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Using Traditional Ecological Knowledge to Develop Closure Criteria in Tropical Australia

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Abstract

The Northern Land Council is one of a number of similar statutory bodies created by the Australian Federal Government upon implementation of the Aboriginal Land Rights Act in 1976. One of its more important functions is to act as a land manager on behalf of Australian Aborigines living in the northern part of Australia's Northern Territory on Aboriginal freehold land. The ultimate and desirable outcome for rehabilitating exhausted mines is to leave the affected land in a state that has future value for use by subsequent generations. For companies to meet this goal, and ensure that stakeholder satisfaction is obtained, consultation with land owners prior to mine closure is essential. Although best practice now dictates that planning for closure should be undertaken at the commencement of the mining phase, this was often not done and represents a problem for older mines now facing closure. This paper describes practical means that have ensured effective consultation and achieved acceptable levels of stakeholder satisfaction. Achieving stakeholder satisfaction requires that traditional ecological knowledge is included in the mine closure process. Results demonstrate that both aboriginal and non-Aboriginal people perceive that there is a role for traditional ecological knowledge, not only for development of closure criteria, but throughout the environmental impact assessment process. A means by which this information can be obtained in a culturally sensitive manner, and used in conjunction with western science to achieve a mutually acceptable long-term outcome for mine rehabilitation, is presented. Outcomes are compared to those from systems in place in Canada and New Zealand, and barriers to success in Australia are discussed.

1 Introduction

As scientists, we strive to define environmental landscapes in physical terms so that we have points of reference against which we can assess our attempts at reconstruction where such is required. From the western scientific viewpoint, this is the fundamental reason for the development of mine site closure criteria. However, reconstruction of the biophysical environment's associated cultural and social landscapes is of equal importance to indigenous landowners, and represents an inestimably more difficult task, unless we, as scientists, can properly understand the cultural and social reference points that are held by those landowners.

For a long time, the association between the biophysical environment and socio-cultural health of indigenous societies was not recognized. While links of this nature are now recognized internationally (United Nations, 1999; Wolfensohn, 2004), development of meaningful policy and suitable practical guidelines to conserve them, or restore them once damaged or destroyed is still lacking. Consequently, the cultural and social reference points that represent cornerstones of indigenous society are often not considered when closure criteria are being developed, and as a result, many rehabilitation and closure plans are designed to meet the short-term needs of the mining company, and not the long-term requirements of indigenous society. This is of immense distress to traditional people, who have witnessed and endured the destruction of their own sustainable environment and socio-cultural systems only to see them replaced by damaged lands that offer little or no value to future generations.

To adequately address this, common ground must be established between western science and systems of traditional ecological knowledge. In order to achieve this, mining companies, regulators and practitioners need to engage fully with indigenous landowners when making decisions that affect their land. How we do this is no easy matter.

First, it is clear that if traditional ecological knowledge held by indigenous people is to have a role in mine site rehabilitation, meaningful and scientifically-defensible ways of integrating socio-cultural perspectives with environmental decision making processes must be developed. Systems have been set up in a number of

countries, but their value and success has yet to be demonstrated. For example, in the Yukon, mine reclamation and closure policies now require scientific, traditional and local knowledge to be considered by operators and government agencies during planning and implementation (Yukon Government, 2005). However, a study of indigenous involvement in six mining projects across Canada indicates that success in integrating traditional ecological and western science into a useable process has so far been limited (Cleghorn, 1999).

In a recent review of the remediation plans for the Anvil Mine complex (Chan et al., 2007) it is reiterated that the traditional values of First Nations people regarding the ecosystem need to be respected, and their spiritual connection to the land needs to be captured through a conscious effort to restore the spirit of place, even though the physical and biological features may be different to what existed prior to mining. Here, the clear implication is that whatever consultation process was put in place was ineffective, because traditional knowledge, if sought, was not included into the plans.

Second, if traditional ecological knowledge is used to develop mine site rehabilitation criteria, then systems capable of measuring whether or not the outcomes have been achieved to the satisfaction of indigenous people need to be designed. The Cultural Health Index used by the Maori to assess the health of streams and waterways (Tipa and Tierney, 2006), represents one of the first examples of the successful integration of traditional and western points of view that has led to the development of an appropriate decision making tool. Indices of this nature are of immense importance to indigenous groups, because they place western science in a context that they can understand – while also providing practical means by which they can assert their custodial role, and assess both environmental impacts and any progress towards rehabilitation.

