BEST PRACTICE ENVIRONMENTAL MANAGEMENT IN MINING

Environmental Monitoring and Performance

Environment Protection Agency

3. ENVIRONMENTAL PERFORMANCE ASSESSMENT

3.1 ENVIRONMENTAL PERFORMANCE AND EVALUATION

Environmental performance needs to be measured against objectives set out in the EMP. The monitoring program will reflect these objectives, describing the information necessary to produce a systematic, comprehensive and informative report on environmental performance. Such a report will then permit clear conclusions about the state of the environment and identify the need, if any, for more intensive studies or appropriate remedial action. An annual cycle of reporting and review is common for external regulatory purposes. Figure 6 shows the processes and relationships in establishing and reviewing EMPs in New South Wales.

Performance assessments are based on monitoring program data and provide the basis of information to the public, technical environmental reports to regulators, and feedback for review of environment management plans.

With the progressive change from regulatory inspections towards self management and independent auditing, there is now considerable emphasis on internal review. Internal environmental performance evaluation is based on the results of monitoring programs, special investigations, remedial activities and research and development. There are issues of 'due diligence', managerial responsibility, and international and Australian standards for quality control, which are influencing the nature and rigour of internal environmental auditing and review. Most larger mining companies employ environmental staff, both at corporate level and on individual mine sites, to manage and monitor environmental issues to ensure quality control and minimise risk and, most importantly, to achieve good environmental performance.

Most regulatory organisations favour the option of self management, whereby the mining company establishes itself, through performance and communication, to be pro-active and open in presenting its performance in environmental management. Self management reduces the resources required by government to supervise mining operations. Where self management is successful, government is able to rely on the following outputs to establish achievement of objectives:

- documented environment management systems;
- company reports, which should be public documents, prepared under conditions of their licence, and research and development reports;
- check monitoring; and
- periodic compliance/performance audit.

The licence reports must include statements that clearly indicate whether or not the company has complied with its licence conditions. Government also requires certification by mine managers or other accountable people, that various standards have been met. The mining company will focus on meeting the requirements of its licences and communicating its environmental performance to government and the community. It should be noted, however, that there are considerable long term benefits to the company and to the mining industry as a whole in achieving an environmental performance which exceeds the license requirements. Figure 5 shows how check monitoring by the regulator is used in conjunction with company monitoring.

External independent surveys or audits can be conducted by appropriate consultants or environmental auditors with less emphasis on detailed check monitoring by government. There is a trend towards the use of accredited environmental auditors who are independent of mining companies, government and consultants.

3.2 ENVIRONMENTAL AUDITING

Environmental auditing, as the name suggests, has strong similarities to financial auditing. It is part of the process of review (Box 6).

Audits are being undertaken to check that the company is complying with its own environmental policies and with legislated environmental requirements, and to check for risk exposure and possible adverse publicity. Although audits can be driven by the need to minimise potential legal liability, they are increasingly seen as one of a number of management techniques that together comprise successful environmental management.

Audits are conducted on the basis of pre-designed site specific audit protocols.

BOX 6 — WHAT IS ENVIRONMENTAL AUDITING?

Management tool. The audit is not an end in itself, but serves to facilitate management control of environmental practices.

'Systematic assessment'. Auditing involves a structured approach following an established protocol.

'Periodic'. Audits are conducted periodically in relation to the overall review process.

'Documentation'. An audit results in a written report.

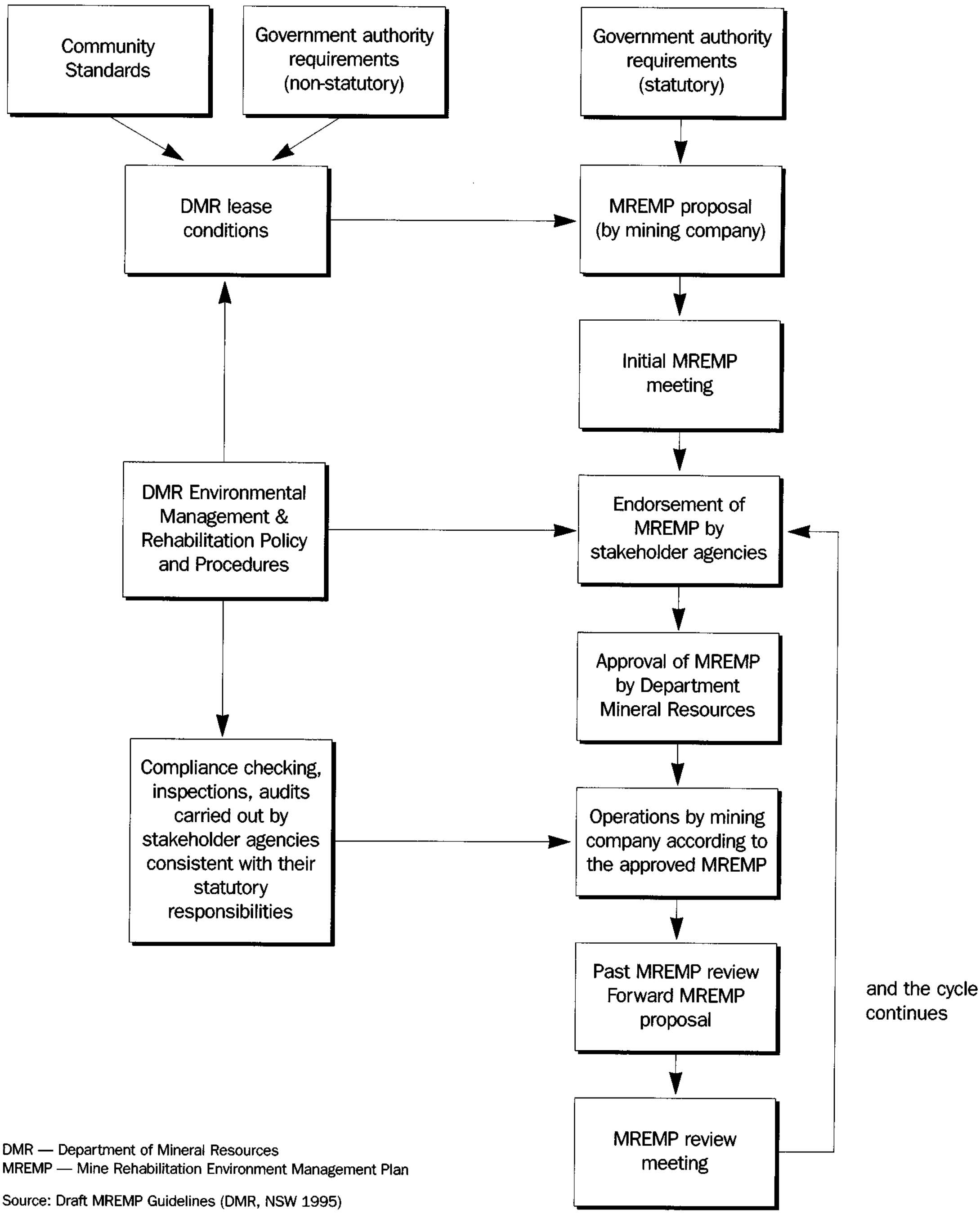
'Environmental risk'. Audits highlight environmental risk faced by a company, and should recommend action to minimise risk.

'Compliance'. Some compliance assessment is part of every audit, although the degree to which strict legal compliance is assessed is determined by the audit objectives.

'Objectivity'. While there is some acceptance of self-auditing for internal review, there is a distinction between such self-assessment and verified independent auditing. *Auditors* are generally independent of the organisation being audited.

Adapted from Brown (1993)

Figure 6: Processes and relationships in establishing and reviewing EMP's.



DMR — Department of Mineral Resources
MREMP — Mine Rehabilitation Environment Management Plan

Source: Draft MREMP Guidelines (DMR, NSW 1995)

CASE STUDY 5

NORTHPARKES MINES, NSW
Environmental Monitoring Program and Performance Assessment

AREA	FREQUENCY	PROCEDURE
Noise: background noise	Monitoring equipment set up on one of three main neighbouring properties once per month or if requested by neighbour.	Road and Traffic Authority background noise logger set up 10m from neighbour's house. Noise data is logged for up to 10 days. Cassette tapes high noise levels. Data downloaded and graphed.
Blast overpressure and vibration	Monitor every blast in open cut operation. Monitoring equipment set up on at least one of three main neighbouring properties or if requested by any other neighbour.	Blast and vibration monitor and B&K peak noise monitor set up 10m from neighbour's house. Blast over pressure and vibration recorded. Data downloaded and graphed.
Dust: total dust fallout quantity	33 dust fallout monitoring gauges installed on and outside mine lease. Samples collected each month.	Every 30 days all dust gauges are collected and replaced with new bottles. Samples are sent to outside laboratory for determination of total solids.
Analysis	Analysis of dust generated on site and dust collected in selected fallout gauges occurs on a quarterly basis.	Dust generated on site is analysed for contaminants. Dust collected in selected fallout gauges is analysed for contaminants.
Surface water: creeks, dams	Creeks and dams within and outside of the mining lease are sampled after each major rain event or on a quarterly basis.	After each major rainfall event that results in the local creeks flowing, or on a quarterly basis, the local creeks and dams are sampled to analyse for any contaminants.
Retention ponds (RPs); sediment ponds (SPs)	RPs (6) and SPs (5) are sampled on a monthly basis.	All RPs and SPs are sampled each month to analyse for contaminants to allow management of water flow on site and contain any potentially contaminated water within the process system.

ANALYSIS AND REVIEW OF RESULTS	COMPLIANCE REQUIREMENTS	OTHER DETAILS
Results graphed with compliance conditions. Data reviewed comparing data with compliance conditions.	Background noise dB(A)L90 not to exceed historical background noise by more than 5dB(A) for more than 5 days in a month.	If results show any increased levels experienced consultants contracted to carry out more detailed monitoring. Government bodies notified. Review of current operating practices.
Results plotted out to show waveform for blast overpressure and vibration. Results checked against compliance conditions.	Max overpressure allowed (115 dBL) Max vibrations allowed: 5 mm/sec.	If results exceed levels allowed the blast design is reviewed. (1 open-cut blast, exceedence has occurred).
Results from laboratory are plotted against historical data to show monthly levels of total dust. Results are checked against historical data for any anomalies.	Compliance conditions state that dust generation must be minimised.	If results succeed historical data then further review of mining operations, climatic conditions and surrounding farming activities is carried out.
Content of elements in dust is analysed by external laboratory. Results are checked against quality guidelines (ANZECC, Dept Health, etc).	Compliance conditions state that the operation must not impact on surface water (creeks) in the region.	
Water samples are sent to outside laboratory for analysis of water quality. Results are checked against quality guidelines (ANZECC, Dept Health, etc).	Compliance conditions state that the operation must not impact on surface water (creeks) in the region.	
Water samples are sent to outside laboratory for analysis of water quality. Results are checked against quality guidelines (ANZECC, Dept Health, etc). Any contaminated sites are pumped into the process water dam and cleaned out.	Compliance conditions state that the operation must not impact on surface water (creeks) in the region.	These ponds ensure that any spills are contained within the process area.

