Assessing an Assessment: The Ok Tedi Mine

Patricia K. Townsend and William H. Townsend

Any forum for the discussion of sustainability at a global level must include mining, simply because its environmental impact is so disproportionately great. In the United States, for example, mining contributes less than one tenth of one percent of gross domestic product yet is the largest source of hazardous waste[2] and consumes energy at a level disproportionate to its economic contribution. The Ok Tedi Mine in Papua New Guinea has in the past decade become the icon of irresponsible riverine disposal of tailings and waste rock from large-scale mining and a central case study for the discussion of the environmental impact of industrial-scale mining.[3] Numerous small ethnic groups depending on local ecosystem services for food, fuel, and housing, a newly independent state, and several large multi-national corporations engaged with each other over the mineral resource. It is a pattern repeated throughout the developing world, but here with environmental consequences that are better documented than in most places.

The Ok Tedi Mine is located in the Star Mountains in Western province of Papua New Guinea (PNG), near the border with the Indonesian province of Papua. (See Figure 1.) [MAP TO FOLLOW IN SEPARATE ELECTRONIC FILE] The terrain is heavily forested, extremely rugged limestone karst country with rainfall exceeding 8 m per year. The mine is named for the Ok Tedi, an upper tributary of the Fly River, which flows into the Gulf of Papua and adjacent Torres Strait. The Fly is one of the world's largest tropical rivers, and its fish fauna is the most diverse in the Australasian region (IUCN 1995:1, 22).

The mining town at Tabubil has a population of approximately 5000, of whom nearly 2000 are direct employees of OTML (Jackson 1993:80, 121). Prior to mining, the immediate area was inhabited by the Wopkaimin, a group of some 700 hunter-horticulturalists who belong to the Mountain Ok family of languages (Hyndman 1994:5). This inland area was only brought under colonial Australian administration in 1963, while administration and missions had established contact and control in the coastal area a century ago and had extended their reach into the middle Fly by the 1950s. Papua New Guinea attained national independence in 1975.

The Ok Tedi mine began production of gold twenty years ago, in May 1984. The developer was a multinational consortium consisting of three large multinationals -- BHP, Amoco Minerals, and a German consortium led by Metallgesellschaft AG. The mine moved to full production in 1987, producing copper concentrate that is piped to Kiunga, transferred to barges that travel to the mouth of the Fly River, and there trans-shipped to ocean-going ships for smelters in Japan, Asia, and Europe. The copper concentrate contains sufficient gold and silver to subsidize the costs of producing copper to a level manageable even in an era of low copper prices. A period of 27 years of mining will remove Mount Fubilan, leaving a deep pit after 2010.

Ten years ago, in May 1994, Ok Tedi became the object of highly-publicized litigation against BHP, then the majority owner, in the Australian courts (Banks and Ballard 1997, Kirsch 2002). Downstream landowners from villages along the Ok Tedi and the Middle and Lower Fly sought to recover damages and attain a measure of environmental protection and remediation. With the out-of-court settlement of that case in January 2004, their hopes for adequate compensation and future environmental protection seem no closer to fulfillment, for the income stream to meet those goals depends on a continuation of business-as-usual at the mine. Forty per cent of the ore body remains to be mined between 2002 and 2010. [5]

Environmental Impact Studies

As the magnitude of social and environmental problems surrounding Ok Tedi became widely apparent, there were many attempts to understand where the project had gone wrong. Some of these hinted that "if only" there had been a better environmental impact assessment, things might have gone differently (Hughes and Sullivan 1989, McKillop and Brown 1999, Roberts 1999, White 1995). Hence, it seems appropriate to examine the pre-project environmental studies and assessments from the early 1980s to see what they contained, and, in a very general way, how their predictions have held up. When choosing to focus on the pre-project assessments, we were not unaware that the World Conservation Union and the PNG Department of Environment and Conservation had conducted a regional environmental assessment of the Fly River (IUCN 1995). Indeed, the IUCN assessment is more the sort of assessment that is intended in the Millenium Ecosystem Assessment, even in its use of scenario analysis for planning purposes. However, as we will show, the IUCN assessment was constrained by assumptions and decisions from this earlier body of work.

The Ok Tedi (Mining) Act of 1976 required the mine developer to conduct a program of environmental studies. In this era it is difficult to imagine how forward-looking this requirement was, but at the time this was the most rigorous environmental standard for a mine in a developing country. Raymond Mikesell, highly respected economist of the mining industry, at a conference in 1981 said of the Act, “The most comprehensive environmental protection provisions in any mining agreement of which I am aware are found in the PNG-Ok Tedi agreement.” He was impressed that the requirements covered social as well as environmental impact, and that the environmental study was to be “taken fully into account in the detailed proposals for construction of the mine and infrastructure and the mode of operations, which proposals must be approved before the granting of the mining lease” (Mikesell 1984:79).

The EIS as a requirement of major developments had only been established in the United States from January 1, 1970 (through legislation passed in 1969). Similar legislation was enacted in Australia in 1974. One significant difference between legislation in the U.S. and Australia is that in the U.S. it is government agencies that are responsible for Environmental Impact Assessment (with the costs carried by the private company) while in Australia it is the developer or the developer’s consultants that prepare the EIA—and it was the Australian precedent that was followed in PNG. Papua New Guinea’s 1975 constitution was remarkable for the environmental principles it espoused, but these were only implemented in the 1980s (Pintz 1987:38-39, Bein and Rivers 1999:74-75). International lending agencies were even slower to require environmental impact statements of their projects; the World Bank did not require environmental assessments of all its projects until 1989.

