Exploring the EIA/Environmental Management Relationship: Follow-up for Performance Evaluation

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1. Introduction

Environmental impact assessment (EIA) follow-up studies or audits can be conducted for a variety of reasons. Previously many audits have focused on scientific aspects of EIA, particularly the utility and accuracy of impact predictions (eg. Bisset 1984, Culhane *et al.* 1987, Buckley 1991, Bailey *et al.* 1992). More recent studies have emphasised other aspects of EIA performance including monitoring programmes and environmental outcomes (eg. Environmental Protection Department 1995, Au and Sanvicens 1996, Arts 1995, 1998). This paper presents the results of an audit of six projects that have undergone EIA in Western Australia that focuses on environmental management outcomes. The emphasis is on the actual impacts that occurred once the projects became operational and the environmental management actions (mitigation) undertaken to avoid or minimise impacts. To achieve this required some consideration of impact predictions as well as a detailed examination of environmental monitoring programmes for the case studies.

Background information on the role of environmental management in EIA in Western Australia is presented in Bailey (1997) and a complete account of the environmental management audit study results discussed here can be found in Morrison-Saunders and Bailey (1999). In this audit, environmental management activities were examined with respect to three stages of EIA based on the principal approval decision point–predecision stage (activities identified prior to decision-making on a project such as preparation of environmental impact statements and public review), postdecision stage (eg. activities that originated when the project was constructed and implemented) and transitional stage (activities identified during the predecision stage but subject to further investigation and modification during the postdecision stage). This paper presents the results of the management audit study, including some practical examples and concludes with some future directions for EIA follow-up and reflections on the role of science in EIA.

2. Objectives of EIA Monitoring & Auditing

Arts & Nooteboom (1999) identify four purposes of EIA monitoring and auditing programmes as follows:

- integrate with other existing environmental information such as state of the environment reports and environmental management systems;

- improve scientific knowledge. For example, feedback from prediction accuracy audits can be used to improve EIA predictions for future projects, and ecological monitoring programmes can improve scientists' understanding of environmental cause-effect relationships;
- public acceptance and legitimisation. Ongoing monitoring and audit programmes may allay public concerns about the effects of a particular activity or project leading to improved public acceptance of proposals. The results of such programmes may also legitimise the EIA decision-making process if it is evident that the environment is being protected adequately; and
- controlling of projects and their environmental impacts. Compliance audits can verify that projects have been correctly implemented and are being operated in accordance with approval conditions and relevant environmental standards. Environmental monitoring programmes provide feedback on the actual impacts that arise from a project, thereby enabling these to be understood and managed.

The emphasis of this study is on the last objective as the management audit reported on here focuses on environmental performance evaluation for projects that have undergone EIA. Before introducing the environmental management audit approach, it is worth noting some of the shortfalls of other EIA audits.

3. Problems With Some EIA Audits

In previous research Bailey *et al.* (1992) undertook prediction accuracy and compliance audits for a number of Western Australian case studies in order to evaluate EIA performance. While these audits provided useful feedback on aspects of the EIA process in Western Australia, they were not able to determine the extent to which the environment was actually protected and managed by the EIA process. As Carbon (1995) stated:

> Those who are concerned with the accuracy of environmental predictions should focus instead on the effectiveness of management processes to protect the environment. The important question to ask afterwards is 'was the environment protected?'

In this research it is argued that ideally EIA audits should provide information on environmental management performance.

The problem with prediction accuracy audits is depicted in Figure 1. If a prediction that 'no impact is expected to occur' turns out to be accurate or a prediction that expects an impact to occur turns out to be inaccurate, then in both cases no environmental impact actually eventuates. This means that the prediction accuracy audit findings, which are normally expressed as the percentage of accurate or inaccurate impact predictions, do not provide any feedback on actual environmental outcomes for the projects investigated. While it is clearly desirable to obtain a high level of predictive accuracy in EIA, this information may not communicate useful information on what changes actually occurred in the environment when a particular project was implemented.