CASE STUDY 5

NORTHPARKES MINES, NSW
Environmental Monitoring Program and Performance Assessment (continued)

AREA	FREQUENCY	PROCEDURE
Ground water: tailings bores Seepage sump	Tailings bores (3) and seepage sump are monitored on a monthly basis. Levels are measured and if contain any liquid this is sampled.	The tailings monitoring bores and seepage sump are levelled each month with samples collected if any liquid occurs in them. The samples are analysed for contaminants.
Underground water extraction	Bore water levels (25) around the underground mine are monitored every month to monitor impact of aquifer extraction on neighbouring property bores.	The bores are levelled every month and the data is graphed.
Rehabilitation progress	Rehabilitation will occur each year. Each area of revegetation will be surveyed 12 months, 2 years and 5 years after planting to ensure success.	Surveys of revegetated areas will occur every 12 months, 2 years and 5 years.
Agricultural land: weed control	Inspection for noxious weeds on the mine lease and Company owned property is continual but particularly Spring/Autumn.	Weed control can be by manual chipping or by chemical spray using the chemical recommended for each type of weed.
Feral animal control	Inspection for feral animals on the mine lease and Company owned property is continual but particularly Spring/Autumn.	Control of feral animals is by trapping, baiting or shooting as recommended by Dept of Agriculture and Pasture Protection Board.

ANALYSIS AND REVIEW OF RESULTS	COMPLIANCE REQUIREMENTS	OTHER DETAILS
Samples are sent to outside laboratory for analysis of quality. Results are checked against quality guidelines (ANZECC, Dept Health, etc) Any contaminated sites are pumped into the process water dam and cleaned out.	Compliance conditions state that the operation must not impact on surface or underground water in the region.	The bores and sump allow monitoring of any potential seepage from the tailings dam to prevent contamination of the ground water or surface water.
The results are graphed against historical data. Results are compared with previous data to ensure neighbouring bores are not decreasing in level as the underground aquifer is extracted.	Compliance conditions state that the operation must not impact on neighbouring property bore water supply.	
The results will be reviewed to determine success of rehabilitation areas. The results will be reviewed to determine success of rehabilitation areas.	Areas disturbed by mining operations are to be rehabilitated at the completion of mining activities.	Research into rehabilitation of the tailings dam, waste material stockpiles and open cut mines is a major part of rehabilitation planning.
Treated sites are inspected 2 weeks after sprayed/chipped. If treatment not successful further treatment is carried out	Conditions of Approval state noxious weeds on the mine lease must be controlled in accordance with requirements of the Dept of Agriculture and Pasture Protection Board.	Northparkes Mines is committed to the eradication of all noxious weeds on the mine lease and company owned property.
Areas where feral animals have been trapped or baited are inspected every three days. If method of control is not successful further trapping/bailing is carried out.	Conditions of Approval state feral animals on the mine lease must be controlled in accordance with requirements of the Dept of Agriculture and Pasture Protection Board.	Northparkes Mines is committed to the eradication of all feral animals on the mine lease and company owned property.

CASE STUDY 5

NORTHPARKES MINES, NSW
Environmental Monitoring Program and Performance Assessment (continued)

AREA	FREQUENCY	PROCEDURE
Management — non leased land	Agricultural land within the mine lease is managed by Northparkes Mines. This is a continuous fulltime function requiring regular weekly inspections.	This land is inspected on a regular basis to allow management of fencing, soil fertility, water flow as well as weeds and feral animals.
Leased land	Inspections of this land occurs biannually with an officer from the Dept of Agriculture.	Agricultural land owned by North Mining Ltd not within the mine lease is leased back to neighbouring farmers. These farmers have a strict lease agreement which they must comply with. Inspections of this land occurs twice a year to ensure the lessees are operating in accordance with the lease conditions.

These can take the form of checklists, questionnaires, written guidelines, rating systems and specific questions. The table of contents of the EMP provides a handy and logical checklist for audit purposes.

3.3 FEEDBACK TO ENVIRONMENTAL MONITORING PROGRAMS

There is a range of methods by which to review environmental performance, both internally and externally, via formal audit procedures described earlier and less formal methods which are valuable in providing feedback on environmental performance. It includes industry workshops and conferences and open days. This process can be significant in the sharing of ideas and the development of improved methods. Benchmarking is a procedure which can also be undertaken to assess one company's performance against another in a similar mining context.

The most important aspect of the review process, however, is the feedback on monitoring programs and management systems. The review will highlight strengths, weaknesses and gaps. Where modifications are deemed necessary, the EMP and monitoring program should be revised in pursuit of continued improvement in the quality of environmental performance.

ANALYSIS AND REVIEW OF RESULTS	COMPLIANCE REQUIREMENTS	OTHER DETAILS
Fence condition, pasture content, potential erosion areas are checked to ensure the land is maintained in good condition. Any areas requiring attention are highlighted and repairs or new works carried out.	Conditions of Approval state that agricultural land must be maintained in accordance with recommendations of local government authorities.	Northparkes Mines is committed to good management of the agricultural land owned by North Mining Ltd.
Inspection of the leased land provides detail on condition of the land, particularly condition of paddocks for pastures or crops, fences, weed content, feral animals and water flow to prevent erosion. Any areas requiring attention are noted. Discussions with the lessees detail works to be implemented to ensure the areas are correctly managed.	Conditions of Approval state that agricultural land must be maintained in accordance with recommendations of local government authorities.	Northparkes Mines is committed to good management of the agricultural land owned by North Mining Ltd.

ERA, RANGER MINE
Environmental Monitoring Program and Performance Assessment

AREA	FREQUENCY	PROCEDURE
Surface water: • retention ponds • creeks • billabongs • sumps • wetland filters	 weekly * monthly * monthly * monthly * as required for research purposes. * daily & weekly during a release	 Water samples taken and chemistry analyses completed. Water levels checked via gauge boards and stream gauging.
Groundwater: • monitoring bores • piezometers • dewatering bores • land application bores	 monthly bi-monthly six-monthly some more frequently weekly during irrigation.	 Water level in bores measured using dip-meter and piezometer level read. Water samples taken using bore pump.
Biological screening: • retention ponds • creeks • billabongs • wetland filter	 During wet season prior to and during release of retention pond water. As required for wetland filter research.	 Control water obtained from creek. Pond water at a range of dilutions prepared and microscopic aquatic organisms (hydra, cladoceran and fish embryos) used to assess toxicity.
Soils	Three-yearly.	Collection, preparation, digestion and analysis according to standard metl
Uptake of contaminants by biota: • mussels in creeks • vegetation in land application area.	 Annually and on non-regular occasions (eg. for retention pond 2 release).	 Mussels sampled from downstream billabong. Mussel tissue ashed and analysed for contaminant uptake. Vegetation sampled and analysed for contaminant uptake.

ANALYSIS AND REVIEW OF RESULTS	COMPLIANCE REQUIREMENTS	OTHER DETAILS
Results graphed and tabulated for inclusion in reports. Comparisons made with previous reporting period. Collated in quarterly/six monthly water management and annual environmental reports.	Limits established for receiving waters during release of water from retention ponds.	Hydrology and chemistry combined for load calculations during release. Results used in research on wetland filtration, seepage management etc.
As above.	Tailings bores and piezometers needed to monitor stability and seepage aspects of tailings dam. Land application (irrigation) area monitored for mobility of salts and other elements.	Data included in research projects on seepage modelling.
Results tabulated, statistically analysed and included in reports. Internal and external review by government authorities.	Used as part of process to determine dilution rate of release water.	Government standards and safety factor (x10 or x100) before applying the results of toxicity tests.
Reported three-yearly and in annual report.	Results compared to historical data.	Monitoring sites are located along drainage channels around the lease area.
Internal and external review by government authorities in the annual report.	Results compared to previous data. Also judged on relevant ANZECC standards for edible criteria.	

CASE STUDY 6

ERA, RANGER MINE
Environmental Monitoring Program and Performance Assessment (continued)

AREA	FREQUENCY	PROCEDURE
Sediment control	Annual.	Annual erosion survey undertaken and wet season plan prepared for remediation.
Weeds	Bi-annual.	Visual inspection to assess success of previous weed control efforts and plan future control of these areas or new outbreaks.
Fire	As required.	Control of wildfires during dry season and planned burns conducted late wet season/early dry season.
Area dust and personal dust	Weekly Daily dependent on level of dust found.	High volume dust samplers and personal samplers are used to collect the sample on a filter paper. Radiometric and gravimetric analysis are undertaken.
Stack emissions — uranium, sulfur dioxide and acid mist	Emissions are measured from the calciner and product packing stacks. Calciner and product packing: monthly. Acid plant: Sulfur dioxide and acid mist emissions are measured from the acid plant stack every three months.	The USA EPA methods for stationary sources are used. A representative sample over a four-hour period is collected from each stack.

ANALYSIS AND REVIEW OF RESULTS	COMPLIANCE REQUIREMENTS	OTHER DETAILS
Written report/photos, recommendations and budget requirements. Internal review.	Minimise soil loss from mine area and surrounding lease due to disturbance.	Comprehensive pond system ensures runoff contained in ponds/sediment control structures prior to overflow to creek system.
Sketch map prepared and weed control methods planned in liaison with government authorities (Department of Primary Industry & Fisheries) and neighbours in National Park (Australian Nature Conservation Agency). Mission grass main weed problem. Internal review and reporting.	N/A	Encourage use of native species by residents in gardens in Jabiru township via education and supply of plants from Ranger nursery during establishment of town.
Research on fires helping to refine timing and nature of burn. Internal review and external review during research field days on site.	N/A	Protection of mine assets and monitoring equipment in surrounding woodland, a key requirement for fire monitoring/management.
Results are reported on a quarterly and annual basis. On an annual basis the results are compared with the previous period results.	Results are compared with the allowable limits as per the Authorisation to Operate.	The results from the personal air sampling and the consequent radiological analysis are used to assess radiation exposure due to inhalation of radioactive particles.
Results are reported on a quarterly and annual basis. On an annual basis the results are compared with the previous period results.	Results are compared with the allowable limits as per the Authorisation to Operate.	The results are used as inputs for some atmospheric modelling work.

ERA, RANGER MINE
Environmental Monitoring Program and Performance Assessment (continued)

AREA	FREQUENCY	PROCEDURE
Radon-222 Progeny Exposure	Weekly and monthly depending on areas monitored.	Automatic area monitors are used to measure average concentrations of ambient radon progeny (decay product of Radon-222 gas). Samples are collected in the immediate operations area and the surrounding environment. Areas are usually monitored for a minimum of 24 hours and up to seven days continuously. Average concentrations are measured every hour at various locations.
Gamma Exposure	Personal monitors are used to measure individual employee exposure to gamma radiation. These are worn every day by employees working in the process plant. The monitors are analysed on a quarterly basis.	Worn by employees who are likely to receive the highest exposure to gamma radiation, eg employees who work in the process plant and the mine.
Blasting	Every blast (daily for six months of the year)	A blast vibration monitor is located adjacent to the pit on the southern side to measure the magnitude of each blast.
Ore and waste dumping (Restricted Release Zone – RRZ)	Daily during mining phase.	Grade control prior to blasting plus discriminator reading of each truck road for uranium content. Scintillometer measurements over surface of waste and ore stockpiles are made to check only <0.02% uranium is on waste stockpile (outside RRZ boundary).

