Appendix 1
Indicator Micro-organisms

Waterborne pathogens

Waterborne pathogens are micro-organisms that cause disease in humans. The most common waterborne pathogens are members of three groups of organisms: bacteria, protozoans and viruses.

Viral pathogens

A number of enteric viral pathogens, such as the hepatitis A virus, may be detected by water quality testing. These tests may detect the presence of viruses, identify strains and (in some instances) count them. This is a new and evolving field that is attracting considerable scientific interest and debate.

However, on the basis of current knowledge, the direct detection of viral pathogens is not a feasible option for routine assessment, for the following reasons:

- Viruses can occur intermittently in the environment and can be difficult to detect. Viruses can associate with insoluble particles and are typically incorporated into the bottom sediments. The sampling of water may not indicate the presence of viral pathogens. Sediment samples may also need to be collected.
- Some viral pathogens may persist in the environment, particularly in bottom sediments, for up to several months. Such monitoring may not be indicative of a recent pollution event or current water quality.
- There are insufficient epidemiological data available on the interpretation of viral pathogen test results to link the detection of viruses to health effects. This makes the undertaking of health risk assessments difficult at the present time. For example, the results of available studies from ocean sewage outfalls may not be applicable to estuarine or fresh waters because of the different behaviour of viral pathogens in these environments.
- There is a lack of standards to determine acceptable viral pathogen levels (if any) in water. This makes the assessment of water quality, wastewater discharge quality and disinfection standards difficult.
- Tests to detect the presence of viral pathogens and to identify and (in some instances) count them are relatively new and expensive. The collection of water and sediment samples for such tests is specialised and labour intensive. A high degree of quality assurance and quality control is required.

It is important to note that because of technical difficulties in isolating viruses from environmental samples, a negative result (for example, no viral pathogen isolated) cannot necessarily be interpreted as no viral pathogen present or no health risk.

Indicator bacteria

Various indicator micro-organisms are used to test for faecal contamination of recreational waters and the possible presence of waterborne pathogens. Indicator bacteria are used to indicate recent faecal contamination and as indicators of health risk (by referencing results to recognised guidelines).

Importantly, the relationship between indicator bacteria (of any type) and health risk is not consistent, because other factors (such as the incidence of illness in the catchment) also have a bearing on health risk. Indicator bacteria are good indicators of recent faecal contamination but imperfect indicators of health risk.

The coliform group of bacteria has been the most widely used indicator organism (e.g. APHA 1992; USEPA 1983). In particular, the faecal coliform sub-group was initially chosen because of its consistent association with the faecal wastes of warm-blooded animals.

Faecal coliforms have been renamed *thermotolerant coliforms* in recent years, as some genera within the group are not of faecal origin. However, to be consistent with previous Beachwatch reports, the terminology 'faecal coliforms' is still used in this report. Faecal coliforms have long been utilised as indicator organisms in NSW waterways.

However, because of the relatively short lives of these organisms in the marine environment, they can be used to detect the presence of faecal contamination for only a short time after a contamination event (for example, Gerba et al. 1979; Vivian 1986). Moreover, some studies have demonstrated a number of deficiencies in the use of faecal coliforms as indicator organisms in marine waters (Palmer et al. 1984; Cornax et al. 1991; APHA 1992). Some epidemiological studies have shown less of a link between faecal coliform densities and illness rates in bathers than that obtained using *enterococci*. This is another type of bacterium that has a consistent association with the faecal wastes of warm-blooded animals and has a longer life in seawater.

For this reason, many countries recommend guidelines for recreational waters in terms of enterococci (USEPA 1986). Correspondingly, in NSW enterococci use as an indicator organism is increasing, although faecal coliforms are still often measured simultaneously.

The Australian and New Zealand Environment and Conservation Council (ANZECC) has recommended guidelines for recreational water quality in terms of both faecal coliforms and enterococci (ANZECC 2000). In 2008 NHMRC released new guidelines for managing the risks in recreational waters (NHMRC 2008). These guidelines recommend measurement of enterococci in marine waters.

The Beachwatch Program

Beachwatch has been testing for faecal coliforms since the program commenced in 1989, and groups (such as Sydney Water Corporation) have monitored faecal coliforms at Sydney's beaches since 1965. Faecal coliform levels at Sydney's ocean beaches were often well above national health guideline limits before the construction of the deepwater ocean sewage outfalls in 1990 and 1991. Once the extended outfalls were operational, faecal coliform levels dropped to levels consistently below the national health guideline limits.

As a result of the then emerging scientific literature on the value of using enterococci as an indicator of faecal contamination in marine waters, in 1993 Beachwatch commenced sampling for enterococci in addition to faecal coliforms. Previously, samples were analysed for faecal coliforms and faecal streptococci. (Enterococci are a sub-group of faecal streptococci and are differentiated from other faecal streptococci by growth in the laboratory at a higher temperature and salt concentration.)

Results for Sydney's ocean beaches show that lower rates of compliance with water quality criteria are detected using enterococci than with faecal coliforms. In essence, enterococci provide a more rigorous test of beach cleanliness in seawater.

Faecal coliforms are extremely abundant in treated sewage (about one to ten million cfu in every 100 millilitres of primary treated effluent); as a result they are useful indicators of faecal contamination in the marine environment, despite their rapid die-off after being released. If high levels of faecal coliforms are detected in marine waters, it is likely that the pollution event was recent.

However, because of their greater tolerance of the marine environment, the presence of enterococci may indicate residual contamination of marine waters. Also, these bacteria are thought to survive in marine waters for periods that parallel the survival times of some pathogenic microbes.

DECCW has not identified any study that has established a consistent relationship between the levels of faecal coliforms and enterococci. Neither has any study been widely acknowledged that unequivocally establishes a clear relationship between the levels of faecal coliforms or enterococci in Australian waters and enteric viral pathogen levels and associated health risks.

DECCW recognises that faecal coliforms and enterococci are useful indicator organisms that are available for testing for faecal contamination of recreational waters.

Recent developments

New guidelines for recreational water quality were released by NHMRC in June 2005, and following review in 2006 they were officially released in February 2008 (NHMRC 2008). The guidelines incorporate many of the most recent directives of the World Health Organization's guidelines for recreational waters (WHO 2003). The NHMRC guidelines have also drawn upon aspects of 'Catchments for Recreational Water: Conducting and Assessing Sanitary Inspections (WSAA 2003) and the New Zealand 'Microbial Water Quality Guidelines for Marine and Freshwater Recreational Areas' (NZMFE 2002).

