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EFFECTS OF CHANNEL MORPHOLOGY, DREDGING & FLOW REGULATION ON WATER QUALITY IN THE HAWKESBURY-NEPEAN RIVER, WITH SPECIAL REFERENCE TO STRATIFICATION

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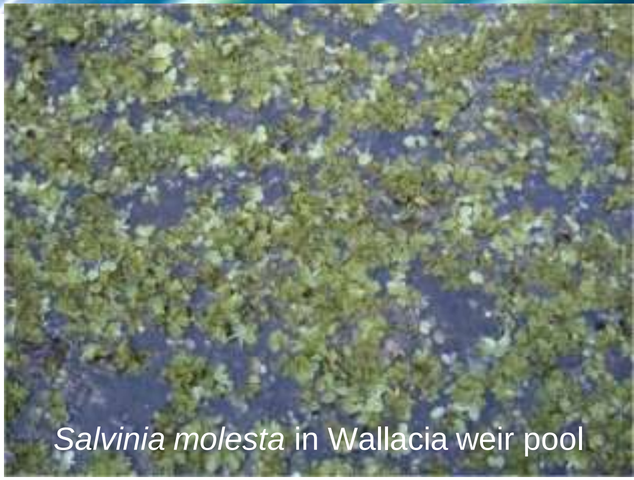
OUTLINE:



Salvinia molesta in Wallacia weir pool

1. Background
2. Channel Morphology
3. Stratification
4. Development, Persistence & Breakdown of Stratification
5. Cyanobacterial Blooms
6. Environmental Flows

Hawkesbury-Nepean River is a weired & highly regulated river system which is/has been used for recreation, sewerage disposal, water supply and a source of sand & gravel

BACKGROUND

Many water quality monitoring and modeling programs do not acknowledge that stratification may occur in rivers. As a result, only surface waters are sampled and an erroneous assessment of water quality and aquatic habitat quality and availability occurs. Where large interbasin water transfers substantially reduce summer streamflows on rivers with deep pools, persistent stratification is probable (Turner & Erskine 2005). Threshold pool depths may also be involved in the development of stratification so that dredging which increases pool depths and reduce fluvial turbulence may increase the potential for stratification.

22 large dams are present in the Hawkesbury-Nepean River catchment and 15 weirs have been built on the Nepean River alone. Flow regulation and interbasin water transfers for water supply to Sydney and Wollongong can divert all discharges up to 7.87 m^3/s from the upper Nepean River and its major tributary, the Cataract River (total catchment area of 896 km^2), as part of the Upper Nepean Water Supply Scheme. Most of Sydney's water supply is sourced from Warragamba Dam, a 2.057×10^9 m^3 capacity dam on the Warragamba River, which is the largest (9000 km^2 catchment) in the Hawkesbury-Nepean catchment. But Goulburn, Gosford-Wyong, Blue Mountains, etc also obtain their water supplies from the Hawkesbury-Nepean catchment.

CHANNEL MORPHOLOGY

From: Erskine (1998)

Alternating sandstone-confined and floodplain/shale reaches on Hawkesbury-Nepean River (Warner, 1983)

10 homogeneous channel reaches (Erskine, 1998):

Reach 1. Headwaters Reach (8 km) Steep headwaters on Tertiary basalt & Triassic shales

Reach 2. Upper Floodplain Reach (3 km) Floodplain on dip slope of Hawkesbury Sandstone

****Reach 3. Upper Sandstone Gorge*** (83 km) Steep gorge with some deep pools

****Reach 4. Camden Alluvial Reach*** (33 km) Shale & floodplain with dredged weir pools

****Reach 5. Bents Basin Gorge*** (4.3 km) Steep gorge

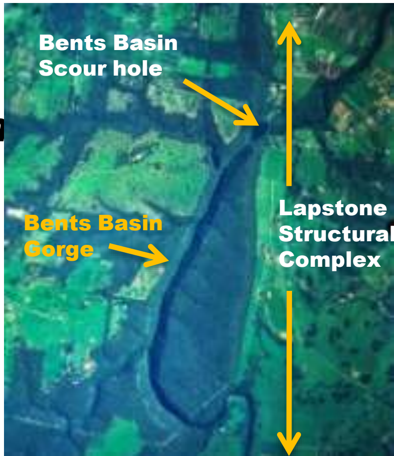
****Reach 6. Wallacia Alluvial Reach*** (10 km) Shale also

