Freshwater Long-Term Ecological Research Sites in Victoria

Overview
The National Climate Change Adaptation Research Facility (NCCARF) was established by the Australian Government in 2007 to identify the research and information required to adapt to the physical impacts of climate change. To help achieve this goal, national ‘adaptation research networks’ were setup across the following eight themes: 1) Water Resources and Freshwater Biodiversity; 2) Terrestrial Biodiversity; 3) Primary Industries; 4) Marine Biodiversity and Resources; 5) Human Health; 6) Settlements and Infrastructure; 7) Emergency Management; and 8) Social, Economic and Institutional Dimensions.

The Water Network comprises four main research themes: freshwater biodiversity – coordinated by Griffith University (QLD), water resources – coordinated by the University of Newcastle (NSW), climate scenarios – coordinated by CSIRO and water governance – coordinated by Uniwater (VIC). A capacity building theme is also coordinated by the network coordination team at Griffith University. The Network is administered through Regional Nodes, whose role is to consult with water researchers in each state in order to build collaborative, multi-discipline research proposals. The Victorian Node is coordinated by Uniwater.

A consultation process was conducted in late 2009, which began with interviews with 35 Victorian water researchers to discover areas of common research interest, followed by the production and distribution of a discussion paper to the Victorian Node. Feedback on this discussion paper was collected and summarised into two main research foci: (1) **freshwater long-term ecological research sites**; and (2) **systemic and adaptive water governance**. A ‘synthesis’ was written around the freshwater LTER idea, which led to strong feedback and enthusiasm for a workshop to further develop the idea. A workshop on "freshwater long-term ecological research (LTER) sites in Victoria" was held on Thursday the 18th of March 2010, attended by 30 water researchers. This document summarises the outcomes of the workshop.

To progress to the next phase of the Victorian LTER program planning process, we request that the network (i.e. water researchers – you!) provides Phil Wallis and Jane Catford with:

- Hypotheses that address effects of restoration activities and climate change impacts (in addition to the research questions listed on page 10);
- Feedback on the key selection criteria for sites (see page 2); and
- Suggestions about additional sites that may be suitable for the LTER program (see page 2).
Summary
A long-term ecological research (LTER) program in Victoria would support climate change adaptation by helping to identify the impacts of climate change on freshwater and estuarine ecosystems and determining the long-term effects of restoration activities.

Our approach to planning a freshwater LTER program in Victoria is to first formulate overarching research hypotheses that address climate-related ecological processes, conditions and impacts. Testing these hypotheses in particular sites will increase understanding of climate change impacts, ecosystem function and responses, and the utility of restoration activities. Sites would be selected based on key selection criteria. Criteria proposed at the workshop are listed as follows:

- A sub-catchment or hydrological unit(s) of an appropriate size ~1,000 – 10,000+ ha
- Management interest – water supply or streamflow
- Surface water and groundwater responses to climate change
- Intervention possible – restoration ecology
- Variety of land uses and sub-catchments
- Nested catchment scales / paired sites
- Good existing data availability / some historical records
- Ability to test climate based research hypotheses to understand processes
- Presence of a hydrological/ecological gradient
- Consortium, infrastructure, cross-discipline, practicality

A selection of potential catchments for locating aquatic LTER sites was also proposed at the workshop (below). It should be noted that these catchments are generally too large to be considered as ‘sites’; rather, sub-catchments within these would be chosen as LTER sites.

- Ovens River
- Broken River
- Goulburn River
- Wimmera River
- Glenelg River
- Grampians region
- Western District Lakes
- Yarra River
- Barmah/Gunbower Forests
- Western Port Bay region
- Gippsland Lakes (Mitchell River)
- Murray River, upstream of Lake Hume

There was support for a focus on restoration experiments rather than disturbance experiments, which are potentially destructive. This support recognises the ‘adaptation’ focus required for research funded by NCCARF, as well as offering the potential for stronger public support for activities that restore natural environments and that inform adaptive management.

The plan for advancing this proposal is to refine the selection criteria for potential LTER sites and to collect and list climate-based research hypotheses that are testable under a freshwater LTER program. The selection criteria will be circulated to the network for comment. Following the collection of feedback, the Victorian Node coordinators will draft a proposal that seeks funding from NCCARF to develop rigorous selection criteria for nested LTER sites and to score potential sites.

The outcome of this scoping project would be a business case, developed in collaboration with state government agencies, for a freshwater LTER program in Victoria. There is also potential to extend this scoping study to other states. The scoping study will identify existing data sources, synthesise and recommend protocols for data management, and will provide a detailed overview of potential LTER sites. The study will be framed in the context of relevant policy and management interest in Victoria through extensive consultation with state government agencies.