Thermotolerant (faecal) coliforms and *E. coli* have traditionally been used to assess the level of faecal contamination of waters from both humans and animals. While it is now widely recognised that *E. coli* are preferable to thermotolerant coliforms (because many members of the latter can grow in the environment), epidemiological studies do not show a clear dose–response relationship between these coliforms and bathers' disease outcomes. In contrast, faecal streptococci and enterococci have shown a clear dose–response relationship to disease outcomes in temperate north European waters (WHO 2003).

The NHMRC 2008 guidelines were adopted by the NSW government in May 2009 at the start of the winter sampling period. Beachwatch has reviewed its monitoring and reporting protocols on the basis of these guidelines, and is now using enterococci as the single preferred indicator as advocated by WHO (2003) and NHMRC (2008).

Appendix 2
Quality Assurance Laboratory Results

Overview of sample preparation

Six independent laboratories are used to assess the relative accuracy of samples gathered to generate Beachwatch and Harbourwatch water quality data. At the start of every month three samples are submitted to each of the six laboratories participating in the quality assurance program.

All samples used in the quality assurance program were collected from the environment. They were collected from a location in the lower Parramatta River (not a swimming site). Each laboratory analysed its three subsamples for faecal coliforms and enterococci bacteria.

Overview of data analysis

On each occasion the individual results from each laboratory (i.e. the six replicate samples) were used to calculate the geometric mean of each of the samples; this mean will be referred to as the *consensus mean*. This consensus mean is used to represent the best available estimate of the true density of the particular bacterial group in the sample. The individual results for each laboratory have been compared with the consensus mean to calculate the relative deviation.

For each sample result from each laboratory, the difference above or below the consensus mean was calculated. This value represents how close to the best estimate of the average the laboratory came for each sample. These results were expressed as $\log_{10}$ values.

Performance of all laboratories

The distribution of deviations from the consensus mean for the environmental samples for faecal coliforms and enterococci is presented in the box plots of Figure 32 (see page 5 for explanation of box plots). Data from all laboratories are summarised in Figure 33.

The variation among faecal coliform results was generally small for all six laboratories and similar to that determined in previous years. Laboratories reported between 61% and 94% of their results within 0.3 log units of the consensus mean (equivalent to a halving or doubling on a normal scale).

Similarly, the variation among laboratories for enterococci was relatively small. With the exception of Laboratory C, a high percentage of results were reported within the acceptable range. Laboratories reported between 56% and 83% of their results within 0.3 log units of the consensus mean (equivalent to a halving or doubling on a normal scale).

Performance of contracted laboratory

Distribution of data

The contracted laboratory is Laboratory A in Figure 32.

For faecal coliforms, the contracted laboratory showed a high level of accuracy with 81% of results within 0.3 log units of the consensus mean. Values greater than +0.3 log units or less than -0.3 log units reflect samples that were double or half the consensus mean, respectively. As can be seen from Figure 32 and Figure 33, four values were under-reported and outside the 0.3 log unit. The laboratory was notified of this incident and since then all results have been reported within the acceptable range.

For enterococci, 78% of the contracted laboratory's enterococci results were within 0.3 log units of the consensus mean (equivalent to a range of half to twice the consensus mean). Most enterococci results outside this range were under-reported, only slightly outside the 0.3 log unit range and at low bacterial densities, as shown in Figure 33.

Laboratories E and F conduct the laboratory analysis for the Illawarra and Hunter samples, respectively. Illawarra results had a high level of accuracy with 89% of faecal coliform results and 81% of enterococci results within 0.3 log units of the consensus mean (equivalent to a range of half to twice the consensus mean). Hunter results for faecal coliforms were the most accurate of the six laboratories, with 94% of the results for faecal coliforms within 0.3 log units of the consensus mean (equivalent to a range of half to twice the consensus mean. For enterococci, 75% of the Hunter laboratory's results were within 0.3 log units of the consensus mean.

Differences between the results from the contracted laboratory and the other laboratories were further investigated by statistical analysis.

Figure 32: Deviation from the Consensus Mean for Each Laboratory in the QA Program