****Reach 7. Fairlight Gorge*** (26 km) Gorge (deep pools)

****Reach 8. Penrith Alluvial Reach*** (24 km) Extraction

****Reach 9. Windsor Estuarine Reach*** (25 km) Tidal freshwater - dredged

Reach 10. Hawkesbury Estuarine Reach (120 km) Tidal and saline



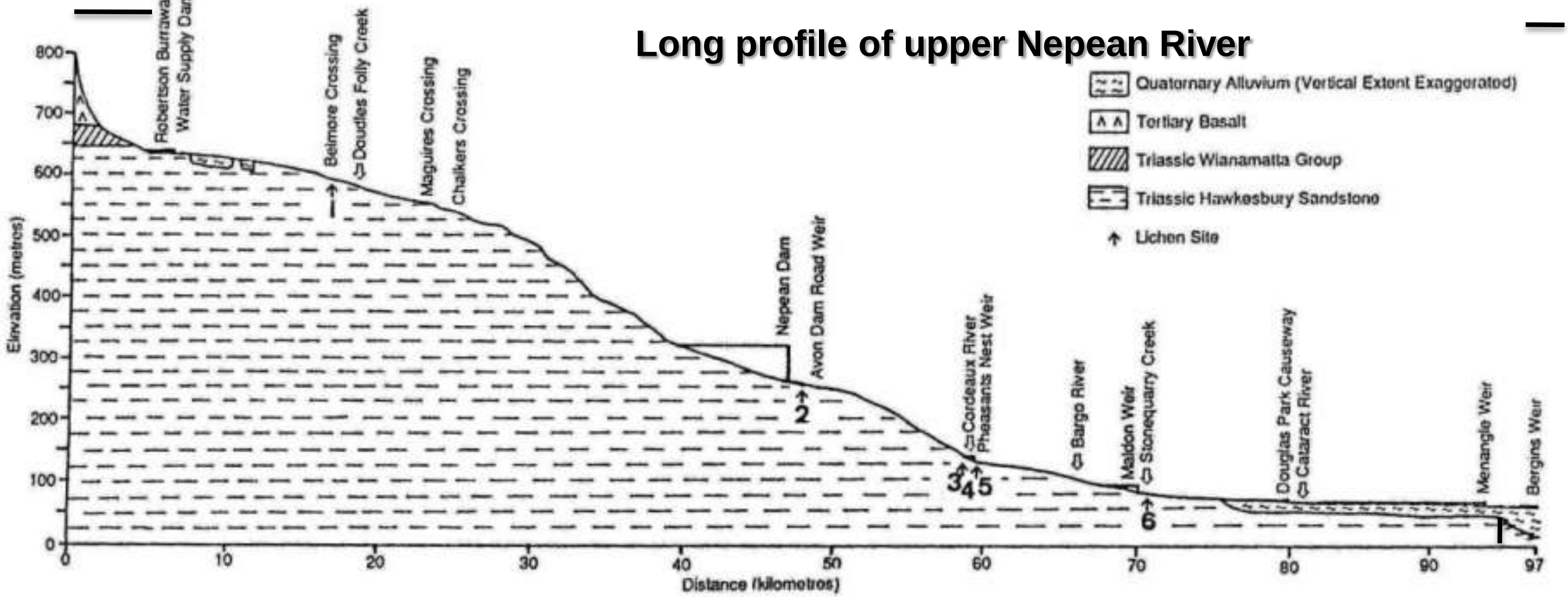
CHANNEL MORPHOLOGY

Headwaters Reach

Upper Floodplain Reach

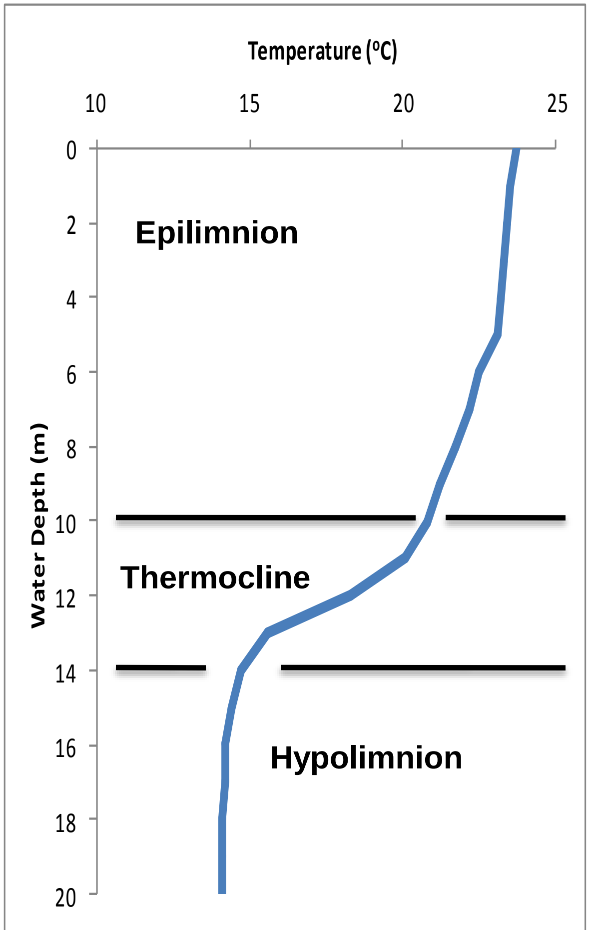
Upper Sandstone Gorge

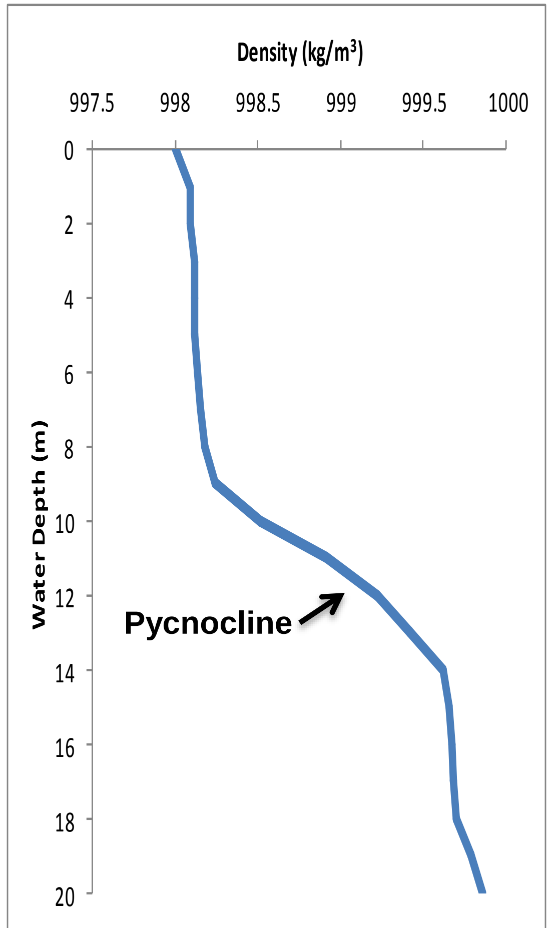
Camden Alluvial Reach



Deep pools in Upper Sandstone Gorge downstream of Stonequarry Creek, dredge pools in Camden Alluvial Reach, Bents Basin scour pool, deep pools in Fairlight Gorge and dredge pools in Windsor Estuarine Reach investigated

STRATIFICATION



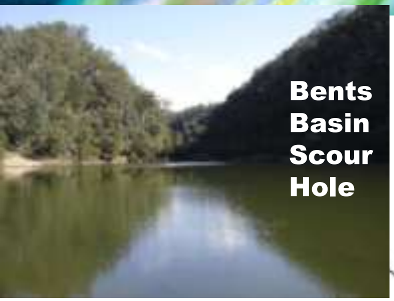


Temperature and density profiles in Bents Basin, Nepean River, on 20 March 1996

Stratification: development of a 3 layered water body comprising:
1. Epilimnion or surface layer of relatively warm, well oxygenated, well mixed, less dense water;
2. Metalimnion or middle layer where rate of change in water quality parameter is greatest for the depth profile (thermocline, pycnocline, oxycline, chemocline, halocline generally coincide);
3. Hypolimnion or deepest layer of relatively cold, deoxygenated, poorly mixed, less dense water
Stratification supposedly does not develop in well mixed rivers!!!

