appropriate remedial structures to reduce wind erosion of the tailings dam and to monitor the effects of water abstraction on riparian vegetation.

An extensive network of monitoring stations is used to record dust, noise, sulphur dioxide and radiation levels on the mine property and Arandis, whilst automatic weather stations record climatic variables at three sites. Routine measurements of radiation levels are also collected in Swakopmund several times per year.

Use of vehicles for routine data collection and servicing of fixed monitoring equipment causes slight disturbance to plant and animal communities through temporarily increased noise and dust levels. However, whilst the effects of such disturbance may be more important in the case of scarce species, the overall impact is considered to be negligible.

The preventative and remedial activities carried out have had extremely important positive impacts through the control and reduction of noise, dust and radiation levels over the entire mine works. This, in turn has had important positive impacts for the health and social values of all mine personnel.

4.4 Tailings Disposal

The environmental impacts that have already occurred or continue to occur as a consequence of tailings disposal practices at the Rössing Mine are summarized in Table 4.5. Each type of activity and the resulting impacts are described more fully below.

4.4.1 Tailings Dam

The Rössing Mine tailings dam has a basal area of approximately 585 hectares at present (Table 4.2). This is projected to increase to a maximum area of between 660 and 760 hectares, depending on the construction techniques used, by the year 2010. The tailings dam has had several important negative impacts on the surrounding environment and has been the focus of considerable attention aimed at reducing these impacts.

The most severe negative impacts associated with the tailings dam are those due to elevated dust and radiation levels (IAEA, 1981), the loss of scenic diversity, the loss of plant, animal and bird habitats and the contamination of groundwater by seepage (Table 4.5).

Wind erosion of fine tailings is considered to have had an important negative impact. This accentuates the visual intrusion of the tailings dam and wind-blown sand has been deposited in areas up to 2.5 kilometres away from the tailings dam. During exceptionally strong winds, tailings can be blown westwards to the Atlantic Ocean some 65 kilometres away. The progressive rise of the tailings dam wall with the construction of each additional bench increases its susceptibility to wind erosion. Whilst the prevailing winds can easily disperse fine particles, high wind speeds during the winter months are also capable of moving the coarser tailings for considerable distances.

Radon exhalation from the exposed tailings surface averaged 0.80 Bq m^{-2} sec^{-1} with a standard deviation of 0.62 Bq m^{-2} sec^{-1} (Strydom *et al.*, 1989). However, while the radiation levels are considered to have important negative impacts, a variety of remedial measures are being tested and the most practicable will be implemented.

TABLE 4.5: Matrix of environmental impacts resulting from tailings disposal activities at the Rössing Uranium Mine.

Environmental Characteristics		Activities causing environmental impact (See list of activities in footnote)		
Category	Element	1	2	3
Geology	Regional System	0	0	0
	Local System	-1	-1	0
	Special Features	-1	-2	-2
Geomorphology	Soil Quality/Type	-1	0	0
	Erosion Status	-2	-1	+1
Climate	Climatic Pattern	0	0	0
	Microclimate	-1	0	0
Hydrology	Surface Waters			
	(Perennial)	0	0	0
	(Temporary)	-1	0	0
	Underground Water	-3	-1	?
Vegetation	Regional Zonation	0	0	0
	Local Patterns	-2	-1	0
	Variations (season)	0	0	0
	Endangered Species	-2	?	0
	Alien Vegetation	-1	0	-2
Animals & Bird Life	Corridors	?	?	?
	Habitat Variety	-1	0	0
	Habitat Extent	-2	0	0
	Endangered Species	-3	0	0
Aquatic Life	Variety	0	0	0
Air Quality	Dust	-3	-2	+1
	Radio-nuclides	-2	-2	+1
Noise	Intensity	-1	-1	-2
	Duration >40 db	-1	-1	-1
Aesthetics	Landscape Diversity	-2	-1	-1
	Scenic views	-3	-1	-1
Social	People at Home	0	0	0
	People at Work	0	0	0
	People at School	0	0	0
	People at Play	0	0	0
	Vehicle Occupants	0	0	0
	Pedestrians	0	0	0
Socio-economic	Regional Income	0	0	0
	Education Standard	0	0	0
	Demographic pattern	0	0	0
	Land values	0	0	0

1 = Tailings dam 2 = Tailings pond management
3 = Dust and radiation control measures

Noise disturbance is considered to be low in the vicinity of the tailings dam, though it is of minor importance near the pump stations and the tailings pond. Vehicles travelling along the roadways constructed on the tailings benches cause elevated noise and dust levels for short periods. These impacts are considered to be minor.

Seepage from the tailings dam has had very important negative impacts on the underlying groundwater. Prior to completion of the de-watering wells and seepage trenches, chemical analyses of underground water from the Khan River showed that the seepage front had travelled down Pinnacle Gorge and reached the river. Whilst the underlying geological formations effectively reduce the acidity of the seepage water and thereby limit the quantity of heavy metals in solution, the impacts of the seepage water and its salt load are considered to have had serious negative impacts. In addition, seepage fronts have travelled approximately half-way down Panner Gorge reaching monitoring borehole L8 and have reached Dome Gorge trench near the security offices (Figure 3.11). The implementation of effective seepage control measures has largely reduced their impact, though they still have an important negative influence. The impacts of the seepage control system are described in detail in Section 4.6.2.