ANALYSIS AND REVIEW OF RESULTS	COMPLIANCE REQUIREMENTS	OTHER DETAILS
Results are reported on a quarterly and annual basis. On an annual basis the results are compared with the previous period results.	Results are compared with the allowable limits as per the Authorisation to Operate.	Results from area measurements of radon progeny concentrations are used to calculate employees' radiation dose due to the inhalation of radon progeny.
Results are reported on a quarterly and annual basis. On an annual basis the results are compared with the previous period results.	Results are compared with the allowable limits as per the Authorisation to Operate.	The monitors are analysed by the Australian Radiation Laboratory and the results combined with the radiation doses from dust and radon progeny to get the total radiation dose to individual employees.
Chart records from the monitoring device are forwarded to the supervising authority monthly.	All blasting operations shall be conducted so that Mt Brockman and the aboriginal sacred sites in the environs are not damaged.	Mine blasting operations have taken place within the limits set for ground vibration magnitude.
Grade control plus discriminator records plus calibration. Notebook records of surface checks of radioactivity.	All material with >0.02% uranium must be contained in RRZ for water management purposes.	

CONCLUSION

To achieve best practice the environmental aims and objectives of both the community and industry must be applied through an environment management plan and an environmental management system. The environmental monitoring program collects the necessary information and interprets it against these aims and objectives to assess environmental performance.

Monitoring is necessary across the whole range of mining activities that are likely to produce undesirable environmental impacts. A monitoring program can include many sub-programs, such as: water; land; biology; air and noise; processes and wastes; and heritage values. Such comprehensive monitoring provides the necessary information for assessing the environmental performance of a mining operation.

Environmental performance assessment produces information for the community on the environmental impacts of the operation and allows the operator to review and, if necessary, modify any aspects of the operation that may be causing unacceptable environmental impacts. This assessment also provides technical environmental reports to help government in assessing the efficiency and adequacy of a project's environment management plan.

Environmental auditing is also part of the assessment process which, through checklists, questionnaires, written guidelines, rating systems and specific questions, can confirm the effective operation of the environment management plan.

The comprehensive and systematic framework for developing effective environmental monitoring and assessment outlined in this module provides the basis for mining operations to achieve a high level of environmental performance.

FURTHER READING

ANZECC & NHMRC 1992, *Australian and New Zealand guidelines for the assessment and management of contaminated sites.*

ANZECC Endangered Flora Network 1993, *Threatened Australian Flora.*

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APPENDIX 1

DETAILED REQUIREMENTS FOR ENVIRONMENTAL MONITORING SUB-PROGRAMS WATER MONITORING

Water Quality

The following information is provided because some aspects that are critical to meaningful monitoring are not documented elsewhere. They are based on the experience of more than 15 years of intensive monitoring and research in the wet-dry tropics of Australia. Some are also determined by requirements implied in the *National Water Quality Guidelines for Fresh and Marine Waters (ANZECC:1992) and Guidelines for Drinking Water (NHMRC: 1987).*

The quality of water can vary substantially from mine to mine and may result from introduced process chemicals or from the mineralogy of the material being mined. Physico-chemical constituents of water are grouped as general parameters — the major common ions and physical characteristics — or as trace elements. There are also special categories such as radionuclides, nutrients and organics. In order to monitor water quality it is necessary to know the characteristics of the natural water and what might be introduced to them from mining operations.

Waters are first characterised by analysis to water supply standard for major ions and general parameters and by ICP-MS scan for trace elements. Thereafter quality is monitored by analysis or measurement of key indicators. Box A lists water quality groups and units of measure. Note that in the case of acid mine drainage the trace elements of significance cannot be evaluated reliably prior to commencement of the contaminant generation processes. It is necessary to re-evaluate this periodically and there are key acidity levels in mine waters which provide warning of worsening acid generation activity. Until the development of ICP-MS technology for direct analysis of water, geochemical testing of various rock lithologies in the orebody to determine elemental enrichment served as a useful guide.

Where trace elements are specified as key indicators, they should be analysed to reliable quantitative standard to a detection limit which is at least 10% of the guideline limit recommended for ecological water quality (ANZECC: 1992). Except in a few cases of lighter metals, the halogens and metalloids, arsenic and selenium, ICP-MS scans to quantitative standard are cost effective and provide an adequate level of accuracy. For identification of organic compounds, GC-MS technology is used based on US EPA Standard Procedures. There are other techniques available but some do not meet the detection limit criteria for some elements.

Analytical laboratories should be NATA registered (or should demonstrate compliance with ISO 9000 quality assurance standards) for each type of analysis required, to ensure that standard analytical methods are used. Note that there is no Standard Method for determination of uranium in water nor is there a reliable standard procedure for preservation of water samples for environmental assessment of cyanide which may contain sulfide, thiocyanate or oxidants. Further research is needed.

While only one or two of the common major ions found in waters may be specified as a key indicator, it is necessary to analyse for the full suite of common ions for quality control purposes and to detect discrete events and long term trends in anion composition. The units of measure for the major ions are mg/L, µg/L for trace elements and mBq/L for radionuclides.

Special attention must be paid to sampling method and to preservation and handling of samples prior to analysis. Refer to AS 2031[1]. For natural waters (pH >5), all samples must be filtered in the field to <0.45 µm. Note that the ANZECC guidelines recommend that samples for metal analysis be prepared in accordance with procedures for acid extractable metals, which is performed on an unfiltered sample. This procedure can result in incorrectly high and misleading results. Some parameters — pH, total alkalinity, conductivity, turbidity, DO and biotoxic forms of chemical species which cannot be preserved for transport to laboratories — must be measured in the field. Tasmania's environment protection regulations[2] also provide a useful guide.

Field equipment for short interval logging of key indicators such as pH, Eh, EC, chloride, sulfide, nitrate, phosphate, temperature, turbidity, DO and temperature is available and provides a practical monitoring tool. Remotely logged data must be verified by a low intensity laboratory-based monitoring program.

Water management

The extent of monitoring required depends on whether or not the mine has been designed for controlled release of water to the environment or with a 'rare release' water management system. The rare release of 1 in 100 annual exceedence probability (AEP 100) based on annual water balance is becoming acceptable[3] as design criteria for 'rare release' systems. In this case monitoring of EC and pH with annual scans for trace element composition will be adequate.

Concentrations in ponds can be expected to vary seasonally but EC measurements are adequate to follow these trends for monitoring purposes. Show location of water management system components on a map or aerial photograph. Record pond areas, water levels, volumes and transfers. Box B provides standard units of measure of water management parameters.

Groundwater can be affected by water supply extractions, mine dewatering and contamination. Monitoring typically requires measurement of water levels relative to a local datum or mean sea level (MSL) and key water chemistry parameters. These parameters indicate the direction and rate of movement of contaminant plumes. Close attention must be paid to siting, logging and construction of monitoring bores, and assessment of their condition should be made annually (a simple measure is depth to bottom). Depending upon the purpose of the monitoring bore and the nature of the aquifer, sampling may require pumping or bailing, or insitu measurement of quality (eg pH or EC)

Rainfall (mm), streamflow and mine site runoff (m^3/s to 0.01) are required for water management practices involving discharge to the environment. Historic data will have been considered for hydrological design criteria for mine facilities but it is necessary to continue to monitor these to revise estimates of water

1 Standards Australia, AS 2031.1 1986 Part 1 — Chemical — Selection of Containers and Preservation of water samples for Chemical and Microbiological Analysis

2 Environmental Protection (Water Pollution) Regulations, Tasmania 1992

3 This judged by public acceptance through the EIA process

balance and stochastic risk analysis of discharge potential, and to understand specific hydrological events.

Rainfall is usually measured daily which is satisfactory for most purposes, as are daily measurements of pond levels and volumes. Rain gauge density can be important for detailed hydrological studies. However, for general monitoring and operational water management, where pond volumes are measured directly, one gauge per 10 km^2 is suggested. For most water balance information and system modelling, weekly totals are satisfactory.

Runoff or streamflow data are not usually recorded for mine sites except where dilution criteria are established for controlled discharge of mine waters to receiving streams. Determination of chemical load, which also requires streamflow data, is rarely used as a pollution control criterion. Because chemical impact is a molecular process, concentration is the key factor. Discharge is determined by measuring stage height and referring to the relevant rating curve, having obtained the rating curve by field calibration of flow and height measurements. AWRC Water Management Series No 18 provides some further guidance on the collection of various hydrometeorological data. The USGS Handbook of Recommended Methods of Water Data Acquisition is also informative.

LAND MONITORING

Clearing and topsoil management

Show location of proposed clearings and topsoil stockpiles on a plan or near-vertical aerial photograph at a scale of 1:5000. Record areas (hectares), quantities (m^3) and content of potential regrowth stock if appropriate. Geographic information systems (GIS) can be used to superimpose mine structures and clearing plans on baseline soil and vegetation surveys and land unit maps to assist management of clearing and topsoil.

Erosion control

Conduct regular erosion surveys of the project area with particular reference to cleared areas, mine earthwork structures (dams and waste dumps), access tracks, exploration drill sites, gravel pits and fire breaks. Check for performance of erosion control works (gully control structures, sediment traps, drop structures, earthen drains, etc) following periods of rainfall. Check for germination success on planted areas and for natural regeneration. Report locations and areas of disturbance, successes and failures maintaining a systematic photographic record.

Weed management

Report weed outbreaks and conduct regular mapping of their location (frequency and scale of mapping will be determined by the severity of the potential threat). Regular checks must be made to ensure that:

- heavy equipment prior to entry on site is free of soil/vegetative materials;
- topsoil use is limited if weeds are likely to be encouraged by this practice;
- fire is prevented where it encourages the spread of weed species;
- grazing of inactive portions of the project area is limited, to avoid overgrazing and weed invasion;
- hay bales are not introduced as a revegetation mulch, or temporary sediment control structure unless they are checked and verified as weed free;
- employee awareness regarding prevention of exotic plant introduction is maintained at a high level; and.
- site weed control is compatible with regional weed control programs.

Fire management

Examine areas identified for protection from fire at appropriate intervals to enable assessment of fire risk and intervention (eg control burning and strategic firebreaks) where necessary. Inspect safety measures such as fire breaks, equipment (condition), review contingency plans, awareness and training programs, fuel accumulation data, etc. Critical areas may include revegetated areas, specific wildlife habitat and infrastructure.

BIOLOGICAL MONITORING

Detailed baseline studies during the EIA process will have determined the appropriate basic parameters (eg species presence, species abundances, inter and intra species interactions, species habitat associations, species life history strategies, etc). As it is usually impractical to monitor entire systems indicator species, processes or communities are usually selected. Indicator species or processes ideally should be highly sensitive to the impacts being monitored. If an indicator species is to be chosen then the parameter(s) to be monitored needs to be selected.

Such parameters may include:

- species density;
- breeding timing;
- juvenile or adult mortality rate;
- population growth rate;
- incidence of disease;
- brood size, adult or juvenile size;
- diet;
- population, sex ratio; and
- physiological, biochemical, histopathological parameters, etc.

Indicator processes to be examined may include the movement of energy through the food chain. Indicator communities generally examine relative abundances of a particular group of species (eg soil microfauna, aquatic micro-invertebrates, etc), predator-prey relationships, etc.

