Paper from: *Brownfield Sites*, CA Brebbia, D Almorza & H Klapperich (Editors).
ISBN 1-85312-918-6

Monitoring the effectiveness of remediation: A case study from Homebush Bay, Sydney, Australia

E. Laginestra
Sydney Olympic Park Authority, Australia

Abstract

Sydney Olympic Park, the main venue of the 2000 Summer Olympic Games, contains world class sporting facilities, residential areas, a commercial centre and extensive parklands. It was previously 760 hectares of degraded land that required extensive restoration and remediation.
Remediation of the site commenced in 1992, well in advance of the US Brownfields initiative, and provides useful information for other contaminated land managers in the selection of clean-up options, environmental monitoring and assessment, and adaptive management success.
Treatment of the estimated 9,000,000 cubic metres of waste was carried out in-situ, as a preferable alternative to off-site transfer. This has necessitated ongoing monitoring to ensure the remediation options chosen remain effective in protecting environmental health and safety. The monitoring program has provided baseline data and management tools for long term assessment.
Compilation of historic site data provided the necessary context for new monitoring programs, initiated to give a more complete environmental picture, which included leachate toxicity monitoring, sediment quality triad studies, sediment core analysis, bioaccumulation assessment and bioremediation studies. Promising initial results indicate attenuation of leachate toxicity, undetectable impacts on the surrounding environment due to site influences and identification of optimum conditions for bioremediation. The monitoring has also suggested streamlining some monitoring and highlighted areas of potential concern, assisting in the prioritisation of resource allocation.

Paper from: *Brownfield Sites*, CA Brebbia, D Almorza & H Klapperich (Editors).
ISBN 1-85312-918-6

Introduction

Following a successful bid to host the 2000 Summer Olympic Games, work commenced in earnest to rehabilitate 760 hectares of degraded and contaminated land at Homebush Bay, located in Sydney's geographic centre on the southern shore of the Sydney Harbour Estuary. The estimated nine million cubic metres of waste had to be treated within seven years to provide a suitable site for a showcase of "green" development and Olympic goodwill. The remediation was arguably the largest clean up undertaken in Australia (NSW EPA [1]).

The remediation process was similar to other Brownfield projects in that monitoring, hazard and risk assessments were undertaken, clean-up options were assessed and remediation carried out. However, the clean up at the the Sydney Olympic site was distinctive in two ways:

1. due to long term commitments made by the NSW State Government to the public regarding the use of the land after the Olympic Games, programs were set in place to assess the long term effectiveness of the remediation options chosen for the site, and
2. contaminated material was not removed, but consolidated within the site for future management. This provided a benefit by not re-locating a pollution problem but dealing with it in-situ.

The NSW Government assigned AUD$12 million for an "Enhanced Remediation Strategy", a long term monitoring and management program, which included:

- The establishment of an environmental reference group, including representatives from the community, scientific experts and environment groups,
- Biological monitoring, which would go beyond legislative requirements,
- A more coordinated "catchment" approach to remediation, compiling relevant data and corporate memory in a GIS-based decision support system,
- The introduction of an environmental sciences education program that would involve primary, secondary and tertiary students in the monitoring programs, and
- Documenting the experiences and technologies employed for the benefit of industry involved in remediation elsewhere (Knight [2]).

This enhanced remediation strategy outline was the basis of the framework put in place by the Olympic Coordination Authority (OCA) to enable management of the site after the Olympic Games. Remediation works were well underway at this time, and although the community had been involved in the selection of remediation options during the early stages of work, there remained an element of mistrust about the ability of the government to manage the site after the Games were over and the excitement, and possibly the funding, died down. The community needed re-assurance that resources would be available to ensure ecological sustainability and long-term site safety.