The contracted laboratory is Laboratory A

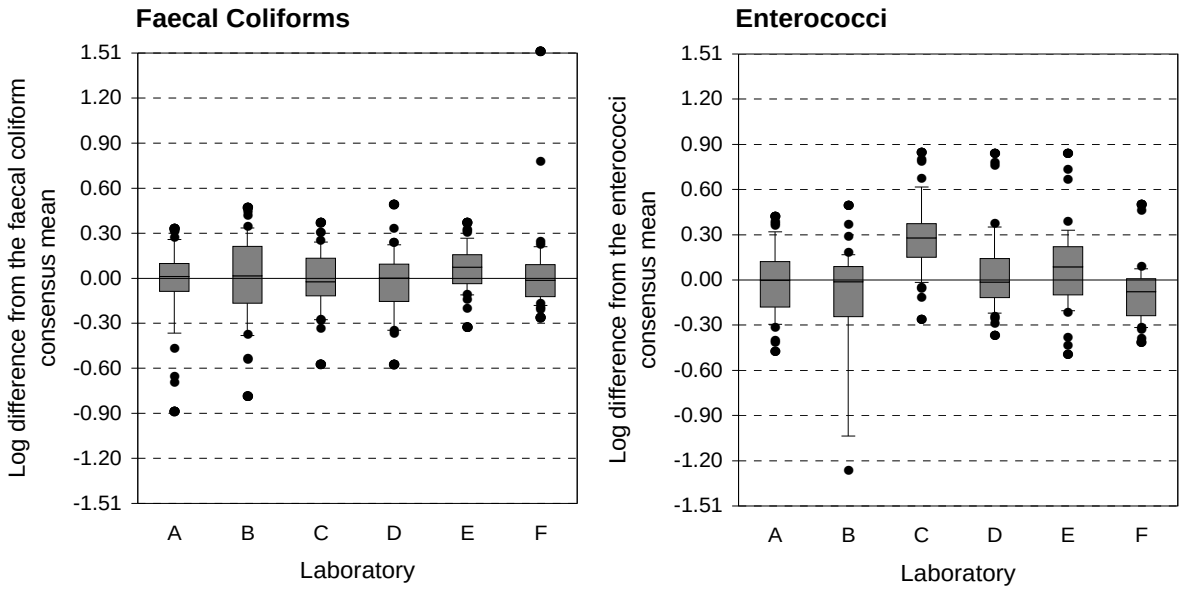
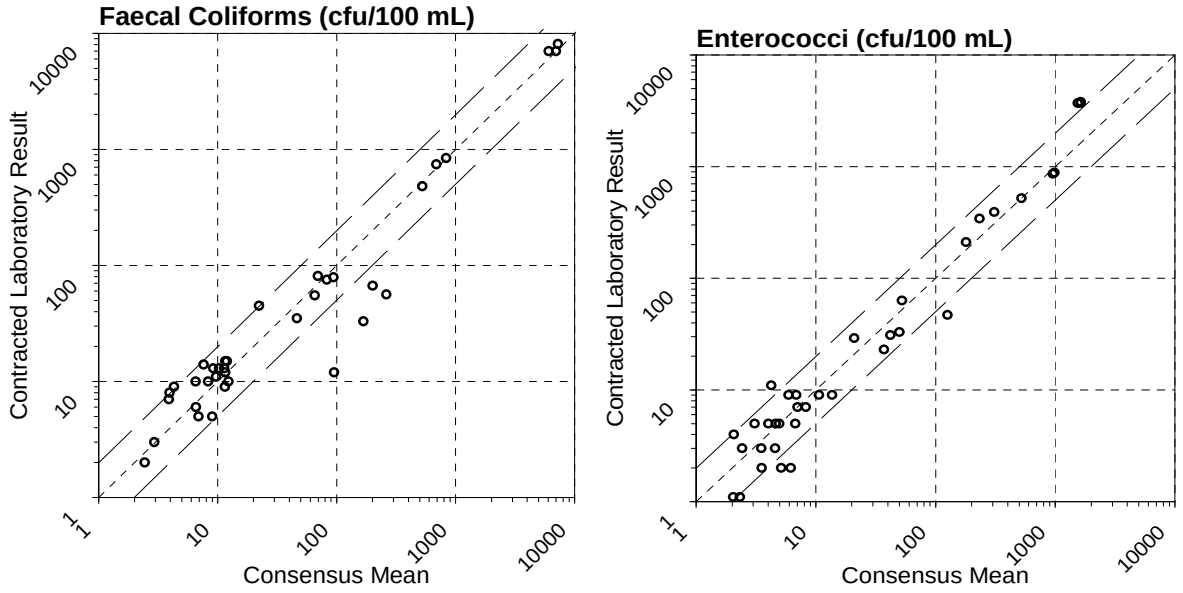


Figure 33: Distribution of Quality Assurance Results for the Contracted Laboratory



Statistical analysis

Faecal coliform and enterococci data were $\log_{10}$ transformed to meet assumptions of normality. A one-way analysis of variance was performed on the faecal coliform and enterococci data. It was found that both faecal coliform and enterococci results were not significantly different among laboratories.

This indicates that results from the contracted laboratory were similar to those of the other laboratories used for the quality assurance analysis.

Conclusion

In summary, although there were some differences among the performances of all laboratories, these were relatively small, and similar accuracy and precision were achieved for most laboratories for both faecal coliform and enterococci results. The contracted laboratory did not differ significantly from the other laboratories in its estimations of faecal coliform or enterococci densities.

Results from Hunter and Illawarra Laboratories also showed high levels of accuracy. Therefore, there is confidence in the compliance levels presented in this report for swimming sites in the Hunter and Illawarra region.

These results confirm that the contracted laboratory is performing analyses of bacterial counts within the acceptable range and confidence can be placed in the accuracy of all results reported by the Beachwatch Program.

Appendix 3
Further Reading

This section provides additional sources of information on monitoring and assessment of bacteriological water pollution and water quality. The information given here is not comprehensive. The intention is to provide a starting point and to list some of the most recent resources available relating specifically to the Sydney region.

1. Reports and texts

ANZECC & ARMCANZ (2000) *National Water Quality Management Strategy*. Australian and New Zealand Guidelines for Fresh and Marine Water Quality, 2000. Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, Canberra.

(Guideline information for recreational water quality indicators)

Apte, S. C., Batley, G. E. and Ashbolt, N. J. (1993). *Rapid Detection of Faecal Coliforms in Coastal Waters*. Australian Water and Wastewater Association 15th Federal Convention 18–23 April 1993, Technical Papers Vol. 2.

(Research and development – monitoring faecal coliforms in marine waters – rapid assessment for early warning)

Ashbolt, N. J. (1995). Health-related water microbiology: Australia leads: But where next? *Water Journal*, Vol. 22 No. 2 May/June 1995, Australian Water and Wastewater Association, Sydney.

(Discussion on research and development for recreational and drinking water quality indicators and guidelines – includes alternative health-related indicators)

Ashbolt, N. J., Riedy, C. and Haas, C. N. (1997). *Microbial Health Risk at Sydney's Coastal Bathing Beaches*. Australian Water and Wastewater Association 15th Federal Convention 16–21 March 1997 Vol. 2, pp. 104–111.

(Microbial quantitative risk assessment at Sydney's urban coastal beaches using historical microbial data – models used to estimate exposure to pathogenic bacteria, protozoa and a model virus – enteric viruses pose the highest risk to bathers at Sydney ocean beaches)

Australian Water Technologies (1993). *Long Term Beach Water Quality Reporting Series – Reports 1–8*. Water Board, Sydney.

Report 1 – Sampling Strategies and Methods of Analysis 1965–1992

(Summary of bacteriological data held by AWT for the period 1965–1992 from Sydney and Illawarra regions.)

Report 2 – Assessment of Water Quality of Sydney's Metropolitan Beaches

(Beach water quality for the period 1969–1991 for Sydney beaches – assessments are based on appropriate bacteriological water quality guidelines – likely pollution sources are discussed.)

Report 3 – Trends in Densities of Faecal Coliforms at Seven Target Beaches in Sydney

(Examination of trends in faecal coliform levels at seven Sydney beaches between 1969 and 1991 – comparisons are made between pre- and post-deepwater ocean outfall commissioning bacterial counts.)

Report 4 – Assessment of Water Quality of Beaches in the Illawarra Region

(Review of current water quality of Illawarra beaches)

Report 5 – Spatial and Temporal Variations in Bacterial Densities at Selected Sydney Beaches

(Determination of the major sources of variation associated with faecal coliform sampling.)