The 1976 requirement that the Consortium produce an EIS was somewhat undercut by the agreement that no more than K150,000 (US$220,000) need be spent on environmental studies. This severely limited the fieldwork that would be done to establish a baseline against which to measure subsequent impact. The only data collected in the feasibility period was that related to hydrology, water chemistry, sediment transport, landslides, and bird life. On one of the major issues, the fate of soft (or "incompetent') waste rock that would erode into the river system, the Consortium study, conducted by Vanoni and Henderson, optimistically assumed that the sediments would wash through the river system and end up in the Gulf of Papua without significantly altering the riverbed. This study predicted bed aggradation of only .23 m in the Ok Tedi (Pintz 1987:45; Maunsell 1982,Working Paper 5).

The PNG government commissioned its own environmental studies during the feasibility period. Indeed the government spent nearly four times as much as the company on environmental studies at this point (Pintz 1984:80, 89). The government-commissioned study to judge the effect of waste rock and sediments on the river system used computer modeling (then state-of-the-art techniques) and, unlike the consortium's study, considered four different waste disposal strategies to determine the range of potential impacts. The government's consultants from Australian National University built on their experience with the Bougainville mine. They predicted that sediments would pass through the system as slugs of material that might raise bed levels on the order of 4 meters, vastly more than Vanoni and Henderson had predicted (Maunsell, Vol. 3, p.121).[6] This study was the basis for the government restriction of 60 million tonnes of waste rock in the Southern Dumps. Another technical consultant to the government, Everett and Associates, studied the likely chemical impacts of mining on the river. These government reports were not made publicly available at the time they were made, for their secrecy was essential to support negotiations between the government and company, but the Consortium was required to make its studies public.

The Ok Tedi supplementary agreement of 1980 in its Schedule B described the format for a full Environmental Impact Study.[7] This study was produced, at a cost of nearly US$1 million, by Maunsell and Partners, Pty. Ltd. as consultants and delivered in June 1982 (Pintz 1987:55). The EIS was public and copies of all seven volumes are still available in libraries.[8] The first volume was the main report. The other six volumes were a series of working papers. Volumes 2, 3, and 4 contained scientific and technical papers on water quality, waste rock, and sediment issues, Volume 5 on the relationship between people and plants and animals, Volume 6 on aquatic biology, and the biological effects of heavy metals, cyanide, and suspended solids, and Volume 7 primarily on the Port Moresby harbor. A short summary was translated into the trade languages Tok Pisin and Motu. However, there was no requirement that public input or peer review take place.

On the vexed issue of the effect of waste rock on the river system, the report was able to draw on both consortium and government studies, doing its best to reconcile them, compromising by suggesting that the bed aggradation might be on the order of 1 to 2 m from Tabubil to Ningerum and .2 to .5 m in the lower Ok Tedi. Maximum deposition of .3 m was expected on the lower Middle Fly because of the backwater effect of the junction of the Strickland River. One thing that is made strikingly clear in the EIS is that the impact of the mine on the river will be very long term. It was suggested that in the lower Ok Tedi, for example, bed aggradation could reach its maximum of 1.5 m fifty years after the mine closed (Maunsell, Vol. 1, Fig. 3.4, p.64). This time-scale has largely been ignored in most discussions of the mine. Not only do local people assume that cessation of mining will produce a return to pre-mining conditions, even the IUCN scenarios are based on this flawed assumption.

In comparison with the boiler-plate environmental impact statements that have become common nowadays, the Maunsell EIS was unique, drawing upon the expertise of almost everyone who had done any environmental work in the area whether as hydrologist, anthropologist, or biologist. The EIS was a bargain at the price, for researchers such as ecological anthropologist David Hyndman were able to build on their earlier research experience far more than the few weeks in the field allotted by the EIS.

Volume 5 of the EIS, "Population and resource use. Ethnobiology," was produced by the consulting firm Natural Systems Research Pty. Ltd., who contracted with anthropologist David Hyndman, and University of Papua New Guinea biologists David Frodin and John Pernetta to produce three working papers. The terms of reference encouraged them to focus on species of importance to the people living in the Fly watershed. Their ethnoscientific approach allowed them to incorporate the rich local knowledge of several language groups of people indigenous to the area.

Social Impact Studies

The government was responsible to complete the Social Impact Study just as the consortium was responsible for the EIS. The main social impact study was completed for the Department of Minerals and Energy in July 1980 (Jackson, Emerson, and Welsch 1980). Its senior author was Richard Jackson, a geographer, assisted by two postgraduate students, economist Craig Emerson and anthropologist Robert Welsch. Titled *The Impact* *of the Ok Tedi Project*, the study dealt largely with the economic impact of the project, both its expected macroeconomic impact at national level and the prospects for economic benefits to local people through employment and small business development. These economic benefits would, it was hoped, balance the largely negative local social impacts such as increased inequality, conflict, drinking, and prostitution, all of which were dealt with only briefly near the end of the 429-page report.

The Social Impact Study had some very real strengths, compared with the EIS. It was timely (two years ahead of the EIS), available early enough in the planning and construction process that it was used to orient people coming in to the project and had a greater opportunity to influence decisions. Its senior author, Jackson, continued to do research on the mine (Jackson and Ilave 1983, Jackson 1993) and drew lessons from Ok Tedi that influenced several subsequent mining projects throughout Papua New Guinea (e.g. Filer and Jackson 1989).