Prediction		Outcome
No Impact	➔	Accurate
Impact Expected	➔	Inaccurate

Figure 1. Prediction audit problem

A similar problem can arise with compliance audit findings. It is generally assumed that compliance by the proponent with EIA conditions of approval will be sufficient to protect the environment. However this depends upon the wording of specific approval conditions themselves. In some cases where the proponent is required to comply with a particular procedure or meet a particular standard, a compliance audit may not generate any feedback on the actual environmental impacts and performance obtained. An example of a shortfall in compliance audit findings with respect to performance evaluation for an oilfield project is presented in Section 7.

4. EIA/Environmental Management Model

To address the shortfalls in earlier EIA audits, an EIA/environmental management model was devised (Morrison-Saunders and Bailey 1999). This model focuses on discrete environmental management activities undertaken as part of project level EIA. It involves documenting all EIA events from the early stages of project planning right through to project implementation and ongoing operations with particular emphasis on recording all environmental management activities both proposed and undertaken in practice. Assuming that EIA does influence environmental management performance for individual projects, the model seeks to determine when this influence occurs by considering which stage of the EIA process provided this influence.

The EIA process can be divided into three different stages based around the principal approval decision as follows (Morrison-Saunders and Bailey 1999):

- the predecision stage includes activities such as project planning, impact identification and prediction, initial design of environmental management and monitoring actions, preparation of environmental impact statements (EIS), public consultation and approval conditions established by EIA decision-makers. With respect to environmental management activities, the emphasis is on *proposing management actions* that will either avoid or minimise adverse environmental impacts when the project is actually implemented;
- the postdecision stage refers to all activities that eventuate after approval has been granted to proceed with a particular project, which includes the identification of actual environmental impacts (i.e. from impact monitoring programmes) and the implementation of management actions originally proposed in the EIS or subsequently devised in response to observed impacts. The emphasis here is on the actual *management of environmental impacts*; and
- the transitional stage overlaps with both the predecision and postdecision stages of the EIA process. This occurs when the EIA process establishes some important environmental management provisions during the predecision stage that require ongoing attention and modification during the postdecision stage. One example of this frequently used in Western Australia is the establishment of environmental management objectives (i.e. during the predecision stage) that proponents are bound to comply with, but are not constrained in how to do so during subsequent project implementation (i.e. postdecision stage) (Bailey 1997). The emphasis here is on *adaptive environmental management*.

In the management audit based upon this conceptual model of EIA, the focus is on linking the identification of discrete environmental management activities with the relevant stage of EIA where this originally took place.

5. Methodology

Six case study projects that have undergone EIA in Western Australia were selected for examination. These comprised two water supply dams, an offshore oil and gas production facility, an ocean wastewater outfall, a mineral sands processing plant (synthetic rutile plant), and a chemical manufacturing plant (sodium cyanide plant). A description of the case studies is provided in Morrison-Saunders and Bailey (1999). For each of the case studies, information on four distinct components of EIA was collated as follows:

- the identification and prediction of potential impacts in predecision EIA documents. A total of 340 impact predictions were recorded.
- the occurrence of actual impacts as a result of project implementation. A total of 75 individual impacts were recorded;
- the design and implementation of environmental management activities to address potential impacts and actual impacts for each project. There were 284 discrete environmental management actions proposed and/or undertaken in practice; and
- the design and implementation of environmental monitoring programmes. There were 113 individual environmental parameters proposed to be, or were actually monitored in practice.

Information on each of the case studies was gained from the available EIA documentation including the proponent's EIS, assessment reports prepared by the Environmental Protection Authority (EPA) during the decision-making process and follow-up monitoring reports prepared by proponents. Additional information was obtained from interviews with staff representing both proponents and the EPA as well as site visits. The information was stored in a computerised data base.

6. Management Audit Results

Key results from the management audit study are presented in this section. For simplicity, the results for the six case studies have been grouped as total figures and as percentages. A complete breakdown of the results on a case by case basis is presented in Morrison-Saunders and Bailey (1999).