Report 6 – The Influence of Some Environmental Factors on Densities of Faecal Coliforms at Fourteen Sydney Beaches

(Twenty-four hour rainfall, hours of sunshine, wind direction and speed and tide are examined for influence on faecal coliform counts.)

Report 7 – Trends in Visual Sewage Pollution and Densities of Faecal Coliform Bacteria and their Use as Indicators of Bathing Water Quality at 14 Sydney Beaches

(Visual sewage pollution between the years 1969 and 1990 – associations between faecal coliform counts and visual sewage pollution indicators.)

Report 8 – Trends in the Concentration of Grease at 13 Sydney Beaches

Australian Water Technologies, Sydney Water, NSW Environment Protection Authority (2000). *Offshore Sediment Program 2000: Report* – Final, AWT, Sydney.

Bartram, J., Rees, G. (2000). *Monitoring Bathing Waters: A Practical Guide to the Design and Implementation of Assessments and Monitoring Programs.* European Commission, World Health Organization, and United States Environmental Protection Agency, E & F Spon, London.

(European guide to developing a recreational water quality monitoring program)

Beachwatch (1995). *Beachwatch Winter Season 1994*. EPA (NSW), Sydney.

(Bacterial monitoring results for Sydney ocean beaches, Winter 1994 – visible sewage pollution indicators – correlation study between faecal coliforms and rainfall for ocean beaches)

Beachwatch (1995). *Beachwatch 1995 Season Report*. EPA (NSW), Sydney.

(Bacterial monitoring results for Sydney ocean beaches, Summer 1994–1995 – visible sewage and stormwater pollution indicators – correlation between visible indicators and bacteria – correlations between rainfall and bacteria – effluent and plume distribution study from Cronulla and Warriewood shoreline outfalls)

Beachwatch (1996). *Harbourwatch 1995 Season Report*. EPA (NSW), Sydney.

(Bacterial monitoring results for Sydney Harbour, Botany Bay, Georges River and Port Hacking beaches, Summer 1994–1995 – background to Harbourwatch program – pollution in Sydney Harbour – factors affecting water quality in Sydney Harbour)

Beachwatch (1996). *Beachwatch and Harbourwatch 1996 Season Report*. EPA (NSW), Sydney.

(Bacterial monitoring results for Sydney ocean, Sydney Harbour, Pittwater, Botany Bay, Georges River and Port Hacking beaches, Summer 1995–1996 – changes to Bulletin criteria – impact of drains on flagged areas – sediment bag monitoring of faecal coliforms – Secchi disk – community expectations of Beachwatch)

Beachwatch (1997). *Beachwatch and Harbourwatch 1997 Season Report*. EPA (NSW), Sydney.

(Bacterial monitoring of Sydney, Hunter and Illawarra ocean beaches, Sydney Harbour, Pittwater, Botany Bay, Georges River and Port Hacking – communications initiatives – microbiological quality assurance program – post–rainfall recovery study.

Beachwatch (1998). *Beachwatch and Harbourwatch 1997–1998 State of the Beaches*. Sydney, Hunter, Illawarra. EPA (NSW), Sydney.

(Bacterial monitoring of Sydney, Hunter and Illawarra ocean beaches, Sydney Harbour, Pittwater, Botany Bay, Georges River and Port Hacking – communications initiatives – microbiological quality assurance program – post–rainfall recovery study – Olympic study)

Beachwatch (1999). *Beachwatch and Harbourwatch 1998–1999 State of the Beaches*. Sydney, Hunter, Illawarra. EPA (NSW), Sydney.

(Bacterial monitoring of Sydney, Hunter and Illawarra ocean beaches, Sydney Harbour, Pittwater, Botany Bay, Georges River and Port Hacking – microbiological quality assurance program – effect of rainfall on Sydney beach compliance – post–rainfall recovery study – Olympic study)

Beachwatch (2000). *Beachwatch and Harbourwatch 1999–2000 State of the Beaches*. Sydney, Hunter, Illawarra. EPA (NSW), Sydney.

(Bacterial monitoring of Sydney, Hunter and Illawarra ocean beaches, Sydney Harbour, Pittwater, Botany Bay, Georges River and Port Hacking – microbiological quality assurance program – effect of rainfall on Sydney beach compliance – Olympic study)

Beachwatch (2001). *Beachwatch and Harbourwatch 2000–2001 State of the Beaches*. Sydney, Hunter, Illawarra. EPA (NSW), Sydney.

(Bacterial monitoring of Sydney, Hunter and Illawarra ocean beaches, Sydney Harbour, Pittwater, Botany Bay, Georges River and Port Hacking – microbiological quality assurance program – Beachwatch on the Web– effect of rainfall on Sydney beach compliance – Olympic study)

Beachwatch (2002). *Beachwatch and Harbourwatch 2001–2002 State of the Beaches*. Sydney, Hunter, Illawarra. EPA (NSW), Sydney.

(Bacterial monitoring of Sydney, Hunter and Illawarra ocean beaches, Sydney Harbour, Pittwater, Botany Bay, Georges River and Port Hacking – microbiological quality assurance program – effect of rainfall on Sydney beach compliance– The Beachwatch Partnership Pilot Program case study – Sutherland Beaches study – Darling Harbour study)

Beachwatch (2003). *Beachwatch and Harbourwatch 2002–2003 State of the Beaches*. Sydney, Hunter, Illawarra. EPA (NSW), Sydney.

(Bacterial monitoring of Sydney, Hunter and Illawarra ocean beaches, Sydney Harbour, Pittwater, Botany Bay, Georges River and Port Hacking – microbiological quality assurance program – effect of rainfall on Sydney beach compliance – post-rainfall recovery study – The Beachwatch Partnership Pilot Program case study – Darling Harbour, South Maroubra Rock Pool and Boat Harbour special studies)

Beachwatch (2004). *Beachwatch and Harbourwatch 2003–2004 State of the Beaches Report*. Sydney, Hunter, Illawarra. DEC (NSW), Sydney.

(Bacterial monitoring of Sydney, Hunter and Illawarra ocean beaches, Sydney Harbour, Pittwater, Botany Bay, Georges River and Port Hacking – microbiological quality assurance program – effect of rainfall on Sydney beach compliance – post-rainfall recovery study – The Beachwatch Partnership Pilot Program case study – Darling Harbour and Yarra Bay special studies)

Beachwatch (2005). *Beachwatch and Harbourwatch 2004–2005 State of the Beaches Report*. Sydney, Hunter, Illawarra. DEC (NSW), Sydney.