The social impact study had some weaknesses obvious from the outset as well as others that would become apparent only later. It was too narrowly focused on business, too little on local and provincial government and the subsistence system. It needed a political scientist, but it did have an anthropologist, whose contribution was underplayed. The report merely referenced Welsch's 1979 report on land, without summarizing or exploring its relevance or asking him to discuss the baseline subsistence system he had observed during his long-term ethnographic fieldwork among the Ningerum.

As was the case with much of the EIS, the scale of the social impact study would turn out to have been inappropriate, focusing on the Tabubil-Kiunga axis rather than the entire watershed—In other words, it assumed that the main impacts would be carried by the 150 km road rather than the 1000 km river.

Neither the social impact study nor the environmental impact study included a cultural heritage component, an omission that would now be unthinkable in impact analysis. Neither team included an archaeologist or an ethnohistorian [9] This gap was creatively addressed on their own initiative by the National Museum and Art Gallery and the Institute of Papua New Guinea Studies (IPNGS). At the Museum, the archaeologist Pamela Swadling assembled a volume titled *How long have people been in the Ok Tedi impact area?* (Swadling 1983). From the collections of the Museum, reviews of the literature, advice from anthropologists and linguists, and additional surveys, she assembled as complete and accurate a picture of the prehistory of the area as it was possible to make at the time, in an attractive format. Though the study was done with Museum resources, OTML provided some funds for printing. Of all the "impact" studies, this was the only one that handled the issue of scale adequately. In order to make sense of the peopling of the Fly catchment, Swadling had to set wider boundaries than the other studies had.

The IPNGS also contributed missing pieces of cultural impact analysis by commissioning ethnographers who had done long-term research in the impact area to write reports. A respected senior anthropologist Frederik Barth followed up his earlier research among the Faiwol with a brief cultural impact study of the villages closest to Tabubil (Barth and Wikan 1982, Barth 1983). Having a female co-researcher who attended to the impact of the project on women helped to fill a glaring gap, but the report did not have official status or initiate a program of monitoring or mitigating change.

Another important dimension of environmental impact is the impact on public health. This dimension of impact was addressed by many surveys from the 1970s through the 1990s, most of them from the medical faculty of the University of Papua New Guinea or the medical staff of OTML (e.g. Flew 1999; Nurse 1990; Schuurkamp 1992; Ulijaszek et al. 1987, 1989). To review these studies would require another lengthy paper. To summarize briefly, the mine development brought a high standard of modern health care to Tabubil, in a part of Western Province that, until then, had essentially no health services and evidenced poor nutrition and high infant mortality. Thanks to these services, made available to residents whether employed by the mine or not, as well as to improved income and education, health status dramatically improved. This improvement (rightly) became a major OTML public relations theme. The achievement is marred only by the new vulnerability of the mine's own local staff to a modern set of health threats such as obesity, heart disease, and sexually transmitted diseases. Meanwhile, health services in the once-better-served southern half of the province were transferred from well-established church health services to provincial government (newly affluent with mine royalties but lacking in administrative capacity). This generally led to a collapse of rural services that is reflected in poor rates of child immunization and outbreaks of diseases such as yaws.

What did <u>not</u> happen is that little or no effort was made to link the health studies to the environmental studies, either in the initial EIS or later. Even the so-called "peer review" team of five internationally distinguished scientists brought in to review the OTML science program in 1997 through 2000, for example, did not include anyone with medical background (OTML Environment Peer Review Group 2000).

Difficulties emerging in the construction phase

Stage I construction was authorized on August 18, 1981, with production scheduled to begin on May 1984. This means that construction was already underway as the EIS was being prepared. The EIS was completed in June 1982, a year after construction began. While some alterations might be possible to reflect findings of the EIS, the decision not to build a mine was no longer an option. Indeed the EIS was based on a single alternative, the project as described in the feasibility documents (including a tailings dam and stable waste rock dumps), rather than examining the implications of a full range of alternatives for mitigating environmental damage.

In November 1982, fifteen months after authorization of construction, the project was already eight months behind schedule.[10] Meanwhile, construction on the Ok Menga hydroelectric project started with excavation of the power station foundation in unstable soils. The steep terrain and unstable soils led to an earth movement which could not be controlled, and, in January 1983, the hydroelectric project was abandoned.[11]

With the hydro construction cancelled, the contractor (Bechtel) concentrated on the process plant construction to make up for lost time. Behind the scenes, OTML designed an interim tailings scheme that they hoped would allow removal of the Ok Ma dam construction from the critical path. In August 1983 the PNG National Executive Council rejected the Interim Tailings Scheme, which involved discharging the tailings fines into the river. The Ok Ma tailings dam was needed, in any case, for the much larger volume of tailings during the copper production phase that would start two years after gold production. Not to build it would be an admission that the company intended to take the gold and run.

Bechtel continued to develop the construction site for the Ok Ma tailings dam, building an access road to the site, a workshop, construction camp, and stone quarries for the dam. By late 1983, Bechtel was excavating for the Ok Ma dam foundation, even though basic site geology was not yet done and no design for the dam had yet been given to the government for approval.[12]

On January 7, 1984, a landslip occurred in which a large, shallow area of land moved a few meters. This landslide provided the ammunition OTML needed to request again that construction of the mine process plant be allowed to proceed on its original schedule without construction of the tailings dam. On January 25, the State approved the Interim Tailings Scheme without technical consultation and allowed the mine to go into production without the environmental protection that had been agreed upon. Responding to the decision to discharge tailings fines directly into the watershed prompted a University of Papua New Guinea biologist to quietly undertake a study of the toxicity of these tailings to mosquito fish and shrimp. His results indicated that the discharge could be toxic to shrimp as far downstream as the Middle Fly (Mowbray 1988:117).