Impact predictions and related environmental management activities

The impact predictions were examined to determine the extent to which they conform with the ideal rational-scientific format in a manner similar to that of Culhane *et al.* (1987). They were also matched with environmental management actions to determine whether predicted impacts were responded to by project managers.

It was found that the scientific basis of predictions had no bearing on how these were utilised in the EIA process with respect to the formulation of environmental management activities. Predictions expressed in vague and qualitative terms were equally likely to have management actions associated with them as the more scientific, quantitative impact predictions. Hence there was no connection between predictions expressed in accordance with rational-scientific ideals and environmental management outcomes. However, it was found that predictions addressing important issues identified by the EPA for each project were more likely to have a corresponding management action than others. In other words, the EIA process effectively channelled effort onto environmental issues of concern to decision-makers. If appropriate environmental management action is the most important outcome of the EIA process, then it appears that impact identification accompanied by an evaluation of importance may be more valuable than engaging in rigorous quantified prediction, especially if the resources available to conduct the predecision stages of EIA are limited.

Reasons why predicted impacts did not occur

One important measure of the success of EIA in protecting the environment used in this study relates to the avoidance of predicted impacts through environmental management strategies. Predicted impacts were compared with the list of impacts that were actually identified for each case study, and where a predicted impact had not occurred, the reason for this was determined (Table 1).

Why Didn't Impact Occur?	No.	
Successful Environmental Management to Avoid Impact	47	*14%*
Design Change to Avoid Impact	2	*<1%*
Accurate Prediction (i.e. a prediction of no impact was found to be correct)	57	*17%*
Inaccurate Prediction (i.e. impact expected to occur but didn't)	12	*4%*
Other Explanation	37	*11%*
No Information Available to Verify	49	*14%*
Not Applicable (i.e. the predicted impact did occur in practice)	136	*40%*
Total	340	*100%*

Table 1. Reason why predicted impacts did not occur

Overall, 60% of the predicted impacts had not eventuated in practice at the time of the audit. For each case study there were examples where the implementation of planned environmental management actions successfully avoided the occurrence of predicted impacts (14% of predictions). Other reasons why predicted impacts did not eventuate in practice relate to the issue surrounding predictive accuracy discussed previously (21% in total) as well as other explanations (11%). For 14% of impact predictions, there was insufficient information available to determine whether or not an impact had occurred, highlighting a deficiency in environmental monitoring programmes for the six case studies.

Predictive success and related management activities

Unlike the predictive accuracy audits of Culhane *et al*. (1987) and Bailey *et al*. (1992), predictive success was classified in this audit in the context of the occurrence of actual impacts (Table 2). All six case studies were found to have some impacts that were inaccurately predicted, although three of them did not record any new or unexpected impacts. Hence the actual identification of potential impacts during the predecision stage of EIA was successful for these three projects even though they were not all accurately predicted. It should be noted that additional environmental impacts may have occurred in practice for all of the case studies which have not been detected owing to deficiencies in environmental monitoring programmes.

Predictive Success	No.	
Accurate	43	*57%*
Inaccurate	22	*29%*
Unexpected	10	*14%*
Total	75	*100%*

Table 2. Success at Predicting Impacts

For many of the impacts, a management response was not required: these included the beneficial effects as well as the inevitable and/or accepted adverse outcomes of the projects that could not be avoided or minimised in any way. Only three impacts from the six case studies were not responded to by project managers, where a response could have been initiated. It was found that a management response was instigated for many of the observed adverse impacts irrespective of whether they had been identified in impact predictions (either accurately or inaccurately) or were new and unexpected impacts. Overall 25% of observed impacts were inaccurately predicted or unexpected but were associated with an environmental management activity. Bailey *et al*. (1992) and Bailey (1997) have previously noted that environmental management responses can occur in relation to inaccurately predicted impacts and also in the absence of any impact prediction. The results reported on here further highlight the value of issue identification in EIA for environmental management over an emphasis on rigorous impact prediction.

