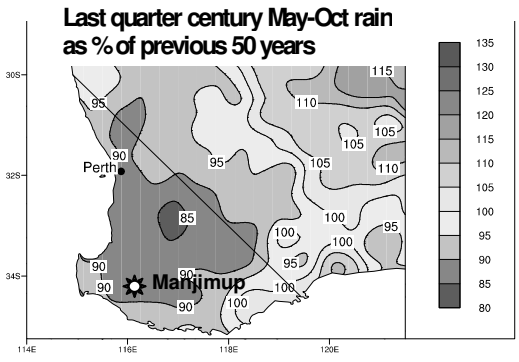

Figure 3. Average May-Oct. rainfall for 1976-2001 as a percentage of average May-Oct for 1925-1975

It is to be expected that this warming trend has increased potential evapo-transpiration and thereby has contributed to the decrease of stream-flows, although the abrupt decrease matches with rainfall and suggests that the rainfall decrease has been the major cause.

2. Perceptions and Actions – mid 80s to mid 90s

In 2002 it is possible to look back on these observations with 20/20 hindsight and the benefit of strategic research into climate variability and its insights into climate behaviour. However, if one examines the rainfall and stream-flow plots of Figures 1 & 2, for what could be seen in the mid 80s, the position confronting decision-makers at that time can be better understood.

In 1987 water managers in particular were concerned by what they saw. The dry years since the mid 70s were of concern. The system was operating at its nominal capacity, restrictions to supply had been required because of drought in the late 70s, and the dry run of years since then, presumed to be an extreme run in a random distribution of annual rainfalls, was becoming uncomfortably protracted.

In 1985 the Villach conference issued its warning on global warming. In 1987 CSIRO produced national climate change scenarios and joined with the Australian Government's Commission for the Future to convene the conference '*Greenhouse: Planning for Climate Change'*. In that review, and consistently since that time, modelling of climate change has indicated significant rainfall decline is likely in south-western Australia as a consequence of rise in atmospheric pressures in these latitudes.

The then Water Authority of WA took part in this conference with preparation of a paper (Sadler et. al., 1987) which reviewed Perth's future water

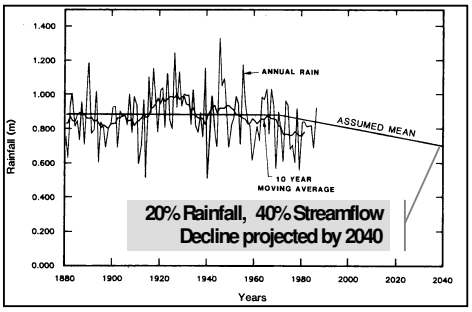

Figure 4. Rainfall Scenario adopted for 1987 review of Perth's Water System

development in the context of the CSIRO scenarios for rainfall decline in the region. It is relevant to note that the CSIRO scenario was for a 20% decline in south-west rainfall by 2040 (Fig. 4). This was expected to result in a 40% decline in stream-flows and declines in various groundwater resources ranging from 0% to 40%. The estimated cost of adapting to this scenario was calculated as having a 1987 present value in the order of $500M.

The paper recognised that the dry run was, in all likelihood, natural and observed that:
'the magnitude and timing of the suggested decline are very much matters for speculation'.
However it recommended that an
'incremental strategy be adopted for responding to the expectations'.

2.1. Re-rating the water system yield

Following the recommendations out of this review paper the Water Authority announced a strategy of incremental water system adjustments effectively assuming that the rainfall and yield would track down a trend-line such as in Fig. 4. In an initial adjustment, the water system yield was written down by some 13 %. This response implied some earlier scheduling of future water source developments and continued promotion of demand management. Decisions would be reviewed from time to time based on experience and advances in climate science.

This decision by water managers was controversial at the time and remained so for many years. However, against what has transpired, a decline of some 50% in stream-flow by 2002, not 2040, the decision was far from extreme.

As dry conditions continued, between 1987 and 1995, incremental downwards adjustments were made to the assumed yield of the water system, mostly in respect to surface sources. This was done by using only the last 40 years of record to determine mean and variability and periodic re-adjustment of means on that basis as years of drought continued through the decade. In 1995, the preparation of a major new strategic plan for *Perth's Water Future,* continued with this incremental policy but noted that recorded stream-flows for the past 20 years *were only two thirds of the average of the past 40 years.*

The 1995 plan was still assuming that *the flows for the past 20 years were an extended drought, devoid of high flows, which (high flows) would recur in the medium term.*

The plan and, its method of calculating averages, were regarding the experience more as an extreme run in a random process and, at most, having only a small component of the decrease attributable to any trend or jump in climatic change. However, it acknowledged that
if this is not the case… then the yield may have to be decreased to reflect the statistics of the last 20 years.