A long-term remediation monitoring program would not only provide information regarding the ongoing effectiveness of the safety systems in place but provide ongoing lessons from the field. Lessons learned from case studies

Paper from: *Brownfield Sites*, CA Brebbia, D Almorza & H Klapperich (Editors).
ISBN 1-85312-918-6

have helped shape government policies (Pepper [3]) so continued learning from experience, a form of adaptive management if well documented and assessed, should allow improvement in the state of the environment and reduce the repetition of mistakes. This long term approach is consistent with the United Nations Environment Program in sustainably managing world resources (UNDP [4]). The fundamentals of an ecosystem approach include the integration of multiple issues, systemic management and a longer term view, working across a variety of spatial and temporal scales.

Background

The Sydney Olympic Park site was formerly degraded land affected by past site practices including agricultural, industrial and waste dumping activities during the 19th and 20th centuries. The type of contamination included petroleum waste, industrial rubble, asbestos and flyash, unexploded ordnance, putrescible municipal waste, abattoir discharge and dumped or spilled chemical wastes.

By the end of the 1980s most of the 760 hectare site (now largely Government owned) was unsuitable for most urban uses and was a contamination source for Sydney's waterways. At this time the site was identified as a possible location for major sporting facilities and a series of Masterplans were produced, incorporating the potential for Olympic development which would help resource the cleanup and development costs. The contamination of the land was recognised as a possible constraint to development so a detailed investigation program was instigated in 1990 to estimate clean up costs. The initial cost estimates cast a cloud over the economic viability and proposal to bid for an Olympic games, nor did it include any ecological or landscaping costs (Pym [5]). A rethink of the proposed remediation works was required.

The consideration of the end-use was an important aspect of the clean-up method. Most Brownfields sites clean up degraded industrial land for use as industrial land. At the Sydney site, the final end-uses desired included residential, commercial and recreational uses.

Remediation activities

Ultimately, the strategy adopted for remediation of Sydney Olympic Park was to manage the risk by blocking exposure pathways. To determine the best options for clean up at the site a good understanding of the site's conditions, specific characteristics, contamination type and the proposed end-uses was required.

There are a number of frameworks outlining what should be included in an ideal clean-up project (US EPA [6], Smartgrowth Network [7], ANZECC & NH&MRC [8], NEPC [9]). All the frameworks agree on determining the hazard based on site specific information, using a coordinated approach and community involvement. Feedback is required from long-term projects to add the requirements needed for frameworks for long-term monitoring of remediation projects where contamination remains in place.

Paper from: *Brownfield Sites*, CA Brebbia, D Almorza & H Klapperich (Editors).
ISBN 1-85312-918-6

At Homebush Bay, targeted soil, surface water and groundwater studies were initiated in 1991 and migration pathways for volatiles and liquids determined. While the final end-uses affect the selection of clean-up methods in an area, the types of treatment options available for the site were constrained by the variety and haphazard mixtures of the wastes. A number of treatment options were proposed and the community was involved in discussion and selection of the options and kept informed of progress (Pym [5]).

The initial remediation plan involved stripping the topsoil from hectares of contaminated land and containing it in a huge pit created by the former brickworks, with the remaining landfill areas contained by the construction of barrier walls, perimeter drains, capping and installation of gas control systems. This was abandoned following the discovery of a threatened frog species in the brickpit. The final model settled upon retained the strategy of "move and contain", but with significant modifications. As the site was largely owned by the Government, it was treated as one area and did not require approvals to move contamination within the area, minimising approval time and transport problems.

The options selected for waste treatment at the site were consolidation, bioremediation and thermal desorption. Mixed and unknown wastes from waterways plus contaminated soils and sediments were consolidated into four main containment mounds, with capping and perimeter drainage installed for these and five other waste areas. Where the wastes were either known or could be separated they were treated, either by bioremediation using indigenous microorganisms to breakdown petroleum contamination, or by thermal desorption plus catalytic conversion for scheduled chemicals. Two containment methods were used:

1. a totally enclosed "dry" landfill contained by a double layer HDPE membrane and covered with a carpark; and
2. an isolated, but not enclosed, "wet" landfill, where drains were installed on the downstream side to collect contaminated groundwater and leachate, so blocking the migration pathway to surfaces or waterbodies.