As in New Zealand and the Yukon, Australian Aboriginal environmental knowledge contains a complex system of ecological and cultural indicators that are linked to the environment, and to cultural and social activities. For example, the flowering of the species *warrkarr* indicates to the Yolŋu of northeast Arnhem Land that it is time to harvest *marrandjalk* (sting-ray). Should the importance of this species not be recognized, and should it not be possible to reinstate it during mine site rehabilitation, an important cultural cue will be lost. The loss of cultural cues is a significant problem, because such cues contain lessons about survival, and how to use the environment in a wise and appropriate manner.

At a deeper level, the socio-cultural truth is far more complex, as this example also contains a spiritual component that remains undisclosed, except to those who have attained the correct level of initiation within tribal society. Taboos of this nature, a general reluctance to disclose information and nuances of language all contribute a degree of difficulty encountered when trying to uncover and use traditional ecological knowledge. Consequently, databases and geographical information systems that record traditional ecological knowledge are incomplete, and our capacity to place the information into its correct context, and use it effectively as a tool to assist in the rehabilitation process remains limited.

This paper presents an alternative and simple system that can be used to design rehabilitation plans and develop closure criteria that meet the expectations of indigenous landowners, fused with the rigor of western science. It entails a top-down consultative approach that is driven by traditional landowners, and is discussed within the context of its application to rehabilitation activities on two mines in Australia's Northern Territory, both of which already have broad closure targets defined by law. This paper also constitutes a small part of a much larger work being undertaken by the Northern Land Council that seeks to integrate traditional ecological knowledge with western science and to ensure that it becomes an integral part of all levels of environmental impact assessment in Australia.

2 Methodology

A questionnaire-style survey was first used to understand the perceptions held by Aboriginal people of how mining affects the environment, and to identify the matters that were of principal concern. The survey was undertaken with three culturally distinct groups of Aboriginal landowners (Biniŋ from the Jabiru region; Yolŋu from the Gove Peninsula; and Kurdanji from Borroloola), all of whom are affected by large mining projects. Individual responses to the questionnaires were recorded, followed by group discussions and the generation of a consensus response. Comparative responses from non-indigenous people living in the same locations were similarly recorded. These surveys were done in accordance with the ethical requirements of the Charles Darwin University in Darwin.

Two mines located in tropical Australia were identified to serve as case studies suitable for developing a process that can be used to derive closure criteria based on traditional ecological knowledge. These were the Ranger and Nabarlek Uranium Mines. Ranger is due to close in ten to fifteen years time, while Nabarlek is currently in its eighteenth year of rehabilitation. Both mines have broad-based environmental requirements that provide the company with direction toward closure, but do not serve as specific closure criteria.

Direct participatory dialogue with senior traditional owners about these environmental requirements was then undertaken, in order to determine what specific traditional knowledge was useful for input to the closure process. Consultation was undertaken in accordance with unpublished and confidential protocols and procedures that have been developed and refined by the Northern Land Council over the past thirty years. These protocols and procedures have no time limitations, and have been designed to reflect customary Aboriginal law.

Detail that provided a holistic view of the environment was first sought, followed by specific information relevant to each environmental requirement. This allowed identification of a list of landowner expectations that form the basis for future land use agreements, but which also included lists of specific flora and fauna species and estimates of appropriate populations within the final vegetation patterns. It was then possible to use computer graphics to simulate the post-mining environment and by implication, its function and performance. Finally, spiritual and cultural values were ascribed to the biophysical parts of the landscape and correlated against general scientific parameters. From these, generalized but key closure criteria that met indigenous landowner and scientific requirements were determined.

The process proposed here for incorporating traditional ecological knowledge into development of closure criteria is shown in Figure 1. Where scientific closure criteria had already been proposed for consideration by traditional owners, as had occurred for Ranger and Nabarlek Mines, the process commenced at the second line.