As with all Victorian Node activities, this exercise will be conducted through collaboration between all interested individuals, research institutions and government agencies in Victoria.
Full Workshop Outcomes

Background
Brendan Edgar - NCCARF

Brendan Edgar, in facilitating the workshop, firstly made the point that we need to focus on ‘adaptation’ as distinct from ‘mitigation’.

John Langford - Uniwater

John Langford, in his introductory remarks, highlighted that we need long-term ecological data in order to know how to adapt to climate change. This also helps us to find out whether we’ve achieved something through adaptation measures. There is also an opportunity under the Water Act 2007 (Cth), with respect to the Murray-Darling Basin, to provide information that helps determine sustainable levels of environmental water.

The synthesis that came out of the consultation proposed that a combination of human-impacted and un-impacted sites be considered:

The two sorts of sites will enable complementary research questions to be addressed. For example, studies of “reference” systems will enable natural adaptation mechanisms to be examined, such as the role of dispersal and dispersal pathways, the importance of refugia, the impacts of extreme disturbance events and the existence of ecological thresholds. Studies conducted in human-impacted systems will enable the relative impact of different threats to be ascertained, and the effect and value of remediation activities determined. Such remediation activities might include the release of environmental water, exclusion of livestock from riparian zones, and water quality treatment prior to its release into aquatic ecosystems. These sites will be suitable candidates for adaptive management where long-term monitoring is required to inform, update and validate management decisions.

Jenny Davis (Monash University)

Jenny Davis noted that “there is much less ecological data than climatic or hydrological data”. In examples drawn from her work in Western Australia, Jenny showed that invertebrate sampling combined with climatic and hydrological data showed the presence of a “boom and bust environment” in targeted sites, which otherwise would have been an unknown factor in the management of these sites. Jenny advocated the use of “sentinel sites” in protected areas, so that climatic impacts can be separated from other impacts.

The Australian Water Resources Information System (AWRIS) provides an opportunity for incorporating ecological data.

The ‘Australian Antarctic Data Centre’ supports Australia’s Antarctic research program by providing data management and spatial data services. Data is catalogued systematically in a metadata catalogue, which includes links to project websites, researcher contact details, publications and site locations.

The Murray-Darling Basin Authority’s ‘Fish Information System’, in its third pilot stage, provides a common framework for cataloguing fish data across different states and state agencies.

We are seeing higher climatic variability in south-eastern Australia. There are some advantages to high climatic variability and climate change. For example, with lower rainfall and runoff, salinity is less of an issue, and can cause some exotic fish to die when water bodies dry up.


Existing data collection
Sabine Schreiber - Department of Sustainability Environment – water quantity and quality

Sabine Schreiber presented on DSE water quality data. A partnership arrangement exists in Victoria, including north west, north east, south west and Gippsland regions (excluding Melbourne) to collect water quantity and quality data across 790 sites. This includes rivers, reservoirs, lakes and some irrigation channels. A significant historical record is available (digitised), with 33 data quantity sets going back more than one hundred years. Data quality sets are typically within the last 40 years.

Leon Metzeling - Environment Protection Authority – macroinvertebrates

Leon Metzeling presented on EPA's Rapid Bioassessment Data (RBA). EPA Victoria manages the statewide collection, storage and reporting of macroinvertebrate data and is often badged as AUSRIVAS. This program has been in place since 1990 but has varied in effort over the years due to changes in funding sources. Since 1990 over 2,600 sites have been sampled using a standardised sampling protocol which requires specimens to be identified to approx. family level. This protocol is essentially the same as that used in NSW, Qld and Tasmania; comparability has been confirmed by joint samplings between Victoria and the two former states. Along with macroinvertebrate data from two habitats (edge and riffle) additional data is also routinely collected – water quality (including nutrients), instream physical form, riparian condition and catchment information.

Within the RBA program there are three types of sites: reference sites, test sites and fixed sites. The reference and test sites are sampled using external funding (eg. Sustainable Rivers Audit, Southern Basins, Victorian Water Trust etc; the fixed sites are an EPA internally resourced program.

Reference sites – these are defined as near natural, minimally impacted or best available and free of point source discharges. They have been used to build AUSRIVAS models and define environmental quality objectives for use in state government policies. This suite of ~200 sites are scattered across the state and are currently being sampled for the third time. The first collecting period was 1990-97, the second 2000-05 and the third will be from 2008-12. Most of these will have had 8 site visits (or more) when the third round is completed. In the first round, all specimens were identified to the lowest practical level (usually genus or species) but in subsequent samplings only the EPTs (Ephemeroptera, Plecoptera, and Trichoptera) have been identified beyond family.