Implementation of proposed management actions

The proportion of environmental management activities proposed prior to the principal approval decision point for individual case studies ranged from 87% to 100% (95% averaged overall) and so it is of interest to examine the extent to which these were implemented in practice once the projects became operational. Whilst similar to a compliance audit, the main difference here is that this research focused upon any proponent commitments or suggestions made by EIA decision-makers for environmental management activities specifically. This may extend to proposals not included in approval conditions whilst leaving out other approval conditions not specifically related to management activities (eg. the requirement for proponents to prepare annual reports on their projects) and thus produces a different suite of activities to study to that of a compliance audit.

The implementation status of proposed environmental management is shown in Table 3. A high implementation rate (87%) was evident. Very few proposed management actions were not implemented but could have been (3%), some related to future events (eg. project decommissioning stage) so were not applicable at the time of the audit (4%) and two could not be verified due to a lack of information (1%). The remaining 5% of management activities were new actions that were not recorded in the predecision or transitional stage EIA documentation (eg. a response to an unexpected impact).

Was Proposed Management Action Implemented?	No.	
Yes	249	*87%*
No	9	*3%*
Not Applicable Yet	10	*4%*
No Information	2	*1%*
New Action	14	*5%*
Total	284	*100%*

Table 3. Implementation of proposed management actions

The high implementation rate of management actions for this research indicates that projects proceeded largely as proposed during the predecision stage of EIA. In other words, the planning stages of projects were largely successful in establishing how the projects would be implemented in practice (Morrison-Saunders and Bailey 1999).

The implementation status of proposed environmental management actions was examined with respect to their legal status. It was found that voluntary commitments by the proponent and non-binding recommendations for management were equally likely to be implemented as their legally binding counterparts. It is particularly noteworthy that a 100% implementation rate was recorded for the ocean outfall project which was assessed under the early EIA procedures in Western Australia at a time when there were no provisions for making EIA approval decisions legally binding. These findings suggest that having a legal basis for EIA approval conditions is not a prerequisite for ensuring that appropriate environmental management occurs.

Origin of environmental management actions

Table 3 established that 5% of management actions originated during the postdecision stage of EIA for the six case studies. These were mostly responses by proponents to unexpected impacts. Of the remaining 95% of management actions, 80% originated during the predecision stage (Table 4). These included proponent commitments to specific project design requirements, operation standards and procedures, and other actions aimed at avoiding or minimising the occurrence of potential impacts. The EPA also contributed to predecision environmental management actions with recommendations for proponents to follow a particular course of action. The results clearly indicate that the greatest influence of EIA in terms of the number of management activities occurs during the predecision stages of the process (i.e. making available important information on how projects should proceed up to the time at which the principal approval decision is made).

The remaining 15% of management actions originated during the transitional stage of EIA. Most of these were EPA recommendations that either established management objectives for the proponents to meet or required reports and environmental management programmes (EMPs) to be undertaken on particular issues. In some cases proponents also made commitments to undertake EMP studies or their equivalent. The common factor linking these transitional activities was the establishment of management objectives during the predecision stage of EIA that required ongoing attention during the postdecision stage, thereby promoting an adaptive management approach.

Origin of Management	No.	
Predecision Stage	226	*80%*
Transitional Stage	44	*15%*
Postdecision Stage	14	*5%*
Total	284	*100%*

Table 4. Origin of environmental management actions

Origin of environmental monitoring activities

A similar examination of the origin of environmental monitoring activities was undertaken (Table 5). In contrast to the environmental management activities, relatively few monitoring activities were specified in the predecision stage (25%). Instead, there was greater emphasis on the transitional stage of EIA (46%). This reflects the common practice of prescribing EMPs during the predecision stages of EIA in Western Australia for which the details are finalised by the proponent during the postdecision stages (Bailey 1997). In these cases the environmental parameters to be investigated were identified in the predecision EIA documentation but the particular monitoring technique was not specified. The exact monitoring details were resolved once project approval had been granted and detailed environmental investigations were being undertaken.

