Environmental flow response and socio-economic monitoring

Hunter Valley, Central and Lower North Coast - progress report 2010
The NSW Office of Water manages the policy and regulatory frameworks for the state’s surface water and groundwater resources, to provide a secure and sustainable water supply for all users. It also supports water utilities in the provision of water and sewerage services throughout New South Wales. The Office of Water is a division of the NSW Department of Primary Industries.

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Introduction

WHAT IS THE PURPOSE OF THIS REPORT?
This report provides an update on the monitoring and evaluation activities undertaken in 2009–10 to assess the ecological and socio-economic performances of water sharing plans adopted in the Hunter Valley and on the central and lower North Coast. It provides an interim assessment of outcomes of the investigations and identifies priority needs for future monitoring and evaluation activities.

WHY DO WE NEED TO MONITOR WATER SHARING PLANS?
Water sharing plans provide water to meet environmental and socio-economic needs, and spell out the rules governing access to water. The Hunter Valley and the central and lower North Coast contain a number of important environmental assets and support valuable wine, coal and agricultural industries. Important environmental assets include the Hunter Estuary, the Kooragang Wetlands, Barrington Tops, Wallis Lake, Tuggerah Lake and the Myall Lakes.

It is important to know whether the water sharing plans are meeting their environmental objectives, so that their effectiveness can be reviewed at the end of their 10-year period of operation. This information will be used to make informed decisions on how the plans might be improved when they are renewed. To achieve this, the NSW Office of Water undertakes ecological monitoring and evaluation activities focused on specific clauses and performance indicators within the plans.

WHAT WATER SHARING PLANS ARE CURRENTLY IN PLACE?
Eleven water sharing plans in the Hunter Valley and on the central and lower North Coast are currently gazetted (Figure 1):

- Water Sharing Plan for the Jilliby Jilleby Creek Water Source 2003 (Unregulated River)
- Water Sharing Plan for the Ourimbah Creek Water Source 2003 (Unregulated River)
- Water Sharing Plan for the Karuah River Water Source 2003 (Unregulated River)
- Water Sharing Plan for the Wybong Creek Water Source 2003 (Unregulated River)
- Water Sharing Plan for the Tomago Tomaree Stockton Groundwater Sources 2003
- Water Sharing Plan for the Kulnura Mangrove Mountain Groundwater Sources 2003
- Water Sharing Plan for the Lower North Coast Unregulated and Alluvial Water Sources 2009
- Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2009
- Water Sharing Plan for the Central Coast Unregulated Water Sources 2009.

More details of these plans can be found on the NSW Office of Water website www.water.nsw.gov.au go to Water Management > Water Sharing Plans.
FIGURE 1
Location of the Water Sharing Plans in the Hunter Valley and on the central and lower North Coast.
WHAT HAS INFLUENCED THE WATER SHARING PLANS’ OPERATION IN 2009–10?

Regulated rivers—water availability
Available water determinations for general security access licences for the Hunter and Paterson regulated river water sources were 100 per cent at the start of the 2009–10 water year and continued at 100 per cent to June 2010. Figures 2 and 3 (over page) show the available water determinations for general security access licences in the Lower Hunter Regulated River over the last 25 and 10 years respectively.

Unregulated rivers—water availability
Annual allocations to all categories of access licences for the Tomago Tomaree Stockton and Kurnura Mangrove Mountain groundwater sources were 100 per cent.

WHAT ENVIRONMENTAL ISSUES ARE ADDRESSED BY THE WATER SHARING PLANS?

Regulated rivers water sharing plans
The Water Sharing Plan for the Hunter Regulated River Water Source has rules to ensure environmental security of the Hunter Estuary. These rules include the Planned Environmental Water Supplementary Access Rules (Clauses 16(2) and 51(2)), which include 12 hours of target flow at Liddell and Singleton before access is allowed. The intent is to protect the initial flow in freshes to enhance carbon and nutrient movement to the estuary. Clause 51(6) limits extraction to 50 per cent of inflows. The end-of-system flow targets for environmental water (Clause 15 (c)) are intended to provide water to the estuary and to restore some variability at the low flow end of the hydrograph (linked to inflows).

The Water Sharing Plan for the Paterson Regulated River Water Source also has end-of-system flow targets, as well as 2,000 megalitres of Environmental Contingency Allowance (Clause 14).

Unregulated rivers water sharing plans
The water sharing plans for the Jilliby Jilliby Creek, Ourimbah Creek, Karuah River, Wybong Creek, Lower North Coast Unregulated and Alluvial, Hunter Unregulated and Alluvial, and Central Coast Unregulated water sources set cease-to-pump rules to protect very low flows, and for some water sources sets daily flow sharing rules to protect a proportion of flows for the environment.

Groundwater sharing plans
The Water Management Act 2000 requires that water be allocated for the fundamental health of a water source and its dependent ecosystems as a first priority. This means that extraction from a groundwater source must
not have a significant impact on any ecosystems that rely on groundwater.

Groundwater levels in the Tomago Tomaree Stockton and Kulnura Mangrove Mountain groundwater sources are monitored in areas where intensive groundwater extraction occurs. This monitoring allows the sustainable management of extraction and the minimisation of any impacts on associated groundwater-dependent ecosystems, surface water and other users. In the Tomago Tomaree Stockton Groundwater Sources, the groundwater quality is monitored under conditions on Hunter Water Corporation’s groundwater licence to ensure that the interface between the freshwater (low-salinity) aquifer and the saltwater estuary remains stable.

WHAT ECOLOGICAL MONITORING IS OCCURRING?

Regulated rivers water sharing plans

The Integrated Monitoring of Environmental Flows (IMEF) scientific program was established in 1997 to assess the ecological benefits of environmental flow rules in the State’s regulated rivers and the Barwon–Darling River. The program has since been revised to monitor and evaluate the ecological performance of the water sharing plans for the regulated rivers.

The following projects are under way in the Hunter and Paterson regulated river water sources.

Water Sharing Plan for the Hunter Regulated River Water Source

The Water Sharing Plan for the Hunter Regulated River Water Source, developed by the Hunter River Management Committee, focuses on establishing a balance between extractive use and the broader needs of the Hunter River and estuarine environment. The flow management rules were designed not only to meet the river flow objectives, but to also accommodate existing rules that had been put in place to preserve the ecological functioning of the Hunter River.

One of the key considerations was the high reliability of supply needed by industry (particularly power generation), and planning to ensure some level of supply during the worst drought on record, together with the more general security of supply for agriculture.

FIGURE 4
Zoo plankton sampling in estuary.
The Hunter River Management committee developed a set of flows rules with the aim of maintaining or improving the ecological condition of the Hunter River and estuary (Paradice et al. 2008).

**Rule one**
A 20,000 megalitres Environmental Contingency Allowance (divided between 10,000 megalitres from Glenbawn Dam and 10,000 megalitres from Glennies Creek Dam) for use for special-purpose environmental or river management releases, sourced from previously unallocated ‘shelf water’ that otherwise would have been sold off for commercial use.

**Rule two**
1. Pumping is delayed for 12 hours from the declaration of a flow event (existing orders can still be diverted)
2. Minimum seasonal flow targets for several locations along the river, and an end-of-system (inflow) target for the Hunter Estuary
3. Up to 50 per cent of extraction from high flow events, if flow conditions are met.

**Rule three**
High flow pumping conditions in the associated tributaries are linked to the Hunter Regulated River flow rules.

**Rule four**
In-principle support for separation of surface water and groundwater system management plans (where the systems are not interconnected).

**Rule five**
In-principle support for variable end-of-system flow targets.

**Rule six**
Access strategies for water users in the tidal pool section.

**Rule seven**
Continued development of the Hunter Salinity Trading Scheme.

**Rule eight**
No further allocation from Hunter River storages.

The rules attempt to provide a return to more natural flow conditions in the Hunter River system, restoring some of the flow variability and maintaining end-of-system flows. In response to the implementation of these rules, the NSW Office of Water undertook a number of studies to gain a better understanding of the water needs of the Hunter River and estuary. These studies were grouped into two groups to reflect the ecological processes addressed.

**Studies of flows, phytoplankton and nutrients**
These studies have aimed at explaining the specific instream flow requirements of the Hunter River system, providing further scientific evidence to support the adoption of these rules and to define the minimum flow requirements.

**a) Glennies Creek environmental contingency allowance scouring flow study**
The Water Sharing Plan for the Hunter Regulated River Water Source established an environmental contingency allowance (ECA) of 20,000 megalitres a year to be used for contingencies and environmental purposes in the Hunter catchment. The ECA allows for ‘strategic use’ to improve river health rather than for ongoing operational uses.

Concern about the possible negative impacts of Glennies Creek Dam on Glennies Creek downstream of the dam prompted the use of part of the ECA to investigate how a high flow scouring release could restore river ecosystem functioning in the stretch of river below the dam to pre-dam levels. This study forms part of a component study of the statewide IMEF program.

The construction of Glennies Creek Dam has resulted in substantial changes in the flow pattern of Glennies Creek. The current flow management regime provides a relatively constant flow, in contrast to the previous natural wetting and drying regime and random high flow events. As a consequence of
this flow regulation, stream biofilm and macroinvertebrate community structure, and hence stream biodiversity, are thought to have changed. Local landholders have also reported siltation in pools below the dam, further highlighting possible changes in stream condition.

The study was designed to assess the impacts of changes in flow regime on stream biofilm and macroinvertebrate communities on cobbles present in riffles on three sections of stream in the Glennies Creek subcatchment. Six sites were sampled: two on Glennies Creek below the dam considered to have been negatively impacted by the dam’s presence (one immediately below the dam wall, the second 5 kilometre downstream), two control non-impacted sites on Carrow Brook (above the dam’s influence) and two control non-impacted sites on the unregulated Goorangoola Creek (at a similar latitude but in an adjacent valley to the affected sites). Problems with dam infrastructure prevented a proposed scouring release, and the study was suspended in 2005. Only pre-impact data were reported.