Test sites – these are sites selected at random and are usually visited in just one year and then not again. They could contribute to spatial analysis of trends within regions.

Fixed sites – since 1997, 19 sites have been sampled every 6 months. All were selected from the existing dataset with some being first sampled in the 1990s while three were sampled in a pilot program starting in 1982 (Latrobe River). The fixed sites are located in the Wimmera (3 sites), Glenelg (2), Campaspe (2), Ovens (2), Moorabool (1), Yarra (2), Latrobe (5), and Mitchell (2). The list was extended in 2008 with the addition of five stream in alpine areas, these streams having been sampled at irregular intervals from the mid 1990’s. It’s worth noting that the two Yarra sites are within the closed catchment. All specimens are identified to the lowest practical level (usually genus or species).

Sentinel sites – established in all catchments within the last 2-3 years. These will be sampled each time their catchment is sampled. In the northern catchments, this will be every 2 years; in the southern catchments it will be every 4 years.

Three quantitative data collections are worth noting from the following rivers: Wimmera, Latrobe and Yarra.

Wimmera: benthic invertebrates have been collected from 3 sites in the lower Wimmera River from 1985 - present. Sampling has been irregular with ~18 years with spring samples and 8 years with autumn samples. Five replicates are taken on each occasion using an airlift sampler as well as water quality (in situ, nutrients, some phytoplankton) and habitat measures. The data have been
reported in Metzeling et al. (1993) and Humphries et al. (2000). EPA hold all the data but it is now an unfunded program.

**Latrobe**: sites in the Latrobe catchment were first sampled by the Museum of Victoria in 1979-80. Six sites in the upper catchment were re-sampled on three occasions using the same method (same Surber sampler in fact!) between 1997-99. All specimens were identified to the lowest practical level (usually genus or species). EPA hold all the data and it has been reported in Metzeling et al. (2002).

**Yarra**: EPA funded the sampling of 10 sites in the Yarra from the closed catchment down to Dights Falls between 1983-1987. The site in the closed catchment was re-sampled using the same method between 1997-99. All specimens were identified to the lowest practical level (usually genus or species). EPA hold all the data and it has been reported in Metzeling et al. (2002).

**Water quality**: EPA used to collect monthly water quality data from five lakes in the Western District of Victoria from 1984 - 2003. Our network was merged with DSE (rural) and Melbourne Water (urban) in the mid-1990s. I believe the routine lakes sampling program has ceased.

**Western District Lakes**: In recent years EPA has investigated the condition of lakes in the WD due to large numbers of eels and fish dying (EPA 2007). A soon to be published study has broadened this work to examine the invertebrates (macro and micro), algae, diatoms and water quality of 28 lakes in the region in response to the recent drying conditions (sampling occurred in 2002-08; in press EPA 2010). This study compared recent biological data with that collected by Prof Bill Williams at 18 of the lakes in 1992 and contracted CSIRO and Latrobe Uni to project water levels and salinity to 2050.

EPA engaged CSIRO Marine and Atmospheric Research to rework the latest Global Climate Models used for the IPCC Fourth Assessment report, to provide projections of climate change effects on precipitation, runoff and lake evaporation for 49 lakes around Victoria. EPA collaborated with CSIRO and Latrobe University to examine the impact of the predicted climate change by 2030 on lake levels and salinity in four lakes, using water balance models. The four lakes chosen for modelling were Lakes Purrumbete, Bullen Merri, Gnotuk and Keilambete. These lakes were chosen because they all have a reasonable historical record of lake levels which can be used to validate models, and they represent a range of lake types: deep saline Bullen Merri and Gnotuk), deep fresh (Purrumbete) and moderately-shallow saline (Keilambete).

**Rhys Coleman - Melbourne Water – waterways data**

Rhys Coleman presented on Melbourne Water data sets, which are gathered from long-term routine monitoring of fixed sites, as well as long-term intermittent monitoring, snapshot surveys and through the community Waterwatch program. These data sets contain information on water quality, pollutant loads, hydrographics, public health (microbes) and drought impact. Melbourne Water have also commissioned reviews of long-term monitoring (Butcher 2003; Webb and King 2006; Webb and Walsh).

**John Koehn - Department of Sustainability Environment – fish**

John Koehn talked about DSE’s ‘Victorian Biodiversity Atlas’, which contains an aquatic fauna database including fish and macroinvertebrates. The database contains a range of historical and project-based data. The largest data set is of Murray River fish, which goes for approximately 15 years. There is also 5 years of Barmah data, collected by Alison King as part of The Living Murray monitoring. There is also data from Sustainable Rivers Audit (MDBA), Regional Forest Agreement sites and a long-term dataset from the Kiewa River (post-fire) that will be published soon. The Department of Primary Industries also manages commercial fisheries data and also has some recreational fish data.