Origin of Monitoring	No.	
Predecision Stage	28	*25%*
Transitional Stage	52	*46%*
Postdecision Stage	33	*29%*
Total	113	*100%*

Table 5. Origin of environmental monitoring activities

Many new monitoring programmes were developed in the initial EMP documents prepared during the postdecision stage of projects, but prior to project implementation (i.e. developed as final project design details became available). This requirement for an EMP to be prepared, therefore, appears to have provided the opportunity for proponents to focus monitoring efforts on particular issues. These monitoring activities were classified in the postdecision stage of EIA (29%).

Taken as a whole, the results for the origin of environmental monitoring activities indicate that a flexible and adaptive approach to monitoring was adopted. For the public, this should be a satisfactory outcome of EIA as it is evident from project decision-making that the proponent is expected to undertaken environmental monitoring even if the exact details are not specified at that time. For proponents, this flexible approach is advantageous as they do not need to invest time and financial resources on monitoring activities until the approval to commence has been granted. However, from a scientific point of view, this approach may be undesirable as it will reduce the opportunities for baseline monitoring to be undertaken prior to project implementation.

Relationship between monitoring and management activities
Some shortfalls in environmental monitoring programmes have previously been identified which meant that some impact predictions and the implementation status of some management activities could not be verified. Despite this, there was a strong link evident between monitoring and environmental management activities (Table 6). The majority of monitoring programmes (62%) were related to one or more management actions in some way suggesting that 'monitoring for management' was occurring. If adaptive management is to result from EIA, it is important that environmental management actions are enacted in response to monitoring outcomes.

Any Associated Management?	No.	
Yes	70	*62%*
No	9	*8%*
Not Required	34	*30%*
Total	113	*100%*

Table 6. Relationship between monitoring and management activities

7. Examples From the Management Audit

To illustrate how environmental management activities for the predecision, postdecision and transitional stages of EIA materialised in practice, three examples from the six case studies are presented.

Predecision Environmental Management: Sodium Cyanide Plant
The sodium cyanide plant is an industrial plant that manufactures sodium cyanide for use by the gold mining industry in the extraction of the metal from gold bearing ore. The plant is located in an industrial area situated within the metropolitan region of Perth, the capital city of Western Australia. EIA of the plant was undertaken in 1987.

In assessing the proposal, the EPA found the proposed sodium cyanide plant to be environmentally acceptable in the proponent's preferred location. However, it did not approve of the proposed transportation by road of the sodium cyanide product from the plant site to the gold mining areas of the state where the product is utilised. The principal concern related to the proposed transport of sodium cyanide solution through urban areas and designated surface and groundwater catchment areas. In the event of a road accident resulting in spillage of the sodium cyanide solution, it was maintained that serious water contamination and/or human injury could result. Consequently, the EPA recommended that the proposal as put forward in the original EIS not be approved for this reason (EPA 1987a).

During the EPA's assessment process, several alternatives to road transport of liquid sodium cyanide were examined including the use of rail transport and the transport of solid sodium cyanide by road tankers. Hence, although the EPA had recommended against the proposal as put forward in the original EIS, they were actively suggesting ways of making the project environmental acceptable. In May 1987, the proponent submitted a second EIS outlining a proposal to transport sodium cyanide solution by rail. The second EIS included a quantitative risk analysis of the various transport options and scenarios which indicated that rail was the safest option. In assessing the modified proposal, the EPA concluded that subject to a number of conditions, the transport of sodium cyanide solution by rail through urban and designated water catchment areas to rail terminals which were as close as practicable to the intended markets (from which point road tankers would be used) was environmentally acceptable (EPA 1987b). The plant was subsequently constructed and commenced operations in 1988.

This example demonstrates how an environmental issue central to project decision-making was resolved during the predecision stages of EIA. In this case, an iterative approach to EIA was adopted which enabled the proponent to proceed with the project after initially being denied approval. It is interesting to note that in 1994/95 a further EIA was conducted for this project following which some road transportation of sodium cyanide from the plant was permitted. This proposal was based on the proponent's successful road transport record from rail terminals to mine sites without incident, the availability of new data on the safety of road versus rail transport and impending closure of several rail routes (EPA 1995).