Shortly after the approval was given to stop work on the Ok Ma tailings dam, three separate engineering firms reported workable nearby alternative sites for a tailings dam. OTML judged their cost to be too high and proceeded to look for a cheaper solution.[13]

Waste rock was yet another environmental issue that remained troublesome during the construction phase. The 1980 agreement had specified a (somewhat arbitrary) maximum of 60 million t of incompetent waste to be deposited in the failing Southern Dumps. The remaining, mostly competent waste rock was to be retained in stable Northern Dumps.

From the beginning of production in 1984 about 20,000 t per day of weak waste rock was dumped or pushed from Taranaki and Vancouver into Sulphide Creek in the Northern Dump. This dumping contributed to accelerated channel incision and side slope instability, which had been a concern in the EIS. On August 22, 1989, an estimated 170 million tonnes of rock slid down the Ok Gilor toward the Ok Tedi (Read and Maconochi 1992). The massive Vancouver Landslide prompted OTML to commission a landslide and erosion hazard analysis. The consulting geologist drily remarked, "In this way the study differed from most other published hazard mapping exercises in that it was undertaken on a fairly intensive basis partway into an established project rather than at the feasibility or planning stage" (Hearn 1995:51). Once again, the lack of timely studies had contributed to unnecessarily severe environmental impact.

Impact of mine waste on the river system

The intent of the Ok Tedi agreement was that impact on the river system would be minor, with virtually no impact below the confluence of the Ok Tedi and the Ok Ma. This was based on all tailings being retained in the tailings reservoir, the Government's limit of 60 million t of incompetent waste going into the Southern Dumps, and the rest of the overburden going into the stable Northern Dumps. With the failure of the Northern Dumps, the project-induced Vancouver Landslide, the failure of the Ok Ma dam to retain tailings, and an increase in the mining rate from a projected 16 million t per year to a capacity of 30 million t per year, the amount of waste entering the river system increased dramatically over the levels predicted in the EIS. The EIS-projected mine and actual operating mine were now completely disconnected: all waste from the mine was dumped into the river system.

The impact of the increased waste was most dramatic in the Ok Tedi, but it was marked even in the Fly River itself. At Kuambit, for example, near D'Albertis Junction (where the Ok Tedi enters the Fly), background sediment load was determined to be 6.9 million t per year or 124.2 million t from 1981 through 1998. The Maunsell EIS projected an additional 166.8 million t being discharged, an increase of 134 percent over background. From 1981 through 1998 the total waste produced by the Ok Tedi Mine that entered the watershed, by the company's own reporting, which is not likely to be an underestimate, was 884 million t, increasing the solid wastes to 8 times the background load at Kuambit (OTML 2000, Van Zyl 2002a). (See Figure 2.)

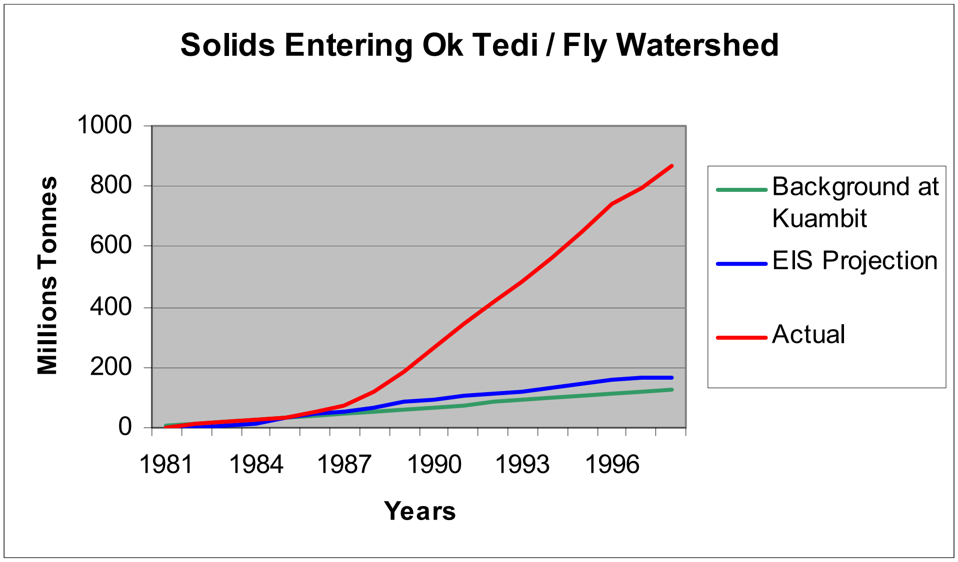

Figure 2. Solids entering Ok Tedi / Fly watershed 1981-1998.
(Data from Maunsell 1982, Vol. 4, Table 8.9, p.42; OTML 2000; Van Zyl 2000a; Salomons and Eagle, Table 2, p. 323).

This volume of sediments has several kinds of impact: an increase in turbidity, river bed aggradation (as the sediments settle out of suspension), and changes in water chemistry (as the copper and other metals in the sediments go into solution or form complexes with other materials in the river).

River bed aggradation is generally acknowledged to be the most serious consequence of the increased volume of sediments. (See Figure 3.) At high water it led to over-bank flooding that blanketed forests and gardens with fine mud, smothering vegetation and contributing to forest dieback. By 2002, 1461 sq km of vegetation had been impacted (OTML 2002:45). The riparian environment was altered, with the loss of fish habitat and dramatically declining numbers and diversity of fish (Storey and Marshall 2003). A program of dredging started in 1998 has reduced bed aggradation to some extent (though the prospect of acid drainage from the stored dredged tailings remains disturbing). Controlling bed aggradation is of economic importance because shipments of copper concentrate down the Fly River depend on maintaining the shipping channel.