(Bacterial monitoring of Sydney, Hunter and Illawarra ocean beaches, Sydney Harbour, Pittwater, Botany Bay, Georges River and Port Hacking – microbiological quality assurance program – effect of rainfall on Sydney beach compliance – post-rainfall recovery study – Darling Harbour special studies)

Beachwatch (2006). *Beachwatch and Harbourwatch 2005–2006 State of the Beaches Report*. Sydney, Hunter, Illawarra. DEC (NSW), Sydney.

(Bacterial monitoring of Sydney, Hunter and Illawarra ocean beaches, Sydney Harbour, Pittwater, Botany Bay, Georges River and Port Hacking – microbiological quality assurance program – effect of rainfall on Sydney beach compliance – post-rainfall recovery study – Darling Harbour special studies)

Beachwatch (2007). *Beachwatch and Harbourwatch 2006–2007 State of the Beaches Report*. Sydney, Hunter, Illawarra. DECC (NSW), Sydney.

(Bacterial monitoring of Sydney, Hunter and Illawarra ocean beaches, Sydney Harbour, Pittwater, Botany Bay, Georges River and Port Hacking – microbiological quality assurance program – effect of rainfall on Sydney beach compliance – post-rainfall recovery study – Darling Harbour special studies)

Beachwatch (2008). *Beachwatch and Harbourwatch 2007–2008 State of the Beaches Report*. Sydney, Hunter, Illawarra. DECC (NSW), Sydney.

(Bacterial monitoring of Sydney, Hunter and Illawarra ocean beaches, Sydney Harbour, Pittwater, Botany Bay, Georges River and Port Hacking – microbiological quality assurance program – effect of rainfall on Sydney beach compliance – post-rainfall recovery study – Darling Harbour special studies)

Guest, C., Douglas, R. and Woodruff, R. (1999) *Health and the Environment*. Australian Conservation Foundation, Australian Medical Association, Fitzroy, Vic.

(Public Health – Environmental Health – Environmental Study – Health Planning, Australia)

Healthy Rivers Commission (2000). *Independent Inquiry into the Georges River – Botany Bay System*. HRC, Sydney.

(Analysis and assessment of water quality of Georges River – Botany Bay catchment health)

Healthy Rivers Commission (2000). *Securing Healthy Coastal Rivers: A Strategic Perspective*. HRC, Sydney.

Healthy Rivers Commission (2002). *Independent Inquiry into Coastal Lakes.* HRC, Sydney.

(Analysis and assessment of water quality of NSW Coastal Lake health)

Kirby, A., Van Roo, S. and Collie, T. (1995). *Georges River and Botany Bay Faecal Coliform Monitoring Program, February 1993 – March 1994*, Interpretive Report No. 94/104, Sydney Water Corporation, Sydney.

(Analysis of trends in faecal coliforms in Georges River and Botany Bay – development of sampling strategies for faecal coliforms specifically for Georges River and Botany Bay – correlations with rainfall – pilot faecal coliforms recovery study)

Laws, E. A. (2000). *Aquatic Pollution: An Introductory Text* – 3rd Edition. John Wiley and Sons Inc, New York.

(Background information on marine water pollution issues in a global context)

Leeming, R., Nichols, P. D. and Ashbolt, N. J. (CSIRO Division of Marine Research) (1998). *Distinguishing Sources of Faecal Pollution in Australian Inland and Coastal Waters using Sterol Biomarkers and Microbial Faecal Indicators*. Urban Research Association Australia, Melbourne.

(Background, assessment and analysis of sources of faecal pollution within Australian coastal waters)

Legge-Wilkinson, M. (1996). *Human Impact on Australian Beaches*. Surfrider Foundation Australia Limited, Sydney.

(Analysis of results from the SOS95 Beach Questionnaire organised by Surfrider Foundation Australia, which documented and assessed human impacts on beaches around Australia)

National Health and Medical Research Council (2005) *Guidelines for Managing Risk in Recreational Water*. NHMRC, February 2008.

NSW Department of Land and Water Conservation (2000). *NSW Water Conservation Strategy*. NSW DLWC, Sydney.

NSW Environment Protection Authority (1995). *Provisional Water Quality Investigations Manual: Preferred Methods for Sampling and Analysis*. EPA (NSW), Sydney.

NSW Environment Protection Authority (1996). *Sydney Deep Water Outfalls Environmental Monitoring Program: Final Report Series Volumes 1–7.* EPA (NSW), Sydney.

(Provides background information, overall assessment and results of the Sydney Deep Ocean Outfalls program)

NSW Environment Protection Authority (2000). *NSW State of the Environment Report 2000*. EPA (NSW), Sydney.

NSW Environment Protection Authority (2000). *NSW State of the Environment Report 2000: Water Backgrounder*. EPA (NSW), Sydney.

(Aimed at water quality professionals – standardised monitoring for State of the Environment reporting – management of water quality investigations – sampling procedures – parameters (physico-chemical and biological) and analytical methods – quality assurance and quality control – budgeting – data handling)

Raffensperger, C. and Tickner, J. A. (1999) *Protecting Public Health and the Environment: Implementing the Precautionary Principle*, Island Press, Washington

(Precautionary principle – environment protection – government policy, United States – health risk assessment)

Roberts, E. R. (2000). *Water Quality Control Handbook*, McGraw-Hill. New York.

(The Theory and Quantification of Water Pollution – Water Quality Management – Water Pollution Regulations – Water Pollution Control – Residuals)

Salmon, I. (2002). *Water (NSW) A to Z, covering all NSW waters, Inland–Estuarine–Marine*. Lablex Pty Ltd, Main Beach, QLD.

(Aimed at water industry specialists, this manual provides an up-to-date A to Z directory of information about NSW receiving waters – covers everything from algae to zone of aeration – includes notes on Water and the Law)

Short, A. D. (1993). *Beaches of the New South Wales Coast – a Guide to their Nature, Characteristics, Surf and Safety*. Australian Beach Safety Management Program, Sydney.

(Comprehensive guide to NSW beaches – Includes beach dynamics, rip profiles, surf characteristics, Surf Life Saving Club information, surf rescue and water safety)

Southern Sydney Regional Organisation of Councils (2001). *The Tide Is Turning – Final report on the Botany Bay Program*. SSROC, Sydney.