The consolidated mounds were shaped and landscaped with a mounded shape and semi-permeable capping allowing air-flow within the mound to enhance natural attenuation of toxicity over time. The surface capping and landscaping provided a zone where volatile gases appeared to be broken down by bacteria and taken up by the vegetation. Stormwater was redirected around the mounds and away from the cap to reduce inflow. Monitoring of leachate toxicity, system integrity, mound and landscaping cover was required to ensure the effectiveness of this remediation strategy.

The topography and the groundwater flow at the site have largely been altered due to reclamation, excavation and finally, the remediation. Shallow groundwater that previously flowed towards the waterways has been caught in leachate drains or re-directed past geotextile or clay barriers. The landform now consists of several hills and viewing mounds, re-aligned creeks and new water features. Approximately 460 hectares of the site are parklands, containing remnant forest and wetlands, rehabilitated grasslands and wetlands, and recreational areas. The majority of the containment mounds are located in the

Paper from: *Brownfield Sites*, CA Brebbia, D Almorza & H Klapperich (Editors).
ISBN 1-85312-918-6

parklands. The parklands are significant in terms of their size, the presence of endangered, locally rare and internationally protected migratory species and the range and connectivity of different habitat types.

Post Remediation Monitoring

Funding for the Enhanced Remediation Strategy monitoring lasted 18 months. To collect the site information and prepare the groundwork for future monitoring within the set time frame, a staged approach was taken (Laginestra [10]). Important steps included defining the program scope, identifying contaminant sources, establishing an independent review team, determining the site functions, setting up the data collection system to compile historic monitoring data and then implementing the new monitoring programs.

After discussion with managers and scientific specialists, a list of questions likely to be asked in the future were developed:

- Is the site safe?
- Have the remediation actions taken to improve the site been effective, and do they remain effective?
- Are the ecosystems improving in health and providing suitable habitat for desired species/communities?
- If there are adverse impacts observed, are they caused by activities on-site?
- Are the adverse impacts observed changing over time, and do the changes enhance the environment?
- What are the issues of concern at various site locations and is current monitoring adequate to address these issues and to detect change?

To be able to answer these questions and ensure protection of the environment, the new monitoring programs had to determine:

- the current status of the site and surrounding ecosystems,
- the possible hazards posed by the site,
- the site risks and management controls in place to minimise these risks,
- the success of the innovative remedial technologies,
- the suitability and success of the maintenance monitoring regime,
- the change in toxicity of leachate over time, and
- an estimate of when the contamination may reduce to an acceptable level.

Data compilation

To assess the site status as a whole and identify data gaps, all monitoring data from different Authority divisions were collected, sorted by media (soil, groundwater, surface water, sediment and air) and spatially identified before being entered into a database. Geographic location and other metadata are essential for managing data. They allow managers to layer data in a GIS system (to identify patterns or conflicts), assess the quality of the data and view trends by area or media.

Paper from: *Brownfield Sites*, CA Brebbia, D Almorza & H Klapperich (Editors).
ISBN 1-85312-918-6

It is important to understand the site history when preparing future management plans. Variations in site condition can be explored and often explained by knowing past land-uses by location, so unnecessary or environmentally harmful management actions can be avoided. Consequently, the management of data and capture of corporate memory are essential elements in effective long term monitoring programs (Hudson *et al.* [11]). Using GIS techniques, number of maps were prepared for use as management tools. These included:

- types of vegetation/habitat,
- vegetation changes over time (from 1930 to 2000),
- monitoring site locations, historical landuse/ownership,
- groundwater flow direction,
- surface water catchments,
- land use constraints (leachate mounds and drainage systems, protected/ endangered species, public safety risks, horticultural chemical usage), and
- catchment pollution sources.

