GROUNDWATER AND STREAM WATER INTERACTIONS IN WIDDEN BROOK, UPPER HUNTER VALLEY, NSW: II

Peter Somerville[1], Ian White[1], Ben Macdonald[2], Sue Welch[3] & Sara Beavis[1]

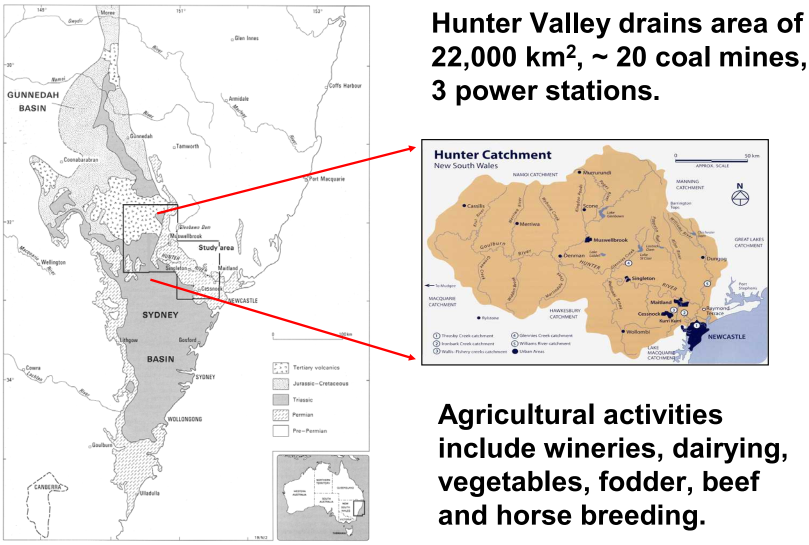
[1]CRC LEME, Centre for Resource and Environmental Studies
[2]Centre for Resource and Environmental Studies,
[3]CRC LEME, Department of Earth and Marine Science,
Australian National University, Canberra, ACT 0200.

INTRODUCTION

Stream and groundwater connectivity plays a vital role in the health of riverine ecosystems, which currently face stresses from current unsustainable land management practices such as overgrazing, groundwater extraction, and sand mining (Hancock 2002). Extended drought conditions related to El Nino episodes and higher evaporation rates have significantly altered the hydrology of catchments in south-east Australia. The key benefit of restoring hydrological connectivity of stream flows with shallow groundwater in unconfined aquifers is increased groundwater recharge, leading to increased stream flows in dry seasons and enhanced ecological function of the hyporheic zone (Boulton 2000).

Research at Widden Brook is being undertaken by a consortium consisting of: the Australian National University, Southern Cross University, the University of Newcastle, the NSW Department of Natural Resources of New South Wales (DNR) and CSIRO. The project seeks to test the hypothesis that *'lateral and vertical hydrological connectivity is important for floodplain sustainability and can be improved by reinstating secondary floodplain channels and wetlands, and creating artificial pools on the main stream'.*

The purpose of this work is to present the results of goundwater and stream water surveys undertaken in November 2005 and March 2006 in Widden Brook in the upper Hunter Valley, New South Wales (Figure 1) and to discuss the implications of these results for water quality in the catchment. Widden Brook flows from the Wollemi National Park (elevation ~350 m based on GPS measurements) and discharges into the Goulburn River, a right bank tributary of the Hunter River 40 km to the north at an elevation of ~150 m (White et al. 2004). The catchment is characterised by Permian sediments of the Wollombi Coal and Wittingham Coal Measures which are overlain by the high escarpments of Triassic Narrabeen Sandstone (Beckett 1988). Tertiary basalt peaks of Oligocene age can be seen in the catchment at Nullo Mountain (1140m) in Wollemi National Park, at Mount Pomany (1100m) and at Mount Coricudgy (1256m) (Yoo et al. 2001 Table 1).



Hunter Valley drains area of 22,000 km², ~ 20 coal mines, 3 power stations.

Agricultural activities include wineries, dairying, vegetables, fodder, beef and horse breeding.

Figure 1. Location of Hunter Valley, New South Wales

Blackwater Creek (flow from the south-east) and Emu Creek (flow from the south-west) are the two main tributaries of Widden Brook. Blackwater Creek receives groundwater with low salinity from the Triassic Sandstones in the Wollemi National Park to the south-east, flows all year even during extended dry periods, and supplies most of the stream water to Widden Brook. In contrast, Emu Creek flows only after substantial rainfall. It is generally dry all year, although field work has shown there to be sub-surface flow during dry periods. Widden Brook incises a floodplain with terraces consisting of sodic soils in the upper catchment and broadens out to an extensive floodplain from mid-catchment. The New South Wales government declared the upper Hunter a drought zone in early 2006. During the water quality survey in November 2005, there was stream flow to the confluence with the Goulburn River, but stream flow in March 2006 was reduced to a series of pools.