Postdecision Environmental Management: Saladin Oilfield Development

This case study provides an example of an adaptive environmental management programme instigated during the postdecision stage of EIA in response to scientific uncertainty on environmental performance outcomes. The Saladin oil field, located 25km offshore from the north-west coastline of Western Australia and immediately adjacent to Thevenard Island, has been developed by West Australian Petroleum Pty. Limited (WAPET). Thevenard Island, which is approximately 5km long and 1km wide, is a designated nature reserve for the protection of native flora and fauna. Oil has been pumped from four offshore and three onshore wells since 1989. Oil production and storage facilities plus staff accommodation have been located on a small lease area at one end of the island. The treated oil is pumped through a 7km offshore submarine pipeline to a tanker mooring in deep water (WAPET, 1992).

The project was subject to EIA in 1987. One of the requirements of the EIA decision-making process was for the preparation of an EMP document prior to project commencement. This was duly completed in 1988 and outlined the proposed environmental management and monitoring activities to be undertaken by the proponent. In both the EIS and EMP documents, considerable emphasis was placed on the risk of oil spills and many impact predictions were dedicated to this issue. One of the EIA conditions of approval required the preparation of an oil spill contingency plan which outlined management measures to be undertaken in the event of an oil spill (EPA, 1987c).

In practice there had been no major oil spills up to the time of this audit. This can be attributed to the high level of standard industry safeguards utilised by the proponent. The EIA for this project was one of the first produced for the oil industry in WA and consequently there was little information or guidance on what issues to focus on. Participants interviewed for the research suggested that a disproportionate amount of attention was given to the risk of a major oil spill occurring, which in terms of the industry standards adopted is fairly unlikely to occur, while many of the more serious potential long-term and ongoing impacts such as the disposal of produced water were given relatively little attention (Morrison-Saunders 1996a).

The material extracted from each of the production wells contains a mixture of oil, gas and water which is pumped to the processing facilities on Thevenard Island for separation. Once the oil and gas have been recovered, the remaining 'produced water' which contains residual oil plus residual levels of treatment chemicals such as biocides, corrosion inhibitors, scale inhibitors and oxygen scavenger, requires disposal. Originally, the produced water underwent a number of cleanup stages before being commingled with the reverse osmosis water supply plant waste and sewerage treatment plant water from the island workforce facilities. This combined wastewater was then discharged into the ocean in water of 15m depth via an approximately 1km offshore pipeline at rates up to 2,940m^3/day (WAPET, 1993). A legally binding EIA approval condition required that oil in water concentrations discharged from the water treatment plant should not be greater than 50 mg/l (EPA, 1987c). Subsequent monitoring reports compared the results of water quality monitoring with this criteria. While the criteria was exceeded from time to time, it was generally found to be complied with (WAPET, 1993).

Despite compliance with EIA approval conditions, some concerns existed regarding the potential environmental impact of the wastewater outfall. The produced water represented a potential long-term chronic impact of oil and the other contaminants on the marine environment rather than the short-term acute affects that would be associated with a major oil spill event. Monitoring programmes that targeted this issue included dilution and dispersal modelling of the wastewater outfall plus marine biological monitoring of coral, seagrass and algae growth patterns and sediment hydrocarbon concentration. No adverse environmental impacts have been detected by the biological monitoring programme (WAPET, 1993). However, it may be that environmental change has occurred which the monitoring programme was not able to detect. In reporting on the biological monitoring programme in Appendix 4 of the 1992 triennial monitoring report it was stated that:

> The complexity and variability in community structure and population dynamics coupled with the relatively small and unreplicated transect areas which are being monitored, is a potential concern because the present programme lacks the sensitivity to detect all but gross and acute (mortality) effects of a major oil spill should one occur. For example, without replicate transects to ascertain the extent of within-site variation, chronic and gradational effects would be difficult to detect (WAPET, 1992).

Hence a potential adverse environmental impact may have occurred that has gone undetected despite the implementation of monitoring programmes.