Leachate monitoring

The new monitoring programs implemented to help assess the environmental health status included toxicity testing alongside the chemical analysis and biological monitoring. Toxicity testing was used to assess the biological impact of chemicals and mixtures in the leachate and whether any impacts were observed in the surrounding environment. Toxicity testing is not mandatory in Australia, but as contaminated site assessment and water quality guidelines use a risk based approach, they provide invaluable risk management information.

The first stage of leachate monitoring tested seven analysis techniques to provide information on the most sensitive tests for use in long-term monitoring and to give an indication of the relative toxicity of different leachates. Estimates of toxicity due to ammonia were also calculated from toxic unit charts for each method (CSIRO [12]). Further toxicity testing with the four most sensitive methods identified major compounds of concern using Toxicity Identification and Evaluation (TIE) techniques. This is essential information for the assessment of leachate treatment alternatives by management. Chemical analyte concentrations had generally decreased from the pilot study (SKM [13]), however, these results need to be assessed with caution as different laboratories were involved in the second round of tests. The third round of testing will commence in April 2002.

Site environmental status monitoring

Toxicity tests were also used in a weight-of-evidence approach for assessing possible adverse impact on sediment in the surrounding waterways and on petroleum contaminated soils undergoing bioremediation.

A sediment quality triad (SQT) project (the use of toxicity tests, chemical analyses and benthic monitoring as described in Chapman [14]) was undertaken

Paper from: *Brownfield Sites*, CA Brebbia, D Almorza & H Klapperich (Editors).
ISBN 1-85312-918-6

to assess impact in the surrounding waterways. Concurrently, edible fish species were caught and analysed for chemical concentrations in muscle and liver tissues to assess bioaccumulation. The combined results indicated that the impact observed in the samples taken from the site and surrounding areas did not appear to be statistically different from other sites in Sydney Harbour (EVS [15], The Ecology Lab [16]). Again, results require careful evaluation due to problems with the experimental design (EVS [15]). The SQT project had not been set up solely for OCA, but was part of another Sydney Harbour project. Valuable lessons regarding the preparation of monitoring programs were learnt from this project, and led to the refinement of monitoring program quality checklists (Statzenko and Laginestra [17]). Sediment cores were also taken from selected sampling sites to provide information on the history of contamination and provide background chemical levels. As not all the samples provided background chemical levels, a bathymetric survey of the main waterway was conducted to provide information for future sampling sites. Despite the drawbacks, the cores did provide supporting information on the health of the site's waterways and changes in sediment chemical levels over time.

Extensive monitoring has been undertaken at the petroleum contaminated site of Wilson Park. As bioremediation has been found to be successful in other petroleum contaminated sites (Maier *et al.* [18]), it was chosen as the treatment method at Wilson Park, which had not been contaminated with other pollutants. Trials were undertaken to establish if the indigenous population of microorganisms that had developed at the site were breaking down the petroleum wastes. The trials indicated that the indigenous microorganisms were involved in attenuation and that benzene was being degraded in the treatment ponds within five days. The microbial community involved in the degradation has been characterised using DNA comparisons (Hanitro [19]). This project also determined the optimum site conditions required for microbial degradation to occur. Toxicity testing and chemical analyses of the soil, elutriate washes and the treatment pond water and sediment were undertaken to provide baseline information on contamination levels. From these results, a chemical concentration trigger level has been determined for toxicity re-analysis.

Integration with other programs

As part of the Enhanced Remediation Strategy, three other programs were initiated alongside the Biological Monitoring Program. These were the Databank Program for managing the data and harnessing corporate memory, the Education Program to provide learning programs and tools for schools and the community, and the Advocacy Program, which arranged seminars and managed the environmental reference group. The programs interrelated closely, as the education program required information from the monitoring program, with most data being managed through the databank. Information gained from the Enhanced Remediation Strategy has been prepared for release through a number of methods including educational CDs, seminars, school curriculum courses (developed with NSW Department of Education and Training) and adult

Paper from: *Brownfield Sites*, CA Brebbia, D Almorza & H Klapperich (Editors).
ISBN 1-85312-918-6

education short courses. Other partnerships are being sought to develop the research program, utilise the databank and extend the education program.