Phytoplankton was monitored at 11 sites between August 1998 and May 2003 (Figure 5). Nine of the sites were located in the Hunter River between Glenbawn Dam and Glennies Creek, upstream and downstream of major tributaries and reaches, to assess the effects of tributary algal inputs or dilution. The other two were located in major tributaries (Dart Brook and the Goulburn River) to determine any impacts on the mainstream phytoplankton community. Sampling ceased after 2 years’ data showed clear effects and further sampling would not add any new information. Although a full continuous data set would have been advantageous for analysis purposes.

c) Water quality sampling 1998 to 2003

The water quality monitoring program mirrored the phytoplankton data collection above. The Hunter River appeared to be a relatively well mixed system, so grab samples were taken from riffles at each site, weekly in summer (October to March) and fortnightly in winter (April to September). Field meters measured electrical conductivity, pH, temperature and turbidity. Water quality samples were taken from 0.1 metres below the water surface, filtered on site (0.45 μm) and frozen for analyses of biologically available nutrients, including phosphorus, reactive silica, nitrogen, nitrogen oxides (NOx) and ammonia (NH3).
d) Hunter Integrated Monitoring of Environmental Flows
phytoplankton studies -2006
low flow (drought) study
Phytoplankton was monitored to provide a broader understanding of the Hunter Rivers’ phytoplankton ecology. The results will be used to advance our understanding of phytoplankton growth, temperature and flow relationships. The studies identified the risk of diatom blooms occurring in summer in warm, slow water (>23 °C) and potential mitigation options using flow manipulation. The drought conditions in the Hunter Valley in 2005 and 2006 resulted in extremely low ‘natural’ river flows and dam storage levels, thus further restricting options for flow supplementation from dam releases. These reduced flows provided an opportunity to further investigate the low flow phytoplankton ecology of the Hunter River system.

e) Mid Hunter growth of Cyclotella meneghiniana and Nitzschia spp.
Freshwater blooms of Cyclotella meneghiniana and Nitzschia spp. have been recorded frequently in the middle section of the Hunter River, since a large outbreak was reported in 1994. This river section is relied on heavily for irrigation, domestic water supply, stock watering and cooling water for power generation, and its flows are highly modified by impoundment, flow regulation and water extraction. Substantial reductions in total discharge, smaller floods and summer flows are suspected of increasing the prevalence of diatom blooms.
Environmental contingency flows have been provided to many rivers in NSW for wetland replenishment, facilitation of fish and bird breeding, and suppression and flushing of algal and cyanobacterial blooms. Manipulation of flow is one of only a few ways in which phytoplankton growth can be controlled in a river. Environmental flow provisions in the Hunter River include protection of low flows through limits on water extraction and an ECA held in storage. However, the effectiveness of these provisions at suppressing and flushing phytoplankton blooms was not known. So this study was conducted to reveal the environmental factors that lead to the development of blooms of diatoms in the Hunter River, and to evaluate the potential of environmental flows for suppressing them. As flow manipulation may be useful, flows to prevent the occurrence of blooms are proposed. Data were collected at two sites on the Hunter River with frequent
diatom blooms: at Bowmans Crossing and at Moses Crossing (Figure 6 - see page 11). Here the river is wide, free flowing, generally well mixed, and shallow (usually less than 0.5 metres at lower flows).

f) Nutrient limitation study
This study was designed to reveal how nutrients affect the growth of algae. With the use of historical data sets, a series of in situ nutrient addition bioassays were conducted to show which nutrients limit phytoplankton growth. From January to August 2005, phosphorus, nitrogen and silicon were added to the water.

The study sites, Moses Crossing and Bowmans Crossing (Figure 6 - see page 11), are located mid-river and in key locations that have a history of diatom blooms. At both sites the river is wider and shallower than upstream and there is minimal riparian vegetation. The river is generally free flowing and the water column is well mixed and shallow (less than 0.5 metres deep). However, some deep pools do exist.

A total of four treatments, with four replicates per treatment were used at each site. The treatments were: control (nothing added), + phosphorus (phosphorus added), + nitrogen (nitrogen added) and + silicon (silicon added).

g) Carbon and nutrient cycling in the hyporheic zone
The hyporheic zone is the saturated habitat below the stream bed, which can also extend into the stream banks. It is an area where surface water and groundwater exchange takes place, and it plays a crucial role in the biogeochemical transformation of water by microbial biofilms. It also harbours invertebrates that graze biofilms, contribute to secondary production, and can alter the porosity of the zone through their movement or burrowing. Flow events enhance the hyporheic processes by flushing silt, oxygenating the sediments and stimulating microbial processes. Rule 2 is designed to protect small and medium freshes from being extracted via pumping.

Three sites were chosen for the study: the Hunter River at Aberdeen (a cobble and sand bed site) and two sites near Jerrys Plains, at Bowmans Crossing and Moses Crossing, between Muswellbrook and Singleton (both gravel and sand bed sites). The study investigated the impacts of an environmental flow release on water temperature, conductivity, dissolved oxygen and nitrate concentrations in surface and subsurface (hyporheic) water at upwelling and downwelling zones. The environmental flow release, created via a special environmental release from Glenbawn Dam of 5,000 megalitres a day over 3 days, was designed to mimic a medium flow event. An unplanned mid-sized flood that occurred 20 days before this release possibly reduced the assessed stimulatory benefits.

It was hypothesised that the flow pulse would flush the sediments with oxygenated water, stimulating hyporheic microbial activity and nitrification, and enhancing nitrate concentrations. Samples were collected before, 7 days after and 49 days after the flow release.

Studies of estuary inflow needs
The maintenance, frequency and size of freshwater inflows has been identified as critical to the maintenance of estuary health. The following studies provide evidence to support the contention that the flow rules achieve end-of-system flow targets that maintain small and medium freshes.

a) Environmental flow rules and Hunter Estuary productivity study
This study tested the hypothesis that ‘protecting or restoring a portion of freshes and high flows, and otherwise maintaining natural flow variability (River Flow Objectives 3 and 6), through off-allocation use restrictions and dam releases, will maintain the supply of nutrients and freshwater pulses to the estuary, thereby maintaining salinity structure
(fresh/saline wedge) and sustaining production of organisms such as prawns and fish’. It was established to develop an integrated Hunter Estuary Process model that could link the changes in estuary salinity structure (and associated changes in nutrient and sediment input) derived from implementation of environmental flow rules to changes in estuary productivity. The project was divided into two stages:

Stage 1 Development of Hunter Estuary salinity model
Consultants BMT WBM were commissioned to develop an estuary inflow model that could be used to predict movement or changes in the estuary’s salinity structure, using 67 years of Hunter, Paterson and Williams Rivers inflow data sourced from the Hunter IQQM model and an estuary catchment (Wallis Creek and coastal areas) rainfall runoff model. BMT WBM (2010) developed a TUFLOW-FV two-dimensional plan-view hydrodynamic model that provided data for 38 representative locations.

Stage 2 Independent review and interpretation of modelling results
Dr Brian Williams (University of Newcastle) assessed the expected flows and resultant salinity in the estuary under natural conditions, present conditions and estimated future conditions, with and without the implementation of water sharing plans. Scenarios included an approximation of the proposed Tillegra Dam to support planning decisions in the Hunter Valley.

b) River and estuarine nutrient delivery study
Water quality was monitored at six sites from the upper Hunter River Estuary (Morpeth) to the mid Hunter River (at Liddell) to collect data on changes in volume, nutrient load and water source as a result of the operation of the 50 per cent pumping rule and the 12-hour rule. The sites (Figure 7) were chosen with reference to river travel times, location and aggregation of major extraction and water use localities, and the influence of tributary inflows. The study set out to collect baseflow data against which data from flow events could be compared. The sampling program began after the flow rules were adopted, and hence the data reflect
the effectiveness of the rules. Baseflow samples were collected over 24 hours, and flow event samples were collected for periods consistent with the size of the event. A number of events were sampled in 2002, 2003 and 2005. The 2005 sampling unfortunately coincided with the start of severe drought, and hence event size and frequency were restricted. The water samples were analysed for total organic carbon, dissolved organic carbon, total nitrogen, oxidised nitrogen, total phosphorus, soluble phosphorus, electrical conductivity and turbidity. The linking of the sampling sites with that of gauging sites allowed for collected water quality concentrations to be used to calculate loads.

c) Hunter Estuary carbon inflow studies
This study was performed to establish whether dissolved organic carbon is carried in the first 12 hours of a flow event. Dissolved organic carbon is carried with inflows that wet benches and floodplains. A follow-up study undertaken by the NSW Office of Water and the University of Technology, Sydney, examined how plankton responds to the delivery of organic carbon.

Water Sharing Plan for the Paterson Regulated River Water Source
Freshwater fish study in the Paterson River

This study examined the association of fish assemblages with flow regime in two regulated and two unregulated tributaries of the Hunter River between 2006 and 2007. Patterns in the spawning period and diet of fish were studied to understand the potential indirect effects of flow regulation on fish assemblages. Hydrological analysis revealed that flow regulation in the two regulated tributaries affected the frequency of small floods, increased base flows, eliminated cease-to-flow events and decreased variability in seasonal flows. Storm events caused dams to spill and induce large floods in regulated rivers at similar frequencies to neighbouring unregulated tributaries.

Benthic macroinvertebrates study in the Paterson River

This study documented the effects of river regulation on physical and chemical attributes and invertebrate communities, and tested responses to a pulsed flow release. It was hypothesised that regulated rivers would have fewer invertebrate taxa (species etc.), higher invertebrate density, altered community composition and increased contribution of autochthonous (derived on-site) sources to the invertebrates’ diets. A pulsed flow release was hypothesised to decrease the density of invertebrates positively affected by regulation, alter the community composition to more closely resemble that of an unregulated river, and increase the contribution of allochthonous (derived off-site) sources to their diets. The study assessed the differences between regulated and unregulated rivers in aquatic invertebrate density, richness, community composition and the densities of individual taxa. The contributions of allochthonous and autochthonous food sources were also determined.

Unregulated rivers water sharing plans

Low flow and pool refugia study in the Wybong Creek Water Source

The Water Sharing Plan for the Wybong Creek Water Source imposes a cease-to-pump condition based on the 95th percentile of all days with flow. At the gauging station this is approximately equivalent to the 80th percentile of all days (including days with no flow). The aim of this condition is to protect low flows throughout the Wybong Creek catchment. Water users argued that the stream gauging station forming the primary control was located in a section of stream that was unrepresentative of flow conditions in the majority of the stream. In 2006, they made representations to the Department regarding these matters, as well
as the lack of equity between the water sharing plan and the proposed water access rules in the two neighbouring water sources. At this time, the cease-to-pump condition had been in place for 220 consecutive days, despite flows along most of the stream upstream of the gauge. The plan was suspended owing to the severe drought. Visible flow conditions at a number of reference points have since been implemented.

A study was undertaken with the aim of determining the relationship between flows at the gauge site and upstream, whether the gauge was unrepresentative of catchment flows, and whether the water quality in pool refugia deteriorated during very low flows. Photo-point monitoring and flow gauging were undertaken at key sites along Wybong and Cuan Creeks (Figure 8). Thermistor strings were installed at key refugia to determine whether electrical conductivity and temperature changed during very low or no flows.