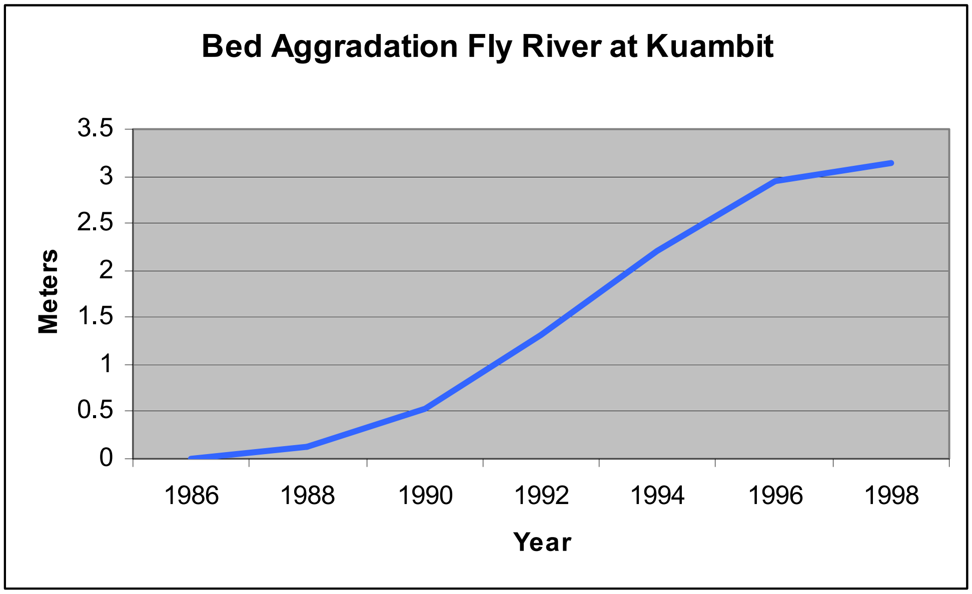

Figure 3. Bed aggradation at Kuambit. (Data from OTML 2002 p.14 Fig. 10)

The increase in suspended solids (turbidity), while significant, does not have as dramatic an impact as bed aggradation. The Ok Tedi and Fly carried a good deal of sediment prior to mining, particularly following major landslides in the geological unstable headwaters area. The EIS had projected an increase in suspended sediments for several sites, for example, just below D'Albertis Junction, where the Ok Tedi joins the Fly, suspended sediments were expected to rise from 140 mg/l to 400 mg/l . The TSS was considered to be a straightforward and uncontroversial enough measure (in comparison with other measures such as copper in the water or fish catch) to be accepted as the single measure of the environmental compliance of the mine from 1989 onward (though monitoring of other environmental conditions was to be continued as well). In 1989 the APL (Acceptable Particulate Level) was established as 940 mg/L at Nukumba in the Fly River just below the Ok Tedi. This requirement was an annual average for each calendar year and was presumably set at a level that the company thought it could readily attain.

Of the metals discharged into the river system, copper is the one of greatest concern for aquatic life. (See Figure 4.) It is present in the waste rock as well as in the tailings, even after approximately 85% of the copper is removed by processing. The waste has an average copper content of 0.15%. (For perspective, recall that ore is processed which contains as little as 0.5% Cu.) The Ok Tedi ore body is considered to be quite "clean," lacking in large amounts of the toxic heavy metals such as lead, mercury, and arsenic that are frequently associated with such ore deposits (Hettler, Irion, and Lehmann 1997:285).

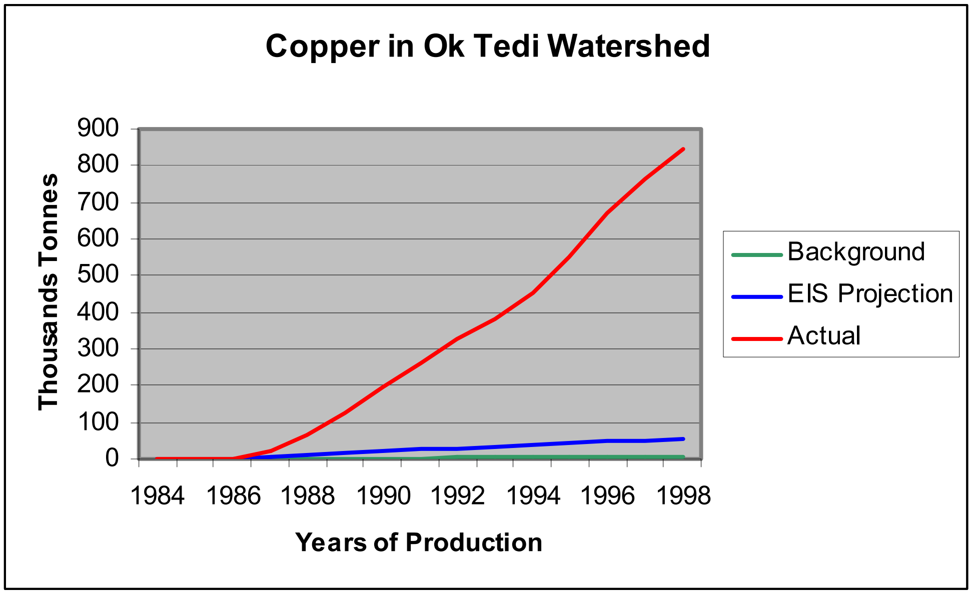

Figure 4. Copper in Ok Tedi watershed. (Data from Maunsell 1982, Vol 1. Fig. 3.5, p.65; Van Zyl 2002a, Table H1)

Sediments enriched in copper originating from the mine were identified as early as late 1984 (six months after the start of mining) as far downstream as Lake Daviambu in the Middle Fly (Nicholson 1996) and at other sites in the floodplain of the Middle Fly during 1991-93 (Hettler, Irion, and Lehmann 1997).