The importance of input from the community group to the success of the programs cannot be overemphasised. Group members were paid to attend and were provided with meeting protocols. The program managers reported on program status at each meeting and results were discussed. The serious tensions encountered at the beginning eventually resolved to trust through sharing of information and strong management support. For a potentially contentious site very little controversy arose.

Management actions based on monitoring and assessment

The Sydney Olympic Park Authority has already used data obtained from the post remediation monitoring program. The site-specific information and land-use constraints provided valuable information for preparing the Millennium Parklands Plan of Management (as required under the SOPA Bill [20]). The Plan of Management must consider current and long-term usage at each site location. Tender contracts for landscape managers include the monitoring regime and reporting requirements based on monitoring information. It is hoped that as contractor monitoring results are delivered to managers, issues or emerging trends by site can be highlighted and fed back into the research program. Information from the bioremediation work regarding optimal site conditions has been incorporated into site procedures.

A post remediation reference manual has been prepared for the site as a base line document for site managers. It compiles, by location, information on history, ecology, attributes and uses, issues, recent monitoring, monitoring gaps and issues for consideration. To prepare this document, remediation monitoring was assessed alongside the compliance monitoring. Monitoring required by legislation includes water quality monitoring, leachate chemical assessment, maintenance programs (including system integrity assessment), and endangered flora and fauna monitoring (birds, frogs and wetlands). Recommendations and issues for consideration arising out of the combined monitoring assessment form the second stage of preparing a long-term management plan, which is to determine risk priorities and further streamline the programs.

Future management issues

Sustainable management decisions at a remediated site cannot be purely political expediencies if we are to manage in a truly ecologically sustainable way. The development of future research monitoring has been based on our assessment of the site monitoring results. Areas proposed for next year's research include testing for endocrine disruption, leachate re-use options, efficacy risk assessment (determining residual risk or identifying new risks), hydrological studies (including sediment monitoring and pollution load modeling), monitoring after events and studying the effectiveness of landscape monitoring regimes.

Paper from: *Brownfield Sites*, CA Brebbia, D Almorza & H Klapperich (Editors).
ISBN 1-85312-918-6

Frameworks under development to enhance site management capabilities include decision support systems, adaptive management and streamlining feedback mechanisms, and identification and management of confounding effects.

Conclusions

A number of conceptual problems arise where contamination is left in place with the expectation that future land use and natural degradation will protect the environment (Simon [21]). Short-term monitoring frameworks can usually be provided, but where the site could pose a risk for decades, and there is potential for site use or ownership changes, we need to ensure continued protection of the environment. Contaminated land managers need to learn from other site examples about the issues and advantages of different methods, and the effectiveness of controls over the long-term.

The State Government made a commitment to manage the restored Sydney Olympic Park site for the long-term. The remediation strategy chosen at the site has so far appeared to be successful, judged against other Brownfields case studies and from our monitoring results. Although the monitoring data, amassed since 1992, was not collected for assessment of long-term effectiveness of the remediation options, it is now being compiled and managed to provide baseline data for future questions regarding changes over time. The assessment of historic data with the addition of the weight-of-evidence monitoring by site function is starting to highlight successes and define areas to concentrate on. Natural attenuation appears to be underway in the leachate mounds, but modifications have had to be made to prevent erosion. Bioremediation appears to be successful, but requires active maintenance in the treatment ponds.

Elements highlighted as contributing to a successful clean-up (Pepper [3]) also present at the Sydney Olympic Park site include:

- the presence of a proactive authority who coordinated the different levels of government and consolidated the project management teams under one roof,
- project leadership driven by key individuals with backing from senior management,
- Strong community participation,
- Use of innovative remedial technologies,
- Financing advantages, including prime location and piggy-backing on a major public works project

By not transferring the contamination problem and receiving funding from the government to monitor the long-term effectiveness, without fear of changes to landuse or transfer of ownership, valuable information can be obtained for assessment by Brownfield site managers.