**FIGURE 8**
Monitoring sites for the low flow and pool refugia studies in Wybong Creek.

**LEGEND**
- Photo point, low flow gauging and pool refugia
- Photo point
- Photo point and refugia
- Photo point and low flow gauging
- NPWS reserves
Riffle modelling in the Karuah River Water Source

This study was undertaken to examine the effectiveness of the very low flow cease-to-pump condition for maintaining connectivity and low flow habitats in the Karuah River. The broad objective was to verify that a calibrated HEC RAS model of a riffle is capable of predicting wetted surface area at a range of low flows. Additionally, it aimed at determining relationships between flow and wetted surface area at the three riffles in the Karuah River to be used in verifying cease-to-pump flows.

The study trialled the ‘field-transect method’, a hydraulic modelling method for setting cease-to-pump flows in unregulated rivers. The method requires a relationship to be developed between river flow and an in-stream characteristic that is important for an ecological process. This relationship allows the likely environmental implications of different flows to be compared in terms of the river characteristic. An example is measurement of the flow that will connect billabongs. For setting cease-to-pump flows, the hydraulic characteristics of riffles, such as wetted area, are targeted. An extension of the field-transect method is the ‘flow-event method’ that uses the same relationship between flow and a river characteristic, but it compares the frequency and duration of events resulting from different management options. Analogous to the earlier example are the frequency and duration of flows that connect billabongs owing to different management options.

For setting cease-to-pump flows, the frequency and duration of adequate hydraulic characteristics of riffles, such as wetted area or longitudinal connectivity, could be evaluated.

The relationships that are intrinsic to both methods can be developed from either direct measurement or modelling of the particular characteristic. For this study, the HEC RAS modelling application was selected to simulate the hydraulic characteristics (e.g. wetted area, water depth, water velocity) of the riffles. A supplementary tool was used to support the modelling by automating the calculating and importing of riffle cross-sections and displaying the resulting wetted area as a GIS layer.

The three sites chosen for the study were:
- Karuah River at Monkerai
- Karuah River at Greens Crossing
- Karuah River at Booral.

Photo-point monitoring and low flow verification

The NSW Office of Water established a program to assess the ecological outcomes of the 20 water sharing plans for unregulated water sources that were gazetted in 2004. The first aim of ecological monitoring is to determine whether the environmental objectives of the plans are being achieved.

A photo-point monitoring program was established in the unregulated river sections covered by the water sharing plans for the Jilliby Jilliby Creek, Ourimbah Creek, Karuah River and Wybong Creek water sources. Initial work has involved the establishment of photo-point monitoring sites (see Figure 9 page 17) and an assessment of the catchment hydrology during periods of low flow.

More detailed monitoring of vulnerable habitats may be undertaken during the life of the plans.

Fish sampling is planned as part of the ecological modelling. This new approach will try to determine whether water extraction has affected the fish communities in the Jilliby Jilliby Creek, Ourimbah Creek, Karuah River, and Wybong Creek water sources.
Groundwater sharing plans

Water sharing plan for the Tomago Tomaree Stockton Groundwater Sources

Hunter Water Corporation maintains a wide groundwater resource network within the Tomago Groundwater Source, monitoring over 80 bores for water level, water quality and seawater intrusion. Five key monitoring sites established beyond the influence of extraction bore lines have been monitored since the mid 1970s to indicate the overall groundwater resource condition (see Figure 10 page 18).

The NSW Office of Water monitors two bores (see Figure 11 page 18), both of which have automatic loggers installed to collect water table measurements every 2 hours. The bores were drilled in 2002. Access class licence holders with large entitlements also monitor groundwater as part of their development consent, and submit results as part of their annual reporting requirements.

The NSW Coastal Groundwater Quality and Groundwater-Dependent Ecosystems project, currently being undertaken in collaboration with several universities, local water utilities and councils, focuses on groundwater extraction within high-use coastal sand and alluvial aquifers and how this affects groundwater.
quality and groundwater-dependent ecosystems. The Tomago Tomaree Stockton Groundwater Sources is one of seven pilot sites that are being investigated in detail. The results will be used to support decisions on the remaining northern NSW coastal aquifers.

Water sharing plan for the Kulnura Mangrove Mountain Groundwater Sources

Groundwater monitoring in the Kulnura Mangrove Mountain Groundwater Sources began in 1993 in several private bores. The number of monitoring bores has expanded over the years. Most sites have two or more bores at different depths. The Office of Water has installed 27 water level loggers at 13 sites (Figure 12). The data can be viewed at www.water.nsw.gov.au go to Real-time data > Groundwater.
plan provisions being monitored

WHICH PLAN PROVISIONS ARE WE MONITORING?

Regulated rivers water sharing plans

Water Sharing Plan for the Hunter Regulated River Water Source

Clause 11: Objectives
The objectives of the plan are to:

(a) protect the natural seasonal variation of low flows during dry periods
(b) protect the initial flow in natural freshes
(c) protect a high proportion of moderate and high flows
(d) protect a high proportion of the natural inundation pattern and distribution of floodwaters supporting natural wetland and floodplain ecosystems
(e) mimic natural flow variability of medium and high flows
(f) maintain rates of rise and fall river heights within their natural bounds for medium and high flows
(g) provide a reserve of water that can be used to assist in management of environmental contingencies

(h) contribute to maintenance of estuarine processes and habitats
(i) contribute to maintenance of the ecological condition of this water source and its riparian areas over the longer term
(j) mitigate the impacts of instream structures
(k) mitigate downstream water quality impacts of storage releases
(l) contribute to protection of recreational and tourism opportunities.

Clause 13: Environmental performance indicators
The performance of the plan is assessed against changes in:

(a) the ecological condition of this water source and dependent ecosystems
(b) low flows
(c) moderate to high flows
(d) water quality
(e) the economic benefits derived from water extraction and use.

Clause 16: Planned environmental water
The plan sets rules for the management of an environmental contingency allowance, which at the start of each water year is
20,000 megalitres in Glenbawn Dam and Glennies Creek. This water is to be released to manage critical environmental events, such as algal blooms and chemical spills, and to provide flows at critical times for purposes such as fish migration and stony bed scouring.

When access to uncontrolled flows is allowed or supplementary water access licences are permitted to extract water, 50 per cent of the daily flow in each river reach is to be protected.

Clause 32: Long-term average annual extraction limit
The plan sets a long-term average extraction limit of 217,000 megalitres a year. This limit allows water extractions to grow by 30 per cent above their current level, and full use of all access licences.

Clause 62: Water delivery and channel capacity constraints
The maximum water delivery or operating channel capacity shall be determined as specified by the Minister, taking into account:
(a) flooding of private land or interference with access to land
(b) the effects of flooding on the floodplain and associated wetlands
(c) the expected transmission losses
(d) capacities of water management structures controlled by the Minister
(e) State Water Management Outcomes Plan targets.

Clause 63: Rates of change to releases from water storages
Rules regarding rates of change to releases from water storages should be specified as defined by the Minister and should take into account:
(a) the environment
(b) damage to river banks
(c) public safety.

Water Sharing Plan for the Paterson Regulated River Water Source

Clause 10: Objectives
The objectives of the plan are the same as defined by Clause 11 of the Water Sharing Plan for the Hunter Regulated River Water Source, above.

Clause 12: Environmental performance indicators
The performance of the plan is assessed the same as defined by Clause 13 of the Water Sharing Plan for the Hunter Regulated River Water Source, above.

Clause 14: Planned environmental water
The plan sets rules for the management of an environmental contingency allowance to manage critical environmental events, such as algal blooms and chemical spills, and to provide flows at critical times for purposes such as fish migration or stony bed scouring, within the plan area.

Clause 32: Long-term average annual extraction limit
The plan sets a long-term extraction limit of 11,175 megalitres a year.

Clause 45: Extraction under supplementary water access licences
Supplementary water access licence holders can extract water only if:
(a) the flows at the flow gauge downstream of Lostock Dam (gauging station number 210021) are sufficient to ensure that the flows at Gostwyck and downstream of Lostock will exceed the threshold flows listed below for at least 12 hours
(b) the source is flow over the Lostock spillway
(c) a discharge through the control valves immediately before has prevented a flow over the spillway
(d) the control valves have released water in excess of other requirements.

The threshold flows mentioned above are:
(a) twice the flow rates at Gostwyck specified in clause 14
(b) the greater of either 40
megalitres a day or twice the
volume of the total installed pump
capacity for water supply works
nominated on a supplementary
water access licence at the flow
gauge downstream of Lostock
Dam (210021).

Clause 56: Water delivery and
channel capacity constraints
The maximum water delivery or
operating channel capacity shall
be determined as specified by the
Minister and in the implementation
manual for this plan, taking into
account the same criteria as defined
by Clause 62 of the Water Sharing
Plan for the Hunter Regulated River
Water Source, above.

Clause 57: Rates of change to
releases from water storages
Rules regarding rates of change to
releases from water storages should
be specified as specified by the
Minister and in the implementation
manual for this plan, and should
take into account:
(a) the environment
(b) damage to river banks
(c) public safety.

Clause 62: Amendment of planned
environmental water
The Minister may amend the
minimum flow targets set for
end-of-system flows on the basis of
further studies of the environmental
requirements of the estuary. The
studies may be undertaken in the
Hunter River, Paterson River or
Wallis Creek tidal pools, as
specified within the Water Sharing
Plan for the Hunter Unregulated
and Alluvial Water Sources.

Unregulated rivers water
sharing plans
Water Sharing Plan for the Jilliby
Jilliby Creek Water Source

Clause 11: Objectives
The objectives of the plan are to:
(a) protect natural water levels in
pools, rivers and wetlands during
periods of no flow
(b) protect natural low flows
(c) protect or restore a proportion
of moderate flows (freshes) and
high flows
(d) maintain or restore the natural
inundation patterns and
distribution of floodwaters
supporting natural wetland and
floodplain ecosystems
(e) maintain or imitate natural low
flow variability in all rivers
(f) minimise the impact of in-river
structures
(g) maintain or rehabilitate
downstream (including estuarine)
processes and habitats.

Clause 13: Environmental
performance indicators
The performance of the plan is
assessed against changes in:

(a) low flows
(b) moderate to high flows
(c) the ecological condition of this water source and dependent ecosystems
(d) the economic benefits derived from water extraction and use.

Clause 17: Flow classes
The sharing of daily flows is based on flow classes set by the plan.

Clause 45: Total daily extraction limit
The plan sets a total daily extraction limit for each flow class set in Clause 17.

Clause 72: Amendment of very low flow provision
The Minister may vary the very low flow levels set in Clause 17 within a small range following field verification that natural water levels in river pools and wetlands during periods of no flow and natural low flow regimes are protected.

Water Sharing Plan for the Ourimbah Creek Water Source

Clause 11: Objectives
The objectives of the plan are the same as defined by Clause 11 of the Water Sharing Plan for the Jilliby Jilliby Creek Water Source, above, and also to:

(a) protect and enhance water-dependent species and sites of significance to the local indigenous community
(b) improve water quality as a result of improved flow.