(Provides information, results and discussion strategies on the 18-month Botany Bay Program, the aim of which was to develop a framework for the integrated management plan for Botany Bay catchment)

Sydney Water (1997). *WaterPlan 21*. Sydney Water Corporation, Sydney.

(Sydney Water's vision for sustainable wastewater management across the Sydney region – establishes priorities, water quality goals and a timeframe for delivery)

Sydney Water (1998). *Annual Environment Report*. Sydney Water Corporation, Sydney.

(Provides information on Sydney Water's environmental performance during 1997–98. Includes water supply operations, sewage and stormwater transport, sewage treatment and resource conservation)

Sydney Water (1998). *Environmental Indicators Monitoring Program Methods Report*. Sydney Water Corporation, Sydney.

(Outlines the methodology for collection, analysis and storage of data on Sydney Water's Environmental Indicators Monitoring Program. Also describes the quality system associated with the program and provides details of indicators used.)

Sydney Water (1999). *Annual Environment Compliance Report*. Sydney Water Corporation, Sydney.

(Provides information on Sydney Water's environmental compliance during 1998–1999)

Sydney Water (2000). *Annual Environment and Public Health Report 2000*. Sydney Water Corporation, Sydney.

(Provides information about Sydney Water's performance in managing a range of environmental and social impacts.)

Sydney Water (2000). *Environmental Indicators Monitoring Program Compliance Data 2000*. Sydney Water Corporation, Sydney.

(Contains raw data and results gathered from Sydney Water's Environmental Indicators Monitoring Program.)

Sydney Water (2000). *2000–2005 Environment Plan*. Sydney Water Corporation, Sydney.

(Provides information on the long-term strategic plan for Sydney Water Corporation)

Sydney Water (2001). *Towards Sustainability Report*. Sydney Water Corporation, Sydney.

(Information about Sydney Water's performance against a suite of ESD and stormwater management indicators for period 1 July 2000 to 30 June 2001 – progress towards the objectives set out in Sydney Water's Environment Plan 2000–2005)

Sydney Water (2001). *Environmental Indicators Compliance Report 2001*. Sydney Water Corporation, Sydney.

(Contains raw data and results gathered from Sydney Water's Environmental Indicators Monitoring Program – progress towards Sydney Water's Special Objectives according to the means set out in the *Sydney Water Act 1994* and the *Protection of the Environment Administration Act 1991*)

Sydney Water (2002). *Towards Sustainability Report*. Sydney Water Corporation, Sydney.

(Information about Sydney Water's performance against a suite of ESD and stormwater management indicators for period 1 July 2001 to 30 June 2002 – progress towards the objectives set out in Sydney Water's Environment Plan 2000–2005)

Sydney Water (2002). *WaterPlan 21* (revised 2002). Sydney Water Corporation, Sydney.

(Long–term strategic plan for providing water, wastewater and stormwater services to four million people in Sydney, Illawarra and Blue Mountains region)

Van Roo, S. and Collie, T. (1993). *Port Jackson Faecal Coliform Monitoring.* AWT Science and Environment Division, Dec. 1993. Prepared for Clean Waterways Program, Pollution Abatement Branch, Sydney Water Board, Sydney.

(Background, assessment and analysis of trends of bacterial monitoring of Sydney Harbour)

Van Roo, S., Garforth, S., Kirby, A. and Collie, T. (1995). *Port Jackson Faecal Coliform Monitoring Program – December 1992 – March 1994*, Interpretive Report No. 94/103. Sydney Water Corporation, Sydney.

(Analysis of trends in faecal coliforms for Port Jackson – development of sampling strategies for faecal coliforms specifically for Port Jackson – correlations with rainfall and other physico-chemical parameters – pilot faecal coliforms recovery study)

Water EcoScience Pty Ltd: Urban Research Association of Australia (1999). *Alternative Microbiological Indicators of Water Quality.* Urban Water Research Association Australia, Melbourne.

(Methods to concentrate viruses and protozoa from water were evaluated to determine the optimum methods in terms of virus recovery, ease of use, labour and material costs)

Waterways Authority (2000). *Sewerage Pollution from Vessels Discussion Paper – Findings and Proposed Actions*. Waterways Authority, Sydney.

(Outlines current situation, legislation – boat populations – infrastructure – other jurisdictions – key findings – public health – environment – pump-out facilities – monitoring, compliance and education – proposed actions)

Wong, T. H. F., Breen, P. F., Somes, D. and Nicholas, L. G. (1999). *Managing Urban Stormwater using Constructed Wetlands*. Cooperative Research Centre for Catchment Hydrology and Department of Civil Engineering, Monash University, Victoria.

(Overview of design and management issues related to the use of constructed wetlands in managing urban stormwater)

2. Internet sites

Australian Water Association - www.awa.asn.au

(Provides broad range information on water resource management for industry and conservation)

Australian Surfrider Foundation - www.surfrider.org.au

(Aimed at surfers. Provides information on pressures and issues affecting the coastal environment.)

Beachwatch - www.environment.nsw.gov.au/beach

(Summary of Beachwatch and Harbourwatch programs, state of the beaches, pollution causes, health information and links to other relevant sites.)

Department of Environment, Climate Change and Water NSW - www.environment.nsw.gov.au

(Information regarding environmental legislation, Department of Environment, Climate Change and Water programs, and other environmental information – Links to other sites relating to the environment. This department was previously known as the Department of Environment and Conservation (DEC) and then the Department of Environment and Climate Change (DECC).)

DECCW Stormwater Homepage - www.environment.nsw.gov.au/stormwater

(Describes the NSW Government's urban stormwater program and stormwater treatment devices as well as Stormwater Trust applications and conditions of funding.)

Department of Water and Energy - www.dwe.nsw.gov.au

(On Friday 27 April 2007 the Department of Water and Energy (DWE) was created. It incorporates most of the functions of the former Department of Energy, Utilities and Sustainability (DEUS) and the water-related functions of the former Department of Natural Resources, as well as the Metropolitan Water Directorate from the former NSW Cabinet Office. Some of the functions of the former DEUS, such as the Energy and Water Savings Funds and Action Plans, have been transferred to the new Department of Environment, Climate Change and Water.)

Department of Environment and Water Resources - www.environment.gov.au

(The Australian Federal Government Department of the Environment and Water Resources (formerly the Department of the Environment and Heritage) develops and implements national policy, programs and legislation to protect and conserve Australia's natural environment and cultural heritage.)