2.2. Need for National research recognition

The 1987 paper also concluded that:
'Because of the socio-economic significance of this region and because it is the region of Australia where the greenhouse effect may have its most severe manifestation in terms of reduced rainfall, the region should have a high priority in national research into climate change'.

From 1989, the State began engaging with CSIRO in associated climate research contracts negotiated through the Department of Environment (Allan& Haylock, 1993).

3. The Pace Quickens 1996

3.1. Big, costly adjustments by Water Sector

By 1996 water managers, in particular, were deeply worried. The sustained failure of the climate mechanisms to produce a 'wet', replenishing, winter of the type which had been common in the earlier parts of the century, was stressing the water supply systems. These systems were designed with storage capacities planned to operate through successions of drought years, but a 20 year 'drought' was well beyond normal expectations.

In early 1996 a *Climate variability and water resources workshop* was held to review the current state of knowledge on climate variability, the impacts on water supply and to identify a way forward including research directions (Ruprecht et al 1996).

The workshop was an important step forward in decision circles. It began to talk specifically of non-linear jumps in decadal climate variability and moved towards interpreting the rainfall experience as such a jump rather than simply an extreme run in a random process. The workshop was cautious about possibly associating such a shift with the enhanced greenhouse phenomenon but recognised that some changes had occurred in global circulation which may be associated with the rainfall decline.

This workshop also concluded that a sustained and integrated program of research was needed and recommended that a '*liaison group*' be formed to explore how this might be pursued.

The workshop also reviewed the assumptions behind planning for Perth's water supply. It noted and agreed with the policy of incremental adjustment, which had applied up to the issue of the Perth's Water Future Plan in 1995. However, it recommended that the newly formed Water Corporation should now review its position on climate change, climate variability and source development.

In 1996 the Water Corporation responded to the workshop advice and the design basis of Perth's water system was radically altered. It was effectively assumed that the climate sequence of the past 20 years was associated with a climate shift rather than being an extreme run in a random sequence. This not only altered the expectations of when or whether the climate would return to *normal.* The possibility of such shifts also implied that water supplies, designed to previous statistical paradigms, were at substantial risk of experiencing protracted strings of restriction years which were socio-politically unacceptable. This latter prospect virtually forced adoption of the past 20 years as the design baseline regardless of whether some complete or partial switch back to *'previous normals'* might occur. This design adjustment cost in excess of $500M to implement. In one step it virtually took the system to, or beyond, the decrease of water source inflows, projected in the 1987 paper, to be reached by 2040 due to Greenhouse driven rainfall reductions.

Despite the scale of this decision, and the nature of debate over previous decisions, the main public contention now came from those who, with benefit of hindsight, believed the adjustments should have been made earlier.

3.2. Agriculture and Environmental Sectors

It is interesting to reflect on how other sectors fared in this climate shift, compared to the water sector.

Broadly speaking, agriculture had fared very well. This sector, in all likelihood, was cushioned to a major degree by its extensive introduction of minimum-till seeding practices in the wheatbelt as good and water-efficient best agricultural practice through the early to mid-90s. Although not introduced in anticipation of climate shift, minimum-till is a sound adaptive practice which adapts well to the late start of the winter season and to the reduced rainfalls which have been associated with the changed climate state. Also (Fig. 3), the marginal wheat-belt areas were unaffected, or less affected, by the decrease and the high rainfall areas of the wheatbelt would have found the absence of very wet years a welcome experience. Agriculture therefore, was not feeling adverse pressures of the observed climate shift and was primarily interested in pursuing opportunities for productivity improvements through application of emerging inter-seasonal forecasting technology. Implicitly rather than explicitly the sector was satisfied that improving tilling practice and new seed varieties were adjusting adequately to climate.

In conservation management sectors, growing pressure was being noted on some ecosystems such as the wetlands systems of the coastal plain and the natural tree population over the Gnangara (groundwater) mound. However, there was a tendency to associate this with water extraction rather than climate shift. The conservation advocacy sector, unsurprisingly, displayed greater interest in control of greenhouse emissions and, at that time in the public domain, often tended to express concern that adaptation would only deal with symptoms rather than cause.