Clause 13: Environmental performance indicators
The performance of the plan is assessed against the same criteria defined by Clause 13 of the Water Sharing Plan for the Jilliby Jilliby Creek Water Source, above.

Clause 17: Flow classes
The sharing of daily flows is based on flow classes set by the plan.

Clause 45: Total daily extraction limit
The plan sets a total daily extraction limit for each flow class set in Clause 17.

Clause 72: Amendment of very low flow provision
The Minister may vary the very low flow levels set in Clause 17 within a small range following field verification that natural water levels in river pools and wetlands during periods of no flow and natural low flow regimes are protected.

Water Sharing Plan for the Karuah River Water Source

Clause 11: Objectives
The objectives of the plan are the same as defined by Clause 11 of the Water Sharing Plan for the Jilliby Jilliby Creek Water Source, above, and also to:

(a) protect and enhance recreational and tourism opportunities
(b) protect and enhance recreational and commercial fishing interests
(c) protect and enhance the oyster industry in the lower Karuah River
(d) improve water quality parameters as a result of environmental flows at low flow periods.

Clause 13: Environmental performance indicators
The performance of the plan is assessed against the same criteria defined by Clause 13 of the Water Sharing Plan for the Jilliby Jilliby Creek Water Source, above.

Clause 17: Flow classes
The sharing of daily flows is based on flow classes set by the plan.

Clause 21: Planned environmental water
In A, B or C class flows, in the first 24 hours after the lower flow level is exceeded on a rising river, the holders of access licences cannot draw this water from the flow class.

Clause 23: Planned environmental water
When the Stroud Weir fish passage is constructed and operational, supplementary environmental water
will be set as follows:

(a) each year from 1 June to 31 July and from 1 October to 30 November, the very low flow and A class flow levels will be increased surpassed to supply a flow of 10 megalitres a day at Stroud Weir

(b) these levels will apply until either at least 10 megalitres a day has flowed continuously for 3 weeks at the weir for each period, or to the end of the period, when the original flow levels will reapply

(c) the Minister, in consultation with the Minister for Fisheries, may set a period shorter than 3 weeks if it is warranted.

Clause 45: Total daily extraction limit
The plan sets a total daily extraction limit for each flow class set in Clause 17.

Clause 75: Amendment of very low flow provision
The Minister may vary the very low flow levels set in clause 17 within a small range following field verification that natural water levels in river pools and wetlands during periods of no flow and natural low flow regimes are protected.

Water Sharing Plan for the Wybong Creek Water Source

Clause 11: Objectives

The objectives of the plan are to:

(a) protect natural water levels in pools during periods of no flows

(b) protect natural low flows

(c) protect or restore a proportion of moderate flows (freshes) and high flows

(d) maintain or restore the natural inundation patterns and distribution of floodwaters supporting natural wetland and floodplain ecosystems

(e) maintain or imitate natural flow variability

(f) maintain groundwater within natural levels and variability critical to surface flows and ecosystems

(g) minimise the impacts of in-river structures

(h) ensure river flow management provides for contingencies

(i) maintain or improve the ecological condition of this water source and its riparian areas over the longer term

(j) recognise and protect the contribution from this water source to downstream water sources’ environmental and basic right requirements

(k) contribute to the achievement of water quality to support the environmental values of this water source.
Clause 13: Environmental performance indicators
The performance of the plan is assessed against the same criteria defined by Clause 13 of the Water Sharing Plan for the Jilliby Jilliby Creek Water Source, above.

Clause 17: Flow classes
The sharing of daily flows is based on flow classes set by the plan.

Clause 20: Recharge of the groundwater component of the water source
The overall basis for water sharing in the plan includes an average annual recharge to the alluvial aquifers of 3,820 megalitres a year.

Clause 22: Planned environmental water
Environmental water in each flow class is the surface water flow occurring in the water source, minus any access permitted under the plan, plus the groundwater storage component of the water source, plus a percentage of the groundwater recharge, minus a specified volume.

In the first 24 hours after an upper flow level specified in Clause 17 is exceeded on a rising river, the holders of access licences may extract only the total daily extraction limit for the flow class that occurred before the flow level was exceeded.

Clause 23: Extraction by water supply work
All approved water supply works within 40 metres of the rivers specified in the plan shall comply with pool control levels and key sites.

Clause 45: Total daily extraction limit
The plan sets a total daily extraction limit for each flow class set in Clause 17.

Clause 55: Water level management
The Minister may declare that to protect groundwater levels within the aquifer, local access rules apply in a defined ‘local impact area’.

Clause 56: Water quality management
The Minister may declare that to protect water quality within the aquifer, local access rules apply in a defined ‘local impact area’.

The studies for varying total daily extraction limits shall:
(a) assess whether existing and proposed total daily extraction limits meet the objectives specified in Clauses 11(e) and (f)
(b) specifically determine the surface flow at the reference point by developing the relationship between the flow and the daily extracted volumes, considering:
(i) surface flow plus extraction on any day
(ii) development of a theoretical flow duration curve based

Clause 76: Amendment of flow levels, pool protection provisions and total daily extraction limits
The Minister may vary the very low flow levels and the initial pool control levels and key sites following field verification, and vary the total daily extraction limit within specified volumes and subsequently the planned environmental water, following studies of water usage and of the connectivity of surface water and groundwater.

The field verification and the review of pool control level should assess:
(a) whether the flow level meets the objectives in Clause 11(a) and (b)
(b) whether the pool control levels and key sites meet the objectives specified in Clauses 11(a) and (i), and specifically consider:
(i) the suitability of the location of the key sites used in assessing pool health upstream
(ii) the drawdown of the water levels within the pools upstream during periods of extraction
(iii) the significance of pools that are affected by drawdown.
on the surface flow plus extraction

(iii) calibration of the curve against rainfall data and a control site in another water source

(iv) reassessment of the river and groundwater connectivity and a review of the groundwater sustainable yield

(v) the relationship of river flow at various sites within this water source for different flow classes, as determined by information from river flow gauging stations

(vi) the water level behaviour in groundwater monitoring bores.

Clause 12: Environmental performance indicators

The performance of the plan is assessed against changes in:

(a) low flows

(b) moderate to high flows

(c) groundwater extraction relative to the long-term average annual extraction limit

(d) the ecological value of key water sources and their dependent ecosystems

(e) the economic benefits derived from water extraction and use.

Clause 17: Flow classes for these water sources

The sharing of daily flows is based on flow classes set by the plan.

The Minister may amend flow classes to establish new or additional flow classes in:

(a) the Upper Barrington River, Upper Gloucester River, Bowman River, Lower Barrington–Gloucester Rivers, Dingo Creek, Lower Manning River, Mid Manning River, Upper Manning River, Avon River and Manning Estuary Tributaries water sources after field verification and the review of relevant studies

(b) the Dingo Creek, Upper Gloucester River and Upper Manning River water sources, on the basis of sufficient data to determine cease-to-pump and commence-to-pump levels and a review of B Class flows at the 50th percentile

(c) the Lower Barrington River Management Zone of the Lower Barrington/Gloucester Rivers Water Source, after installation of an appropriate gauging station and the collection of sufficient data to determine cease-to-pump and commence-to-pump levels

(d) the Manning River Tidal Pool Water Source, following determination of an appropriate location for a salinity probe and assessment of the users and extraction within the water source

(e) the Upper Wallamba River Management Zone of the Wallamba River Water Source to specify very low flows as being at or below the 95th percentile flow, and A Class flows as being greater than the 95th percentile flow, following the installation of appropriate infrastructure

(f) the Lower Manning River and the Dingo Creek water sources following the installation of infrastructure downstream of existing infrastructure

(g) the Wallamba River, Coolongolook River and Myall River water sources, on the basis of further field verification or studies of the flow reference points.
Clause 19: Planned environmental water

The planned environmental water rule:

(a) in the Myall River Water Source, the Coolongolook River Water Source, the Upper Wallamba River Management Zone and the Tidal Wallamba River Management Zone of the Wallamba River Water Source, excluding specific purposes provide for by the plan, does not permit the taking of water within 24 hours after flows have exceeded the very low flow class at the end of the freshwater tributaries.

(b) in the Khappinghat Creek Management Zone of the Wallamba River Water Source, excluding specific purposes provide for by the plan, does not permit the taking of water from a river by water supply works within 24 hours after flows have exceeded the very low flow class at the pump site.

The Minister may amend the plan to identify pools in the rivers in the Dingo Creek Water Source, the Upper Gloucester River Management Zone of the Upper Gloucester River Water Source and any other water sources that require special protection, and establish initial pool control levels at key sites, to prevent the taking of water from a designated pool below a specified level.
Clause 41(6): Rules for granting approvals for water supply works near sensitive environmental areas

The Minister may amend the plan to alter the exclusion distances, to include a new high-priority groundwater-dependent ecosystem, or to remove a high priority groundwater dependent ecosystem on the basis of further studies of groundwater ecosystem dependency.

Clause 58: Total daily extraction limit

The plan sets total daily extraction limits for specific flow classes set in Clause 17.

Clause 69(4): Rules relating to constraints within these water sources

The Minister may amend the dealing rules to permit “no net dealings” between specific management zones within the Bowman Creek Water Source following further studies or field verification.

Clause 86: Amendment of very low flow provisions

The Minister may amend the very low flow class and the bottom of A class set in clause 17 within a small range following field verification and the review of relevant studies. The Minister may vary the very low flow levels set in Clause 17 within a small range following field verification that natural water levels in river pools and wetlands during periods of no flow and natural low flow regimes are protected. The field verification should assess how well the objectives of Clause 10(a) and (b) are met and consider relevant studies of, for example:

(a) estuarine flow requirements studies by MidCoast Water

(b) modelling to show whether percentiles derived for estuary needs should be applied to upstream catchments

(c) any Aboriginal cultural values or sites which may need to be protected by a specific flow regime

(d) the flow level recommended to meet the objectives

(e) the socio-economic impacts of the recommended changes to the flow levels.

Clause 87: Amendment of tidal pool provisions

The Minister may amend the plan to establish or modify flow classes, or amend access licence dealing rules, in the Manning River Tidal Pool Water Source, following a review of the study referred to in Clause 17 and the determination of licence entitlements.

Clause 88: Amendment of pool protection provisions

The Minister may amend the plan to establish pool control levels and key sites for the Dingo Creek Water Source, the Upper Gloucester River Management Zone of the Upper Gloucester River Water Source and any other water source where appropriate. Supporting information should assess whether pool control levels and key sites are required and whether they meet the objective in Clause 10(a), and specifically consider:

(a) the suitability of the location of the key sites used in assessing pool health upstream

(b) the drawdown of the water levels from pools upstream during periods of extraction

(c) the significance of the pools that are affected by the drawdown.