Marine and Coastal Community Network - www.mccn.org.au

(Provides information on marine and coastal environmental issues Australia wide. The network promotes information sharing between community groups, government agencies and industry.)

Ministry for the Environment (NZ) - www.mfe.govt.nz/issues/water/water-quality.html

(Provides information on water quality management issues from a New Zealand perspective, with a link to the NZ *Microbiological Water Quality Guidelines for Marine & Freshwater Recreational Areas*.)

National Health and Medical Research Council - www.nhmrc.gov.au

(Health information in relation to recreational water use)

Natural Resources Commission - www.nrc.nsw.gov.au

(Provides information on standards and targets set by the commission for the state-wide management of natural resources, including biodiversity, land, water and communities)

NSW Maritime Authority - www.maritime.nsw.gov.au

(Contains information regarding NSW coastal conditions, the Annual Report, Corporate Plan and a discussion paper on sewage from vessels. Describes pollutant sources for waterways.)

NSW Department of Health - www.health.nsw.gov.au

(This site contains information on public health issues.)

NSW Department of Primary Industries (Fisheries) - www.dpi.nsw.gov.au/fisheries

(This site contains information on the conservation and management of NSW living aquatic resources. In July 2009, the Department of Primary Industries became part of Industry & Investment NSW)

Hunter Water Corporation - www.hunterwater.com.au

(Water supply, water quality and sewage treatment/disposal information for the Hunter region)

NSW Environment Service Sector website - www.livingthing.net.au

(This site provides a comprehensive listing of environment online information services.)

National Water Quality Management Strategy - www.deh.gov.au/water/quality/nwqms/

(This site contains information on water quality monitoring processes, policies and guidelines.)

Realsurf - www.realsurf.com.au

(Daily surf reports and information for surfers)

Surf Lifesaving Australia - www.slsa.asn.au

(General beach information, surf safety and patrol dates)

Streamwatch - www.streamwatch.org.au

(State community water quality and action network)

Sydney Water Corporation - www.sydneywater.com.au

(Water quality and sewage treatment/disposal information for the Sydney – Illawarra region. Introduces 'WaterPlan 21', the corporation's vision for sustainable wastewater management.)

Waterwatch Australia - www.waterwatch.org.au

(This site contains national information on water quality monitoring and education programs that develop strategies to address water problems.)

World Health Organization - http://www.who.int/water_sanitation_health/bathing/en/

(Latest WHO guidelines for Safe Recreational Water Environments)

3. Other sources

A list of DECCW publications is available from DECCW's Environment Line on 131 555. Alternatively, the list can be viewed on DECCW's website at www.environment.nsw.gov.au/publications/index.htm. The listed publications are available from several State and Federal government agencies.

Other sources of information on water quality are State of the Environment reports published by local councils and the NSW State of the Environment Report, which is published every three years by DECCW.

DECCW's library holds books, reports and journals relating to most aspects of water quality monitoring and assessment. The library is located on level 15 in DECCW's Head Office (59–61 Goulburn Street, Sydney) and is open to academics, researchers, postgraduate students, environment groups, council officers and other government employees. An appointment to use the library resources is essential and can be made by calling (02) 9995 5000.

In the Sydney region there are other specialist libraries and information centres that hold information on water quality and related issues. These centres include the Coastal Environment Centre, the Water Reference Library and the Manly Environment Centre. Government authorities and agencies engaged in water resources management, such as the Department of Water and Energy, Department of Planning and Sydney Water, also have libraries open for research purposes.

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Glossary

Amplification: The modification of a sewage treatment plant, to increase capacity so that more sewage can be treated per day.

ANZECC: Australian and New Zealand Environment and Conservation Council. Although no longer in existence, this organisation provided a forum for coordinated environmental management in Australia, New Zealand and Papua New Guinea until 2001.

Bacteria: A diverse group of micro-organisms inhabiting nearly all terrestrial and aquatic habitats. Specific types are found living in conjunction with humans and animals – see *enterococci* and *faecal coliforms* (below).

Catchment: The area that drains surface runoff from precipitation into a stream, river and/or tributaries or urban stormwater drainage system.

Continuous deflective separator (CDS): A type of *stormwater quality improvement device* (see below) designed to capture coarse sediment, trash and debris. CDSs are installed underground and separate stormwater from gross pollutants in a circular separation and containment chamber.

Colony forming unit (cfu): A micro-organism propagule (spore or cell) from which a colony has grown. For purposes of analysis, one CFU represents one viable organism. Typically, bacteriological data are reported as the number of these colonies in 100 millilitres of sample water.

Contaminant: Any substance, chemical, or micro-organism that makes a medium (water) less suitable for a specific purpose.

Compliance, bacteriological: The finding that waters for *primary recreation* (see below) contain a lower density of CFUs (see above) than the maximum set down in guidelines. See *guidelines, compliance*, below.

Compliance, seasonal percentage: Within a designated season (i.e. summer or winter) the percentage of rolling 30-day periods (see below) that comply with the bacteriological guidelines (see below). There are 31 summer and 22 winter rolling 30-day periods, so compliance is calculated for each of these periods and converted to a percentage of the season's total number.

Criteria: Standards that are based on the analysis of scientific data and provide guidelines for the appropriate use of water.

Density, e.g. enterococci or faecal coliform: The amount of these indicator bacteria present in a standard volume of a water body. The higher the bacterial density the higher the number of cfus (see above) that will be found per 100 millilitres, and hence the greater the contamination.

Enterococci: Bacteria of the genus *Enterococcus* that may be used to determine the extent of faecal contamination of recreational waters. The *Enterococcus* group is a sub-group of faecal streptococci. It is differentiated from other faecal streptococci by growth at higher temperatures and salt concentrations in the laboratory, and the ability to survive in marine waters under conditions that are unfavourable for most other faecal micro-organisms.

Estuary: A partly enclosed coastal water body open to the ocean, characterised by tidal effects and the mixing of fresh water and sea water.

Faecal coliforms: Mesophilic bacteria that inhabit the intestines of humans and other warm-blooded animals. Faecal coliforms are abundant in bird and mammal faeces and are used as indicators of sewage pollution in marine and fresh waters. These organisms have a relatively short life-span in marine waters, indicating the presence of relatively recent sewage contamination.

Fresh water: Water with a low concentration of dissolved salts (salinity less than 0.5 parts per thousand).