Because the agricultural and environmental sectors, at that time, were not encountering the manifest decision problems confronting water supply they were primarily treating climate change adaptation as issues of the future rather than the present. In an action sense, the position was only slightly more advanced in water resource allocation aspects of water resources management.

4. The formation of IOCI, 1998-2002

In October 1997, responding to calls from such quarters as the 1996 Climate Variability and Water Resources Workshop and private advocacy for study (B.J. O'Brien, 1998, pers. comm.) of natural variability and inter-seasonal forecasting, a review of application potential was undertaken across a range of government agencies. Following from recommendations of this review the Western Australian Cabinet endorsed the establishment of the Indian Ocean Climate Initiative (IOCI). The expressed goals of this endorsement were to -
'develop more effective seasonal forecasting and understanding of climate variability in the Australian South West with particular emphasis on the effects of the Indian Ocean'.

This Cabinet endorsement sealed the negotiation of a somewhat unique research partnership. A number of State Government agencies and the WA Region of the Bureau of Meteorology had

negotiated a contributing partnership for establishment and direction of strategic research agreements with CSIRO and the Bureau of Meteorology Research Centre. Those research bodies, in-turn, agreed to match the State investment, in kind, dollar-for-dollar.

The nature of this agreement was fundamental to its success. The research was to be directed by a Panel (IOCIP) comprising representatives of the contributing partners, the research partners and an independent chair who was also a (part time) coordinator. The research program was to follow carefully formulated strategies developed by the Panel with input from workshop consultations with local practitioners and scientists. The strategy and associated work plans were to be actively monitored and discussed by the Panel, the role of which was also to carry findings into practical usage. The Panel was to achieve this through their institutional networks and programs and by joint Panel activity where appropriate. The strategies were to focus on scientific development of mutual benefit with more specific sectoral applications, potentially following on, through programs of the partners.

There were a number of strengths in this model. Firstly it placed users and scientists in close and frequent dialogue over research directions. Secondly it removed past fragmentation in State pursuit of climate science which had mutual interest to several key sectors. Thirdly, it gave mechanisms for economic flow of information, and fourthly, it created an entity with a voice which was able to carry national and international dialogue of the particular interests and concerns of the region.

In the five years since its formation IOCI has published several reports on understanding of climate variability in south western Australia and conducted several workshops exploring this understanding. As its findings have become more substantive IOCI has sought to be more active in extension of these findings to decision-makers in climate affected industries and to the wider community (Indian Ocean Climate Initiative, 2002).

Significantly as this work advanced, with its focus on the South West and a strong interest in rainfall as a prime variable, the issues of seasonal variability, multi-decadal variability, and global climate change became heavily inter-woven. The changes in fundamental climatic relationships with ENSO and other predictors and the abrupt climatic break of the 70s became central issues. This was so regardless of whether the particular source of interest was in applications based on: simple probabilities using observed climatological statistics; tactical decisions using inter-seasonal forecasting; or long term planning potentially affected by multi-decadal variability and global climate change.

IOCI became increasingly convinced that it had to bring such activities along together and that well conducted work on one aspect was in fact contributing to advancement on another. From such a background IOCI found itself in a growing and logical dialogue with the adaptation component of the State Greenhouse Strategy.

5. Greenhouse Strategies, Water Crises? and all that, 2001-2002

The last two years have been particularly eventful climatically in south western Australia. Collectively these experiences have served to develop wide community recognition of the importance of adaptation, the former poor relation amongst activities in previous State and National Greenhouse strategies.

Coincidentally this was also a time when the first (five year) Stage of the Indian Ocean Climate Initiative was coming to an end. IOCI had long intended to mark the end of this stage with a report drawing together its findings in a form appropriate to decision-makers. The publication (IOCI, 2002) found itself appearing at a time when such information was in high community demand.

5.1. Tough years for several sectors

In 2001, after a quarter century of poor replenishing rains, the South-West suffered an extremely dry year with the second lowest stream-flows on record (Fig. 3). Water supplies throughout the region were severely affected. Then, just the following year (2002), the region was hit by agricultural drought which brought massive crop failures in the wheat-belt, one of the most climatically reliable areas in Australia for winter crop production, and again had water supplies strained at their limit.