Clause 90: Amendments for alluvial aquifers downstream of the tidal limit

The Minister may amend the plan to include provisions and rules for any alluvial aquifer that is downstream of the tidal limit, and within or outside of the area of the plan.

Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources

Clause 10: Objectives

The objectives of the plan are the same as defined by Clause 10 of the Water Sharing Plan for the
Lower North Coast Unregulated and Alluvial Water Sources, above.

Clause 12: Environmental performance indicators
The performance of the plan is assessed against the same criteria defined by Clause 12 of the Water Sharing Plan for the Lower North Coast Unregulated and Alluvial Water Sources, above, and also the extent of fluctuations in groundwater level.

Clause 17: Flow classes for these water sources
The sharing of daily flows is based on flow classes set by the plan. The Minister may amend flow classes or establish new or additional flow classes in a number of water sources based on further studies or the installation of gauges or salinity probes.

Clause 19: Planned environmental water
The Minister may amend the plan to identify pools that require special protection and to establish initial pool control levels at key sites, to prevent the taking of water below a specified level.

Clause 41(7): Rules for granting approvals for water supply works near sensitive environmental areas
The Minister may amend the plan to alter the exclusion distances, to include a new high-priority groundwater-dependent ecosystem, or to remove an ecosystem on the basis of further studies of groundwater ecosystem dependency.

Clause 59: Total daily extraction limit
The plan sets total daily extraction limits for specific flow class set in Clause 17.

Clause 70: Rules relating to constraints within these water sources
The Minister may modify the rules relating to access licence dealings within the Upper Wollombi, Upper Goulburn and Rouchel Brook (excluding Back Creek) water sources to allow upstream dealings, on the basis of studies which define groundwater-dependent ecosystems or aquatic environmental features and their water requirements.

Clause 71 and 74(6): Rules for change of water source and water allocation assignments between water sources
The Minister may amend the rules relating to prohibition of trading into the Upper Goulburn River Water Source to allow “no net gain” dealings, on the basis of studies which define groundwater-dependent ecosystems or aquatic environmental features and their water requirements.

Clause 87: Amendment of tidal pool provisions
The Minister may amend the plan to establish or modify flow classes, or amend access licence dealing rules, in the Wallis Creek, Paterson River and Hunter River Tidal Pool water sources, following a review of the study referred to in Clause 17 and the determination of licence entitlements.

Clause 88: Amendment of pool protection provisions
The Minister may amend the plan to establish pool control levels and key sites. Supporting information should assess whether pool control levels and key sites are required and whether they meet the objective in Clause 10(a), and specifically consider:
(a) the suitability of the location of the key sites used in assessing pool health upstream
(b) the drawdown of the water levels from the pool upstream during periods of extraction
(c) the significance of the pools that are affected by the drawdown.

Clause 91: Amendments for alluvial aquifers downstream of the tidal limit
The Minister may amend the plan to include provisions and rules for any alluvial aquifer that is downstream of the tidal limit and within or outside of the area of the plan.
Water Sharing Plan for the Central Coast Unregulated Water Sources

Clause 12: Environmental performance indicators
The performance of the plan is assessed against the same criteria defined by Clause 13 of the Water Sharing Plan for the Jilliby Jilliby Creek Water Source, above.

Clause 17: Flow classes for these water sources
The sharing of daily flows is based on flow classes set by the plan. The Minister will amend the plan to establish flow classes in the Mooney Mooney Creek and Mangrove Creek water sources, on the basis of further investigations to determine surface water levels and flow reference points that allow rule development.

Clause 19: Planned environmental water
The Minister may amend the plan in the Wyong River, Mangrove Creek, or Mooney Mooney Creek water sources to establish a first flush rule in accordance with monitoring and investigations.

Clause 47: Total daily extraction limit
The plan sets a total daily extraction limit for each flow class set in Wyong River Water Source.

Clause 75: Amendment of flow classes, planned environmental water, share components and daily extraction limit provisions
On the basis of the verified outcomes of any monitoring and investigations associated with the Wyong River Environmental Flows Study, the Minister may:
(a) amend the flow classes set in Clause 17, including additional flow classes
(b) set or amend very low flow access conditions for access licences for local water utilities
(c) amend the planned environmental water rules specified in Clause 19
(d) amend the system operation rules
(e) amend the share component of the access licences for local water utilities or major utilities
(f) amend the percentage extraction for access licences for local water utilities.

Groundwater sharing plans
Water Sharing Plan for the Tomago Tomaree Stockton Groundwater Sources

Clause 11: Objectives
The objectives of the plan are to:
(a) manage groundwater extractions from these groundwater sources within the extraction limit of each groundwater source to preserve and enhance terrestrial vegetation dependent on groundwater and ecosystems
(b) manage groundwater extractions from these groundwater sources within the extraction limit of each groundwater source to preserve and enhance wetlands
(c) manage groundwater extractions from these groundwater sources within the extraction limit of each groundwater source to preserve the groundwater-related features of the coastal dune environment and associated ecosystems
(d) manage groundwater extractions from these groundwater sources within the extraction limit of each groundwater source to preserve hypogean ecosystems
(e) manage groundwater extractions from these groundwater sources within the extraction limit of each groundwater source to preserve hyporheic ecosystems
(f) manage groundwater extractions to ensure that such extractions do not cause any reduction in the beneficial use of these groundwater sources, or any local impacts on groundwater quality, including salt water intrusion or lateral movement of contamination.

Clause 13: Environmental performance indicators
The performance of the plan is assessed against changes in:
(a) groundwater extraction

(b) climate-adjusted groundwater levels

(c) the condition and extent of groundwater-dependent ecosystems, including vegetation and wetlands

(d) groundwater quality

(e) the economic benefits derived from groundwater extraction and use.

Clause 16: Recharge
The overall basis for water sharing is the average annual recharge to each groundwater source. The average annual recharge to each groundwater source may be varied following further studies.

Clause 18: Planned environmental water
The plan sets rules to ensure that the long-term average storage component of each groundwater source and 30 per cent of the average annual recharge to each will be reserved for the environment. The Minister may vary the proportion of recharge reserved, on the basis of further studies of groundwater ecosystem dependency.

Clause 36: Water level management
The Minister may declare that to protect water levels within these groundwater sources, local access rules are to apply in a defined 'local impact area'.

Clause 37: Water level management
The Minister may declare that to protect water quality within these groundwater sources, local access rules are to apply in a defined 'local impact area'.

Clause 38: Protection of groundwater-dependent ecosystems
The Minister may identify further high-priority groundwater-dependent ecosystems and include them in the plan on the basis of further studies of groundwater ecosystem dependency.

Water Sharing Plan for the Kulnura Mangrove Mountain Groundwater Sources

Clause 11: Objectives
The objectives of the plan are to:

(a) manage groundwater extractions to protect and enhance ecological processes and the diversity of terrestrial groundwater dependent ecosystems in these groundwater sources

(b) manage groundwater extractions in these groundwater sources to protect baseflows to rivers and related ecosystems

(c) manage groundwater extractions to protect and enhance ecological processes and the diversity of subsurface groundwater dependent ecosystems in these groundwater sources

(d) manage groundwater extractions to maximise the economic benefit of groundwater use within these groundwater sources

(e) recognise the high quality and beneficial use (raw drinking water) of water of these groundwater sources, and encourage its use where appropriate

(f) manage groundwater extractions to protect and enhance groundwater dependant species and sites of significance to the local Aboriginal communities in these groundwater sources.

Clause 13: Environmental performance indicators
The performance of the plan is assessed against changes in:

(a) groundwater extraction relative to the extraction limits

(b) climate-adjusted groundwater levels

(c) water levels adjacent to high-priority groundwater-dependent ecosystems

(d) groundwater quality
(e) the economic benefits derived from groundwater extraction and use.

Clause 16: Recharge
The overall basis for water sharing is the average annual recharge to each groundwater source. The average annual recharge to each groundwater source may be varied following further studies.

Clause 18: Planned environmental water
The plan sets rules to ensure that the long-term average storage component of each zone in the groundwater source is reserved for the environment. The Minister may vary the proportion of recharge reserved as environmental water on the basis of further studies of groundwater ecosystem dependency.

Clause 37: Water level management
The Minister may declare that to protect water levels within these groundwater sources, local access rules are to apply in a defined ‘local impact area’.

Clause 38: Water quality management
The Minister may declare that to protect water quality within these groundwater sources, local access rules are to apply in a defined ‘local impact area’.

Clause 39: Protection of groundwater-dependent ecosystems
The Minister may amend the exclusion distances on the basis of further studies of groundwater ecosystem dependency.

Clause 40: Protection of aquifer integrity
The Minister may declare that to protect the integrity of the aquifers within these groundwater sources, local access restrictions are to apply in a defined ‘local impact area’.

For more information on water sharing plans visit www.water.nsw.gov.au
WHAT HAS THE ECOLOGICAL MONITORING TOLD US SO FAR?

Regulated rivers water sharing plans

Water Sharing Plan for the Hunter Regulated River Water Source

Studies of flows, phytoplankton and nutrients

Glennies Creek environmental contingency allowance (ECA) scouring flow study

Macroinvertebrates and periphyton (organisms attached to objects) collected immediately below the Glennies Creek Dam wall had significantly different community structures from the other five sampling sites (Carter et al. 2011). Biofilm periphyton diversity, as measured by numbers of taxa (species etc.) and abundance (cells per millilitre), was also significantly different. More taxa and greater abundance were found immediately below the dam wall than at the other sites. In contrast, periphyton health was no different between the six sites. This result contradicts the initial hypothesis.

The results suggest that the downstream site on Glennies Creek had recovered somewhat from the disturbances created by the dam. The results have been used to assist in the development of management options.

This scouring flow study was designed to look for improvements in stream health after a scouring flow release. Results from a complementary Integrated Monitoring of Environmental Flows study in the Murrumbidgee River catchment found that a scouring flow release reset biofilm and macroinvertebrate community structure, but that there was a rapid return to the earlier conditions. This analysis has identified a number of impacts on stream biofilm health and macroinvertebrate diversity in Glennies Creek that could be derived from the Glennies Creek Dam and the flow regulation. The loss of diversity related to ecosystem dislocation, in-stream temperature suppression as a result of deep off-take releases, change of riverbed substrate and water quality impacts suggest that an integrated approach should be adopted for ECA water releases.

Hunter integrated monitoring of environmental flows phytoplankton studies—1998 to 2003

Phytoplankton were grouped into
Cyanophyceae, Chlorophyceae, Bacillariophyceae and flagellates. Growth peaked frequently during summer at most sites. The then limit for Cyanophyceae (15,000 cells per millilitre) in water for stock or recreational use was exceeded only once and was not translated further downstream than Broad Crossing, several kilometres from the dam. The trigger for Bacillariophyceae (40,000 cells per millilitre) in water for ECA use was not exceeded.