METHODS

A preliminary water survey was undertaken in the catchment in March 2004 (White et al. 2004). Stream water was collected along the entire length of Widden Brook and groundwater was collected from several existing pumps and bores in the catchment. For the purposes of this study, stream water samples have been collected from twelve sites along Widden Brook over a distance of approximately 30 km. This sampling area is representative of the course of the creek through Triassic Sandstone in the upper catchment and incision through the floodplain with terraces consisting of sodic soils in the middle catchment. Groundwater has been collected from nine groundwater pumps and bores to variable depths: from five pumps (spear points) in the shallow alluvial aquifers; and from four bores in the floodplain terraces. A piezometer network has been installed along five sections of the catchment to complement these groundwater sources. The pump/bore/piezometer network has been designed where possible to access groundwater from both the right and left banks of the Widden and so provide a cross section of groundwater flow. Three stream gauges have been installed to measure stream flow and stream height, which will provide longitudinal groundwater flow data for discharge and recharge at losing and gaining sections respectively in the Widden.

Water samples were analysed in the field for pH, electrical conductivity (EC), dissolved oxygen (DO) and Eh. Total alkalinity was determined by titration within hours of sample collection. Concentration of ferrous iron and sulfate of selected samples were measured in the field by spectroscopy according to APHA (1998). Filtered water samples were analysed for major cations (ICP-AES), major anions (IC) and trace metals (ICP-MS).

RESULTS AND DISCUSSION

Groundwater chemistry

The results of groundwater chemistry analyses are summarised in Table 1. Groundwater sites are listed in order downstream (17 to 25 km section of Widden Brook, Figure 2) and indicate significant increases in the concentration of bicarbonate ions downstream, which peak in the mid-catchment on the broad floodplain at Baramul and Widden Studs.

Table 1. Groundwater chemistry in Widden Brook

Groundwater	Source*	Collected	pH	EC (uS/cm)	Na (mg/l)	Ca (mg/l)	K (mg/l)	Mg (mg/l)	Cl (mg/l)	SO4 (mg/l)	HCO3 (mg/l)
Raglan Street pump	afs	Nov-05	6.65	344	58.57	4.78	3.91	8.37	52.19	5.33	122.23
Windmill bore	fpb	Mar-06	7.34	1332	183.55	33.19	10.05	44.10	183.00	5.28	340.38
Baramul-terrace	afs	Nov-05	7.03	319	35.81	5.84	3.74	7.15	38.04	3.10	82.73
Baramul-pines	afs	Nov-05	6.81	306	38.30	8.18	3.41	9.34	50.43	2.25	116.09
WS-kindy	fpb	Mar-06	6.9	397	46.37	20.99	1.20	25.92	51.94	8.06	333.46
WS-spear	afs	Nov-06	7.11	546	43.17	21.61	1.21	25.89	50.87	10.65	203.09
WS-DNR bore	fpb	Mar-06	7.44	1088	126.37	39.14	1.19	63.58	57.26	12.28	588.65
WS-stallions	fpb	Mar-06	7.75	660	77.51	23.26	7.04	25.27	110.05	63.84	571.57
WS-Emu Creek well	fpb	Mar-06	7.31	1436	184.21	53.67	13.26	53.78	102.57	22.52	554.83

* afs = alluvial floodplain spear point (pump); fpb = floodplain terrace bore

The bicarbonate/chloride ratio (mmol/l) of groundwater is generally >> 1. This value is significantly higher than the seawater ratio suggesting that mineral weathering as a result of water-sediment reactions, rather than aeolian deposition of salts, is a major contributor of ions to groundwater and stream water. Trace metal (Sr, Ba, Cr, Cu, Ni) concentrations in groundwater (~ 10-20 ppb) are an order of magnitude higher than in streamwater, reflecting weathering reactions at variable depths in the sub-surface sediments.

Sulfate concentrations generally reflect differences in oxidation state between the alluvial floodplains and floodplain terraces. Low concentrations of sulfate (<5mg/l) were recorded in the groundwater of the alluvial floodplains, while in the floodplain terrace groundwater sulfate was an order of magnitude higher (>10mg/l). Limited ferrous iron data from spectroscopic analysis, suggests low concentrations (<1mg/l) in the alluvial floodplain groundwater and concentrations up to 17 mg/l ferrous iron in the floodplain terrace groundwater. The results also indicate a difference in the concentrations of sodium and chlorine in the alluvial floodplain and the terrace groundwater: sodium (35-60 mg/l) and chlorine (38-52mg/l) in the alluvial floodplain groundwater; sodium >120mg/l and chlorine >100mg/l in the floodplain terrace groundwater.

Groundwater chemistry suggests that groundwater in the bores located on sodic floodplain terraces is oxidized and brackish (EC 1200-1500 µS/cm, Fe^{2+} up to 17mg/l)), whilst in the spear points and piezometers in the shallow alluvial aquifers, groundwater is reduced though less brackish (EC 300-700 µS/cm, Fe^{2+} <1mg/l).