**Sam Lake – Monash University – some of his thoughts on LTER sites (from PowerPoint slides)**

Monitoring, especially ecological monitoring and long-term monitoring, has been greatly neglected, if not deliberately shunned in Australia (e.g. stream restoration, Snowy). This may be because of the fear of the “filing cabinet” syndrome.
However, there are records which may produce highly interesting insights; e.g. Chessman (2009) 13 year trends in climate change and invertebrates (1.2°C rise per year), Rose et al., (2008) Vic EPA—statewide assessment of drought. Perhaps, as a preliminary step there should be a search for similar sets of data that can be matched with hydro-meteorological data sets. LT research is greatly boosted if it can occur at places where there has been and now is long-term and ongoing monitoring and recording.

Sites must be integrated with the landscape—the full ‘scape’ approach. The emphasis on aquatic should give way to the full ‘scape approach. Ideally, this occurs where the links between land and water are vital; e.g. floodplains, catchment land use and streams.

Any site must have a long-term, resilient institution responsible for its continual upkeep. As US experience shows, the sites are expensive to maintain, but this can be alleviated by researchers (with their grants) to the sites. Ideally the sites should also serve as an educational centre/asset.

Where are the funds? And for how long are they guaranteed. Australian funding bodies have consistently championed the short-term.

There should be a set of criteria for supporting a site. e.g., “representativeness”, long-term records, strong institutional backing, support from agencies, leaders to run the site, important/valuable ecosystems, projects already present, community support etc.

The ‘scape approach is recognized, climate change abiotic variables can be systematically monitored, hypotheses are developed for ecological responses to climate change and monitoring methods decided.

Feasibility to undertake experiments to elucidate mechanisms for responses, site findings can be compared with other sites, decision on standard set of variables to be measured at each site. Provides basic data for incoming researchers and allows fruitful cross-site comparisons.

Cross-comparison can be very insightful e.g. LTER in USA, Phoenix (the new) cf., Baltimore (the old), agreed cross-site experiments e.g. LINF-Lotic Inter-site Nitrogen Experiment.

As mentioned earlier, the ways that monitored variables act on populations, assemblages and ecosystems can be elucidated by experiments (large-scale). Examples include deforestation and leakage from catchments at Hubbard Brook LTER, “hydrologic drought” in urban streams in Baltimore LTER, Fire, streams and savanna at Kapalga N.T.

To detect climate change impacts at any site requires an understanding of the history and nature of past and current disturbances. With human settlement on site catchments, past and current degrading/disturbing forces could mask any climate change impacts. Need for tools to discriminate the legacies and impacts of disturbances (past, present) from climate change. Climate change is a long ramp beset by natural and human-induced disturbances (pulses, presses, ramps). Expected changes and ecological surprises. This raises the impelling question of “ecological memory”; past disturbances influence the response to future disturbances.

Given the level of human disturbances over most of Victoria and the MDB, proactive restoration could be a key form of building the capacity for biota to contend with Climate Change. Effective (not rinky-dink, itsy-bitsy) restoration is a long-term venture and should bring land and aquatic processes together. Need to remember that we are now in a period of “non-stationarity”; the extent of which depends on past records. Thus restoration goals may be shifting. Measurement of abiotic variables in different contexts; e.g. rising temperatures in streams with and without riparian shading.

Climate change will undoubtedly stress biota and change ecological processes. Thus, a major direction of research is to gain an understanding of resistance—the capacity to withstand stress, and the capacity to adapt. (biota adapt, ecosystems don’t). Resistance is negatively correlated with vulnerability. Highly stressed biota are vulnerable. Different organisms have different stress tolerances, and thus at an ecosystem level species deletions may occur. Such deletions may disrupt or at least change ecological processes; e.g. decomposition, nitrogen metabolism. The
important point is to link organisms to ecological processes (note that many processes are microbiologically mediated).

Climate change may not mean steady changes in abiotic variables. Rather the changes may be more “sawtoothed”. Drying by increased frequency of droughts or as modeled, droughts of increasing severity. Wetting by floods rather than gentle rainy periods.

Resilience refers to the capacity for biota to suffer but recover from disturbance. Usually, it refers to the return to the pre-disturbance state with pre-disturbance environmental variables. However, with climate change, especially with its current rate and human pressures, the pre-disturbance state does not necessarily exist. Thus, to survive biota need to recover and adapt to the new pre-disturbance state.