Small phytoplankton blooms during summer were characterised by chlorophytes downstream of Glenbawn Dam. These were dominated by *Planctonema* (12,397 cells per millilitre) during January 2000 at the dam and *Oocystis* (18,915 cells per millilitre) in May 2001 at Broad Crossing. In general these taxa were translated downstream at decreased abundance to Tyrells and Broad Crossing. During September 2001, the potentially hepatotoxic cyanophyte *Microcystis* was recorded between Glenbawn Dam and Tyrells at levels exceeding recreational guidelines.

During summer 2001–02; and *Aphanizonomenon*.

Larger phytoplankton blooms occurred in the unregulated Dart Brook and Goulburn River. In Dart Brook these were characterised by Bacillariophyceae, dominated by *Cyclotella* (26,892 cells per millilitre) during February 2000 and *Synedra* (35,570 cells per millilitre) during February 2002. In the Goulburn River they were dominated by the chlorophyte *Planctonema* (16,233 cells per millilitre) in February 2001, and low concentrations of the potentially neurotoxic *Anabaena* were recorded during summer 2001–02.

The Hunter River at Aberdeen and Muswellbrook did not experience any major phytoplankton peaks during the study period. At Denman it experienced an early summer Bacillariophyceae (*Synedra*) peak, followed a month later by a chlorophyte bloom characterised by *Planctonema* (23,008 cells per millilitre).

The three sites below the Goulburn River tributary junction, more than 100 kilometres from the dam, experienced peaks or blooms of Bacillariophyceae each summer. During summer 1998–99, *Nitzschia* dominated at up to 33,050 cells per millilitre at Moses Crossing. During the following summers, *Cyclotella* dominated. During summer 2001–02, these early summer peaks were followed by blooms of chlorophytes dominated by *Planctonema* at up to 24,983 cells per millilitre. Moses Crossing is several kilometres downstream of Liddell Weir, which is used for extraction by Macquarie Generation.

Water quality sampling 1998 to 2003

Electrical conductivity, temperature, pH, total silica, total reactive phosphorus, nitrogen oxides and turbidity increased with distance downstream from the dam as unregulated tributary inflows mixed with the nutrient-deficient Glenbawn Dam outflows. Dart Brook and Goulburn River had higher median concentrations of silica, phosphorus, nitrogen and electrical conductivity than the Hunter River. The load of nutrients is proportional to the river discharge. The importance of the unregulated tributaries in supplying nutrient loads is highlighted by the low flow volumes and low nutrient loadings in the Glenbawn Dam discharge, which increase markedly by Muswellbrook. The Goulburn River increased the flow to four times the dam outflow and silica concentrations to twelve times.

The results indicate that phytoplankton communities may be structured by environmental gradients as influenced by water source.
Hunter integrated monitoring of environmental flow phytoplankton studies—2006 low flow (drought) study
A 3-month sampling program investigated phytoplankton community dynamics in the middle reaches of the Hunter River at Jerry Plains under low flow conditions (Carter unpub.).

No diatom blooms were observed, even though the prevailing conditions were considered to be conducive to diatom growth according to previous studies.

However, further factors (in addition to low flow and elevated water temperature) may have contributed to the previous diatom blooms. The results from this study clearly identify the need for additional work to determine the relationship between phytoplankton and low flows in the Hunter River.

The results are relevant to the setting of minimum flow rules to avoid nuisance phytoplankton growth in the middle section of the river. Factors in addition to flow and temperature may need to be considered as predictors of bloom risk in the river. Further work will be required to quantify these.

Mid Hunter growth of Cyclotella meneghiniana and Nitzschia spp. Diatom blooms in the middle reaches of the Hunter River are a frequent nuisance to river users. During a 4-year study, blooms of Cyclotella meneghiniana and Nitzschia spp. coincided with water temperatures above 23 degrees celsius and flows below 400 megalitres a day that lasted for more than 12 days (Mitrovic et al.)
Water temperature was positively related and prior flow was negatively related to the abundance of both diatoms. A laboratory study confirmed that *Cyclotella* growth increased with temperature from 15 to 25 degrees celsius with a slight decrease at 28 degrees celsius. Nutrient addition experiments indicated that nutrients are seldom limiting to growth (although bloom periods were not tested). The results suggest that a combination of faster growth at higher temperatures and longer retention times during low flows allows bloom populations to develop. Flows above 400 megalitres a day might suppress blooms.

**Nutrient limitation study**

The phytoplankton populations found in the Hunter River at Moses Crossing and Bowmans Crossing were generally not limited by nutrients (Mitrovic et al. 2008). Only 11 phytoplankton genera showed significant responses to nutrient additions. Ambient nutrient concentrations were likely sufficient for the other phytoplankton. The most limiting nutrient was silica.

The growth, distribution, and abundance of phytoplankton were highly variable in space and time, and different nutrients limited growth at different times.

A key objective of the study was to determine whether any nutrients limited *Cyclotella* or *Nitzschia* growth in the Hunter River. Ambient nutrient concentrations did not limit *Cyclotella*, which still bloomed. However, the addition of nutrients did promote some growth, suggesting that during a bloom, nutrients do limit *Cyclotella* growth in the Hunter River.

Carbon and nutrient cycling in the hyporheic zone

The pulse flow event raised water levels by 38 cm at Aberdeen, 32 cm at Bowmans Crossing and 28 cm at Mosses Crossing, creating enough head pressure to drive water into the hyporheic zone. There were no lasting effects on dissolved oxygen or conductivity at most sites, although dissolved oxygen in the downwelling zone at Bowmans Crossing dropped from 110 to 27 per cent saturation after 49 days (Hancock 2003, Hancock and Boulton 2005). In the downwelling zones at all sites, hyporheic nitrate concentrations declined initially following the release, but then rose or levelled off by day 49. This initial drop was attributable to either the flushing of nitrate from the sediments or changes in microbial denitrification. At two sites, nitrate concentrations had increased by day 49 in the upwelling zones. At the third site, it fell significantly, in association with very low dissolved oxygen and reduction of nitrate.

This study has provided a number of insights into how future studies should be managed. The data provide further evidence of the importance of flow events to the maintenance of stream health. They also highlight the spatial heterogeneity of the hyporheic zone within and among sites on a regulated river, and emphasise the need for multiple site surveys and an understanding of groundwater dynamics in order to assess the responses of the hyporheic zone to environmental flow releases.

**Studies of estuary inflow needs**

Environmental flow rules and Hunter Estuary productivity study

The river flow and estuary salt-wedge modelling found that the flow rules increased the flow of fresh water into the Hunter Estuary, as intended (Carter 2010). This small increase in inflow was translated into a small improvement in estuary salt-wedge dynamics. However, the magnitude of the changes in salinity was considered to be too small to be easily quantified through field investigations.
Studies of estuary health collected data to support an estuary function model of the productivity benefits expected from the water sharing plan. A survey of fish larvae identified 50 taxa organised into distinct assemblages in each of three salinity zones.

Studies of the salinity tolerance of two barnacle species showed that the development of *Tesseropora rosea*, a rocky-shore species, was restricted to a salinity range of 25 to 35 parts per thousand. *Elminius covertus*, an estuarine species, was more tolerant, but its growth stages were prolonged at higher salinity levels, resulting in greater mortality. These results provide further evidence of ecosystem complexity when we consider the effects of salinity change.

A preliminary study of the community structure of winter plankton identified greater chlorophyll a levels and phytoplankton counts in the freshwater tidal habitat than in other locations in the Hunter Estuary, indicating the importance of freshwater inflows. The salinity structure also influenced zooplankton species distribution.

The modelling study provides for the first time a cumulative assessment of the impacts of all water sharing plans on the estuary’s inflow and functioning. It categorically links catchment action to that of estuary functioning. In doing so, it raises a number of issues that will need to be addressed in later revisions of these plans. The model provides a tool for this ongoing assessment work.

The results from the modelling show that the effects of inflows are interrelated, and hence water management and extraction decisions should not be considered in isolation for each river system. The results clearly demonstrate the need to consider the cumulative impact of any water sharing plan decision (including tidal pool licensing decisions) on Hunter Estuary functioning.

The modelling of the combined impacts of the water access rules of the four Hunter catchment water sharing plans shows that the rules are largely maintaining the salinity conditions within the estuary, as intended.

A number of changes to the estuary’s salinity structure were identified at specific times or under specific flow conditions:

1. In low flow times the end-of-system flows result in the freshening (or lowering) of estuary salinity relative to more natural times
2. Pumping during high flows reduces the size of some high flow events. This lessens the impact of the event and could interfere with the estuary’s salinity structure

3. The flow rules have resulted in an increase in small to medium event inflows, sometimes improving the estuary’s salinity structure.

These modelling results have also identified a number of fundamental questions that should be answered in order to contribute to sustainable water planning in the Hunter, Paterson and Williams Rivers catchments, as discussed below.

1. Definition of inflow needs
The water sharing plans are intended to manage freshwater extraction from the rivers so as to maintain and enhance Hunter Estuary functioning. This intention assumes that the current inflow regime is consistent with the ecological needs of the estuary, yet we have no evidence either way. Therefore, further modelling work should be undertaken to define an optimal inflow regime (and hence extraction regime) that will maintain the salinity structure and ecological health of the estuary.

2. Identification of habitats, ecosystems and species needs that water sharing plans need to address
The modelling results report salinity concentration and length of time it is maintained at a number of locations
in the Hunter Estuary. To link the water sharing plans to more specific measurable outcomes, it will be necessary, among other tasks, to:

(a) define the salinity regime (and hence inflow timing and frequency) that will help maintain the Ramsar-listed wetlands in the lower Hunter Estuary

(b) define the inflow regime (size and frequency of freshes) required to support fish recruitment

(c) define the inflow regime required to support and maintain the extractive user rights of estuary tidal pool pumpers.

3. Clarification of issues associated with Seaham weir operation and functioning

Although the water sharing plans are designed to maintain or improve estuary health, Seaham Weir (a structure licensed under the Water Act and whose operational rules are determined through the corporate licensing process) could harm the ecological functioning of the Williams River. If the management actions can be linked, there could be significant ecological benefits for the estuary.

Better understanding of these fundamental issues will also contribute to the review of the current water sharing plans. The Hunter Estuary salinity model can help in the review and refinement of flow rules.

River and estuarine nutrient delivery study

Base flow sampling found that over 24 hours, the carbon and nutrient concentrations remained relatively stable at around 3.3 mg/L dissolved organic carbon, 0.055 mg/L total phosphorus and 0.25
mg/L total nitrogen, although values depended on the proportion of dam flow in the base flow.
The dissolved organic carbon, phosphorus and nitrogen concentrations all increased significantly during rain events, and these nutrients were carried down the river and delivered to the upper reaches of the estuary. The flow rules, which restrict pumping of this water, allow these nutrients to remain in the river system, stimulating aquatic food webs and ensuring delivery to the estuary.