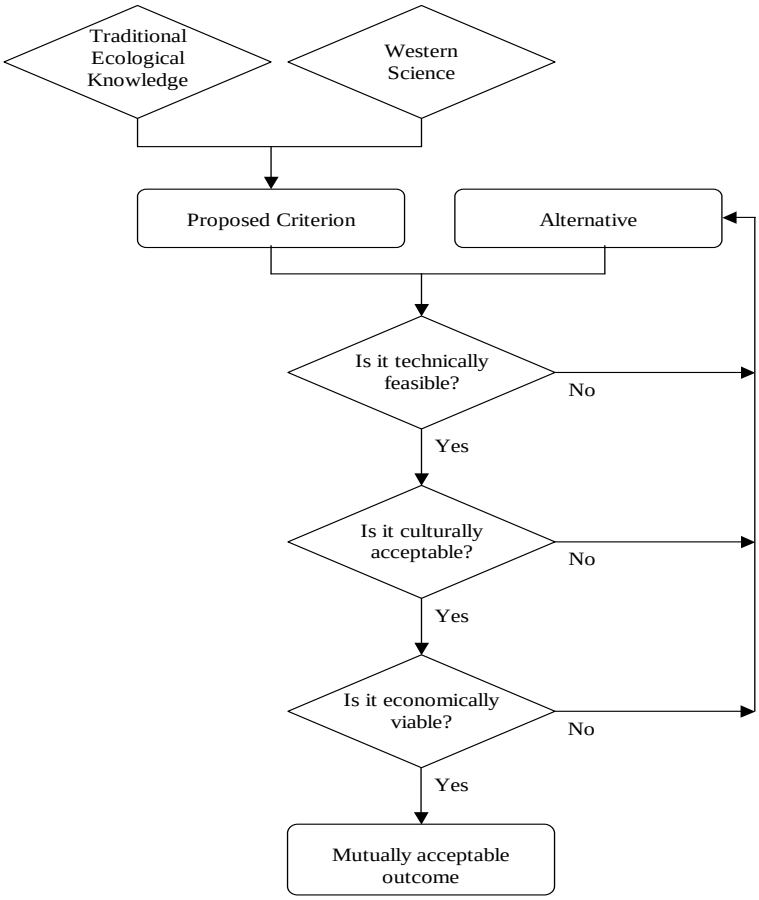

Figure 1 Flowchart of the process used for development of mutually acceptable closure criteria

3 Results

3.1 The perceptions of Aboriginal Australians in the tropics

A total of forty-five Aboriginal people from three distinct cultural groups (Biniŋ, Yolŋu and Kurdanji) were surveyed. Outcomes were consistent across groups and within each group, based on analysis of sub-groups based on gender and geographical location. Close to 80% of respondents indicated that they had serious concerns about how mining was affecting the environment, especially traditional food sources and personal health. 67% of all respondents also felt that communication and consultation on environmental matters was poor. This appears to have led to a high degree of distrust being directed by these Aboriginal communities towards mining companies and regulators.

With respect to future rehabilitation, the matter is less clear. Fifty-five per cent of respondents believed that the mining companies lacked sufficient knowledge to rehabilitate the environment effectively, while 83% considered that traditional ecological knowledge had a role to play in the design of a useful post-mining environment, and the development of rehabilitation plans. A similar pattern was observed for non-indigenous people from the same remote areas, with more than 80% of respondents indicating that mining companies need to consult more widely when preparing their rehabilitation plans. These results are not surprising given that traditional and many rural lifestyles depend on renewable natural resources and a sense of place in the environment to ensure survival, and will continue to do so in the more remote parts of Australia.

The main concerns among Aboriginal people is that although they are willing to help, companies will ignore their concerns and aspirations for the future, and that the outcomes of mine site rehabilitation will not be of the necessary quality to ensure their survival in the post-mining environment. This perception has been reinforced over the years by apparently unsuccessful attempts at rehabilitation of sites such as Rum Jungle, which continues to drain large amounts of acidic waste into what were once fertile tropical waterways. Given the fundamental Aboriginal philosophy that “our land is our life”, there remains an interest in ensuring that traditional lifestyles can be maintained and there is a perceived need for recognition that western scientists cannot achieve this alone. Aboriginal Australians firmly believe that their traditional ecological knowledge can and should be used to assist rehabilitation: it is against this backdrop that detailed closure criteria are now being developed for Ranger Uranium Mine, and have been proposed for Nabarlek.

3.2 Developing closure criteria that integrate traditional ecological knowledge

Over the years there has been much rhetoric about using traditional ecological knowledge to develop closure criteria, but to date none appear to have been reported in detail, and no processes leading to them have been described. This is possibly because integrating two systems of ecological knowledge that work over different periods of time (i.e. traditional and western scientific systems) is no trivial exercise.