As biota adapt to climate change-generated disturbance, the speed of climate change may outstrip the speed of adaptation (genetic or otherwise). Such limits may mean migration as an adaptive response/ or proactive restoration alleviating the impacts of climate change. One good point about climate change is that dealing with it effectively means a long-term commitment to research, proactive interventions and monitoring. Climate change cannot be dealt with by short-term reactive measures (e.g. pipelines, flushing flows).

We know the steps:

- identifying the problem
- devising hypotheses and remedies
- deciding on and implementing action(s)
- post- and pre-intervention monitoring
- evaluation
- revision and return

This is fine in principle (Walters, Holling), but very rarely properly implemented - at least in Australia (but good for PR). Main hindrance is the lack of monitoring.

Adaptive management takes time but it could be an effective way to adapt to climate change, and other disturbances (e.g. river regulation and environmental flows). But it requires a long-term commitment. This argues for some sites to be in human-disrupted landscapes. Indeed, an illuminating comparison may be between identical ecosystems in natural and human-changed ‘scapes.

It is important to stress that to be effective LTER sites need strong, committed and long-term support. This may be better achieved with universities being site leaders, but in partnership with management agencies and research organizations. Education from school children to post-graduates and with volunteers is a key role of LTER sites in USA. Secure data storage and access is a crucial component of any LTER site.

Extensive drying predicted for south-east Australia---droughts, megadrought. Target to consider for climate change and LTER. Drought has a large spatial extent, is a disturbance of deficiency, may be predictable in onset but less so for ending (floods or slow release).

Comprehensive and long-term analysis of drought integrated across land/water ‘scapes (meteorology, hydrology (surface and groundwater, water tables), geomorphology, biogeochemistry, and ecology (populations, assemblages, ecological processes).

**Breakout discussion**

The workshop broke out into three groups to address the following questions. Ideas from all three groups have been grouped together.

1. **What data will help us observe and adapt to climate change and how?**

   All groups agreed that data would need to be collected for a range of key variables across sites; for example, air temperature, water temperature, rainfall, etc…. Surrogate variables could also be developed. Data for additional variables would be selected based on the particular hypotheses that
experiments at a site were trying to address. Conceptual models would guide selection of variables. A systemic process-based model could be used to derive mechanistic reasons for observed changes.

Remotely sensed data would be collected for study sites. This could include satellite products (e.g. NDVI) as well as airborne data (e.g. soil moisture). Palaeoecological data and historical or anecdotal data could also form a part of LTER sites.

Overall, data collection should be guided by climate modelling and anticipated human responses to climate change. A ‘grand hypothesis’ should be developed, which focuses on processes rather than patterns, within which a series of questions would apply to any LTER site.

2. What are the limitations and issues faced?

Questions were raised about the nature of a LTER site. It was suggested that sites should be located along disturbance gradients and ideally be scaled at a sub-catchment scale (1,000 – 10,000 ha). It was also suggested that LTER sites need to be much larger and integrated ‘supersites’, incorporating a CMA or larger region.

The issue of scale is a major challenge in setting up LTER sites. Firstly, many catchments are simply too large to be practical (>100,000 ha). Secondly, ecological processes occur at different scales (spatial and temporal) and thus require different strategies for collecting data and conducting experiments. It was proposed that a ‘whole-system’ approach could be pursued, in which data collection and experiments could be conducted within nested scales.

Research teams need the ability to quickly respond to pulse disturbances. In this regard, attention needs to be paid to sampling resolution. Connectivity elements are also difficult to encapsulate in site-based research and will need attention.

There was considerable discussion about the required trade-off between having numerous sites that represent a range of freshwater ecosystems and having a handful of sites that can be studied in detail. Given the monitoring programs that exist in Victoria and the desire to conduct process-based ecological research that would provide detailed understanding, it was concluded that a few sites would be preferable to many sites. There was general agreement that establishing one or two sites in Victoria would be a great achievement in the first instance (which would be higher than the density of LTER sites in the USA). In time, more sites could follow.

3. What would entice researchers to focus on common LTER sites?

Access to shared data was an obvious enticement to collaboratively work on LTER sites. Barriers to sharing ecological data include issues around ownership of data (intellectual property, etc…), metadata formatting, citation of data and protocols for access to data and its release.

Once a site has been established, it was thought that it would become self-perpetuating: an existing long-term dataset from which to draw would attract more research. The hardest period was thought to be in establishing the sites and gaining seed funding. Data availability and the willingness of researchers to make data publicly available was also an issue.

4. Likely characteristics of suitable LTER sites

The ability to perform large-scale experiments was a popular option. Being able to either give a ‘big kick’ to a catchment, or preferably, large-scale restoration experiments.