Hunter Estuary carbon inflow studies
Dissolved organic carbon is carried into the estuary with inflows that wet benches and the floodplain. This study showed that substantial amounts of organic carbon were carried into the estuary. A follow-up study showed that increases in carbon led to increased growth of bacterioplankton in the estuary (Hitchcock et al. 2010). Experiments showed that the addition of carbon increased zooplankton numbers too.

Water Sharing Plan for the Paterson Regulated River

Water Source

Freshwater fish study in the Paterson River
Fish populations showed no association with flow regulation in abundance, number of species or composition. Yet despite this, fish assemblage composition had lower variability in regulated tributaries than in unregulated tributaries. Changes in composition over time were also reduced in regulated tributaries. Flow regulation had a greater impact after 86 years than after 36 years. A small environmental flow intended to restore some hydrological variability was released from one of the two regulated tributaries in February 2007. Fish assemblages showed minimal change in composition following this flow release. This was not surprising, given that large floods continue to occur in the regulated tributaries and are likely to have a greater short-term impact than a small flow measured over a short period. In contrast, prolonged periods of constant irrigation flows may have a greater long-term effect on fish assemblages by maintaining an unnaturally stable flow environment.

Lostock Dam regulates river flow by releasing water from the bottom of the dam wall, thereby releasing cold water downstream. These releases were associated with reduced a spawning period of a common species, Australian smelt (*Retropinna semoni*), and a delayed upstream migration of juvenile Cox’s gudgeon (*Gobiomorphus coxii*). Changes in the availability and composition of prey associated with flow regulation changed the composition of prey ingested by fish between regulated and unregulated tributaries. Differences were more apparent in the benthic Cox’s gudgeon than in the pelagic Australian smelt. Different fish species are likely to show different alterations in population structure or prey consumption. Generalist species are likely to be more tolerant to both natural and anthropogenic changes to flow regime. Environmental flow releases can be managed to maintain the hydrological variability necessary to conserve fish assemblages and their prey. This hydrological variability needs to maintain critical elements of the natural flow regime, including the small floods and cease-to-flow events that are often eliminated in regulated rivers.

Minimizing the temperature changes associated with bottom releases and maintaining connectivity between river reaches upstream and downstream of dams and weirs will increase the potential for fish assemblages to be conserved in regulated river systems. This is likely to reduce the threat of continued ecosystem degradation with further regulation of river flows to meet growing human demands for water.
Benthic macroinvertebrates study in the Paterson River
The regulated rivers were affected by changes to the flow regime and changes to water quality. Dam construction decreased the mean daily discharge, increased the minimum flow rate and altered the timing and variability of flows. Nutrients were generally increased downstream of the dams, whereas temperature showed higher winter and lower summer ranges. Invertebrate density increased and community composition was altered downstream of the dams. Although distinct invertebrate communities were observed in discrete flow categories, changes to communities appeared to be related more to indirect effects of dampened flow variability on food resources and water quality than to direct effects of flow velocity. Invertebrate communities in the regulated river assimilated predominantly autochthonous (derived on-site) sources, whereas those in the unregulated rivers assimilated a greater contribution of allochthonous (derived off-site) sources, supporting the expectation of higher autochthonous production in regulated rivers. Increased nutrients, more prolific algal production and fewer scouring flows in the regulated river were likely mechanisms. Invertebrate density, richness and community composition varied commonly at the site-scale, and differences between the regulated and unregulated rivers were observed. Many invertebrates responded either positively or negatively as predicted. The pulse flow release from Lostock Dam on the Paterson River in February 2007 decreased overall invertebrate density, in particular that of chironomids. Responses were more pronounced in areas of slow flow (<0.3 metres per second) and at the site closest to the point of release. Helicopsyche (a caddisfly), which is harmed by river regulation, showed potential recovery at the site closest to the dam. The flow release proved capable of removing taxa benefited by regulation and increasing disadvantaged taxa, most effectively at the site immediately downstream of the dam. The results indicate that river regulation alters both the structure and function of invertebrate communities through complex, interrelated mechanisms. Effective assessment and future management therefore require assessment of both structural and functional attributes to elucidate how the effects act.
Unregulated rivers water sharing plans

Water sharing plans for the Jilliby Jilliby Creek and Ourimbah water sources
A photo-point monitoring program was established for the Jilliby Jilliby Creek and Ourimbah Creek water sources. However, owing to the sandy nature of the streambed, the photo-points often altered significantly following a fresh, and gauging of very low flows did not yield accurate results. The project was therefore discontinued until a better method could be found.

Water Sharing Plan for the Karuah River Water Source
The low flow modelling project at three sites in the Karuah River met its objectives. It demonstrated that the HEC RAS model could be used as a predictive tool for assessing a range of low flow scenarios and to verify the very low flow cease-to-pump level.

Modelling of flows of 1 and 30 megalitres a day at the riffle at Greens Crossing showed flow disconnectivity at 1 megalitre at day (Figures 13 and 14). Modelling of the 3.5 megalitres a day cease-to-pump condition showed flow continuity.

**FIGURE 13**
Modelled wetted area and water’s edge for 30 megalitres a day flow at Greens Crossing riffle.

**FIGURE 14**
Modelled wetted area and water’s edge for 1 megalitre a day flow at Greens Crossing riffle.
Water Sharing Plan for the Wybong Creek Water Source
The low flow and photo-point monitoring project for the Wybong Creek Water Source verified that the low flow cease-to-pump level at the gauge site did not reflect ‘typical’ flows throughout the rest of the long profile of Wybong Creek (Figure 15). Despite flows of less than 0.5 megalitres a day at the gauge, flows upstream were generally above 0.5 megalitres a day (Figure 16). The loss of flow is attributed to the changes in geomorphology within Wybong Creek. Significant variations in flow occur down the long profile, depending on whether flow is lost to groundwater (losing stream) or gained from groundwater (gaining stream). Flows at the lower end of the stream in particular tend to be losing, as reflected in the results at the gauging station compared with other sites. The loss of flow was not attributable to water extraction for irrigation, as the same pattern of gaining and losing was recorded while the cease-to-pump condition was being enforced.

These results were used in validating the need to amend the cease-to-pump level in the Water Sharing Plan for the Wybong Creek Water Source. The plan has since been amended, and cease-to-pump levels are now based on visible flow at a range of reference sites.

**FIGURE 15**
Flow in Wybong Creek and cease-to-pump since plan commencement.

**FIGURE 16**
Flow in Wybong Creek during cease-to-pump conditions at gauging station.
Water Sharing Plan for the Central Coast Unregulated Water Sources
The Wyong River is major tributary of the Tuggerah Lakes Estuary, which supports a commercial fishing industry and high ecological values. Wyong Weir, approximately 9 kilometres upstream of the entrance of Wyong River into Tuggerah Lakes, forms an important component of the Gosford/Wyong Councils’ Water Authority (GWCWA) water supply works. GWCWA is the major water user in the water source. In 2008, GWCWA released a consultant’s report detailing the results of an environmental flow study aimed at optimising the environmental flow outcomes and providing adequate water for GWCWA to supply the Central Coast community. The report concluded that water quality and fish migration were key issues that needed to be addressed by any flow rules in the water sharing plan, together with the following key findings (SKM 2008):

- During periods of low river flows, the tidal estuary appears to be dominated by saline incursion, often with poor water quality (low dissolved oxygen)
- During periods of median flows, organic carbon supply to the estuary is partially replenished from upstream reaches, surface oxygen levels are maintained at acceptable levels for aquatic ecosystems, and limited mixing occurs immediately downstream of the weir
- Periods of high flows replenish organic carbon supply to the estuary, and the water column can be fully mixed depending on the magnitude of flow over the weir
- Key fish species include eight species that must migrate between freshwater and the estuary: Australian bass, freshwater mullet, long-finned eel, short-finned eel, common jollytail, freshwater herring, sea mullet and bullrout
- Major migrations of sea mullet, Australian bass and eels are seasonal and may be triggered by a combination of flow and temperature
- The occurrence of larval bass in the freshwater section of the Wyong River above the weir indicates that adult bass have migrated and spawned downstream of the weir during high flow events and that larvae have subsequently migrated upstream via the weir fishway.

The study made a number of recommendations, including major modifications to the existing fishway on the Wyong Weir. The recommendations were included in the final Water Sharing Plan for the Wyong Unregulated River Water Sources.

Links to other projects
Further information on monitoring of water sharing plans for unregulated rivers can be found at www.water.nsw.gov.au go to Water Management > Monitoring > Unregulated Rivers.

Groundwater sharing plans
Water Sharing Plan for the Tomago Tomaree Stockton Groundwater Sources
Long-term water table fluctuations range by 3 to 4 metres and the water table is typically within 0.5 to 8.5 metres above the Australian Height Datum, subject to the location of bores. SKM Pty Ltd prepared a calibrated groundwater model for the Tomago aquifer on behalf of Hunter Water Corporation to estimate impacts on the environment under a range of extraction scenarios. The water table depths below ground surface varied from 0.2 to around 10 metres. The groundwater of the Tomago Groundwater Source typically has low salinity (<200 µS/cm) and is used for a variety of purposes, including town water supply, domestic, stock and industrial. The NSW Office of Water has set the
beneficial use of this aquifer as ‘raw water for drinking water supply’ and ‘ecosystem protection’. As seawater exists on three sides, over-extraction poses a risk of seawater intrusion. Hunter Water Corporation has drilled some specially designed bores to monitor the location and extent of the seawater interface (Figure 17).

Water Sharing Plan for the Kulnura Mangrove Mountain Groundwater Sources
The NSW Office of Water operates a detailed monitoring bore network within the Kulnura Mangrove Mountain Groundwater Sources. The water levels in general showed a declining trend from 2000 to 2007 coinciding with prolonged below-average climatic conditions. With a return to average or above-average climatic conditions, water levels have recovered in most locations. Some

FIGURE 17 Salinity bores used to monitor seawater intrusion (Hunter Water Corporation).
locations show a more subdued recovery, which warrants further assessment of the potential for local impacts.

Links to other projects
Since the start of the Water Sharing Plan for the Kulnura Mangrove Mountain Groundwater Sources, a detailed groundwater model was developed by the University of Technology, Sydney, in collaboration with the NSW Office of Water and Gosford/Wyong Councils’ Water Authority (Alkhatib and Merrick 2006). The findings support recharge estimates used within the water sharing plan, and show that to protect hydraulic gradients which would support groundwater base flow to streams, water resource managers must consider limiting growth in issuing new allocations.