The EIS suggested that amount of soluble copper in the river would systematically decrease proceeding downstream as the mine wastes were diluted by water coming from other tributaries and as copper was adsorbed onto particulate matter. In practice, it has been found that the release of dissolved copper increases going downstream for the first 600 km, so that the highest levels of dissolved copper are recorded in the lower Middle Fly rather than being "diluted to insignificant levels" as anticipated in the EIS (Maunsell 1982:Vol 1:Figure 3.5, p. 65; Apte, Benko, and Day 1995). The combination of release of copper from particles into solution, adsorption onto particles, and complexation by organic matter has proven to be very much more complicated than anticipated.

Although OTML's environmental reports deal with average levels of dissolved copper, maximum levels, or pulses, of copper must also be of concern because of acute toxicity to aquatic life. OTML had been dismissive of the significance of apparent pulses in their own data (regarding them as errors) until a recent study suggested otherwise (Shao et al.2002 cited in OTML 2002:130). Perhaps the most serious risk, as it is now understood, would be if dissolved copper reached levels toxic to algae, this could cause the collapse of the Fly River fisheries (OTML Environment Peer Review Group 2000:7)

The present environmental regime for Ok Tedi, which came into effect in 2001, shifts the focus away from chemical impacts on aquatic life and instead uses an inappropriate drinking water standard. Australian drinking water standards for copper are 2000 ug/L for health and 1000 ug/L for taste, a level which is highly toxic for many species of fish. (OTML 2002:10).

Impact on floodplain of the Fly River and off-river water bodies

Although most effort has been concentrated on riverine impacts, the more serious impact of mine sediments may well be the damage that long-term bed aggradation causes to the wetlands adjacent to the Fly River. Tie channel closure is potentially a serious risk that could have devastating effects on the ecosystem (OTML Peer Review Group 2000:13). The EIS projected that the impact of mine waste would be limited to the 20 m or so adjacent to the river and that deposition would be contained by fringing vegetation (Maunsell 1982:64, Fig. 3.4). Core samples taken from drowned valley lakes between 1991 and 1993 already showed a copper-rich layer 1 to 5 cm thick. This compares with a deposition rate well below l mm/year, perhaps as low as 0.1 mm/year (Hettler, Irion, and Lehman 1997:280; Dietrich, Day et al 1999). With background deposition so low, regeneration of the wetlands could take centuries.

Assessing the EIS

What was missing from the seven volumes of the Maunsell EIS, viewed in retrospect? The most obvious weakness is a vast underestimate of the volume of waste rock and tailings that would enter the river system. The project for which the EIS was written was not the project that was built, and subsequent environmental studies as the project changed were not in the form of an EIS or made available for public or scientific review. They were studies made to justify a course of action that had already been determined on political and economic grounds.

This quantitative shortcoming of the EIS translates into qualitative shortcomings. Instead of the impact being limited to the river channel, the fish swimming in it, and turtles nesting on sandbanks, floods that top the riverbanks now have an impact on off-river water bodies, forests, alluvial gardens, and wetlands. In the impact studies it was assumed that terrestrial resources were largely protected from impact downstream from Ningerum, though it was conceded in the EIS that over-bank flooding would affect gardens there. As a result, impact studies were concerned with how to spread economic opportunities and not how to mitigate damage to the environment and the subsistence of downriver people.

Another shortcoming of the EIS, suggested above in the discussion of three critical landslides in the history of the project (Ok Menga, Ok Ma, and Vancouver), is that the research that might have done the most to protect the environment, had it been done in a timely manner, was not ecological research, but basic geological description. The Ok Menga problems should have sounded the warning. Had adequate geotechnical investigation preceded the attempt to build the Ok Ma tailings dam and the dumping of waste rock, the environmental history of the project might have been very different.[14] As discussed elsewhere (Townsend 1988), the money spent on the various construction projects that failed because of inadequate site investigations, together with some fraction of the (unreported, but huge) amounts spent in defending against litigation from 1994 through 2003, would easily have funded state-of-the-art environmental protection.

The question of Acid Rock Drainage (ARD), which is now the main emerging issue being explored in the mine's research program, was not addressed aggressively in the EIS. The EIS acknowledged that the northern and eastern stable dumps would produce acid leachate that would release large amounts of soluble copper (Maunsell 1982, Vol. 1, Fig. 3.3, p. 63). The leachate would be monitored regularly and the problem addressed as it occurred (p.104).The easy assumption was made that the large amounts of limestone in the area and the high pH of the river system would be sufficient to balance acid formation of the sulfide ores (p. 67). It has now become apparent that parts of the mine pit, sandbars, and the dredged tailings all have the potential to produce acid that will mobilize metals. Only after a risk assessment of the environmental impact of the mine in 1998 was acid rock drainage seriously addressed with a research program. It is now known "with some degree of certainty" that when the mine closes an acid pit lake will be formed, unless something can be done specifically to prevent this (Bolton et al. 2003:163, 171).[15]

The separation of the EIS from the social and cultural impact studies is another weakness that has become more apparent over time. This separation was conventional enough at the time they were written, but the current trend is to work toward better integration of these, as recommended, for example, in the mining industry's own most recent review (MMSD 2002).