Closure criteria are highly dependent upon the nature of the environment and the mine: they vary widely between ethnological groups and thus need to be formally developed on a site-specific basis that accounts for relevant cultural, social and spiritual factors. For example, many faunal species that require reestablishment are totems for people and for groups, with particular species of special importance to men, women or specific relevance to traditional cosmology. Their absence from the post-mining environment leaves a significant tear in the traditional cultural fabric, and ultimately creates social dysfunction. In contrast, at another location, their absence may have no cultural or spiritual consequences. It is therefore of interest to determine if the process used here can be translated across cultures both within Australia and in the worldwide forum.

3.2.1 Ranger Uranium Mine

Ranger Uranium Mine, located within the World Heritage listed Kakadu National Park in Australia’s Northern Territory, commenced operations in 1979. Despite having been in operation for nearly thirty years, and with closure drawing closer, detailed closure criteria have yet to be developed. Sets of ‘Environmental Requirements’ (Australian Government, 1999) that have been imposed on the mining company are currently used as the guiding principles for rehabilitation of the mine, but they do not necessarily require any detailed consideration of the landowner’s wishes. Designed to be non-prescriptive, they do not contain sufficient detail to have value as closure criteria, and so cannot serve as measures against which the success of rehabilitation can be measured.

Following consultation with Biniŋ traditional owners, a number of general expectations that summarize the traditional owner position on what constitutes acceptable closure requirements for rehabilitation of the Ranger Uranium Mine have been derived by the Northern Land Council. These are presented in Table 1, and on closer inspection, are found to complement many of the Environmental Requirements. However, further discussions also revealed that several levels of cultural considerations exist, and these were used to guide development of more detailed closure criteria acceptable to the traditional landowners. These are presented in Tables 2, 3 and 4 and all have been linked with standards or measures used by western science.

This link with scientific standards is especially important because it is against objective scientific measures that regulatory bodies must measure closure criteria. Closure criteria based upon cultural considerations alone do not provide a robust means against which rehabilitation success can be measured, but can provide a means of directing the technical and practical effort to the mining company and regulators. They also provide a means by which western scientific measures can be explained in cross-cultural terms that are more easily understood by non-technical sectors of the community.

Table 1 Biniŋ expectations for rehabilitation and closure at Ranger Uranium Mine

Riparian environment	Must be capable of sustaining appropriate faunal populations including terrestrial, riverine and lacusterine creatures natural to that location.
	Must be capable of sustaining appropriate vegetation patterns especially including species of economic value that were present prior to mining.
	The waters contained must be of a quality commensurate with non-affected systems and must be safe for year-round consumption by Biniŋ and by fauna.
	Radiological and chemical levels must be so low that Biniŋ may enjoy unhindered year round access for camping, hunting and gathering purposes.
	All residual infrastructure and rubbish is removed.
Water bodies	No permanent water bodies other than those that existed before mining are to remain. Sentinel wetlands are tolerable but must be reduced in size over time.
Vegetation	Stable patterns of natural, local vegetation must be developed.
	Vegetation patterns must have sufficient diversity and abundance that the environment is as close as possible to that which existed prior to mining.
	Fire must be managed in a manner consistent with Biniŋ culture.
	Weeds with no economic value must be completely eradicated.
Topography	Full and unhindered view of Mount Brockman from all angles.
	Reconstructed topography as low as possible with no stockpile remnants visible above the tree line.
	A single raised area covering the pits and deconstructed tailings dam is preferable to multiple raised areas.
	Slopes must be as gentle as possible to minimize the risk of erosion.
	Residual surface rocks should not exceed 50 cm in diameter, and should preferably be smaller.
	Reconstructed topography must be aesthetically pleasing and blend with the general landscape.
	Radiological and chemical levels in non-riparian areas must be so low that Biniŋ may enjoy unhindered access for camping, hunting and gathering purposes for a minimum six months of the year.