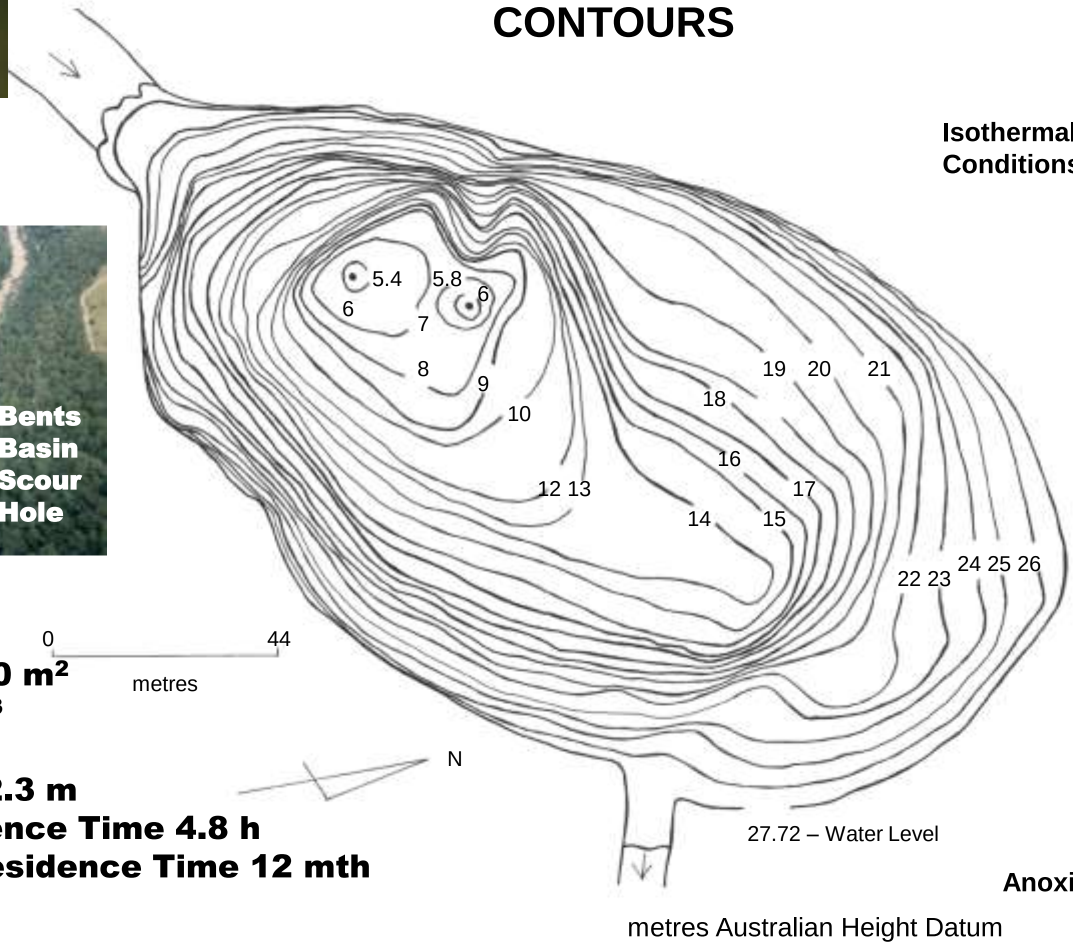
STRATIFICATION

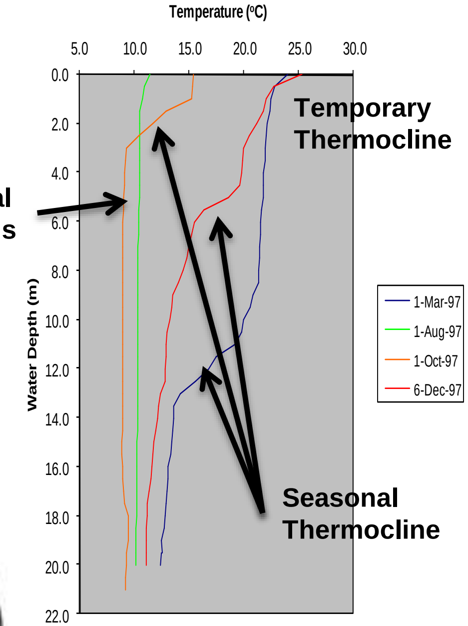
At commencement of spring in warm temperate regions, increasing solar radiation is absorbed in upper few metres of water body and is dissipated as heat, causing surface waters to expand. Heating decreases density of surface water which thereby becomes separated from the cooler bottom water. With onset of summer, solar radiation continues to increase which further increases density differential to a point where wind cannot mix entire water body. With commencement of autumn and cooler conditions, reductions in solar radiation cause a net loss of heat from the epilimnion. Convection currents and wind promote mixing of the cooling epilimnion which increases in depth as the thermocline weakens. Eventually a point is reached where the difference in temperature and hence density between surface and bottom waters are so slight that resistance to mixing is overcome and water body undergoes complete mixing or overturn, leading to the development of isothermal conditions which persist throughout winter (holomixis). Polymictic water bodies mix frequently, every few days or weeks (Wingecarribee Reservoir). Temporary thermoclines can exist within epilimnion and oxygen stratification can development when there is only a thermal gradient (no stratification). Salt stratification increases density difference between epi- and hypolimnion and is common in rivers where there are saline groundwater inflows. Such inflows do occur on Nepean River (Turner & Erskine 1997). Salt stratification is common in some types of estuaries (Turner & Erskine 2005). Shallow rivers, estuaries and lakes (floodplain lakes on Macdonald River) are usually well mixed.