Other types of biological monitoring include bioassays (either in situ or under laboratory conditions) and bioaccumulation studies (in situ or under laboratory conditions). A combination of two or more methods can be used to overcome any disadvantages.

Recently the BACI (Before After Control Impact) method has been used in biological monitoring programs. This method is suitable for use for unreplicated, predictable impacts. Basically, samples are collected simultaneously from impacted and unimpacted (control sites) both before and after the impact. The magnitude of the differences observed are attributed to the impact.

Endangered species — Monitor rare or threatened plants and animals identified during the Environmental Impact Assessment phase of mine development, by periodic observation of the location, population changes and health of these species. A more positive approach is to assist with a species recovery program and a review of the 'endangered' classification.

Feral Animals — Monitoring will include reports of sightings and strategic trapping and disposal of feral animals. In some cases, EMPs specify prohibition of introduction of feral animals, eg domestic cats by mine employees. This should be monitored for awareness and compliance. The State/Territory government department managing feral animals will provide guidelines for the species which need to be controlled and methods of control and management within the mine project area should be compatible with regional programs.

Mosquito/health risk vectors — A vector monitoring program will be developed in liaison with the relevant government health department and will include vector trapping sites, trap design, monitoring frequency and vector control programs.

Aquatic and marine ecosystems — Aquatic ecosystems in the vicinity of mining operations will be regularly sampled to review the health of the ecosystem. A range of trophic levels need to be studied. Marine ecosystems influenced by mining or loading facilities need also to be monitored. The nature of this monitoring will usually involve population and/or contaminant uptake studies.

Soil/plant pathogens — At some minesites where there is the potential to spread plant pathogens by mining operations (vehicular traffic and soil transfer), monitoring programs need to assess the success of management systems implemented to confine the contamination. Representative soil sampling programs will highlight the presence or absence of these pathogens.

Biological screening/toxicity testing

This is carried out to assess the quality of water based on its effect on sensitive aquatic organisms. For example, at ERA Ranger Mine the following are used — cladoceran, hydra, larval fish and fish embryos. These are immersed in various concentrations of the test water (from retention ponds) and control water (from nearby creek). Qualitative responses are analysed statistically to determine the maximum No Observed Effect Concentration (NOEC) and Lowest Observed Effect Concentration (LOEC). Once these concentrations are determined it is possible to calculate the dilution required to ensure no effect on the aquatic ecosystem in the event that pond water were to be released to the nearby creek system.

Different test organisms from different trophic levels are used at different sites where biological screening has been adopted as a supplementary water quality assessment technique. The nature of the test and qualitative changes measured are also specific to that site.

AIR AND NOISE MONITORING

Atmospheric Emissions and Dust

Dust and gaseous emissions of concern should be recorded. These may be related to health or nuisance. These aspects may be provenance, density in air, dust fall, etc. Measurements may be g/m^2, g/m^3, and include dust characterisation, eg mineral type, grain size and morphology. Also organic material may be very important. Wind direction and speed (m/s) may also be important in determining provenance. Monitoring of gaseous and particulate emissions at the source is undertaken where emission standards are set, however, plume and fallout monitoring is sometimes required. Plume studies are usually regarded as special studies, not routine monitoring. Equipment includes automatic weather stations, continuous samplers, opacity meters, isokinetic samplers, etc.

Noise and vibration

Refer to AS 2187.2—1993 which sets out measuring techniques for airblast and ground vibrations and AS 1055.1—1989 which provides a standard for description and measurement of environmental noise (this also relates to occupational health).

PROCESS AND WASTE MONITORING

Acid generating waste materials

These are recognised within Australia and internationally as a significant long term environmental hazard. Acid generation potential (AGP) is used to classify waste rock for management of its placement and some regulating agencies are now requiring documentation of placement. Note that there are no Standard Methods for AGP testing although there are several in common usage and research is continuing on this important issue. Maintain weekly records and report location, classification and quantities (m^3) of various AGP classes of waste. Check weekly to ensure that high sulfide waste is not being used on the mine site for minor works. Where required, provide all AGP test results specifying location, lithology and test method. Minimum recommended number of samples to be taken in each geologic unit for the assessment of AGP ranges from three samples for 10 000 tons of rock to 470 samples for 500 $\times 10^6$ tons of rock (British Columbia Acid Mine Drainage Task Force). For more details refer to the module to be produced later on Acid Mine Drainage in the series.

General waste

Monitor disposal of domestic and industrial wastes to ensure that procedures are followed as outlined in the EMP, usually:

- wastes shall be disposed of in separate areas;
- maximisation of waste recycling (eg oil, drums, metal, etc) and procedures for recycling/reuse;
- leachate and/or overflow minimisation strategies; and
- the location of these waste containment sites (on site plans at 1:5 000).

Ore and product

Monitor ore and product handling areas for spillages and quality of runoff from stockpiles. Report sites, materials, quantities and remedial activities. Where containment methods have been specified in an EMP, monitor for appropriate application.

Waste rock and tailings

Characterise, classify, identify and manage day-to-day placement of waste rock and capping materials where specified in the EMP. Monitor the available water storage capacity in the tailings impoundment to check that the design risk for overflow is not exceeding the contingency volume/freeboard requirement specified in the EMP. Characterise water chemistry of pond waters and drainage waters annually. Assess the solid state speciation of the tails (geochemical characterisation) to determine the likely geochemical fate of metals released via weathering processes. This information will assist in formulating an appropriate rehabilitation plan.

Rehabilitated structures

Where acid mine drainage is a problem, monitor for water and gas within rehabilitated dumps. This involves lysimeters or boreholes to assess the effectiveness of the capping and dump design in minimising the influx of water and oxygen. Bores are also needed in strategic locations around rehabilitated tailings impoundments to monitor seepage.

Hazardous substances

Monitor hazardous storage facilities and work practices to identify local accidental release or its potential. There is a wide range of Australian Standards applying to hazardous substances.

PEOPLE AND COMMUNITY MONITORING

Critical group studies

Select specific diet components and analyse for uptake of contaminants at intervals determined appropriate for plant/animal.

Select site for atmospheric modelling of critical group where airborne contaminants have been identified as a monitoring requirement for nearby populations.

Urban area monitoring system design where populations are located close to mining operations (eg Broken Hill and dust monitoring program). Where dust or gaseous emissions are being studied principles are the same as those outlined in other sections in this appendix.

Special areas management

Monitor for employee awareness and activities, ensure that fences and signposting are maintained. Report incidents and remedial actions. The nature and management of conservation areas, heritage sites and Aboriginal sites of significance will vary from mine to mine.

Box A: Detection Limits and Units of Measure for Physico-Chemical Water Quality Parameters for Environmental Monitoring Programs.

Detection Limit		Unit of Measure
General parameters		
Sodium	0.1	mg/L
Calcium	0.1	mg/L
Magnesium	0.1	mg/L
Potassium	0.1	mg/L
Carbonate	0.5	mg/L
Chloride	0.1	mg/L
Sulfate	0.1	mg/L
Bicarbonate	0.5	mg/L
Fluoride	0.2	mg/L
Hydroxide	0.5	mg/L
Total Dissolved Solids	0.5	mg/L
Total Suspended Solids	0.5	mg/L
General field parameters		
Alkalinity (Ca CO3)	0.5	mg/L
Electrical Conductivity	1	µs/cm
pH	0.1	pH units
Temperature	0.1	°C
Turbidity	1	NTU
Cyanide		
Cyanide-Free (CNf)	5	µg/L
Cyanide-WAD (CNwad)	5	µg/L
Cyanide-Total (CNtotal)	5	µg/L

Detection Limit		Unit of Measure
Nutrients		
Ammonia (as N)	0.05	mg/L
Nitrate (as N)	0.05	mg/L
Nitrite (as N)	0.05	mg/L
Phosphate (as P)	0.02	mg/L
Silica	0.5	mg/L
Trace elements		
Aluminium	5	µg/L
Antimony	3	µg/L
Arsenic	5	µg/L
Bismuth	5	µg/L
Cadmium	0.02	µg/L
Chromium	1	µg/L
Cobalt	2	µg/L
Copper	0.02	µg/L
Iron	20	µg/L
Lead	0.1	µg/L
Manganese	1	µg/L
Mercury	0.01	µg/L
Nickel	2	µg/L
Selenium	0.05	µg/L
Uranium	0.1	µg/L
Zinc	2	µg/L
Radionuclides		
226Ra	5	mBq/L
228Ra	5	mBq/L

Note 1: The list of trace elements is not complete. Use ICP-MS scans to identify key elements for monitoring.

Box B: Waste Management Monitoring Parameters.

Ponds — areas	ha to 0.01 ha
— volumes	ML to 1% of capacity
— levels	m to 0.01m
Transfers	ML/day
Rainfall	mm
Runoff to streams	m^3/sec
Runoff to ponds	ML/day or mm/day
Receiving water flows	m^3/sec
Mixing dilutions	%

FURTHER MODULES PLANNED FOR THIS SERIES INCLUDE

Overview of best practice environmental management in mining
Environmental impact assessment
Community consultation and involvement
Tailings containment
Rehabilitation and revegetation
Onshore exploration for minerals
Onshore exploration and development for oil and gas
Planning a workforce environmental awareness training program
Prevention and control of acid mine drainage
Environmental management systems
Environmental auditing
Water management
Environmental incident and emergency/contingency procedures
Offshore oil and gas exploration and development
Decommissioning and planning for mine closure
Post-mining and land use management
Contaminated site clean up
Use of artificial wetlands for treatment of contaminated water
Noise, vibration, dust control, atmospheric emissions and air quality
Waste management through cleaner production
Landform design and construction

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The series illustration of the Koalas by Christer Erikson was commissioned by BHP Transport in 1988. Reproduced courtesy of BHP Transport.

Front cover Photo: Electro-fishing in the Henty River, Tasmania, to sample fish is part of the monitoring program. Photo: RGC (Tasmania) Ltd.

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Environmental Monitoring and Performance

One module in a series on

BEST PRACTICE ENVIRONMENTAL MANAGEMENT IN MINING

Environment Protection Agency

June 1995

FOREWORD

Environment protection is a significant priority for our society. For government a major role is setting environment standards and ensuring individuals and organisations meet them. Also government, industry and community organisations are working increasingly as partners in protecting our environment for present and future generations.

Representatives of the mining industry in Australia and the Environment Protection Agency, an agency of the Australian Department of the Environment, have worked together to collect and present information on a variety of topics that illustrate and explain best practice environmental management in Australia's mining industry. This publication is one of a series of modules aimed at assisting all sectors of the mining industry — minerals, coal, oil and gas — to protect the environment and to reduce the impacts of mining by following the principles of ecologically sustainable development.

These modules include examples of current best practice in environmental management in mining from some of the recognised leaders in the Australian industry. They are practical, cost-effective approaches to environment protection that exceed the requirements set by regulation.

Australia's better-performing mining companies have achieved environmental protection of world standard for effectiveness and efficiency — a standard we want to encourage throughout the industry in Australia and internationally.

These best practice modules integrate environmental issues and community concerns through all phases of mining from exploration through construction, operation and eventual closure. The concept of best practice is simply the best way of doing things.