Once the assumption had been made that the impact of mine wastes would be limited to the river channel and a narrow corridor along it, the EIS did not need to include significant amounts of baseline data on the subsistence systems of Yonggom of the lower Ok Tedi or the Boazi of the Middle Fly or the Kiwai of the Lower Fly. Nor did these communities and the full range of their subsistence resources need to be monitored. The gap in subsistence studies is particularly striking because the terms of the EIS required that top priority be given to resources of direct commercial or subsistence value (above those of cultural, ecological, or aesthetic value).

Refusal to include the wetlands in the impact area meant that significant subsistence resources were excluded. We have been particularly outspoken about the failure to study or monitor the sago palm (Townsend and Townsend 1996, Townsend 2003)[16]. Planted or wild, sago is the main subsistence staple food from Ningerum down to the estuary of the Fly. This was documented by Hyndman in the EIS, though sago was not studied in detail because it was then not expected to be subject to impact. This starch-producing palm (*Metroxylon)* grows in wetlands, tolerating occasional flooding, so under the changed conditions with over-bank flooding we know it must have experienced impact due to altered patterns of drainage, and perhaps even through uptake of metals. Even so, in planning subsequent environmental studies, no one added sago to the terms of reference.[17]

Among the baseline studies of the EIS and later research, we do not have even the simplest transects through sago stands in the lower Ok Tedi and Middle Fly like those that were done in the same period by researchers in the Purari (Rhoads 1980) or the upper Sepik (Townsend 2003). Transects like these can reveal a great deal about the ecosystems in which the sago palm occurs and local knowledge and management of the sago stands.

People indigenous to the area who spoke out against the mine (ABC Four Corners; Kirsch 1993, 2001; Dundon 2002) invariably raised the damage to their sago as a primary concern. This damage is sometimes phrased as a decline in productivity (the palms have no starch, "only water"). In spite of strongly worded statements by local people, in twenty years of intensive environmental research OTML has done no research on sago. This omission is a powerful example of the company's contempt for local environmental knowledge.

The monitoring of impact

A major part of the EIS was concerned not with describing baseline conditions and projected impacts but rather with proposing an ambitious program of monitoring, selecting sites and specifying methods. An ambitious program of environmental studies was conducted from 1986 to the present by a large environmental department, leading the IUCN to state:

> The environmental studies undertaken over the past decade together with the current on-going monitoring in the Fly River system and delta provide an unprecedented level of biophysical knowledge. It is clear that, if not already, this system will soon be amongst the best studied of the world's major rivers. (1995:43)

This may be true, but what is disturbing is that the results of monitoring were not allowed to suggest the possibility of cutting the rate of production or making other major changes in operation. There was no more tie between the environmental monitoring and the production schedule than there had been between the EIS and the initial mining rate. Rather than allowing the studies to influence the operation of the mine, at each subsequent phase of the project the company rewrote the environmental regime (both the standards used and the monitoring program) to suit its needs.

Enforcement of even these weakened standards was initially in the hands of the Department of Minerals and Energy, presenting a conflict of interest that one of us has discussed previously (Townsend 1988). Transfer of this function to the Department of

Environment and Conservation in 1993 was appropriate, but in the absence of sufficient funding, competent staff, and commitment could not make a real difference (NRI 2002).

Extensive environmental monitoring by OTML was not always to the point, generating large amounts of data without reference to the possibility of meaningful statistical analysis or connecting the dots between separate sets of data to draw cause-and-effect conclusions. Peer review was attained to some extent by allowing scientists and consultants associated with the project to publish in scientific journals in the 1989-1994 period. The publications were limited in scope, and they came to a crunching halt after 1994 with the lawsuit. Selected reports were made available on the OTML web site in the late 1990s as BHP prepared to exit from its ownership and management of the mine.

Independent environmental monitoring might well have been in the long-term interest of the company by improving the credibility of company-sponsored monitoring. However, the company discouraged this from the outset by attempting to keep technically competent government staff away from the project.[18] No government department was given the resources to develop the capability for monitoring. Several scientists at the University of Papua New Guinea, including David Mowbray, John Pernetta, James Kyle, and others, were able to conduct small independent studies early in the project (Pernetta 1988). The company was eager to discredit the (admittedly sketchy and exploratory) independent sampling in the report of the Starnberg Institute (1991) that disagreed with their own sampling results. But OTML was equally hostile to careful and peer reviewed hydrogeological research into the impact of sediments on the floodplain of the Middle Fly River (Hettler, Irion, and Lehmann 1997).

In contrast with the environmental monitoring undertaken by the company, arrangements for monitoring the social impact of the mine were either unclear, un-enforced or both. Social monitoring was absent from the outset. A social monitoring team was employed briefly by OTML in the early 1990s to study the communities that had not directly received payments for leased land but were now receiving benefits through the Village Trust (Filer 1991). The company attempted to bury the critical findings of the team. Of the 12 reports produced by the Social Monitoring project in the early 1990s, only Stuart Kirsch's report on the Yonggom (Kirsch 1993) found its way into outside publication in the University of PNG journal, *Research in Melanesia*.

Conclusions

Taken together, the main environmental study for the Ok Tedi Mine and the various studies of social, economic, and cultural impact that were completed between 1980 and 1982 are a remarkable body of work. The rather limited resources that were available were stretched to put many people with relevant experience to work to produce a patchwork set of reports. Unfortunately, the main environmental study was not done in a timely manner and was not used to make early decisions about constructing the mine. Environmental assessments ring hollow when decisions are ultimately made on economic grounds without reference to the results of the studies (as happened with the abandonment of the tailings dam first in 1984 and again in 1989.)