Table 2 First level relationship between cultural considerations and general mine site closure criteria

<table>
<tr><th></th><th>Cultural Criteria</th><th>Closure Parameter</th><th>Key Closure Criteria</th></tr>
<tr><td rowspan="4">Topography</td><td>Recreation of cultural landscape</td><td rowspan="7">Post-mining landform design</td><td>Geotechnical stability</td></tr>
<tr><td>Protection of existing sacred and ceremonial sites</td><td>Erosion</td></tr>
<tr><td>Re-creation of damaged sacred and ceremonial sites</td><td>Slope</td></tr>
<tr><td rowspan="2">Land use objectives and re-creation of natural landscape</td><td rowspan="2">Aesthetics</td></tr>
<tr><td rowspan="3">Rivers and water bodies</td></tr>
<tr><td>Access for cultural activities</td><td>Contaminant levels in soil</td></tr>
<tr><td>Spiritual implications</td><td>Drainage</td></tr>
<tr><td rowspan="5">Riparian zones</td><td rowspan="3">Sources of food and potable water</td><td>Water quality and human health</td><td rowspan="2">Water chemistry, ecotoxicology and physical parameters</td></tr>
<tr><td>Water quality and biota health</td></tr>
<tr><td>Contaminant levels in arboreal food</td><td>Plant chemistry</td></tr>
<tr><td>Sources of traditional medicines and craft materials</td><td rowspan="2">Vegetation patterns, species and removal of weeds</td><td rowspan="2">Biological abundance
Plant tolerance
Biodiversity</td></tr>
<tr><td>Presence of fauna used as food or in ceremonies</td></tr>
</table>

Having determined the principle environmental concerns, they were translated into a set of broad cultural criteria that could be used to define the closure parameters and general criteria required for development of a closure model. Once done, the scientific measures and studies required became more obvious. For example, Biniŋ place great emphasis on quality of rehabilitation of the riparian environments, because these environments provide water and food and are thus most sacred to their life and culture. Even without discussion of Biniŋ understanding of the ‘spirituality’ or ‘cosmology’ of the riparian corridors, western science would agree that functional riparian buffers and corridors are crucial landscape features, and that stringent closure criteria dealing with biological health and diversity are required.

Second and third level cultural relationships were more difficult to divulge, because these are at the root of Biniŋ culture and mythology, and represent levels of intellectual property and spiritual information that need protection. Consequently, Tables 3 and 4 presented here provide only a brief insight into how Biniŋ perceive and utilize their environment.

What we determine from the data presented in Tables 3 and 4 is that the Biniŋ view is that closure criteria must be based not only on what is scientifically acceptable, but also on what is acceptable in terms of their own cultural and economic survival. Biniŋ have described the reconstruction of vegetation patterns that blend with the surrounding, unaffected areas and indicated the species that are most appropriate, culturally and economically, for future generations. By focusing on well-developed and clean riparian areas with appropriate vegetation patterns, the correct complement of fauna are expected to repopulate the area.

It is their view that, if this formula is followed and managed in accordance with their age-old land management practices, then a living environment similar to what existed before mining must inevitably develop. With this comes a return to spiritual, cultural and social balance. The role of the scientist therefore becomes more important in ensuring that the post-mining landform design can properly support those vegetation patterns (especially with respect to local ecotypes and plants tolerant to the post-mining landscape), and minimize the release of unwanted chemical species that will contaminate the food and water supplies.

Table 3 Examples of second level consideration of relationships between cultural values for the natural landscape and general mine site closure criteria

Parameter	Description	Cultural or Spiritual Value
Landform	Low flat contour with only one or two high points and a full view of escarpment above the tree lines.	Spiritual space - escarpment is a cultural site with spiritual importance.
	Residual surface rocks as small as possible (golf-ball size).	Cultural - ease of foot access.
	No more open water bodies than were present before mining.	Spiritual - water bodies harbor evil spirits.
Vegetation patterns	Reconstruction of open eucalyptus woodland (woolybutt and stringybark) with spear grass and natural djili-djili moving towards pandanus and melalueca is acceptable.	Cultural - presence of species of economic value and return of native fauna.