Geometric mean: A method of estimating an overall mean (or average) from a group of subsamples; this method is resistant to the presence of a small number of very high values. The number of CFUs (see above) in swimming waters can range from nil to millions over a reporting period, so it is difficult to determine a *representative* value. The geometric mean is calculated from the average of log-transformed data, which discounts the influence of very large values.

Gross pollutant trap (GPT): A type of *stormwater quality improvement device* (see below) that is a permanent installation in an urban watercourse and is designed to intercept and retain coarse sediment, litter and debris. Traps usually consist of a combination of floating booms, trash racks and ponds, with provision for access to maintain and clean the trap.

Guidelines, compliance: Rules that are intended to be independent benchmarks to assess the cleanliness of a location on the basis of counts of bacteriological density over a period of time. The guidelines set out the minimum number of samples (normally five) that must be taken over a minimum period (at least 30 days) and the density of bacteria that is acceptable in those samples (see Chapter 1 for an overview).

Indicator micro-organisms: Bacteria (generally faecal coliforms and/or enterococci) that indicate the relative degree of faecal contamination in waterways. Indicator organisms are generally used in the monitoring of recreational water quality, because searching for specific micro-organisms that cause disease, such as viruses, is both difficult and costly. (See Appendix 1.)

Influent: Wastewater entering a sewage treatment plant.

Intertidal protected area: An area between the high tide mark and ten metres seaward of the low water mark where the collection of invertebrate animals is prohibited.

Median: The middle point in a set of data. Defined as the number relative to which half of the scores are greater and half of the scores are lower. For example, from the set of numbers: 1, 5, 6, 8, 10, the median is 6.

NHMRC: The National Health and Medical Research Council. An independent Federal organisation that oversees public health and medical issues on a national scale. On the basis of current research, this organisation produces exposure guidelines intended to protect public health.

Percentile, 80th: Within a sample set of five samples that are from a normally distributed population, the value below which four of the five values (i.e. 80%) used to calculate the median (see below) fall.

Pathogens: Micro-organisms, such as bacteria, viruses and fungi, that can cause diseases in plants and animals. Pathogens are abundant in sewage and may be present in industrial and other types of discharges.

Pollutants: Chemicals, biological substances, particles, or thermal changes that are discharged into bodies of water and are potentially detrimental to the environment.

Pit basket: A type of *stormwater quality improvement device* (see below), in the form of a wire basket that sits inside a stormwater drainage pit to collect rubbish.

Plume: A stream of water that enters a water body and contains an elevated concentration of suspended materials and/or pollutants (see above).

Primary contact recreation: Recreational use of waters that involves bodily immersion or submersion, facilitating direct contact with water; includes activities such as swimming, diving, waterskiing and surfing.

Primary sewage treatment: Physical treatment of sewage, designed to remove solids via settling (as sludge) and floatable solids such as oil, fats and grease by first screening and then ponding the effluent.

Quality assurance/quality control (QA/QC): Procedures and checks used to ensure accurate and reliable results are obtained from environmental sampling and analysis.

Receiving water: The water body into which effluent flows. For example, STPs (see below) or stormwater systems release water into natural waterways such as rivers, estuaries and oceans.

Rolling medians: Medians (middle scores in a subset – see above) in a run of time-series data that is compiled separately from a moving subset of intervals in the series. For example, there is a dataset of seven items labelled A, B, C, D, E, F, G. In this case the median of items A, B, C, D, and E, the median of items B, C, D, E, and F, and the median of items C, D, E, F, and G form a set of three rolling medians.

Rolling 30-day periods: Within a season (i.e. summer or winter), a period that includes five consecutive bacteriological counts and spans 30 days. For example, five samples from the month of January would form one rolling 30-day period. The next rolling 30-day period would include the last four samples from January and the first sample of February. In this way 31 summer and 22 winter rolling 30-day periods are created (the summer season is longer).

Rolling 80th percentiles: As for rolling medians (above), except that the value being calculated is the second-highest score for each subset of five. See also *Percentile, 80th* above.

Riverkeeper: An officer engaged by the Georges River Combined Councils Committee and focused on promoting the health of the Georges River, with a major focus on community involvement.

Secondary contact recreation: Recreational use of waters that involves some direct contact with water, but where the probability of inadvertent swallowing of water is low; includes activities such as paddling, wading, boating and fishing.

Secondary sewage treatment: Biological and/or chemical treatment of sewage, designed to remove the majority of organic matter and solids through several possible processes by using anaerobic bacteria, chemicals and settling ponds.

Sewage treatment plant (STP): The site of convergence and treatment for household, commercial and industrial sewage via the sewerage system. Sewage is treated at an STP to either primary, secondary, or tertiary level before being discharged as effluent to receiving waters.

SewerFix program: An ongoing program conducted by Sydney Water Corporation to reduce the frequency and severity of sewer overflows by identifying and rectifying damage and the ingress of stormwater to sewers.

SSROC: Southern Sydney Regional Organisation of Councils.

Stencilling: The painting of simple educational messages on street gutters adjacent to stormwater drains to heighten public awareness of stormwater pollution. Messages include: 'Drains to beach' or 'Drains to creek'.

Stormwater: Any surface water that arises from precipitation and enters watercourses (above or below ground) can be termed stormwater. In upper catchments stormwater of high quality is captured for drinking water. In urban areas stormwater is likely to contain contaminants and to be of lower quality.

Stormwater quality improvement devices (SQIDs): Structures intended to improve the quality of stormwater effluent reaching receiving waters by removing solid material carried by the waterflow.

Stormwater Trust Grants: Targeted State Government funds made available to Councils to specifically encourage the implementation of education, construction, and planning to improve the quality of urban stormwater.

Tertiary sewage treatment: Physical and chemical treatment of sewage, designed to improve secondary treated sewage by removing fine suspended solids, nutrients and pathogens (by disinfection). Treatment to a tertiary level typically involves a combination of filtration methods, chemical additives and ponding.

Tidal flushing: The process by which water in an estuary is replaced with oceanic water owing to the flow of water caused by the tides.

Trash rack: A type of *stormwater quality improvement device* (see above) in the form of a metal grate installed in a stormwater system and designed to screen litter and other debris from stormwater. An integral component of gross pollutant traps.

Wastewater treatment plant (WWTP): See *sewage treatment plant*.

Water quality: The characteristics of water in regard to its physical, chemical and biological properties.

WSUD: Water-sensitive urban design. The incorporation of rainwater tanks, porous pavements, infiltration trenches, and landscaping in urban design to mitigate the runoff of polluted stormwater to waterways.