The case studies included in these modules demonstrate how best practice can be applied in diverse environments across Australia, while allowing flexibility for specific sites. They achieve this through including practical techniques, recommendations, guidance and advice from Australia's leading mining practitioners.

I encourage mine managers and environmental officers to take up the challenge to lift performance in environment protection and resource management, and to apply the principles in these modules to their mines.

Barry Carbon
Executive Director,
Environment Protection Agency,
and Supervising Scientist

EXECUTIVE SUMMARY

Today's society expects a level of environmental performance that can only be achieved through establishing a set of environmental quality objectives.

These objectives are produced through mine planning for environmental protection, which includes environmental impact assessment (EIA) and community consultation processes. These processes are covered by separate modules in this series.

The quality objectives underlie a comprehensive, reviewable environment management plan (EMP) for a minesite from its initial development to final decommissioning and rehabilitation.

The EMP identifies risks to the environment from the mining operation and outlines strategies for managing these risks and minimising undesirable environmental impacts.

Environmental monitoring provides the information for periodic review and alteration of the environment management plan as necessary, ensuring that environment protection is optimised at all stages of the development through best practice. In this way undesirable environmental impacts will be detected early and remedied effectively. It will also demonstrate compliance with regulatory requirements.

Monitoring programs are not generic. They must be designed and developed specifically for the individual minesite.

Case studies which describe in detail the monitoring programs at bauxite, coal, mineral sands, iron ore, uranium, copper and gold mines are included.

The basic requirements for planning water, land, biological, air, noise, process and waste, and community monitoring programs are described in detail.

The monitoring program is designed to address environmental issues, the nature of potential impacts, pathways, receptors and the appropriate measurement and evaluation techniques.

Environmental performance during mining is usually measured by mining companies and the results are verified by government authorities. This process provides feedback to refine the EMP and monitoring program. It also ensures that the data gathered and presented are always focussed on key environmental issues. The process is vital to implementing best practice environmental management in mining, of which environmental monitoring is a key component.

CONTENTS

INTRODUCTION

Mining companies must achieve good environmental performance to satisfy Australian society's requirements for environmental quality. The environmental quality objectives to be met are most often determined through broad community consultation (refer to a separate module available in this series, on Community Consultation and Involvement), use of established quality standards and statutory requirements. These are, in turn, interpreted by the regulators and mine operators to develop site-specific standards, guidelines and procedures for each mine.

Periodic performance reviews are necessary to assure the authorities and the community, along with mine management, that a mining operation is achieving its environmental objectives. The design and implementation of the monitoring program is, therefore, a key step in providing this assurance.

The process of developing a monitoring program to assess a mine's environmental performance and a summary of the concepts covered by this module are presented in Figure 1.

The Australian mining industry, which shares the community concern about protection of the environment, has been actively developing environmental technology. Standard practice within the industry strives to achieve 'best practice environmental management' in providing a high standard of environment protection. The application of best practice is a dynamic process that involves careful consideration of community expectations, knowledge of the environment and benchmarks in technology. Best practice needs to be tailored for the site to ensure that effective environment protection is compatible with efficient production. Box 1 provides some key definitions and an example of best practicable technology for a specific minesite.

This module outlines the mining industry's approach to best practice in environmental monitoring and in evaluating environment protection performance during the development of a mining operation.

GUIDING PRINCIPLES AND STANDARDS

The community and industry have developed guiding principles and standards to ensure best practice environmental management. These principles and standards, in turn, affect the structure and implementation of monitoring programs to assess environmental performance.

Key concepts, principles and systems are:

- ecologically sustainable development (ESD);
- the precautionary principle (PP); and
- environment management systems (EMS).

Ecologically sustainable development

Ecologically sustainable development has developed from international and national considerations of environment and development. The goal is to achieve development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends.

The objectives are to:

- enhance individual and community well-being and welfare by following a path of economic development that safeguards the welfare of future generations;
- provide for equity within and between generations; and

Figure 1: Process of environmental monitoring and performance assessment — goal, standards and objectives.

GOAL:	Demonstrate to governments and the community that the operation complies with environmental quality objectives determined through the EIA process and achieves good environmental performance.
STANDARDS:	Australian standards for environmental management systems are being developed from the international standards series ISO 14000.
SPECIFIC OBJECTIVES:	• detect short and long term trends; • recognise environmental changes and analyse causes; • measure impacts and compare with predicted impacts; • improve the monitoring system; and • improve practices and procedures for environmental protection.

MONITORING

MONITORING REQUIREMENTS

Specific monitoring requirements are developed in the process of preparing the EMP. They include:

- what to measure;
- where to measure;
- when to measure;
- how to measure;
- evaluation methods to be used;
- additional information required.

ENVIRONMENTAL ISSUES

The following issues, identified during the EIA process, should be specified:

- environmental values to be protected;
- potential hazards;
- potential impacts;
- level of acceptable change;
- level of risk; and
- pathways and impact sites.

PERFORMANCE ASSESSMENT

From the monitoring program:

- identify trends, causes and impacts; and
- assess performance and compliance.

From the assessment:

- modify practices and procedures for environmental protection; and
- modify monitoring program.

BOX 1 — DEFINITIONS

Monitoring is the gathering and evaluation of information for assessment of performance.

Performance is a measure of the success of strategies implemented, when compared with environmental objectives.

Best Practice has been described by the Australian Commission for the Future as 'simply the best way of doing things'.

Best practicable technology (as defined for ERA Ranger Mine) is that technology from time to time relevant to the Ranger Project which produces the minimum environmental pollution and degradation that can reasonably be achieved having regard to;

(a) the level of effluent control achieved, and the extent to which environmental pollution and degradation are prevented, in mining and milling operations in the uranium industry anywhere in the world;
(b) the total cost of the application or adoption of that technology relative to the environmental protection to be achieved by its application or adoption;
(c) evidence of detriment, or of lack of detriment, to the environment after the commencement of the Ranger Project;
(d) the physical location of the Ranger Project;
(e) the age of equipment and facilities in use on the Ranger Project and their relative effectiveness in reducing environmental pollution and degradation; and
(f) social factors including possible adverse social effects of introducing new technology.

Uranium Mining (Environmental Control) Act (1979)

- protect biological diversity and ensure the integrity of essential ecological processes and life-support systems.

The precautionary principle

As part of the National Strategy for Ecologically Sustainable Development, the precautionary principle (see Box 2) underlies the Australian mining industry's environment protection approach to efficient management of the renewable and non-renewable resources on which it depends. Its application in the Australian mining industry is described as:

- adoption by companies of external and internal codes of practice, guidelines, standards and principles for exploration, environmental management, rehabilitation and community relations activities;
- comprehensive study, planning, evaluation and development of project proposals;
- extensive consultation with government, landowners and community groups;
- objective and comprehensive environmental impact and risk assessment of projects;
- comprehensive environment management systems;
- research and development programs; and
- industry environmental review, education and knowledge sharing networks.

BOX 2 — PRECAUTIONARY PRINCIPLE

Where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.

In the application of the precautionary principle, public and private decisions should be guided by:

i) careful evaluation to avoid, where practicable, serious or irreversible damage to the environment; and
ii) an assessment of the risk-weighted consequences of various options.

(Intergovernmental Agreement on the Environment, 1992)

Environmental management systems

EMS is the organisational structure, responsibilities, practices, procedures, processes and resources for implementing and maintaining environmental management. A primary component of an EMS is a reviewable Environment Management Plan (refer also to Environmental Management Systems module in this series).

Currently there is no Australian Standard for EMS. However, the International Standards Organisation is in the process of producing its ISO 14000 series of standards for environmental management, a process in which Australia is participating. These documents relate closely to ISO 9000 quality systems standards. In addition to these, various industry bodies and professional institutions have issued codes of conduct or practice as guides to their members, and this information is available.

Environmental management plans

All Australian mining projects are subject to an environmental impact assessment process based on Commonwealth, State and Territory legislation (refer to Environmental Impact Assessment module in this series). The primary outcomes of this process are the identification of specific issues of concern, a set of broad environmental quality objectives and commitments by the project proponents.

An environment management plan is developed from this process that describes how the company will meet the environmental quality objectives. The environmental monitoring and performance assessment program should be part of the EMP. Figure 2 provides an example of how monitoring is developed from the EIA process and how results are used to modify strategies and assess performance.

Some examples of site-specific standards and guidelines are provided in the Case Studies.

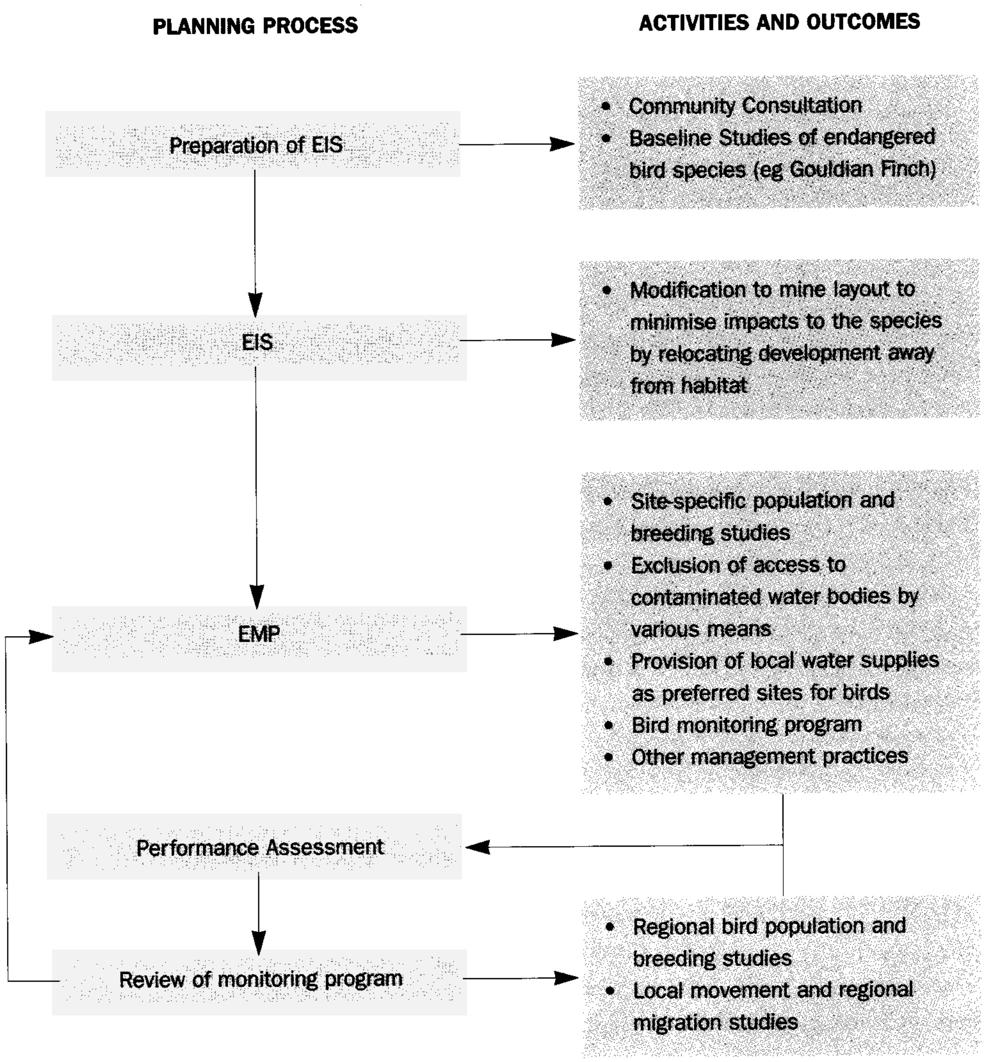
For each of the issues identified during an EIA process, the EMP will specify the following:

- objective of the environmental management activity;
- summary of commitments and requirements;
- existing conditions — operational and environmental circumstances;

- work plan and operations procedures;
- responsibilities of key mine staff;
- monitoring arrangements
  — performance indicators
  — procedures and standards
  — daily practice; and
- evaluative reporting, frequency and procedure.