References

[1] NSW Environment Protection Authority, *State of the Environment Report 1997*, www.epa.nsw.gov.au/soe2000/cl, 2000

Paper from: *Brownfield Sites*, CA Brebbia, D Almorza & H Klapperich (Editors).
ISBN 1-85312-918-6

[2] Knight, The Hon. M., Minister for the Olympics Long Term Monitoring of Remediation Program, *News Release*, March 24, 1998
[3] Pepper, E.M. *Lessons from the Field, Unlocking Economic Potential with an environmental key*, Northeast Midwest Institute, January 1997
[4] United Nations Development Programme, United Nations Environment Programme, World Bank and World Resources Institute (UNDP), World Resources 2000-2001 *People and Ecosystems, The fraying web of life*, World Resources Institute, Washington D.C. April 2000
[5] Pym, J., From Liability to asset: Homebush Bay Remediation 1989 – 2000, *Report for the Olympic Coordination Authority* June 2001
[6] US EPA A Sustainable Brownfield Model Framework, *EPA500-R-99-001*, January 1999
[7] Smartgrowth Network, An Integrated approach for Brownfield redevelopment, A priority setting tool, smartgrowth.org/library/brownfields_tool/brownfields _priority_set.html, September, 1996
[8] Australian and New Zealand Environment and Conservation Council and National Health and Medical Research Council (ANZECC), Australian and New Zealand Guidelines for the assessment and management of contaminated sites, January 1992
[9] National Environment Protection Committee (NEPC), National Environment Protection (Assessment of Site Contamination) Measure 1999, www.nepc.gov.au, 1999
[10] Laginestra, E. Developing a long term monitoring plan for the Homebush Bay Olympic Site, *Australian Journal of Ecotoxicology*, in press 2002
[11] Hudson, J., Hughes, K. and Daffern, P. Harnessing Corporate Memory for the environmentally responsible management of remediated lands, *Proceedings from the 28th annual conference AURISA*, 20-24 November 2000, www.sopa.nsw.gov.au/ecology/science
[12] CSIRO, Centre for Advanced Analytical Chemistry, Toxicity Assessment of Leachates from Homebush Bay Landfills, *Report ET/IR341R*, Prepared for the Olympic Coordination Authority, November 2000
[13] Sinclair Knight Merz, Ongoing Toxicity Monitoring of Leachate, *Final Report for Olympic Coordination Authority*, September 2001
[14] Chapman, P.M. The sediment quality triad approach to determining pollution-induced degradation, *The Science of the Total Environment*, 97/98, 815-825, 1990
[15] EVS Environment Consultants, Sediment Quality Triad Assessment, *Final Report for Sydney Olympic Park Authority*, March 2002
[16] The Ecology Lab, Bioaccumulation of Contaminants in fish, Newington Wetlands, Haslams Creek and reference locations, *Report for the Olympic Coordination Authority*, March 2001
[17] Statzenko, A. and Laginestra, E. Homebush Bay Monitoring Methodology Review, Vol. 2, www.sopa.nsw.gov.au/ecology/science, October 2001
[18] Maier, R.M., Pepper, I.L. and Gerba, C.P. *Environmental Microbiology*, Academic Press, 2000

Paper from: *Brownfield Sites*, CA Brebbia, D Almorza & H Klapperich (Editors).
ISBN 1-85312-918-6

[19] Hanitro Pty Ltd, The demonstration of Bioremediation processes at Wilson Park, Silverwater, *Reports for Olympic Coordination Authority*, October 2000

[20] Sydney Olympic Park Authority Bill, www.parliament.nsw.gov.au 2001

[21] Simon, S.E. Editor's Perspective: The effectiveness of nonpermanent remedies, *Remediation*, Vol 12, #1, 1-4, Winter 2001