Stream water chemistry
Stream salinity in the Widden Brook is illustrated in the increasing concentration of sodium, chlorine and bicarbonate ions in the stream water downstream (Figure 2). Results are shown for November 2005 when there was full flow in the Widden. Whilst the absolute concentrations vary, a similar and consistent trend is recorded for March 2006 when there was limited stream flow.

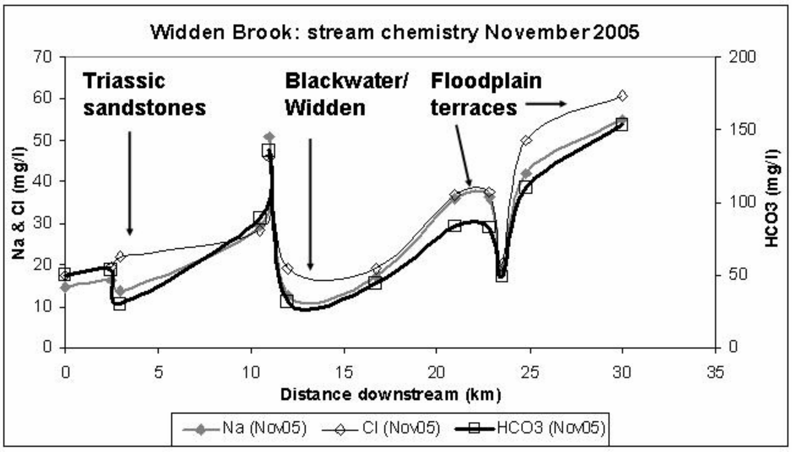


Figure 2. Trend in stream salinity in Widden Brook November 2005. Na, Cl and HCO_3 ions are proxy for electrical conductivity (EC).

Results indicate increasing EC (150-700 µS/cm) and alkalinity along Widden Brook. In the upper Widden Brook, EC is generally < 300µS/cm due to groundwater input from the Triassic Sandstones. EC increases downstream as the Widden incises the sodic floodplain terraces but falls sharply at the confluence with Blackwater Creek (EC 90-120µS/cm). Stream EC increases again downstream (EC > 500-700µS/cm) from the confluence as Widden Brook incises the floodplain terraces at the 17 km point of the catchment described above.

SUMMARY AND CONCLUSIONS

In summary, there is a significant difference in groundwater chemistry between the stream alluvial floodplains and the floodplain terraces. In the shallow alluvial aquifers, water is reduced with low ferrous iron and sulfate concentrations, whilst the sodic floodplain terraces are characterised by oxidized and brackish water with high sulfate and moderate to high ferrous iron. The bicarbonate:chloride ratio >1 of groundwaters indicates mineral weathering reactions in the groundwater aquifers supply ions to the stream water. Stream water chemistry indicates increasing EC and alkalinity downstream, the increase in EC occurring where the stream incises the sodic floodplain terraces and stream water mixes with groundwater with high concentration of bicarbonate ions. Results suggest a Na-Mg-HCO3-Cl groundwater-stream water system in the Widden Brook catchment which contrasts with previous modelling of water chemistry in the south-west upper Hunter.

The bicarbonate:chloride ratio in groundwater indicates mineral weathering reactions, rather than aeolian deposition, are contributing ions to the stream water. However, what is the origin of salts in the groundwater? Some possibilities include: (i) groundwater intercepting saline Permian coal sediments exposed at the valley floor, (2) pyrite oxidation, and (3) reduction of organic matter. At the time of writing this abstract, a drilling program has recently been completed in the Widden Valley at some of the groundwater/piezometer sites described in the methods section above. Analysis of the cores and sediments will help answer this question, but the presence of charcoal deposits suggests reduction of organic matter plays a role in sulfate concentrations in groundwater.

The differences in chemistry between alluvial floodplain groundwater, floodplain terrace groundwater and stream water has implications for future land management in the catchment. The Council of Australian Governments (COAG) has introduced many reforms since the 1990s to manage groundwater policy in the context of increasing aridity in Australia. The NSW Department of Natural Resources has recently introduced Water Sharing Plans to monitor volumes and flows in the catchments of the Hunter Valley. Proposals by landholders to increase agricultural productivity include the construction of in-stream structures in parts of Widden Brook to raise the stream level and to allow recharge by surface flow. The effect of such structures may be to mobilise salts in the floodplain terraces and to consequently increase the concentration of salts in surface flows. Increasing agricultural productivity in catchments will more than ever require an understanding of groundwater-stream connectivity to underpin more sustainable land management in the region.

Future research includes ^{18}O and ^{2}H analyses of groundwater and stream water samples, hydrograph separation analysis and pump tests to estimate stream flow and recharge to the aquifers, dating of charcoal sediments to identify the age of deposition and age of groundwater in sub-surface sediments, using Fe^{2+}-Fe^{3+} cycling as a tracer for groundwater-stream connectivity, and modelling of groundwater-stream interactions to explain salinity in Widden Brook.

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