WAPET have addressed the uncertainty surrounding the management of this issue by making changes to their wastewater disposal methods. This came about following the discovery of holes and leakages in the ocean outfall pipeline several years after project commencement. The leakages meant that some of the waste water was being discharged into relatively shallow waters near Thevenard Island. Initially the management response was to patch up the pipeline leak points. However, this proved to be inadequate as new leak points developed. WAPET identified a number of options including re-lining or completely replacing the pipeline and alternative discharge via disposal wells. The latter option was adopted in practice. From March 1995, produced water has been discharged into disposal wells drilled approximately 600m below the surface of Thevenard Island. At the time of the audit, treated sewage wastewater from the island workforce facilities and reverse osmosis plant reject water continued to be discharged by the ocean outfall. However, within the near future, WAPET have planned for the treated sewage wastewater to be discharged on Thevenard Island via leach drains which will assist in groundwater recharge (Morrison-Saunders 1996a).

The changes to the wastewater disposal methods for the Saladin Oilfield development provides a good example of the evolution of new environmental management actions during the postdecision stage of EIA. By being pro-active in their project management and by adopting a precautionary approach, WAPET are now avoiding the occurrence of an ongoing potential adverse environmental impact and have sought to maximise their overall environmental performance.

Transitional Environmental Management: Big Brook Dam

A good example of environmental management initiatives initiated during the transitional stage of EIA occurred for a water supply dam project on a seasonal brook. The dam, which was subject to EIA in 1985, was constructed by the Water Authority of Western Australia (WAWA) to provide an unrestricted water supply to the Pemberton Trout Hatchery (which previously relied on the much smaller Pemberton Weir several kilometres downstream) and to supplement local town water supply (Morrison-Saunders 1996a). One of the concerns relating to the construction of this 7 metre high earth and concrete embankment was the interruption of upstream fish migration and in particular lampreys which travel from the ocean to the freshwater upper reaches of the brook to spawn (Morrison-Saunders 1996b). The lamprey larvae filter feed in permanent streams for 3-6 years before metamorphosing and swimming downstream to the ocean. Each year between August and November thousands of adult lampreys move up the rivers in the south west of Western Australia, including Big Brook, climbing quite considerable obstacles to reach their spawning grounds (Pen *et al.* 1991). In the EIS, it was predicted that the barrier problems created by the dam and a downstream gauging weir would be overcome by overland migration of lampreys at these points. In terms of environmental management strategies, the proponent made a commitment to maintain suitable surrounding vegetation to allow lampreys to manoeuvre around the dam wall via the banks of the brook. This management strategy was based on observations of lamprey mobility at Pemberton Weir which has similar surrounding vegetation to the Big Brook dam site.

As a condition of approval for the project, the EPA recommended:

> that the Water Authority of Western Australia, in conjunction with the Department of Fisheries and Department of Conservation and Land Management, establish a monitoring programme to determine the effect of the proposed dam on migratory species of aquatic fauna and the effectiveness of the remedial measures proposed in the [EIS]. The results of the monitoring programme should be provided on a regular basis to appropriate Government departments (EPA 1985).

In practice it was found that the dam wall design, including adjacent earthworks and landscaping treatment, was not conducive to lamprey movement. In 1987, during monitoring of the annual lamprey migration, it was observed that lampreys attempting to climb the steep sloping spillway of Big Brook dam were prevented from doing so by recessed expansion cracks in the face of the wall (WAWA 1989). The cracks were filled in to create a smooth surface in 1988. During subsequent monitoring, it was observed that lampreys successfully moved over the filled in expansion cracks but none managed to move more than 1-2m up the wall before being washed down. Lampreys attempting to leave the stream to migrate overland could not negotiate the sharp corners of concrete steps at the base of the Big Brook Dam (Pen *et al.* 1991).