5.2. Water 'Crises' and Summits

In respect to water supply, the region was threatened by the possibility of severe water restrictions, potentially prohibiting external water use in urban areas. Adaptive *'incrementalism'* and *strategic planning* by water managers, through the uncertain, and at times controversial, climatic experience of the last quarter century had, in fact, provided a foundation for the water system to be nursed through this testing period with remarkable

success. Over three decades, with a mixture of anticipation and hindsight, the water sector had progressively written down the sustainable yields of surface water sources in the public systems by some 30% to 50% and is still debating the degree of write down for underground water sources.

Statements of sustainable yields of regional water resources no longer have much meaning in this region unless defined in relation to some particular climatic baseline. This means that there is yet unfinished business for the water resource regulator in terms of regional water allocations. The Water and Rivers Commission began tackling this issue strategically by incorporating climate change considerations in its audit of Western Australia's water resources (Water & Rivers Commission, Nov 2000). The State is fortunate in not having over-allocated resources and has more opportunity than most to set sustainable limits ahead of full resource allocation. However, the climate projections of the South-West also pose some special challenges to future allocation processes.

The water supply sector has managed, through all of this, without severe restrictions which prohibit outdoor water use, but has managed with cooperation from a responsive public as well as through incremental system adaptation. In public perception nevertheless, the experience of 2001 and 2002 is viewed as a *water crisis* and a *crisis for water planning* in particular.

In response to the water supply situation the State Government established a Task Force to over-sight a strategic response and to put forward advice to Government on *'Our Water Future'*. The generation of this advice included a suite of public workshops throughout metropolitan and regional areas, informing the community on the situation, and drawing in public comment on future options. These forums culminated in a three day *Water Symposium* in the State Parliament House with delegates being: nominated from the prior forums; chosen randomly from the electoral roll and from applications to take part; nominated from particular interest and expert groups; or chosen for their expert input.

As an essential and front end input to these various workshops, climate briefings were given based on the integration of IOCI research and the recent IPCC and CSIRO publications on global and national climate change. In addition to the IOCI Stage 1 report, a special pamphlet was prepared integrating material from IOCI, CSIRO and the recent IPCC publications (IOCI, 2002). The material was published in hard copy, CD ROMs and on the web.

The community has shown deep interest in these briefings and associated material. Advice and information from IOCI has been in high demand from a wide spectrum of community members. Recommendations emanating from the Water Symposium included a recommendation for *'Community education in areas of climate change…'* (Cox ed., 2002).

5.3. State Greenhouse Strategy and *Informed Adaptation*

Concurrently with these climatic events the State's Greenhouse Task Force had been working on the re-development of the State's Greenhouse Strategy. An Issues Paper on this Strategy was published in the first days of December 2002 (Greenhouse Task Force, 2002). This Issues Paper recognises climate change as one of the most critical factors affecting the State's sustainability and links Greenhouse Strategy directly to the recently issued Draft Sustainability Strategy (2002). The Draft Greenhouse Strategy sees adaptation strategies as a necessary incremental and ongoing process based on a risk management approach, public awareness and research. The strategy specifically identifies continuation of the Indian Ocean Climate Initiative into a second stage and links to CSIRO's Healthy Country Initiative (aimed at integrated environmental science in the region) as key parts of the response. IOCI in turn is responding to this in its forward development of strategy, and has coined its role as supporting the strategy by supporting decision-makers in '*informed adaptation'*.

6. Moving Forward – Towards Informed Adaptation

The very recent release of an issues paper by the State Greenhouse Task Force has invited public input towards ongoing development of State strategy (Greenhouse Task Force, Dec 2002).

Also as recently as November 28 and 29, 2002, the Indian Ocean Climate Initiative Panel conducted a seminar and workshop in Perth to help develop its strategies for the next five years. This latter event sought to provide –
'*A comprehensive review of - the state of our knowledge and the pathways we will follow.*
An examination of climatological information support for "adaptive" decisions ranging from inter-seasonal tactical decisions to longer term change strategies

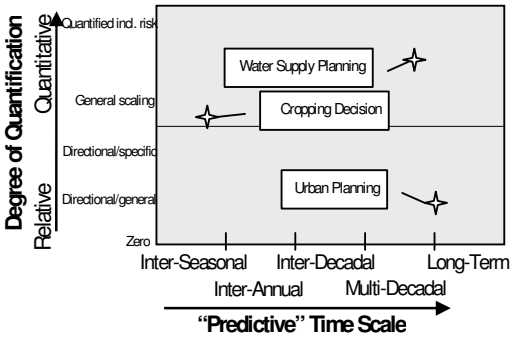

Figure 5. Classification of information requirements by time-scale and quantification

6.1. Defining information needs

The November IOCI workshop started towards a more organised assembly of the information needs of sectoral decision-makers.