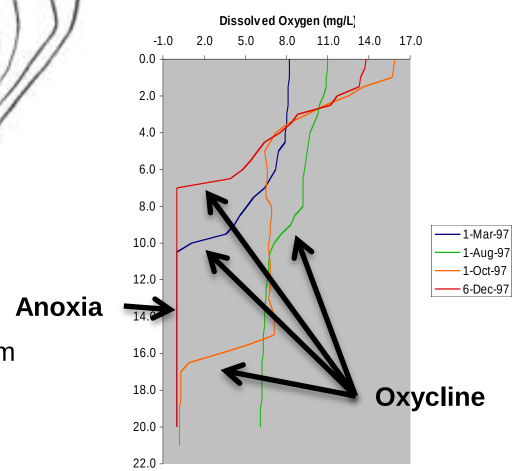


BENTS BASIN SCOUR HOLE

CONTOURS

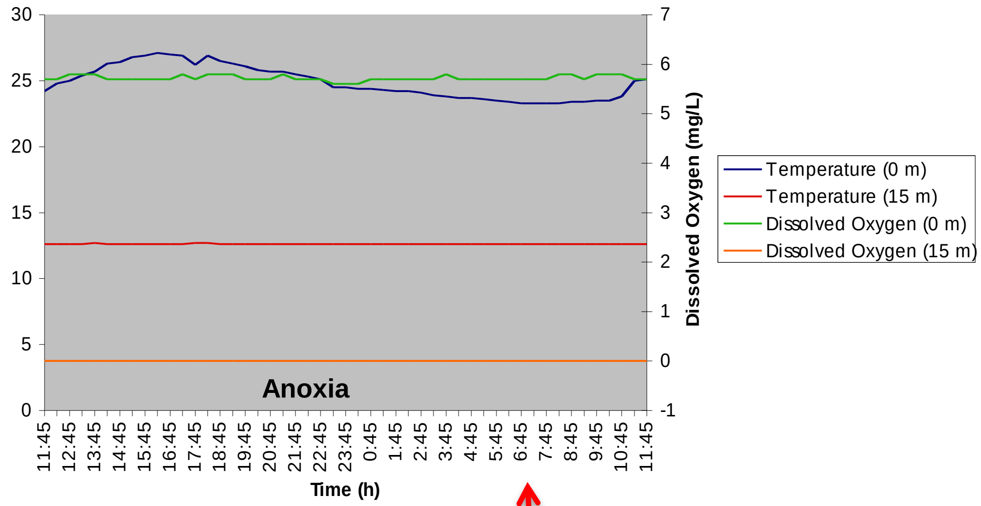




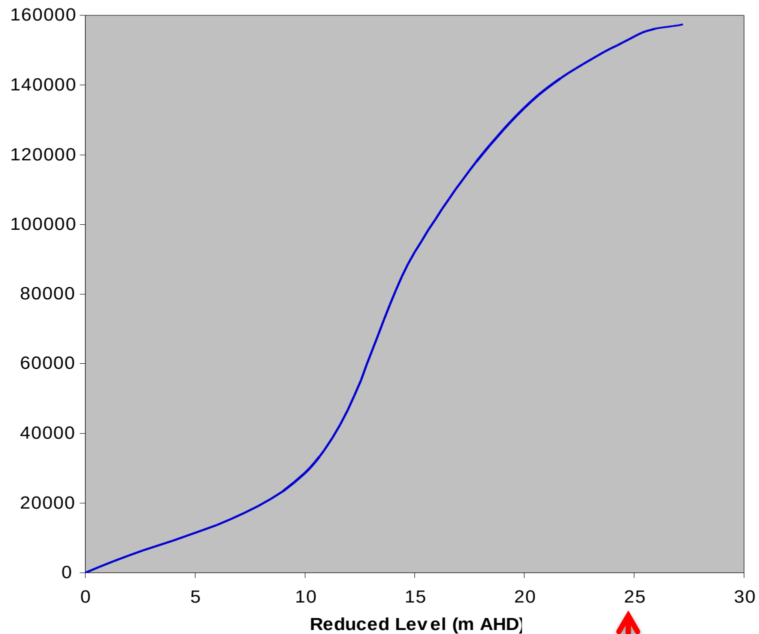


Surface Area 21000 m^2
Volume 160840 m^3
Mean Depth 7.7 m
Maximum Depth 22.3 m
Mean Water Residence Time 4.8 h
Maximum Water Residence Time 12 mth