It was also recorded that while large numbers of adult lampreys migrated upstream as far as the Pemberton Weir, relatively few lampreys actually reached Big Brook dam itself. This was due to the barrier created by the Pemberton Weir and also a small gauging dam (Rainbow Weir) situated between the Pemberton Weir and Big Brook dam (Pen *et al.* 1991). Both of these weirs have vertical walls which the lampreys can climb but they are frequently unable to negotiate the right angle bend at the top. Monitoring observations noted that the lampreys remained amongst the rocks at the base of the two weirs where their numbers built up over time. When the conditions became favourable for overland movement (dark nights during or immediately after rain when the ground was wet), they immediately took the opportunity to move upstream. While some lampreys were clearly successful in this (since several were observed at the base of Big Brook dam), hundreds of dead lampreys were found on the ground adjacent to the Pemberton and Rainbow Weirs. The observers concluded that the lampreys probably responded to the water which runs off the road and along the foot tracks leading to the weirs and subsequently got stranded away from the stream (Pen *et al.* 1991).

The researchers undertaking the monitoring made a series of recommendations to the project managers including the provision of a guided movement system incorporating a wire mesh fence around both the Pemberton and Rainbow Weirs. They also recommended staggering the rim of the dam wall to ensure that there would always be a zone where only a trickle of water was moving over the dam, smoothing the corners of the base steps to permit successful negotiation by lampreys and provision of additional steps to provide a second means by which lampreys could get over the dam wall when all sections of the rim of the wall were being over topped (Pen *et al.* 1991).

At the time of research the guided movement mesh system had been provided for the two weirs and some modifications carried out to the base of Big Brook dam. The project managers were waiting for a major lamprey migration event in order to observe what happens when large numbers of lampreys actually reach Big Brook dam itself. The position of the proponent determined from staff interviews was that modifications to the lip of the dam was an option that may be undertaken if proved to be necessary (Morrison-Saunders 1996a).

The management of the lamprey migration process for the Big Brook dam project provides a very good example of ongoing management and monitoring in accordance with a transitional stage requirement of EIA decision-makers. At the time of EIS preparation and assessment, the full consequences of dam construction and options for lamprey migration management were unknown. Hence it was appropriate to establish a flexible approach to management of this issue. The proponent has been responsive to observed problems including monitoring of the implemented remedial measures and has found alternatives where initial measures have proven to be unsuccessful. It is particularly noteworthy that the management regime established by the EIA process actually extended beyond the scope of the individual project under assessment to include the two existing weirs also the responsibility of the proponent.

8. Conclusions

The previous examples illustrate that the EIA process in Western Australia utilises a flexible approach which promotes ongoing and adaptive environmental management and monitoring. Environmental management activities originated from each of the predecision, postdecision and transitional stages with the latter providing the greatest opportunities for adaptive management to occur.

This paper has identified some limitations of previous approaches to EIA audits with respect to learning about actual environmental outcomes for projects. It is suggested that in the future the emphasis of EIA audits should be upon environmental management activities and outcomes in a similar manner to the management audit presented here.

The management audit has raised some questions concerning the role of science in EIA. Monitoring deficiencies and low accuracy in impact predictions indicate that the level of science in EIA is not as high as is desirable. However there is evidence that environmental management activities can result in the absence of rational-scientific impact predictions and monitoring programmes. It is clear from this that EIA involves more than just science alone. By generating environmental management outcomes at all stages of the process, EIA procedures may be able to provide a 'safety net' that can overcome problems when the science of EIA is lacking. This may be sufficient to ensure that adaptive environmental management occurs in practice. However a certain amount of science is clearly necessary to conduct monitoring and to determine what impacts actually occur. This raises the question of: how much science is needed in EIA?

EIA may be able to take guidance on the level of science necessary from the precautionary principle. When faced with high levels of uncertainty, which should invoke use of the precautionary principle, a greater level of science will be required in the design of management and monitoring activities. A flexible approach to management and monitoring will also be beneficial in these cases as the examples in this paper demonstrate. In other circumstances there may be cases where monitoring is required for socio-political reasons (Arts & Nooteboom 1999) but it does not necessarily have to be scientifically rigorous. Here, the science of monitoring simply needs to be sufficient to alert managers to initiate appropriate responses to real or potential impacts.

In conclusion, the key to effective follow-up and auditing requires a 'monitoring for management' approach that is flexible and which provides opportunities for adaptive environmental management.

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