Any aquatic LTER site needs to be serious; that is, it should be managed by a consortium, include educational and community involvement aspects, be led by champions and foster a culture of inclusivity. An LTER program would need resources for ongoing maintenance, which is especially important for times between grants.

It was suggested that universities would be suitable managers.getHosts of the LTER sites because, unlike governments departments, they are not as vulnerable to changes that come from an altered political climate.
5. More thought needs to be given to the following points:

- What does climate change modelling predict for Victoria, and for different parts of the state, and which variables will affect freshwater ecosystems?
- What does legitimate long-term research actually entail? Should the US model be followed?
- We could have one LTER program with multiple sites rather than many different programs. The proposal could be based on one ‘site’ or ‘supersite’.
- Need to determine the key research questions
- Sites could be located along a climate change gradient or a gradient of disturbance. If there are only a few LTER sites initially, others can be added that are at different points along the gradient in the future.
- Need to select aquatic systems that are considered most important. Public support is important for a long-term program.
- There are opportunities to attract Federal interest if sites are located in the Murray-Darling Basin, e.g. Barmah Forest.
- Must be able to do manipulative experiments. If you want to do flow experiments, you need a tap (i.e. water storage upstream). Burning or forestry experiments are easier to conduct on smaller sites (e.g. sub-catchments). However, the focus should be on restoration experiments, not destructive experiments.
- Large-scale drivers will change, but we have no control over these. Smaller scales give us more manipulative control (e.g. water flows, channel shading, tree planting etc…).
- Climate change is an incremental change – we should focus on impacted areas where we can test some ‘adaptation’ capacity. We could also test impacted versus unimpacted using paired sites (e.g. Barmah/Ovens or Grampians/Wimmera). Different site pairings can answer different questions.
- We don’t need climate change to happen to measure the effects of climate variability (e.g. the current drought is worse than climate change projections).
- Floodplains might provide more interest for a wider range of scientists
- We could look at the switch from surface-water to ground-water dependency of aquatic ecosystems
- Learn some lessons from the CSIRO heartlands project
- In the US LTER program, smaller sites persisted while larger sites fizzled out
- Fulcrum idea: perennial streams with temporary sections – the length of perennial river will recede with time under climate change.
- The aquatic system must be integrated with its terrestrial setting.
- The sensitivity of different systems is important. As realized by American ecologists, endorheic lakes are very good sentinels of climate change–see big issue in 2009 of Limnology & Oceanography. If you use lakes, then analysing sediments (e.g. Gell & Tibbie) in lakes one can also detect previous wet and dry periods-such as those of the Holocene. Such records of previous droughts, for example, are not available for lotic systems.
- How this fits in to current policy (e.g. as defined in the new Victorian Strategy for Healthy Rivers, Estuaries and Wetlands - VSHREW)?
- How this will inform management of rivers in Victoria?
- How much money is required?
• How much effort is required to deliver (people required, number of sites, steering committee meetings etc…)?

• How much involvement with Catchment Management Authorities will be needed, especially if landholder properties are needed for sampling - getting the CMAs involved can help with management - the MDBA RRE project highlighted the importance of this.

• Should we aim for a “Southern Hemisphere Environmental Observation Network”?

• An integrated limnological and palaeolimnological test is essential.

• Test the multiple ecological thresholds of climate change and human perturbations in the LTER site/s (preferably the Western Victoria Lakes or Snowy Mountain regions) for at least the last 500 years using both modern and palaeo approaches

• Develop a "supersite" focal area with radiating arms (gradients) along which consistent data can be collected.

• The effect of snowmelt flows and drying/wetting cycles.

• LTER sites need a “hook” that attracts community and funding support

6. Some suggested research questions/topics:

• What is the relationship between air temperature and water temperature under climate change scenarios and how does this vary in different aquatic systems?

• What is the effect of increased water temperatures on the distribution of aquatic fauna in rivers, estuaries and wetlands?

• What is the effect of increased water temperature on distribution of invasive aquatic flora and fauna species and the effect on the potential for new incursions?

• What are the effects of reduced groundwater height and flows on hydro connectivity (streams and wetlands) for aquatic flora and fauna?

• What effect will reduced precipitation have on the water regime and condition of Victorian wetlands?

• What is the geographic concentration and threats to freshwater biodiversity values currently at their climate limits, and how should they be managed?

• What information do we need to manage climate change impacts on the distribution and persistence of aquatic refugia within catchments?

• How will climate change affect aquatic biodiversity conservation planning and what improvements are required to achieve higher levels of protection?

• How does climate shape aquatic native species distributions at broad spatial scales, and what quantitative predictive models are required to manage aquatic environments?