It is apparent that this classification of information needs is important in the planning of research and development. There are manifest differences between sectors and, within sectors, between specific applications. Mapping of these demands will be one of the tasks for IOCI in determining its forward priorities. Aspects of climate affecting decisions vary. The interest may range from winter rainfall and evapo-transpirative demand, to break of season, incidence of frosts etc..

Time-scale is one important dimension of such classification and the IOCI workshop revealed demand across a range from inter-seasonal tactical decisions, to long term investment strategies or resource management decisions. The other classification which is highly relevant is the extent of quantification required (Fig. 5). It is apparent that one of the reasons the water sector has been such a consistent centre of information demand on climate change is that its decision-making demands quantification of climate expectations and their transformation into estimates of resource availability and system yield. At the other extreme some sectors may not need, or be in a position to utilise, much more than directional trends. Such matters clearly need to be taken into account in setting investigative priorities.

In this same vein of classifying information need, the issue of decision thresholds of various kinds can be directly and indirectly relevant. Thus, for example, some climatic threshold in occurrence of frosts may be a critical determinant in the pursuit, or otherwise of stone fruits as a regional crop.

However, the issue of thresholds also emerged in this workshop in respect to social decisions and may warrant further investigation. Such thresholds may relate climate parameters directly to decisions of individuals but social thresholds might also arise indirectly through institutional decisions which may be catalytic in their effect. In respect to the latter, the example of water, chosen for development of this paper, is highly relevant. Already, the decisions of water managers in respect to Perth's water system are effectively creating a domino effect through society. Urban planning, as a consequence of these water supply policies and trends alone, is being pushed directionally towards structural and lifestyle adjustments.

There may be important lessons in this latter experience, both opportunistic and cautionary. It may happen that societal roll-out of climate adaptation will follow more soundly from leadership in good adaptive planning by various institutions with the resources and sophistication to make informed and considered responses rather than by emphasis on broadcasting which directly promotes response at grass-roots level. This observation is meant to be taken in relative not absolute terms, but it seems evident from the recent experience in the South West community that institutional responses can be a strong source of leadership. The observation also makes it important that relevant institutions are well informed and following balanced programs.

In this latter respect the current regional approaches are encouraging. IOCI partners are introducing the acquired knowledge in rational ways to their institutional decision-making and, as they do so, come in dialogue with their community networks.

An example of this latter approach is in the Department of Conservation and Land Management where the active consideration of possible climate change issues is currently being mainstreamed into the department's various planning processes. Such mainstreaming is not radical but incremental. It makes sure the questions are asked, but in ways which say *'leap don't jump'* and give due consideration to the *'precautionary principle'*. The direct result of this approach in a particular circumstance may be small, but that in itself is an objective lesson (Tuart Response Group 2002). Such lessons, in turn, can be carried through institutional networks to large groups of external stakeholders, such as CALM's

Land for Wildlife Network (Hussey P., pers. comm.).

7. Conclusions – A Canary? Not if we can help! National Laboratory? Potentially!

Practical experience as a guide in adaptation to climate change is a scarce commodity. The real experiences of adjusting to unexpected and currently unpredictable changes of climate state in south-western Australia are one such active example. The region effectively offers some field testing and observational case study of adaptation to a changing decision environment associated with global climate change.

The region has not been caught unawares but has been working at, and debating, these issues for decades and is endeavouring to set itself on a path of informed adaptation. In this sense the rhetorical notion of being a *national canary* is contrary to the regional agenda. However, the region does potentially provide a *national laboratory* with early field testing, not only of scientific tools for adaptation, but also of socio-political, economic and psychological responses.

Some observations already apparent from this experience are:

Here-and-Now Issue

1. Changes, however caused, are already with us. For some regions at least, climate adaptation is a here-and-now issue for decision-makers and not an issue to be put aside.
2. Adaptive responses, and actions to reduce gas emissions, are not alternatives, but are necessary and complementary measures.

Climate Variability and Change Intertwined

3. The development of climate applications based on natural variability and the observation and projection of human induced climate change are strongly inter-twined once elements of change become evident.
4. Traditional disaggregation of change and natural variability in some applications research, in community dialogue and in adaptive response is no longer appropriate in south western Australia and will quickly be inappropriate elsewhere as change becomes manifest.