BENTS BASIN SCOUR HOLE



Bents Basin 6-7 March 1996

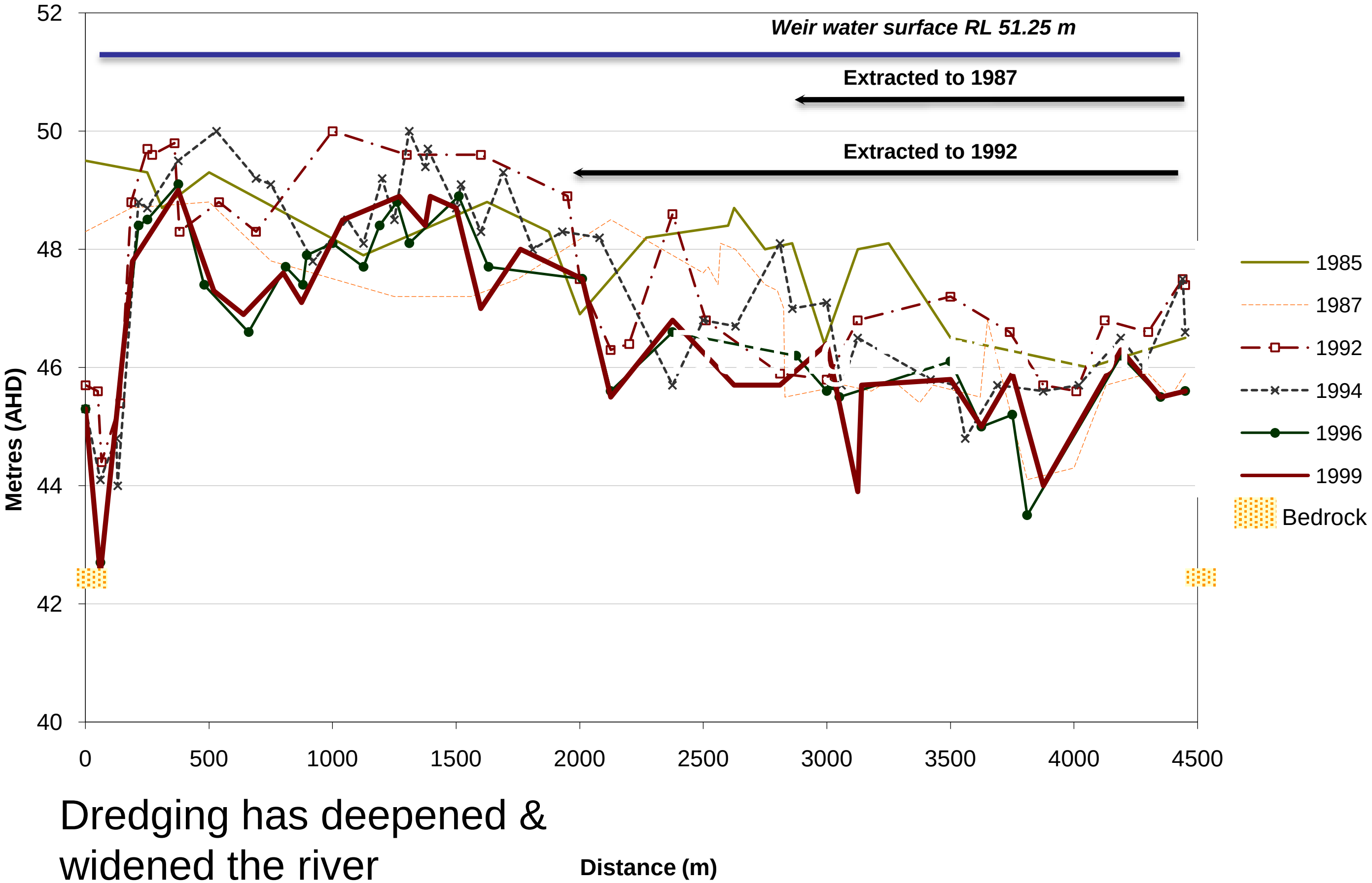


Water surface level (RL) versus volume of Bents Basin

Datalogging demonstrated that stratification persisted through the night

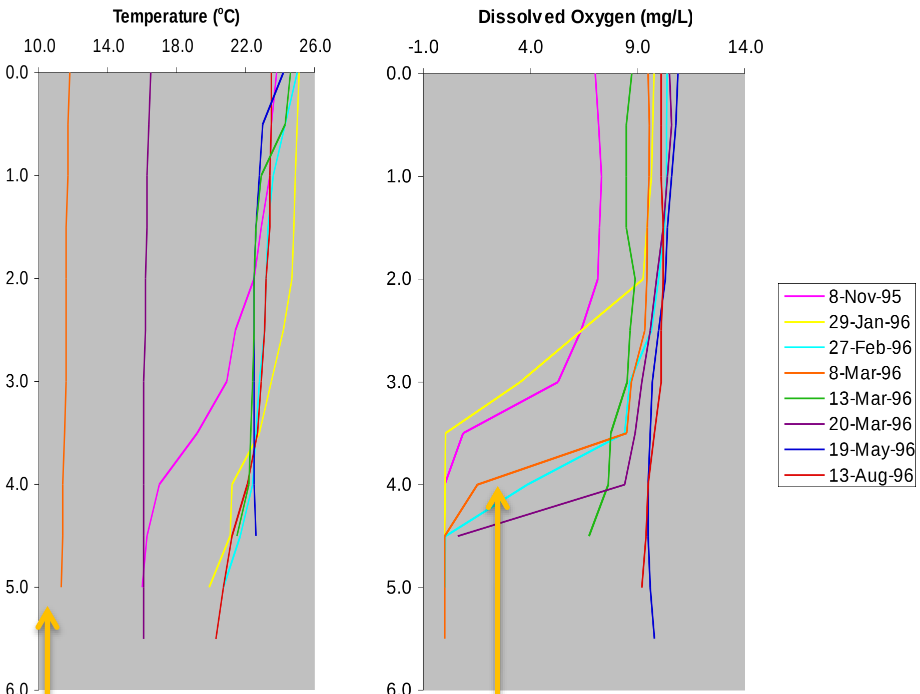
For an oxycline depth of 5 m, 144500 m^3 of scour hole biologically unavailable for aerobic organisms, such as fish

COBBITTY WEIR POOL



Dredging has deepened & widened the river