As the project changed, in ways that dramatically increased the scale of its physical impact, the original impact studies were increasingly irrelevant. Such new studies as were commissioned in the last half of the 1980s to deal with the new situation (the 6th Supplemental Agreement studies) were not made available for public comment or open scientific review. Because of this lack of transparency, one can only suspect these studies were not made in good faith, given the extent of environmental damage that was already apparent by the late 1980s. The company-sponsored program of environmental studies continued to ignore social and cultural impact, even failing to monitor basic subsistence resources such as the sago palm, the staple food for the area, growing in threatened wetlands.

The Ok Tedi Mine has already gained certain fame as a case study of the environmental impact of riverine tailings disposal. Here we suggest that it can also serve as a cautionary tale for any exercise of environmental assessment: Good intentions and good science are not enough to produce a good assessment. In addition, there need to be strong linkages with people who have local knowledge and with decision makers in both government at the private sector. Otherwise, a good assessment can become irrelevant.

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[1] Acknowledgements [TO BE ADDED]

[2] As recorded by the Toxic Release Inventory of the US Environmental Protection Agency.

[3] In addition to academic papers and college classrooms using Ok Tedi as a case study, non-government organizations of all kinds, ranging from industry-sponsored to anti-mining environmental organizations, have developed case materials on Ok Tedi. Recent examples include the World Resources Institute (2003) case study "Ok Tedi: Unearthing controversy," ESCAP (1999), and the MMSD (Van Zyl 2002).

[5] Information about reserves, overseas markets, and current production was verified on the company web site at http://www.oktedi.com/ (downloaded February 23, 2004).

[6] This team, led by Geoff Pickup, included Roger Higgins, who was later to become environmental manager of OTML in the 1980s and, after a stint in American mines with BHP would become OTML's General Manager from 19?? to 2001?.

[7] These terms of reference were also published at the end of the Main Report (Maunsell and Partners 1982, Vol 1, pp. 178-184.)

[8] Subsequent environmental studies were largely secret, and open neither to public comment nor scientific peer review. After agreement was reached in 1989 to mine copper without a tailings dam, there was a period of relatively open scientific communication between about 1990 and 1994, when OTML environmental staff and consultants were allowed to publish some findings in scientific journals. This communication shut down again during the lawsuit. Subsequently, as BHP prepared to exit the project, more monitoring data was again made available, by placing some environmental reports on the company web site. This uneven flow of information, with data released only when it was advantageous and the proper spin could be put on it, has characterized the whole history of the project. This makes it difficult to do a systematic evaluation, though one can only be grateful that the amount of information is still greater than for most projects.

[9] Hyndman did emphasize in his discussion of ethnozoology, the ritual importance of hunting that went far beyond the dietary value of meat.

[10] For more detail on these events see Townsend 1988.

[11] Diesel-burning generators were used during the gold production phase and a run-of-the-river hydro plant provided power for copper production.

12 It is necessary to be quite explicit about this because many sources have erroneously stated that the tailings dam failed when it was near completion. Among these are many Papua New Guinean authors. This suggests that OTML continued to encourage this mis-perception of history. An appendix to the Mining Minerals and Sustainable Development publication Mining for the Future, produced by the mining industry and relying heavily on BHP sources, contains a tabular history of the Ok Tedi mine saying, "1983: Tailings dam constructed as per agreement with PNG government; 1984: Dam collapses." (Van Zyl et al. 2002a:Annex H2)

[13] The Lukwi tailings dam proposal was revisited in additional studies by Klohn Crippen consultants in later years. None of these studies suggested that the construction of the dam was impossible. Most recently, the concern has been that under PNG conditions, maintaining tailings storage after closure to prevent ARD is a challenge that requires innovative design (Murray and Thompson 2003).

[14] This is not mere hindsight speaking, as WHT advised the government of the necessity for such studies after his first visit to the site in 1981.

[15] It will not have escaped notice of those aware of the ownership history of the mine that the first of the private partners to exit (AMOCO and the German consortium) did so in the early 1990s at the time that forest dieback was receiving publicity as the major environmental concern, and BHP-Billiton exited as acid drainage became a concern. Except for Inmet (remaining 18% shareholder, acquired as Canadian subsidiary of one of the original German partners), the government of Papua New Guinea and the people of the Fly watershed are the inheritors of the legacy of past pollution. They are also entering a period in which acid-generating sulfide ores predominate in the ore body over the oxide ores of the earlier phase.

[16] As government representative in meetings with OTML during construction WHT's outspokenness about the dangers of mine wastes entering "the swamps" was conditioned by his long experience of research in

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the Sepik sago swamp forests. In these meetings Higgins, at that time OTML Environmental Manager, was still insistent that not to build a tailings dam was unthinkable.

[17] The environmental regime adopted in 2001 called for examining food crops grown in the flood plain. However, by the end of FY02 this had yet to be undertaken. The section of the annual environmental report dealing with this topic shows complete ignorance of or indifference to the fate of sago resources, and refers simply to the people of the lower Ok Tedi having moved gardens out of the flood plain to higher ground to avoid mine-derived "poison" (OTML 2002:118). Slow-maturing sago could scarcely have been moved in this way. It is also apparent that such studies as are contemplated will be limited to the lower Ok Tedi and not extend to the much more critical lower Middle Fly where sago stands are "wild" rather than cultivated (see Townsend 2003 for problems with this distinction).

[18] Discussed in more detail in Townsend 1988; Jackson 1993: .

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