Table 4 Examples of third level consideration of relationships between cultural values for vegetation and mine site closure criteria

Parameter	Aboriginal or \Common Name	Scientific Name	Cultural Value
Edible plant species	Green bush plum	*Buchanania obovata*	Food
	Red apple	*Syzygium* spp.	Food
	White apple	*Syzygium* spp.	Food
	Yam	*Dioscorea* spp.	Food
	Manbelk	*Pandanus* sp.	Starch from nuts
Economic values			Basket weaving
			String
	Wirndilk	*Haemdorum* sp.	Red/purple dye
	Mandubaŋ	*Eucalyptus* spp.	Clap sticks
	Garrdaka	*Eucalyptus* spp.	Bark paintings and brushes
			Didgeridoos
Weeds	*Rosella*	*Hibiscus heterophyllus*	Food and/or dye
	Bush passionfruit	*Passiflora foetida*	Food

3.2.2 Nabarlek Uranium Mine

Nabarlek, situated in Western Arnhem Land, approximately 70 km north of the Ranger project, was mined out between 1979 and 1980. Despite some claims that the mine site has been rehabilitated, it remains in a state that is unacceptable to the traditional land owners, and hence cannot be issued a closure certificate. The Northern Land Council has determined that the general expectations and cultural considerations are essentially the same as those provided for the Ranger project; however, as Nabarlek already has a reconstructed landform and partially developed vegetation cover, a different emphasis on closure criteria is seen.

By considering the site as a series of small, integrated landscape units, Binin have proposed a series of closure criteria (each specific to a landscape unit) that range from open grasslands to woodlands. They are resigned to the realization that these must be developed and grown on a number of areas that have an unacceptable amount of surface contouring and acknowledge that the spiritual and cultural aspects of the site and the delivery of ecosystem services and goods will remain impaired for a long time. However, overall closure criteria for vegetation quantified in terms of stem density and ground cover have been developed. Presented in Table 5, they also reflect surrounding, undisturbed vegetation patterns and contain key species drawn from lists provided in Table 4 and from the pre-mining phase. The prevailing Binin view is that once the closure criteria are met, natural succession and return of the living environment complete with appropriate fauna and economies will inevitably occur over the next several generations.

Binin generated closure criteria are consistent with the 'Environmental Requirements' ascribed to Nabarlek via agreement between the Northern Land Council and the operating company, Queensland Mines Limited. The intention is to review, periodically, the values once they have been attained to ensure that self-sustaining woodland has developed, and ultimately to use the same techniques to develop similar quantifiable closure criteria for the Ranger project. Unlike Ranger, government based Environmental Requirements concerning rehabilitation do not exist (Australian Government, 1979).

Unfortunately, Nabarlek epitomizes the schism that exists between western science and traditional ecological knowledge. Closure criteria and monitoring methods based on traditional owner requirements are still being argued by the regulatory authority, despite having been clearly elucidated several times by the land owners. It is interesting to note that, even after twelve years of the current rehabilitation strategy, the site is no closer to closure. In consequence, Aboriginal landowners consider that their wishes and thoughts are being ignored and still do not have safe access or the opportunity to undertake their cultural activities despite mining having concluded almost 25 years ago.

Table 5 Proposed closure criteria for revegetation at Nabarlek Uranium Mine (information from a matrix similar to that in Table 4 is used in conjunction with these to develop appropriate patterns of vegetation that closely match surrounding environments)

Vegetation	
Canopy cover	Between 25 and 50%.
Ground cover	Between 15 and 30% where there is no canopy cover.
Native herbage	A minimum of between 10 and 20% of the ground cover shall be native grasses, herbs and sedge.
Average tree density	Overall average for site between 500 and 750 stems per hectare.
Weeds	
Average weed density	Overall average site density of weeds shall be between 10% and 20%.
Specific weeds	Weeds of national significance, including mission grass, shall be eradicated completely from the site.
	Paragrass shall be confined to an area as small as practicable and shall not exceed an average density of 10% across the site.

3.2.3 Perceived barriers to success

Neither Ranger nor Nabarlek Uranium Mines have reached closure, so the workability of proposed closure criteria based on traditional ecological knowledge cannot yet be fully assessed. Belief amongst Biniŋ is that they are suitable, but that belief may be tempered in other situations if the degree of traditional knowledge offered is substantially incomplete. Given the record that western society holds in pillaging traditional knowledge for its own economic gain, such as has happened with many medicinal plant species from places like the Amazon, there is often reluctance on the part of Australian Aboriginal people to divulge necessary ecological information. This is a significant barrier to the process, and one that can be at least partly overcome by ascribing the intellectual property rights to the appropriate cultural group. In the two examples provided here, such rights rest with Biniŋ traditional owners and not with the Northern Land Council.