• How does floodplain change in the Ovens River change biogeochemical processes?
Conclusions
To progress to the next phase of the LTER program planning process, we need:
- Hypotheses that address effects of restoration activities and climate change impacts (in addition to the research questions above);
- Feedback on the key selection criteria for sites (below); and
- Suggestions about additional sites that may be suitable for the LTER program.

Criteria:
- A sub-catchment or hydrological unit(s) of an appropriate size ~1,000 – 10,000 ha
- Management interest – water supply or streamflow
- Surface water and groundwater responses to climate change
- Intervention possible – restoration ecology
- Variety of land uses and sub-catchments
- Nested catchment scales / paired sites
- Good existing data availability
- Ability to test climate based research hypotheses to understand processes
- Presence of a hydrological/ecological gradient
- Consortium, infrastructure, cross-discipline, practicality

Potential study catchments:
- Ovens River
- Broken River
- Goulburn River
- Wimmera River
- Glenelg River
- Grampians region
- Western District Lakes
- Yarra River
- Barmah/Gunbower Forests
- Western Port Bay region
- Gippsland Lakes (Mitchell River)
- Murray River, upstream of Lake Hume

Subsequent correspondence/information:
DSE is currently updating the Victorian Strategy for Healthy Rivers, Estuaries and Wetlands and within that are bolstering their monitoring, evaluation, reporting and improvement component. The Index of Stream Condition is one of the key projects that demonstrate the long-term commitment of Victorian government to monitoring. DSE are also exploring other programs that bolster the state-wide data provided through the ISC which better helps to demonstrate outcomes from outputs, helps to improve the way we spend investment on rivers, as well as provide information on the impacts of climate change on Victoria's rivers.

DSE are keen to see what the LTER bid may look like. However, need to understand whether the intention is to make this project a management specific task, an academic task, or as we suspect a mixture of both.
### Appendix 1: Workshop Agenda

**Workshop:** Thursday 18\(^{th}\) March 2010, Venue – University College  
**Facilitators:** Samantha Capon and Brendan Edgar, NCCARF

<table>
<thead>
<tr>
<th>Time</th>
<th>Topic</th>
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<tr>
<td>8.45 am</td>
<td>Registration and coffee/tea</td>
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<td><strong>Session 1 – Introduction and summary of existing data sets</strong></td>
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<tr>
<td>9.00 am</td>
<td>Workshop introduction</td>
<td>John Langford (Uniwater)</td>
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<td>9.15 am</td>
<td>An overview of aquatic LTER sites</td>
<td>Jenny Davis (Monash)</td>
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<td>9.35 am</td>
<td>Departmental summaries of existing data sets</td>
<td>DSE, EPA, Melbourne Water</td>
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<td>10.15 am</td>
<td>Morning tea</td>
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</tr>
<tr>
<td><strong>Session 2 – The case for aquatic LTER sites</strong></td>
<td></td>
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<tr>
<td>10.30 am</td>
<td>Sam Lake’s perspective</td>
<td>Sam Lake</td>
</tr>
<tr>
<td>11.00 am</td>
<td>Whole group discussion of:</td>
<td></td>
</tr>
<tr>
<td>i)</td>
<td>The benefits of aquatic LTER sites</td>
<td></td>
</tr>
<tr>
<td>ii)</td>
<td>Relevance to climate change adaptation</td>
<td></td>
</tr>
<tr>
<td>iii)</td>
<td>Potential partners and synergies with existing initiatives</td>
<td></td>
</tr>
<tr>
<td><strong>Session 3 – Data collection</strong></td>
<td></td>
<td></td>
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<tr>
<td>11.30 pm</td>
<td>Breakout discussion of:</td>
<td></td>
</tr>
<tr>
<td>i)</td>
<td>What data will help us observe and adapt to climate change and how?</td>
<td></td>
</tr>
<tr>
<td>ii)</td>
<td>Who would be responsible for collecting data?</td>
<td></td>
</tr>
<tr>
<td>iii)</td>
<td>What are the limitations and issues faced?</td>
<td></td>
</tr>
<tr>
<td>iv)</td>
<td>What would entice researchers to focus on common LTER sites?</td>
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</tr>
<tr>
<td>12.00 pm</td>
<td>Report back and discussion</td>
<td></td>
</tr>
<tr>
<td>12.30 pm</td>
<td>Lunch</td>
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<tr>
<td><strong>Session 4 – Site selection</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.30 pm</td>
<td>Breakout discussion of:</td>
<td></td>
</tr>
<tr>
<td>i)</td>
<td>What type of sites should be included? (e.g. sentinel, impacted)</td>
<td></td>
</tr>
<tr>
<td>ii)</td>
<td>What are the essential criteria for potential sites to meet?</td>
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</tr>
<tr>
<td>iii)</td>
<td>Number of sites required (ultimate/good/minimum number)</td>
<td></td>
</tr>
<tr>
<td>iv)</td>
<td>What are some potential sites in Victoria to look into?</td>
<td></td>
</tr>
<tr>
<td>2.00 pm</td>
<td>Report back and discussion</td>
<td></td>
</tr>
<tr>
<td>2.30 pm</td>
<td>Afternoon tea</td>
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<tr>
<td><strong>Session 5 – Building a research proposal</strong></td>
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<tr>
<td>3.00 pm</td>
<td>Whole group discussion of:</td>
<td></td>
</tr>
<tr>
<td>i)</td>
<td>Taking this forward: a proposal working group</td>
<td></td>
</tr>
<tr>
<td>ii)</td>
<td>Role of the network</td>
<td></td>
</tr>
<tr>
<td>iii)</td>
<td>Reflections</td>
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<tr>
<td>3.45 pm</td>
<td>Synthesis and close</td>
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</tr>
<tr>
<td>4 - 5.30 pm</td>
<td>Drinks</td>
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## Appendix 2: Workshop Attendees