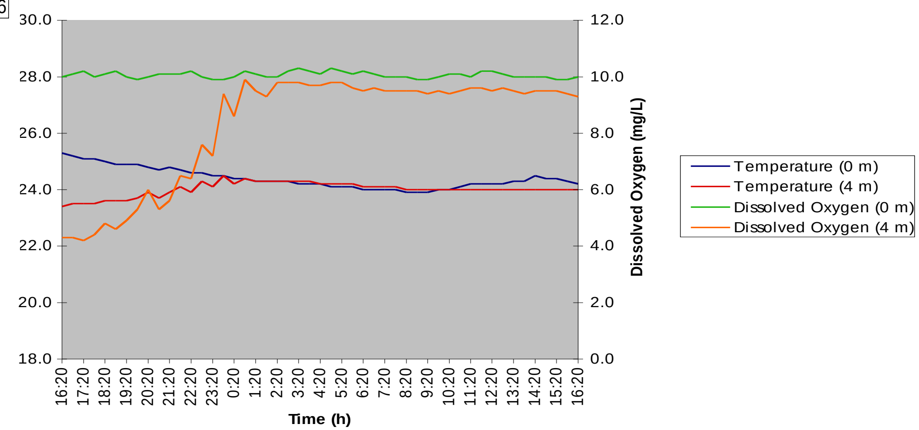
COBBITTY WEIR POOL



- Oxygen stratification can develop & persist in absence of thermal stratification
- Oxygen stratification more biologically important than thermal stratification
- Wind can cause mixing of weir pools

Isothermal profile on 8 March (orange) but strongly oxygen stratified with anoxia below the oxycline

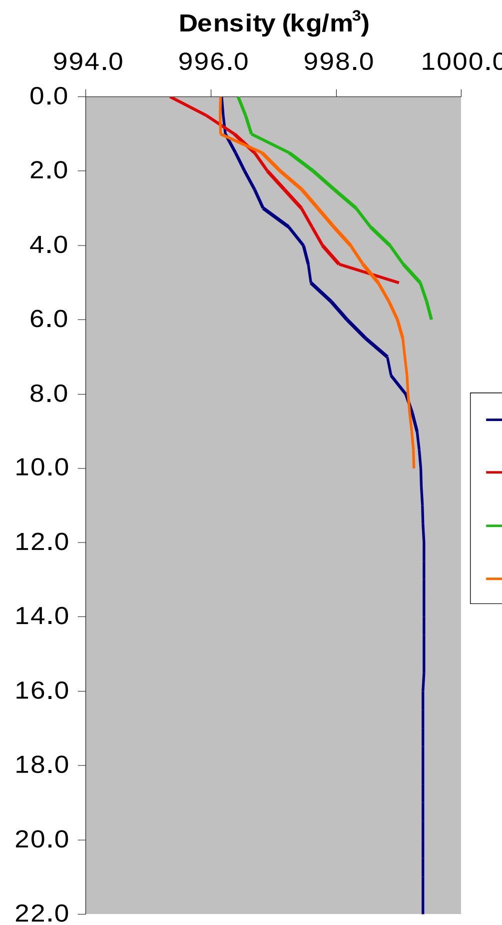
Mixing of Cobbitty Weir pool caused by 50 km/h winds