Where closure criteria based on cultural considerations are developed, there may also exist a temptation amongst scientists and regulators to devise frameworks that score those criteria against a set of expected outcomes. The Maori Cultural Health Index shows that traditional landowners can successfully use these frameworks to develop measures by which they can determine their own level of satisfaction with the outcomes. In conjunction with its Aboriginal constituents, the Northern Land Council is currently testing the application of this index with a view to also adapting it to include terrestrial values. However, Biniŋ traditional owners harbor the fear that mining companies and regulators would attempt to use such an index as the sole means to demonstrate that closure criteria had been met. Should this occur, robust scientific requirements may not be met and a substandard product leading to environmental degradation and a loss of future land value would ensue.

Another barrier to successful implementation of closure criteria based on traditional ecological knowledge relates directly to the reluctance of many non-indigenous people to accept alternative points of view and integrate them in a culturally acceptable manner. Traditional knowledge is often viewed either as mystical or subservient to science and therefore of little value, where in reality it is based upon generations of empirical observation and provides data that cannot be collected over the short-term even by the most complex of scientific methods. A general reluctance to accept and respect the landowners' viewpoint appears to be one of the main problems in progressing rehabilitation not only at Nabarlek but also at a number of mine sites undergoing rehabilitation in the Yukon (Chan et al., 2007).

Further barriers to success are contained within existing consultation processes run by many companies and regulators. These are often driven by industry and undertaken only because they are a requirement of a policy or process. Projects and plans are often presented to traditional landowners as *fait accompli* and any opportunity for real input of traditional ecological knowledge is lost or deliberately ignored in an apparent haste to reach a desired outcome. In contrast, indigenous societies require time to reach consensus and to develop formulated responses. Adequate time is needed to ensure that all affected people are appraised and provided an opportunity for input. In the Yukon this is enforced by legislation, while here it was achieved by allowing the landowners to direct the timing – thus averting unplanned disruption that may otherwise have occurred due to other culturally important activities.

Finally, we should always be aware that rehabilitation strategies and plans are driven largely by economics. In Australia, the law allows the legacy and liability of failed rehabilitation to be transferred from the mining company to future generations of landowners. Regulators accept that many closure requirements are 'uneconomical' for the mining company. Cultural requirements like 'surface rocks on residual stockpiles should not exceed a specific size' are unlikely to be met, because they may be viewed as unnecessary or unachievable criteria. Through not meeting these challenges, companies leave environments that are of little economic value to the landowners, both present and future. Impoverished populations are ultimately expensive for a company and a country to maintain, so using traditional ecological knowledge and practices may ultimately be of economic benefit to companies and to governments because they assist with reestablishment of crucial ecological processes (which tend to have high cultural and spiritual significance) in the landscape.

4 Conclusions

This study shows that achieving consensus on setting workable closure criteria based on a fusion between western science and traditional ecological knowledge that ensures the sustainability of traditional lifestyles post-mining is possible if a number of barriers can be overcome. The approach taken in this study is also important and applicable because it recognizes the right of indigenous people to assert authority over their land, over its ecosystem services, and over the management practices that are undertaken upon it. While it is specific to Aboriginal Australian societies in the tropics, it should still be suitable or easily adjusted for any indigenous society built around similar cultural practices.

Indigenous landowners are not ignorant that economy of scale and generation of scientifically quantifiable standards are cornerstones of rehabilitation success, and are thus of considerable concern to all stakeholders. However, when setting the overarching closure criteria they view company economy and scientific practice as secondary considerations and consider that while science has a strong role to play; economics in particular should not be used to dictate progress towards meeting closure criteria. Their greatest focus is placed upon the need to ensure that existing cultural and spiritual practices and social survival can continue, unhindered, long into the future. By virtue of this, indigenous landowners consider that western science, because of its focus on the physical and limited recognition of cultural and spiritual matters, has an impoverished approach, i.e. in treating traditional ecological knowledge as a 'lower level' of understanding.

A definitive solution is not offered here because demonstration that closure criteria based around traditional ecological knowledge will lead to successful rehabilitation is still in the future; but if there are strong similarities between cultural and spiritual criteria and ecological science criteria, then this suggests there will be a higher probability of success. The challenge to mining companies is to take proper cognizance of indigenous views of the environment and dispense with insular and short-term views of rehabilitation. The need is to develop ongoing consultation processes and long-term rehabilitation plans that meet the needs of traditional society both now and in the future. For, in the words of the great law of the Iroquois Confederacy, "in our every deliberation we must consider the impact of our decisions on the next seven generations".

Acknowledgements

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