<table>
<thead>
<tr>
<th></th>
<th>Name</th>
<th>Institution</th>
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<tbody>
<tr>
<td>1</td>
<td>Nick Bond</td>
<td>Monash University</td>
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<tr>
<td>2</td>
<td>Sam Capon</td>
<td>NCCARF</td>
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<tr>
<td>3</td>
<td>Jane Catford</td>
<td>The University of Melbourne</td>
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<tr>
<td>4</td>
<td>Lynda Chambers</td>
<td>Bureau of Meteorology</td>
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<tr>
<td>5</td>
<td>Rhys Coleman</td>
<td>Melbourne Water</td>
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<tr>
<td>6</td>
<td>Jenny Davis</td>
<td>Monash University</td>
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<tr>
<td>7</td>
<td>Brendan Edgar</td>
<td>NCCARF</td>
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<tr>
<td>8</td>
<td>Mike Grace</td>
<td>Monash University</td>
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<tr>
<td>9</td>
<td>Rob Hale</td>
<td>Monash University</td>
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<tr>
<td>10</td>
<td>Giri Kattel</td>
<td>Murray-Darling Freshwater Research Centre</td>
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<tr>
<td>11</td>
<td>Tanya King</td>
<td>Deakin University</td>
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<tr>
<td>12</td>
<td>John Koehn</td>
<td>ARI, Department of Sustainability and Environment</td>
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<tr>
<td>13</td>
<td>Sam Lake</td>
<td>Monash University</td>
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<tr>
<td>14</td>
<td>Pat Lane</td>
<td>The University of Melbourne</td>
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<td>15</td>
<td>John Langford</td>
<td>The University of Melbourne</td>
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<tr>
<td>16</td>
<td>Ralph Mac Nally</td>
<td>Monash University</td>
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<tr>
<td>17</td>
<td>Richard Marchant</td>
<td>Museum Victoria</td>
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<tr>
<td>18</td>
<td>Sam Marwood</td>
<td>Department of Sustainability and Environment</td>
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<tr>
<td>19</td>
<td>Leon Metzeling</td>
<td>Environment Protection Authority</td>
</tr>
<tr>
<td>20</td>
<td>Daryl Nielsen</td>
<td>Murray-Darling Freshwater Research Centre</td>
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<td>21</td>
<td>Phil Papas</td>
<td>ARI, Department of Sustainability and Environment</td>
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<tr>
<td>22</td>
<td>Gavin Rees</td>
<td>Murray-Darling Freshwater Research Centre</td>
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<tr>
<td>23</td>
<td>Paul Reich</td>
<td>ARI, Department of Sustainability and Environment</td>
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<tr>
<td>24</td>
<td>Belinda Robson</td>
<td>Deakin University</td>
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<td>25</td>
<td>Mike Sammonds</td>
<td>The University of Melbourne</td>
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<tr>
<td>26</td>
<td>Sabine Schreiber</td>
<td>Department of Sustainability and Environment</td>
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<td>27</td>
<td>Mike Stewardson</td>
<td>The University of Melbourne</td>
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<td>28</td>
<td>Geoff Vietz</td>
<td>The University of Melbourne</td>
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<td>29</td>
<td>Philip Wallis</td>
<td>Monash University</td>
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<tr>
<td>30</td>
<td>Angus Webb</td>
<td>The University of Melbourne</td>
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</table>