Cobbitty Weir 7-8 March 1996

SALT STRATIFICATION

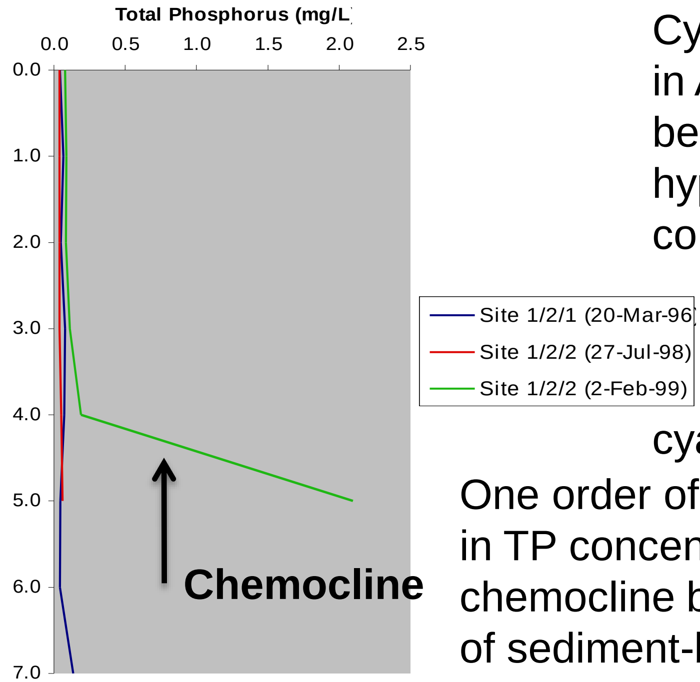
Saline groundwater inflows into bottom of deep dredge holes near Camden



Only temperature contributes to density increase at sites 1/3 and 1/6 but salinity also important at sites 1/1 and 1/2

CYANOBACTERIAL BLOOMS

Microcystis aeruginosa cyanobacterial bloom, showing a surface scum in Cobbitty Weir pool, April 1998

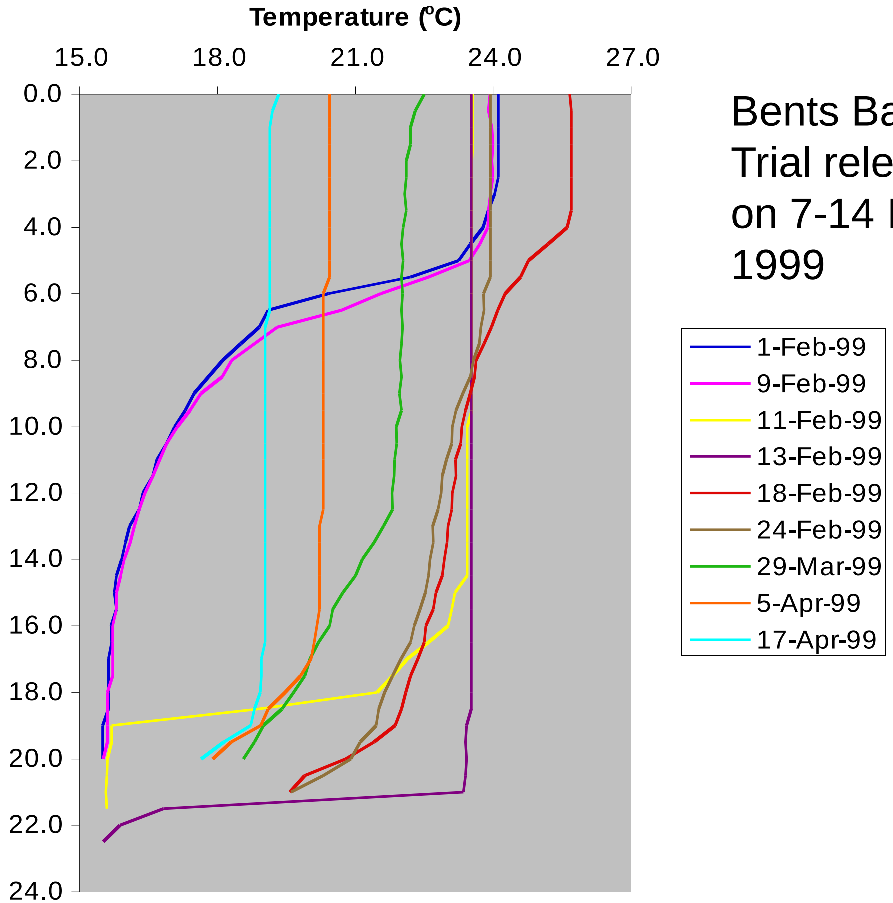


Cyanobacterial blooms in April after holomixis because high hypolimnetic P concentrations mixed with surface waters when temperatures still high enough for cyanobacterial growth