Changed Decision Paradigms

5. The traditional planning assumptions of stationarity and linearity in climate statistics are necessarily giving way to more complex views of climate variability which embrace decadal shifts and evolving baselines.
6. There will always be large uncertainty, but decision-makers must be prepared to make informed judgements and need help in understanding associated risks, expectations and uncertainties.

Partnering in Information

7. Because there are common issues across many sectors partnered research and investigation on these common needs can be efficient, and productive, but also can be valuable in establishing a more balanced development of community awareness.
8. Planning for information support involves forming appreciation of the range of sectoral information needs and priorities. These needs range over different time-scales. They also range in need for detail from broad directional projections of trends, to a need to quantify the expectations to form some physical design basis.

Helping Informed Adaptation

9. Association of user partnerships for strategic climate research (such as IOCI) with activity on State Greenhouse strategies, can be mutually beneficial in creating awareness and working for balanced responses.
10. Mainstreaming of the climate knowledge and the pursuit of informed adaptation into the institutions which are members of such partnerships can provide useful leadership towards balanced adaptive response in the wider community. This path is potentially more effective than is the simple broadcasting of climate information.
11. In the water sector, used as an example in this paper, major adaptations which have been necessary are having a flow-on effect and initiating associated adaptations in other sectors including urban planning and environmental management.

8. ACKNOWLEDGEMENTS

This paper is only made possible by the existence of the IOCI partnership and its guiding Panel.

However, the author must take sole responsibility for some of the closing observations, as yet untested within the Panel. Consequently, this paper does not necessarily reflect an official IOCI view.

9. REFERENCES

Indian Ocean Climate Initiative Panel, Sept 2002, *Climate variability and change in south west Western Australia.* c/- Dept Environment Water and Catchment Protection, Western Australia, ISBN 1-920687-03-3. See also temporary web-site: http://www.wrc.wa.gov.au/ioci/new.htm (report and pamphlet)

Sadler B.S., Mauger G.W. and Stokes R.A., 1988 *The water resource implications of a drying climate in south-west Western Australia.* In Pearman (ed.) *Greenhouse: Planning for Climate Change* pp 296-301. CSIRO 1988. ISBN 0 643 04863 4.

Water Authority of W.A. June 1995, *Perth's Water Future*, Publication No. WP214. ISBN 0 7309 7214 3

Ruprecht, J.K., Bates, B.C. & Stokes R.A., eds. 1996, *Climate Variability and Water Resources Workshop*, Water & Rivers Commission, Water Resources Technical Report Series No. WRT5, ISBN 0-7309-7253-4

Allan R.J. and Haylock M.R., 1993, *Circulation features associated with the winter rainfall decrease in southwestern Australia.* J. Climate, 6: 1356-1367

Indian Ocean Climate Initiative Panel, Oct. 1999, *Towards Understanding Climate Variability in south-western Australia – Research Reports on the First Phase of the Indian Ocean Climate Initiative,* Water & Rivers Commission Western Australia, ISBN 0 643 06599 7

Indian Ocean Climate Initiative Panel, Nov. 2000, *Understanding the Past, Exploring the Future – The Oceans, the Atmosphere and Climate Variability in south-western Australia* Water & Rivers Commission Western Australia, ISBN 1 74043 0557.

Indian Ocean Climate Initiative Panel, Oct. 2001, *Towards Understanding Climate Variability in south-western Australia – Research Reports on the Second Phase of the Indian Ocean Climate Initiative,* Water & Rivers Commission Western Australia, ISBN 0 7307 6679 9

Greenhouse Task Force, WA Government, Dec. 2002, *Western Australia and Greenhouse*, *Issues Paper*, www.greenhouse.wa.gov.au

Cox W.J. ed., Oct. 2002, *Our Water Future, Western Australia's Water Symposium, Vol. 1, Summary of Outcomes.* See also web-site: www.ourwaterfuture.com.au

Tuart Response Group, Aug. 2002, *Status report – Tuart Conservation and Protection,* Department of Conservation and Land Management WA.

Govt of WA, Sept., 2002, *Focus on the Future: the Western Australian state sustainability strategy: consultation draft.* Sustainability Unit Dept of Premier and Cabinet, Perth. ISBN 0 7307 0117 4. See also web-site: www.sustainability@dpc.wa.gov.au