Typical components of an EMP are summarised in Box 3. An EMP will also include a consolidated schedule of monitoring observations, measurements and sample analyses, specifying sites and frequency of data collection.

Figure 2: Development and implementation of monitoring program for protection of an endangered bird species.



BOX 3 — COMPONENTS OF AN EMP

Typical issues addressed in an EMP module include management of:

- land clearing and topsoil;
- water supply and process water;
- ore and product;
- waste rock;
- tailings;
- hazardous substances;
- general wastes;
- biology
  - — endangered species
  - — feral animals
  - — health risk vectors
  - — weeds
  - — habitat maintenance
  - — biodiversity;
- fire;
- dust;
- noise;
- rehabilitation;
- air;
- ground water;
- surface water;
- transport; and
- heritage areas.

1. PURPOSE OF ENVIRONMENTAL MONITORING

Environmental monitoring provides the information for periodic review and alteration of the environment management plan as necessary, ensuring that environment protection is optimised at all stages of the development through best practice. In this way undesirable environmental impacts will be detected early and remedied effectively. It will also demonstrate compliance with regulatory requirements. Environmental monitoring is directed to the key environmental issues that are detailed in Figure 1.

The key environmental issues are to:
- develop improved practices and procedures for environmental protection;
- detect short and long term trends;
- recognise environmental changes and enable analysis of their causes;
- measure impacts;
- check the accuracy of predicted impacts;
- develop improved monitoring systems; and
- provide information on the impact of mining activities.

Baseline data will have been collected during the EIA process and in specifically designed programs. Where special studies (eg research) are required during the mining operation to address gaps in knowledge, a more rigorous approach compared with routine monitoring is often needed. These studies should be clearly distinguished from the monitoring activity even though they may make use of some of the same data.

2. DESIGN OF THE ENVIRONMENTAL MONITORING PROGRAM

2.1 PRINCIPLES OF MONITORING PROGRAM DESIGN

The diversity of climates, ecosystems, land uses and topographies greatly influences the design of environmental monitoring programs. Social factors have also become important elements in environmental management. Best practice for each site is therefore governed by these regional physical and social factors.

The stages involved in designing a program have been summarised in Figure 1 and these will define the sub-programs which form the monitoring program and include such aspects as:

- water;
- land;
- biology;
- air and noise;
- processes and wastes; and
- people and communities, including heritage values.

It is important to ensure that the monitoring technology selected is appropriate. Box 4 provides a framework for design of a monitoring program.

The key requirements for monitoring of water, land, biology, air, noise, processes and wastes, people and communities is addressed in this chapter. However, more details on monitoring for each of these is provided in Appendix 1.

2.2 PLANNING THE ENVIRONMENTAL MONITORING PROGRAM

Key environmental issues are identified during the EIA process (Figure 1) and through specific investigations conducted during the planning and operation of the mine and monitoring commitments made in the EMP (Box 3). All information gathered within the monitoring sub-programs, such as those for

BOX 4 — FRAMEWORK FOR DESIGN OF MONITORING PROGRAMS

- Identify the scope of the monitoring and list the sub-programs corresponding to each environmental issue of the EMP.
- Define the objectives for each monitoring sub-program.
- Specify how information collected will be used in the decision making process.
- Define the spatial and pathway boundaries for the work and select, map or plan scales and sites for observation, measurement or sampling.
- Based on appropriate characterisation studies, select the key indicators for direct measurement, observation or sampling.
- Define how the data will be analysed and interpreted, and how it will be presented in the monitoring report.
- Define the precision and accuracy required in the data.
- Consider compatibility of the data to be collected with historical data and with contemporary related data.
- Set minimum requirements for monitoring air, water, discharges, biological systems etc.

water, land etc. below, will be evaluated and reviewed leading to program modification if necessary.

Six case studies have been chosen from a range of mine types and environments within Australia to illustrate the diversity in structure and content of monitoring programs and performance evaluation. Requirements for monitoring are described below.

Water monitoring

Water is potentially a major transport medium for contaminants. Contaminated excess waters are managed by evaporation, chemical or physical treatment, land application, wetland filters or in-stream dilution. Where excess waters must be disposed of to the downstream or adjacent environment, more detailed attention to water chemistry, aquatic biology and hydrology is required.

A water monitoring program needs to address the following requirements.

- **Determine key water quality indicators** such indicators must be easy to measure and unambiguously related to environmental change in the identified environmental value [Australian and New Zealand Environment and Conservation Council (ANZECC), 1992]. Examples of key environmental indicators for a mine experiencing acid mine drainage would be pH, EC, SO_4 and various trace metals.
- **Identify catchments and define location of sampling sites** for surface and groundwater.
- **Specify temporal sampling frequency,** eg whether continuous or at monthly intervals depending on hydrological variability.
- **Use standard sample collection and preservation techniques as included in AS 2031.**
- **Choose appropriate chemical analytical methods** to achieve maximum sensitivity and reliability of test results (Appendix 1).
- **Use appropriate quality control procedures** for checking reliability of test results (ie calibration, duplicate sampling, external

analysis, standard reference materials, maintenance of equipment).

- **Evaluate and review test results and adjust monitoring program and/or practices.**

The Alcoa Case Study provides examples of surface and groundwater monitoring programs.

Land monitoring

This monitoring relates directly to the land management components of an EMP, ie. minimisation of disturbance, weed control, optimisation of topsoil/subsoil use, fire management, erosion control (earthworks and revegetation), protection of specific landscape features/aesthetic features (Appendix 1).

A land monitoring program needs to address the following requirements.

- **Identify areas to be monitored** for each of the key issues.
- **Specify appropriate method and frequency of monitoring for each aspect,** eg map weeds, maintain photographic records of erosion and sedimentation, check topsoil stockpiles, etc (refer also to rehabilitation and revegetation module in this series).
- **Evaluate and review results/observations and adjust monitoring program and/or practices.**

The Eneabba Case Study provides an example of flora and fauna monitoring for rehabilitation. The Ranger Case Study provides examples of soil, weeds, fire and sediment control monitoring.

Biological monitoring

Biological aspects of the environment usually monitored include endangered species of flora and fauna, feral animals, mosquito/health risk vectors, aquatic and marine ecosystems, and soil/plant pathogens (Appendix 1). Specific indicator organisms may also be used to measure potential impacts on other biological groups. Due to the complexity and dynamics of biological systems, baseline studies over several seasons/years are necessary to define the key indicators that will be used in a monitoring program. It is necessary to commence monitoring immediately prior to the construction phase, and to continue throughout the duration of mining and for some time after decommissioning and rehabilitation.

ALCOA BAUXITE MINING OPERATIONS, WA
Environmental Monitoring Program and Performance Assessment

AREA	FREQUENCY	PROCEDURE
Blast noise	All blasts monitored.	Remote acoustic monitoring system (RAM) at neighbouring residential sites. Typically 5 or 6 sites are monitored. A pilot shot is detonated before main blast. Computer model estimates likely noise levels from main blast.
Environmental noise	Monitored on an as-needs basis.	Manual or remote noise metering devices.
Dust	Monitored on an as-needs basis.	Portable high volume samplers.
Surface water	Comprehensive network of stream monitoring points.	2 or 3 automatic samplers at each mine to measure turbidity. The majority of samplers are situated at W.A. Water Authority stream gauging stations. Turbidity also monitored by stage-rise samplers supplemented by grab sampling.
Ground water	Routine monitoring of ground water is not carried out, as previous monitoring and studies have confirmed that mining has no significant long term effect on ground water in the high rainfall zone (>1100 mm/year rainfall).	In specific representative catchments boreholes are monitored before, during and after mining. Water levels are recorded monthly and salinity levels annually.
Domestic waste water/industrial effluent	Grab samples taken at least monthly from the outlet of the 'Anpress' diffused air flocculation treatment unit used to treat industrial effluent flows. Sewage treatment plants are monitored regularly, usually monthly.	

ANALYSIS AND REVIEW OF RESULTS	COMPLIANCE REQUIREMENTS	OTHER DETAILS
Data from RAM transmitted to central computer by telephone line. Inbuilt analysis module outputs results as histograms. Noise from pilot shots and estimated noise levels from the main blast are compared with the Alcoa standard to decide to proceed with the main blast or not.	Australian Standard Limit 125 dB (linear).	Alcoa internal blast noise standard <115 dB on occupied properties. Voluntary agreement for 95% compliance with this standard.
Results plotted or presented as spreadsheets and compared with the appropriate regulatory standard. Output to A-weighted level.	W.A. noise regulations of 40-50 dB (A) depending on the time of day.	
		Alcoa objective at two of its refineries <120 µg m^{-3} total suspended particulates – used as guide for mining areas.
Data are checked for integrity and entered into an Access database weekly and reported monthly to Alcoa management. Turbidity data are compared with typical range of values for the season and location. Report number of samples with turbidity above agreed Alcoa standards.		Alcoa standards agreed with mine management program liaison group for trubidity are: 25 NTU for first or second order streams within the mining area and 10 NTU for third or higher order streams near reservoirs.
Results entered into database. Data are reviewed and reported periodically to Alcoa and W.A. Water Authority.	N/A	
Anpress effluent analysed for licensed parameters: oil, grease, suspended solids, total disolved solids, detergents, total phosphorus. Sewage effluent analysed for: biological oxygen demand, suspended solids, TDS and bacteriological parameters eg E. coli levels. Anpress results submitted to W.A. water authority and compared with license discharge limits. Sewage effluent results reported to local authority health department.	Set in pollution control license issued by State EPA (Anpress only).	

ALCOA BAUXITE MINING OPERATIONS, WA
Environmental Monitoring Program and Performance Assessment (continued)

AREA	FREQUENCY	PROCEDURE
Rehabilitation: plant establishment	All pits are assessed nine months after rehabilitation.	Density of eucalypts and legumes measured.
Rehabilitation: plant species diversity	15 months after rehabilitation.	The number of native plant species in 50 randomly selected plots at each mine is assessed.
Rehabilitation: evenness of spread and amount of fertiliser applied by helicopter	Three pits at each mine monitored each year.	40 containers placed in each pit to catch fertiliser.
Jarrah dieback disease	12-18 months after clearing	Dieback interpreters locate disease boundaries in the field. 1:10000 maps produced showing contours, mine boundaries and dieback infections.