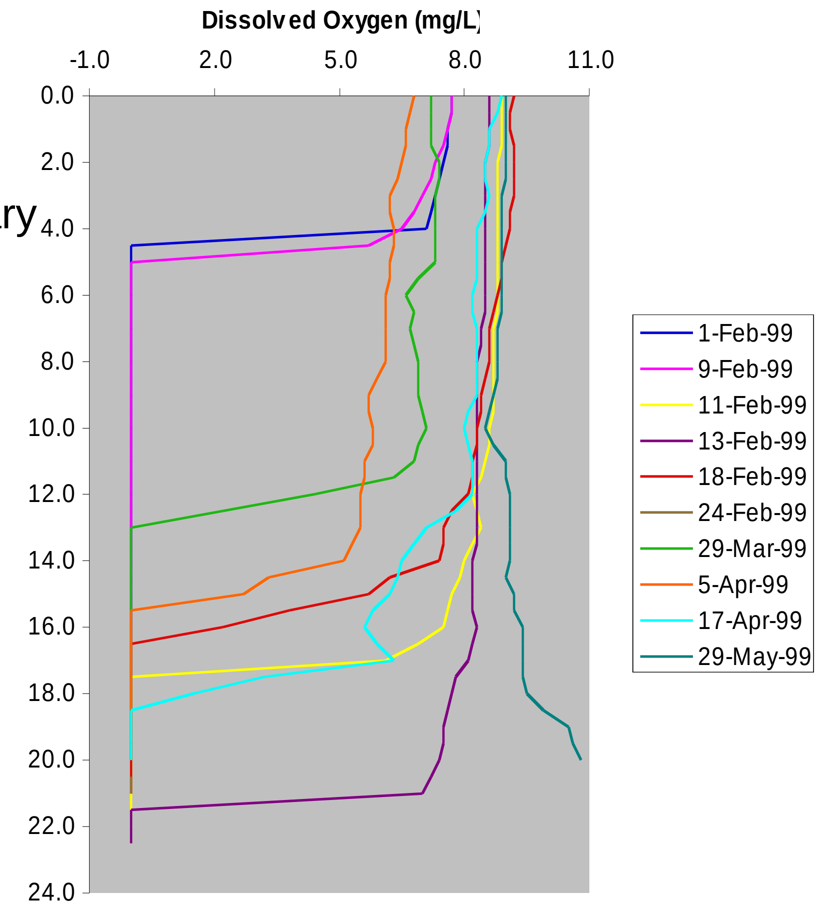
One order of magnitude increase in TP concentration below chemocline because of release of sediment-bound P under anoxic and reducing conditions

Warning sign about blue-green algae erected on bank of the Nepean River at Cobbity

ENVIRONMENTAL FLOWS



Bents Basin
Trial release
on 7-14 February
1999



ENVIRONMENTAL FLOWS

Trial environmental release of 7-14 February 1999. These releases did not reach the study sites until 9 February, with maximum mean daily discharges of between 21.7 and 40.7 m^3/s being recorded on 10 February. Discharge had returned to pre-release values by 20 February. A thermocline or thermal gradient and oxycline were present at all monitored sites (Sharpes, Cobbitty and Penrith weir pools and Bents Basin) immediately before the release. Stratification generally broke down by entrainment over 2-5 days, with two exceptions. An oxycline persisted in the deep hole at Bents Basin although the depth of the oxycline progressively increased from 4 m on 9 February to 19 m on 11 February to 21 m on 13 February. However, it rose rapidly after the cessation of the release to 14.5 m on 18 February. A similar trend was recorded at the deepest site in Penrith Weir pool. At all sites, a thermocline or thermal gradient and oxycline had redeveloped by late February.

Sharpes Weir before the trial release

R_L<20 slow mixing
R_L<2 fast & complete mixing

Sharpes Weir during the trial release

CONCLUSIONS

1. Thermal gradients and stratification develop and persist in the absence of floods between October and April in deep natural scour pools and dredged weir pools greater than 5 m deep
2. Maximum measured temperature difference of 15.4°C in Bents Basin
3. Oxyclines present for the same period but at shallower depths than thermoclines
4. Hypoxia and anoxia common below oxycline and limit aquatic habitat for fish below 5 m in Bents Basin (91.8% of volume) and below 3 m in weir pools (77.8 % of Cobbitty Weir pool)
5. Other factors besides thermal stratification also contribute to oxygen stratification, such as BOD, bacterial respiration, planktonic respiration, plant respiration and chemical oxidation of sedimentary organic matter.
6. Reducing conditions also common below the oxycline
7. Large increases in dissolved TP, Fe, S and Mn below the oxycline
8. Mixing of high nutrient bottom waters during holomixis causes cyanobacterial blooms in weir pools
9. Floods, reservoir releases and strong winds can cause mixing
10. R_L of less than 2 required for rapid mixing by environmental flows
11. R_L between 20 and 2 cause slow mixing which may not completely overturn deep pools
12. Restrictions on dredging depths required (say less than 3 m)
13. Environmental flows must address peak flow velocities and duration to overturn stratified pools

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Thank you for your attention. Any questions (at the end of the presentations)?

Hawkesbury City Council River Summit, Windsor, 13 August 2008

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