Additional research work by CSIRO on the groundwater–surface water connection in the Ourimbah Creek catchment showed a significant connection, with as much as a third of annual stream flow derived from groundwater (CSIRO 2009, unpublished). The Australian Nuclear Science and Technology Organisation and NSW Office of Water are also using naturally occurring isotopes to investigate aquifer recharge rates and measure the age of the groundwater resource.

Groundwater-dependent ecosystems
Many of the NSW coastal sand aquifers are used for municipal water supplies. Most of the bore fields lie within national parks and nature reserves. With increased population growth there will be increased pressure to extract more water to satisfy this growing demand. To predict the effects of increased extraction, the NSW Coastal Groundwater Quality and Groundwater-Dependent Ecosystems project focuses on groundwater extraction within high-use coastal sand and alluvial aquifers and how this affects groundwater quality and groundwater-dependent ecosystems. The Tomago Tomaree Stockton Groundwater Sources is one of seven pilot sites that are being investigated in detail. The results will be used to support decisions in the remaining NSW coastal aquifers. Detailed field investigations will identify rooting depths of various coastal flora species and assess how groundwater levels and quality and other landscape elements determine the distribution of groundwater-dependent vegetation types. Discharge rates, patterns (temporal and spatial) and quality (mainly salinity and nutrients) will be investigated. The project will also study how groundwater discharges relate to the distribution of sea grass communities. It should result in a set of risk-based maps for NSW coastal aquifers that identify those aquifers at greatest risk of a change in beneficial use owing to increased groundwater extraction, climate change or both.

It is envisaged that groundwater-dependent ecosystems (GDEs) will be broadly identified by late 2011. Projects underway include the National GDE Atlas funded by the National Water Commission and river studies funded by catchment management authorities.

Additional water sharing plans
The NSW ‘Macro water sharing plan’ process is expected to have plans in place for all groundwater sources in the Hunter Valley and the central and lower North Coast by the end of 2011. The plans will set long-term average annual extraction limits and rules that will allow only acceptable impacts on users and the environment. Groundwater sources that are highly connected to the rivers will include cease-to-pump criteria.
socio-economic monitoring

In 2005, the NSW Office of Water began a statewide project to monitor changes in the NSW irrigation industry following the introduction of water sharing plans. The project is designed to:

- monitor key social and economic changes at the farm and regional levels arising from water sharing plans
- provide data for the NSW Office of Water’s review and evaluation of water sharing plans
- provide data for the Natural Resources Commission’s review of water sharing plans
- provide a benchmark for other economic and social monitoring exercises in natural resource management.

The project was developed after extensive consultation with stakeholders, including the NSW Irrigators’ Council and the Primary Industries and Economic Development Standing Committee of the NSW Natural Resources Advisory Council.

The project reports on changes in a number of identified social and economic indicators. The data are collected primarily in a 20-minute telephone survey of irrigators who respond to an invitation to participate. A sample size of approximately 10 per cent of the eligible irrigators is targeted for each survey. Additional customised data from the Australian Bureau of Statistics’ Agricultural Census are also used.

The first of the surveys, in 2006, targeted irrigators in areas where the first 31 water sharing plans were implemented in July 2004. These plans included all major regulated rivers in NSW, and represented approximately 80 per cent of the extractive water use in NSW. The 2006 survey collected baseline data reflecting the socio-economic conditions of farms in these areas.

In 2009, a companion baseline survey targeted irrigators in areas where the first 31 water sharing plans were implemented in July 2004. These plans included all major regulated rivers in NSW, and represented approximately 80 per cent of the extractive water use in NSW. The 2006 survey collected baseline data reflecting the socio-economic conditions of farms in these areas.

In 2006, the 2006 survey included irrigators from the Hunter Regulated River, Wybong Creek, Jilliby Jilliby and Ourimbah Creek water sources, and the Kulnura Mangrove Mountain and Tomago Tomaree Stockton groundwater sources.
The median irrigation farm size was 40 hectares, with a 25th to 75th percentile range of 12 to 100 hectares. The statewide median farm size was 159 hectares (25th to 75th percentile range 26 to 621 hectares).

Figure 18 shows that central pivot or lateral move irrigation systems were the dominant irrigation system in use in the Hunter Central Rivers CMA area and compares this to statewide (weighted) results.

Irrigators derived on average 45 per cent of total farm income from irrigated crops and pastures. The statewide average was 51 per cent.

9 per cent of irrigators had used their water entitlement as security for a loan. The statewide average was 30 per cent.

Figure 19 shows the irrigators’ responses to the statement ‘The water sharing plan has made my water rights more secure.’

47 per cent of irrigators employ non-family members on farm, and the percentage increases as water entitlements increase. The statewide average was 52 per cent.

Full-time employment of family and non-family members (excluding casuals) per irrigation farm was 4.6 equivalent full-time (EFT) positions. The statewide average was 3.9 EFTs.

The ratio of water entitlement to EFT employees was 43 megalitres per EFT employee. The statewide average was 270 megalitres per EFT employee.
Figure 20 shows the irrigators’ responses to the statement ‘The water sharing plan has made a lot of difference to water use in this catchment.’

The 2009 survey included irrigators in the remaining river and groundwater areas within the Hunter Central Rivers CMA area:

- The median irrigation farm size was 81 hectares, with a 25th to 75th percentile range of 39 to 202 hectares. The statewide medium was 81 hectares, with the 25th to 75th percentile range of 28 to 81 hectares.

Figure 21 shows the irrigators’ responses to the statement ‘The water sharing plan has made or will make my water rights more secure.’

- 44 per cent of irrigators employed non-family members on the farm. The statewide average was 45 per cent.

Figure 22 shows the proportions of irrigation systems used by respondents in the 2009 survey in the Hunter Central Rivers CMA areas and statewide.

- Centre pivot or lateral move
- Flood or furrow
- Drip system
- Spray or sprinkle

2009 Survey results - Irrigation system by area for Hunter Central Rivers CMA area

2009 Survey results - Irrigation system by area for New South Wales
Full-time employment of family and non-family members (excluding casuals) per irrigation farm was 1.9 EFT positions. The statewide average was 2.1 EFT positions.

The ratio of water entitlement to EFT employee was 93 megalitres entitlement per EFT employee. The statewide ratio was 136 megalitres per EFT employee.

Figure 22 shows that lateral move or central pivot irrigation systems were the dominant irrigation system in use in the Hunter Central Rivers CMA area and compares this to statewide results.

Irrigators derived 29 per cent of total farm income from irrigated crops and pastures. The statewide average was 30 per cent.

5 per cent of irrigators had used their water entitlement as security for a loan. The statewide average was 17 per cent.

Figure 23 shows the irrigators’ responses to the statement “The water sharing plan has made or will make a lot of difference to water use in this catchment.”

monitoring plans for 2010-11

WHAT ECOLOGICAL MONITORING IS PLANNED FOR 2010–11?

Regulated rivers water sharing plans

Planned ecological monitoring for 2010–11 is based on findings that the Hunter River is carbon limited, and inflows carrying carbon may stimulate the food web and create more natural conditions in the estuary (Hitchcock et al. 2010).

Monthly monitoring began in April 2010. Monthly monitoring and event monitoring will be used to determine how the estuary and dependent organisms respond to inflows. The food web will be examined from bacteria through to phytoplankton and zooplankton to track changes in distribution, time and under different flow events.

Nutrients (dissolved organic carbon, inorganic carbon and silica), salinity, dissolved oxygen, pH, visibility and temperature will also be determined. Salinity, temperature and dissolved oxygen profiles will be taken at several sites to look for evidence of stratification, and long-term dataloggers will be deployed to improve our understanding of the ‘salt wedge’ and stratification, and how these may affect biota. For example, it is thought that freshwater inflows maintain and stabilise the longitudinal movement of the salt wedge, thus providing a nutrient-enriched zone for biota.

This monitoring will allow a better understanding of how estuaries respond to the environmental water provisions within unregulated systems like the Hunter Estuary.

The study will also measure the stable isotopes of carbon and nitrogen (i.e. $^{13}$C/$^{12}$C, $^{15}$N/$^{14}$N) in material from the planktonic food chain. Ideally these will be measured before, during and after major freshwater inflows to determine whether trophic (feeding) pathways change. The results will determine the extent to which the delivery of river inflows alters estuarine plankton food webs. In theory, the isotope ratios will provide evidence that ‘fresh’ sources of energy and nutrients delivered with freshwater inflows stimulate food webs, increasing the number of consumers at different trophic levels, and thus addressing the importance of maintaining environmental access rules.

Estuary metabolism will be measured to ascertain the influence of inflows on the balance between autotrophs (organisms that create their own food) and heterotrophs (organisms that feed on other sources). The results will help to explain whether the environmental flows allocated to the estuary are providing a benefit and whether they need to be changed to improve estuary function. They could also be used in models to determine the types and quantities of environmental flows to maximise estuary function.

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The seven sites selected include freshwater tidal pools (Hunter River at Morpeth, Williams River downstream of Seaham Weir, Paterson River upstream of Hinton) and estuarine sections within the upper Hunter (downstream of the Hunter and Paterson Rivers confluence), mid Hunter (upstream of the Williams River confluence) and lower Hunter (downstream of Raymond Terrace and Kooragang Island). In situ experiments will also
be performed to help explain food web processes and the role of environmental flows to the estuary. Models of estuary function and its response to various flow scenarios will be developed, and can then be applied to other estuaries where commence-to-pump or first-flush rules are anticipated or are being developed.

Unregulated rivers water sharing plans
Work is to continue on the low flow and pool refugia study in the Wybong Creek Water Source. Further studies of freshwater inflow from unregulated rivers into the Hunter River Estuary are planned.

Groundwater sharing plans
Groundwater monitoring is continuing in the Tomago Tomaree Stockton Groundwater Sources and the Kulnura Mangrove Mountain Groundwater Sources. A status report for the Kulnura Mangrove Mountain Groundwater Sources is being prepared and should be available in 2011–12.

WHAT SOCIO-ECONOMIC MONITORING IS PLANNED FOR 2010–11?
The NSW Office of Water commissioned the Australian Bureau of Statistics to customise the 2006 Agricultural Census data to the water sharing plans’ boundaries and related water sources. The data will be used to ground-truth components of the survey data set. They will also provide additional socio-economic data to be used to monitor the performance of water sharing plans against their stated objectives.
The third of the planned series of irrigator surveys was undertaken in 2010, targeting the irrigators surveyed in 2006. The results will be compared against the benchmark surveys, and will be used to report against the water sharing plans’ performance reporting requirements.

WHAT IS PLANNED FOR FUTURE WATER SHARING PLANS?
Two additional water sharing plans covering the Hunter Valley and the central and lower North Coast are currently being developed for:

- Lower North Coast Groundwater Sources
- Hunter and Central Coast Groundwater Sources.

WANT MORE INFORMATION?
References