ANALYSIS AND REVIEW OF RESULTS	COMPLIANCE REQUIREMENTS	OTHER DETAILS
Data tabulated and graphed. Aim to have 2000 eucalypts/ha and 2 legumes/m^2.	N/A	Remedial action as required.
Mean and standard error calculated for species diversity at each mine. Results compared with the species diversity in forest control plots	N/A	Improvement in species diversity a component of the mining group business plan.
Rate of application and evenness of spread (uniformity quotient) calculated. Reviewed by mine and environmental staff. Remedial action as required.	N/A	
Area of spread calculated and related to area of mining. Data transferred to GIS. Reviewed by scientific staff and management	N/A	Causes of spread investigated and implications for dieback control procedures considered.

RGC MINERAL SANDS LTD, ENEABBA OPERATIONS
Environmental Monitoring Program and Performance Assessment

AREA	FREQUENCY	PROCEDURE
Dust	Every six days	High volume sampler (24 hours) one location.
	Six monthly	High volume sampler (72 hours) 15 locations. Analysed for radioactivity.
Rehabilitation Flora	Yearly	About 100 x 10 ha blocks. Seven transects x 20 quadrats analysed. Consultant botanists employed who enter data directly into field computers. Species presence, numbers and cover recorded.
Fauna	Six monthly	7 sites x 2 transects
Groundwater Production Bores (20)	Monthly	Water levels taken and translated to Australian height datum, flow rates and pump hours taken, flow meter reading taken. Electrical conductivity and temperature readings taken. Salinity is then calculated from this data.
	Six monthly	Samples taken for major ion analysis.
Monitoring Bores (60)	Two monthly	Water levels taken and translated to AHD. EC and temperature readings taken. Salinity is then calculated from this data.
	Six monthly	Samples taken for major ion analysis.

ANALYSIS AND REVIEW OF RESULTS	COMPLIANCE REQUIREMENTS	OTHER DETAILS
Results checked against licence requirements monthly.	Licence specifies maximum level not to be exceeded.	
Results reported annually to Departement of Mines & Energy, Western Australia. Results used to determine 90 day running average.	Monitoring programmed. Approved each year.	
Results downloaded to internal rehabilitation monitoring system. Species diversity, density and canopy cover reported annually to Mineral Sands Agreement Rehabilitation Coordinating Committee.	Completion criteria negotiated with government for diversity, density and canopy cover.	Information used internally to quantify ecological development of rehabilitation areas
Consultant records species present. Downloaded to internal database	Nil	
Trends analysed internally every month. Reported to water authority on annual basis.	Consumption not to exceed annual allocation limit.	
Trends analysed internally every month. Reported to water authority on annual basis.	State water quality guidelines for untreated raw water.	Some bores analysed for radioactivity.
Trends analysed internally every month. Reported to water authority on annual basis.	Monitoring program approved each year.	Used to assess effect of production bores on aquifer.
Trends analysed internally every six months. Reported to water authority on annual basis.	Monitoring program approved each year.	

A biological monitoring program needs to address the following requirements.

- Define community and species dynamics.
- Select appropriate indicators for direct toxicity or bioaccumulation measurements.
- Consider variations due to space and time (cost, time and uncertainty of biological measurements must be considered).
- Direct impact on biological communities.
- Use widely accepted and standardised methods where possible.
- Collect adequate data for appropriate statistical analysis with special attention on short and long term effects, local and regional effects, individual species and broad community impacts.
- Evaluate and review test results and adjust monitoring program and/or practices.

The Alcoa Case Study provides an example of jarrah dieback disease monitoring and the Hamersley Iron Case Study provides an example of pebble mound mouse monitoring.

Air and noise monitoring

Dust, gases, blasting (vibration) and noise are key issues to be addressed in the EMP and subsequent monitoring program.
An air and noise monitoring program needs to address the following requirements.

- **Define location of monitoring sites** — it is vital that selected locations are appropriate for achieving aims, having regard to point sources, prevailing winds and potential impact sites.
- **Specify temporal sampling frequency** — may be continuous or timed according to specific activities, or during short specific periods for assessment of ground vibration associated with blasting monitoring.
- **Select the most suitable monitoring equipment** to meet the objectives
  - — provide data at required intervals and accuracy
  - — meet appropriate or regulatory standards.
- **Establish appropriate quality control procedures** to ensure reliability of results (ie calibration with standard source materials).
- **Establish appropriate equipment maintenance program** — all atmospheric and vibration monitoring equipment must be maintained to the appropriate government and industry standards and backup provided.
- **Ensure information provided to the user is relevant to** the aim of the program and that data are presented on time and in an easily useable format — in most situations data need to be analysed automatically for which alarm systems may be incorporated.
- **Evaluate and review test results and adjust monitoring program and/or practices.**

The Coal and Allied and Northparkes Case Studies provide examples of dust, noise, blast over pressure and vibration monitoring programs.

Process and waste monitoring

Waste materials, waste rock, tailings, process chemicals, ore and mill products are potential sources of chemical contamination of water, soil and air. Management of water associated with these sources is a key to protection of the environment. A particularly serious issue is the heavy metal leaching associated with the generation of acid mine drainage. Waste rock containing sulfide minerals requires attentive management to control acid generation due to oxidation processes (Appendix 1). Transportation and storage of both product concentrates and wastes should be monitored.

Process and waste monitoring needs to address the following.

- **Establish water and air quality monitoring** in relation to the various wastes.
- **Check placement and management of the different wastes, ore and process chemicals,** eg sulfidic waste rock being placed according to acid generation potential (AGP) classification (Appendix 1).

- **Check engineering quality and stability** of containment structures and covers on tailings dams and waste rock dumps — including effectiveness of compaction and erosion control measures to minimise acid generation and leachate production (refer also to Tailings Containment module in this series).
- **Inspect hazardous storage facilities and work practices, operational conditions and maintenance procedures.**
- **Evaluate and review test results and adjust monitoring program and/or practices.**

The Ranger Case Study provides an example of an ore and waste dump monitoring program.

People and community monitoring

Environmental issues addressed in this monitoring sub-program include the potential impacts on people and culture/heritage within close proximity to the mining operation. These issues require very specialised monitoring

CASE STUDY 3

HAMERSLEY IRON — MARANDOO OPERATIONS, WA
Environmental Monitoring Program and Performance Assessment

AREA	FREQUENCY	PROCEDURE
Environmental dust	9 dust monitoring locations on and off leases. Collected monthly.	Bottles changed monthly. Samples weighed by Hamersley Iron's Laboratory.
Ground water	Monthly.	Depth to water in 5 production and 22 observation bores monitored monthly.
	6 monthly.	Water quality monitored from production and 5 observation bores.
Pebble mound mouse	Quarterly.	Monitor activity in 4 groups of mounds near and remote from the mine.
Waste water drainage from ancillary facilities	Monthly.	Collect samples from either side of plate separators and waste water dam. Analysed in outside lab for hydrocarbons.
Rehabilitation	Biannually/as required.	Plant transects in rehabilitated areas.
Drainage shadow aquifer drawdown	Biannually/as required.	Plant transects in locations identified as potential effect areas.

techniques and, for example, may include studies of foodstuffs, if local bush food is a predominant component of the diet of people living in the area (eg critical group studies), protection of cultural or heritage values (eg sacred sites or historical features) and air/water quality as it relates directly to people.

People and community monitoring needs to address the following requirements.

- Identify critical groups of people and special areas potentially affected by the mining operation.
- Define location of monitoring sites for water or atmospheric monitoring.
- Define access limitations for protection of cultural/heritage sites and check regularly for employee knowledge of restrictions.
- Define diet components for food contaminant uptake studies.
- Use standard sample collection and preservation techniques as included in AS 2031.
- Choose appropriate analytical methods to achieve maximum sensitivity and reliability of test results (Appendix 1).

ANALYSIS AND REVIEW OF RESULTS	COMPLIANCE REQUIREMENTS	OTHER DETAILS
Results compared with historical data. Reviewed monthly and annually as part of the annual report.	Dust must be minimised.	
Results compared with historical data. Reviewed monthly and annually as part of the annual report.	Must monitor performance of aquifer.	
Results compared with historical data. Reviewed 2 times per year and reported in annual report.	Must monitor water quality.	
Compare results with historical data. Reviewed annually for annual report.		Additional research programs undertaken by other Hamersley iron divisions.
Results compared with historical data. Reviewed monthly and annually for annual report.	Stormwater and drainage water to be treated to remove contaminants.	
Species density and diversity and % cover compared between sites and over time. Biannually/as required.		
Species density, diversity and % cover compared between sites and over time. Biannually/as required.		

- Use photographic and mapping techniques to monitor protection of/damage to special areas.
- Use appropriate quality control procedures for checking reliability of test results.
- Define appropriate liaison techniques for consultation with relevant groups of people.
- Evaluate and review test results/observations and adjust monitoring program and/or practices.

The Ranger Case Study provides an example of a blast monitoring program to minimise impacts on a cultural site.

2.3 DATA COLLECTION, EVALUATION AND PRESENTATION

A well planned monitoring program will detect trends and changes to enable intervention/remedial measures to be taken in order to achieve good environmental performance. Within each scientific and technical discipline there are appropriate techniques for collection, analysis and interpretation of data. Interpretations need to be inter-disciplinary to ensure balanced assessments. Care also needs to be taken to ensure compatible levels of accuracy and precision between related data sets in a monitoring program. Box 5 shows the desired features of a monitoring program that will ensure effective information management.

Monitoring information is gathered from areas and points. Maps are an essential data presentation tool and for most purposes maps or an aerial image at 1:5 000 scale are sufficient. A scale of 1:10 000 is adequate for catchment maps and general site maps. The scale of mapping indicates the detail expected. For example, Figure 3 indicates the intensity of vegetation sampling required for a range of map scales. Where more than one mine operates within a region, joint monitoring programs are appropriate. An example of this is shown in Figure 4 where the key land uses within the Pieman River Catchment in Tasmania include mining at four sites and hydro-electricity generation. In this case an integrated, joint monitoring program was implemented.

Review of monitoring information enables evaluation of progress and identification of trends.

BOX 5 — ENVIRONMENTAL INFORMATION MANAGEMENT

Effective monitoring programs have the following features for effective data collection and management:

- realistic sampling program (temporal and spatial);
- sampling methods relevant to source (point source, aerial, 3d);
- collection of quality data;
- compatibility of new data with other relevant data;
- cost effective data collection;
- quality control in measurement and analysis;
- innovations (eg in tracing contaminants and automated stations);
- appropriate databases;
- multi-disciplinary data interpretation to provide useful information;
- reporting for internal management and external checks; and
- presentation in public arena (external assessment).

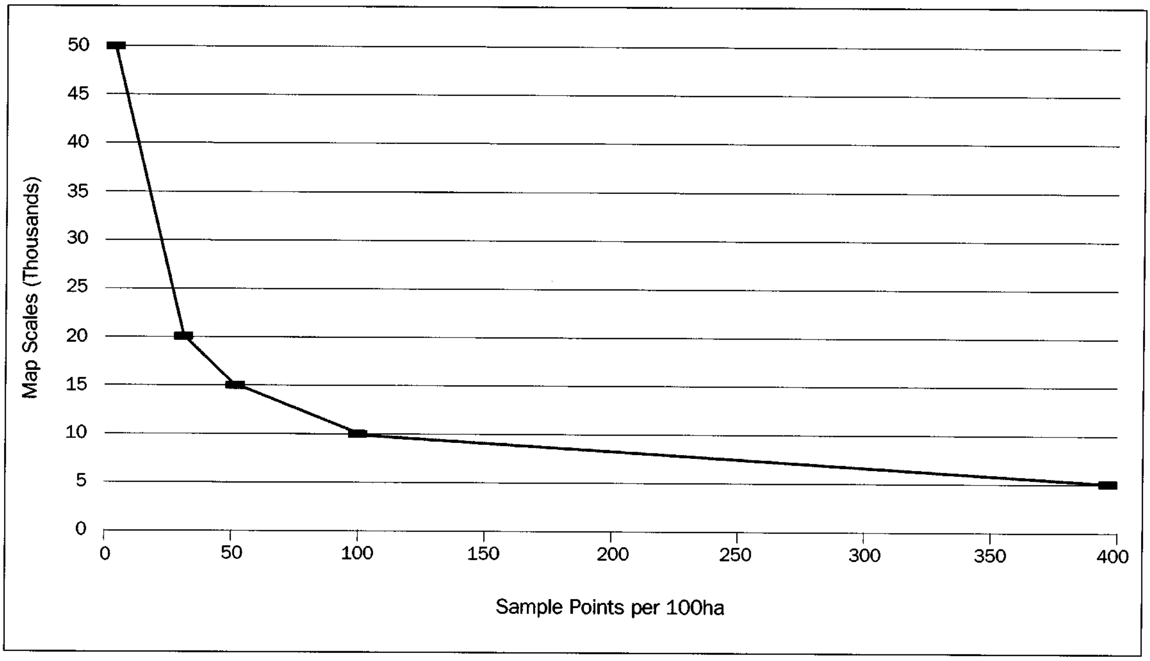


Figure 3: Vegetation Monitoring — Sampling intensity for different map scales.

JOINT MANAGEMENT OF THE PIEMAN RIVER CATCHMENT

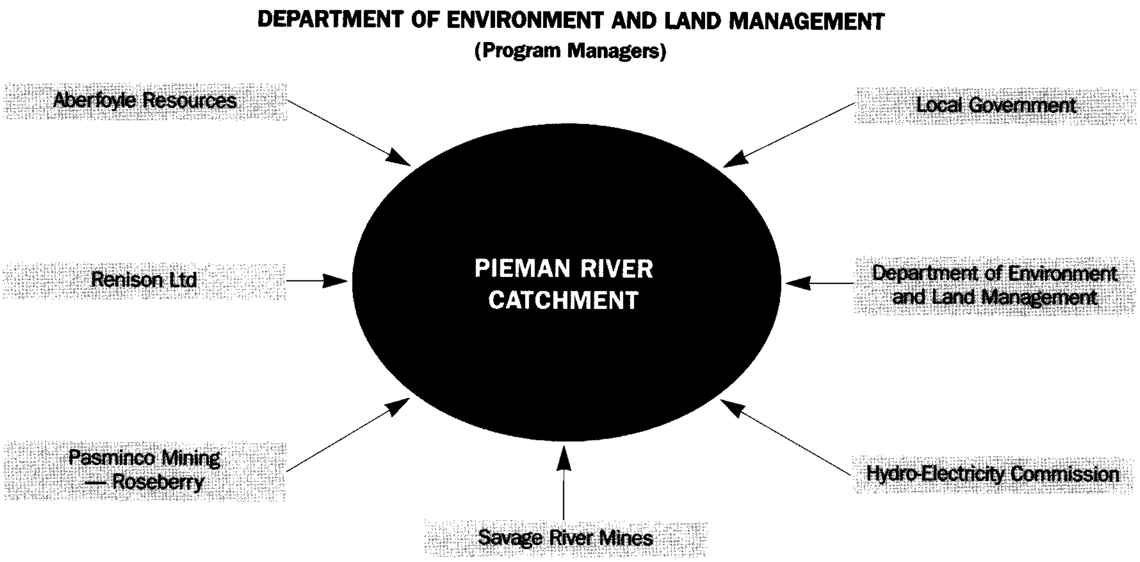


Figure 4: An integrated catchment monitoring program (Tasmania).

The information is analysed by assembling monitoring data in the form of maps, photographic records, data tables and graphs.

Monitoring programs provide time series data which are readily analysed from time series graphs. This can be done by visual qualitative assessment of the graphs or by testing statistical significance of variations, determining rates and directions of change or noting the approach to, or exceedence of, critical levels (eg. water quality guideline levels). There are some relational changes such as relative proportions of chemical constituents in water which can be helpful when presented as triangular plots called Piper diagrams. Longitudinal studies based on numerical data, photographic or descriptive records also provide information on progress and trends. Figure 5 is an example of monitoring data which shows seasonal variation, an extreme event (drought) and the regulator's independent checks on company data.

Computer databases are not merely repositories for data. They can incorporate routines for checking trends, exceedences and compliance. A complex relational database is used by the Northern Territory Department of Mines and Energy for both compliance

CASE STUDY 4

COAL AND ALLIED — MOUNT THORLEY OPERATIONS
Environmental Monitoring Program and Performance Assessment

AREA	FREQUENCY	PROCEDURE
Water	7 monitoring stations (EPA Licence, Condition A17 [iii])	Monthly and/or during overflow events
	7 monitoring stations (Schedule 11 of the *Clean Waters Act, 1970*)	Quarterly (Done to set baseline data).
Dust	11 depositional gauges located around the site (EPA Licence Condition A17[i])	Monthly
	1 high volume sampler located at Tutts Shed (EPA Licence, Condition A17 [ii]).	One day in six.
Noise	7 locations on, and around, the site (EPA Licence, Condition A17 [iv]).	Quarterly.
Meteorology	Automatic weather station on Tharah Dump (EPA Licence, Condition A17 [vi])).	Continuous.
Vibration	2 blast monitors (overpressure and ground vibration) located at Pike's Property. EPA licence condition.	Each blast (one fixed and two portable units).

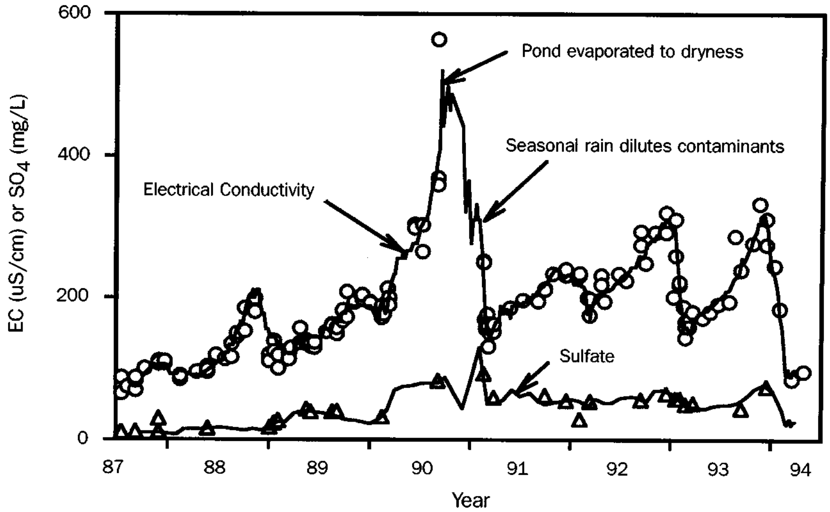
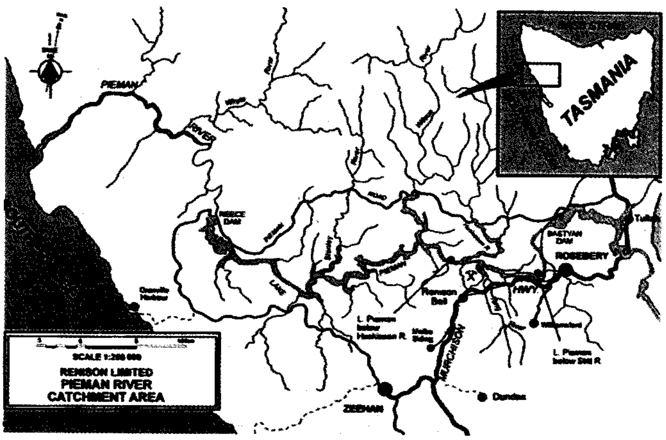


Figure 5: Company monitoring results (continuous lines) show seasonal and long term trends in water quality. Regulator's independent checks (○, △) show integrity of company monitoring.

ANALYSIS AND REVIEW OF RESULTS	COMPLIANCE REQUIREMENTS	OTHER DETAILS
Collection by site, analysis by Envirosciences or Australian Coal Industry Research Laboratories. Results tabled.	Done monthly to assess regional quality. Results checked against ANZECC guidelines.	No discharge licences, therefore very conscious of regional quality.
Collection by P Zib & Assoc. analysis by RW Miller Laboratory (C&A). Reported on a monthly basis and checked for levels.	Done in conjunction with meteorological data Reviews undertaken to assess control . effectiveness	Done in accordance with EPA and Australian Standards.
Undertaken by Caleb Smith Consulting. Reported and tabled for comparison.	Done quarterly to address any impact.	A.S. 1055-1989.
Undertaken by P Zib & Assoc. Tabled and reviewed.	Can be done instantaneously.	No real compliance but data used as assessment tool.
Site/R W Miller personnel. Tabled for analysis.	Done following each blast. To assess levels.	Last year 350 blasts with only 2 exceedences.

evaluation and research. However, spreadsheets are adequate for most monitoring programs and disks in standard formats (eg. DOS, Windows and Macintosh) in common application (Lotus, Excel) can be readily translated. Most of these products are then used for presentation of results and to evaluate environmental performance. All monitoring data are typically appended to environmental reports and made available in electronic form.

The key information products from monitoring include periodic performance reports to government and public reports. Reports to the regulating authority should address the commitments made in EMP, be fully referenced with all statements and recommendations justified.



The Pieman River Catchment Monitoring Program is a coordinated program involving key catchment land users to ensure the protection of aquatic ecosystems.

2.4 COSTS OF IMPLEMENTING AN ENVIRONMENTAL MONITORING PROGRAM

Specific activities designed to achieve best practice environmental management carry a direct financial cost that must be accounted for in any operation. The case studies included in this module show that costs of environmental monitoring programs vary greatly according to the needs of a particular project. For example, for the Northparkes operation (Case Study 5) is a large open-cut and underground copper and gold mine in the central west of New South Wales where wheat and sheep enterprises dominate. The mine's environmental monitoring program costs approximately $350 000 per annum.

By comparison, the smaller Ranger uranium mine (Case Study 6), located in the Kakadu National Park region, has monitoring costs of approximately $1,000,000 per annum due to the sensitivities associated with uranium mining adjacent to the Kakadu wetlands.

However, these costs can generally be offset against the many financial benefits this best practice brings. These can include direct and immediate cost savings such as avoiding unacceptable environmental impacts.

Longer term gains include decreasing future costs for decommissioning and improving the acceptability of a successful operator's future mining proposals. While it is not easy to put figures against these benefits it is easy to see that the up-front cost of best practice in environmental monitoring programs reaps long term gains for the mining industry, the community and the environment.