Loss of plant, animal and bird habitat with the construction of the tailings dam is considered to have had an important negative impact. The habitat types present in nearby areas indicate that the vegetation originally present in the bed of Pinnacle Gorge is unlikely to have contained unique species. Nevertheless, the loss of vegetation in this area, combined with seepage flows, is considered to have had important negative impacts on vegetation in the upper portions of Pinnacle and Panner Gorges. This would be particularly important in the case of plants with a low salt tolerance. Salt crusts on the surface of low-lying areas indicates that some salt migration does occur in damp soils. This will have a negative impact on vegetation, though some species of salt-tolerant sedges have colonized the wetter areas.

Evaporation from the exposed wet surface of the tailings dam will cause slight changes in the local microclimate. These would be accentuated by the sheltering effect of the tailings dam wall. These are considered to have had minor negative impacts, though an increase in humidity and decrease in wind speed will favour the development of plant communities in the lee of the tailings dam.

4.4.2 Tailings Pond Management

The management of the tailings pond on the surface of the tailings dam has recently been adapted to minimize water losses through evaporation and maximize the amounts of water that are re-cycled on the mine. Originally, evaporative losses from the open water surface were considerable but have now been reduced by about 70 %. Additional measures designed to reduce water losses even further include the use of a series of paddocks on the dam surface to reduce the spread of tailings solids. At present, the tailings pond surface covers an area of approximately 30 hectares against the north-western ring berm wall. The liquid collected in the pond is pumped back to the mine as Return Dam Solution.

The increased area of dry tailings dam surface has, however, had a moderately important negative impact through an increase in the wind erosion potential of this surface (Table 4.5). In turn, this has had secondary important negative impacts in that dust and radiation levels are increased. However, seepage losses to the groundwater are reduced, thus having only a minor negative impact. The tailings pond is only visible from the tailings dam berm wall and from the vantage points along the ridge separating the tailings dam from the mine workings. The aesthetic impacts are therefore considered to have minor negative importance.

Since the tailings pond is located within the area affected by the tailings dam, it does not contribute further negative impacts in terms of the loss of plant, animal or bird habitat. Whilst, it is possible that the open water surface might attract birdlife and insects to the area of the tailings dam, the chemical quality of the water is totally unsuitable for animal consumption. The development of small communities of salt-tolerant plants near sub-surface seepage areas will attract insects and birds and have a minor positive impact.

4.4.3 Dust and Radiation Control Measures

A variety of measures have been tested for their efficacy in reducing dust and radiation emissions from the tailings dam; their impacts are summarized in Table 4.5.

The introduction of alien salt-tolerant vegetation for slope colonization and stabilization tests is considered to have had a moderate negative impact through promoting the spread of these species to moist areas where they then compete with indigenous species. Barriers made from wood or old Wabco tyres to reduce wind-blown dust and sand are visually intrusive and have had a minor negative impact on aesthetic values. However, this feature is probably outweighed by the minor positive impacts that these barriers have had through reducing ambient dust levels and countering wind erosion. Tests using rip-rap, bittern sprays and SS100 sprays with alluvium cover have also had an important positive impact in reducing radon emissions from the surface of the tailings dam (Table 4.5). Additional tests with different thicknesses of alluvium cover and SS100 chemical sprays continue to be evaluated.

4.5 Disposal of Mine Waste

The environmental impacts resulting from the disposal of mine waste at the Rössing Uranium Mine are summarized in Table 4.6. Each category of activity and the resulting impacts are described more fully below.

4.5.1 Waste Rock

Approximately 110 000 tonnes of waste rock, as well as low grade and high calc ore, are removed from the Rössing open pit each day and dumped onto designated rock dumps. These dumps are located around the periphery of the open pit, extending into Dome and Pinnacle Gorges (Figure 3.1). Up to the end of 1989, approximately 696 million tonnes of waste rock had been dumped and the basal area of these dumps covers an area of approximately 535 hectares (Table 4.2).
The most severe negative impacts associated with the waste rock dumps are those due to increased noise and dust levels, loss of scenic diversity and loss of plant, animal and bird habitats (Table 4.6). The waste rock dumps in Dome Gorge have almost reached the Khan River confluence and have a severe negative impact on the aesthetic value of this area. Waste rocks dumps in Pinnacle Gorge have had similar negative impacts. The process of dumping from haultrucks is very noisy and this disturbance is accentuated by the noise from waste rock slides. This combination of noises has disturbed animal and bird life in the area and is considered to have had severe negative impacts; these are particularly intense in areas near active dumping sites. Inactive dumping sites are less affected by noise and their negative impact is less. It is interesting to note that inactive dumping sites appear to have provided a wide range of additional habitats for insects. This could be seen as a minor positive impact.

TABLE 4.6: Matrix of environmental impacts resulting from solid and liquid effluent disposal at the Rössing Uranium Mine.

Environmental Characteristics		Activities causing environmental impact (See list of activities in footnote)			
Category	Element	1	2	3	4
Geology	Regional System	0	0	0	0
	Local System	-1	0	0	0
	Special Features	-1	0	0	0
Geomorphology	Soil Quality/Type	-1	0	0	0
	Erosion Status	-2	0	0	-1
Climate	Climatic Pattern	0	0	0	0
	Microclimate	-1	0	0	-1
Hydrology	Surface Waters				
	(Perennial)	0	0	0	0
	(Temporary)	-1	0	0	0
	Underground Water	-2	-1	?	-1
Vegetation	Regional Zonation	0	0	0	0
	Local Patterns	-2	+1	0	0
	Variations (season)	0	0	0	0
	Endangered Species	-2	?	0	?
	Alien Vegetation	-1	-1	0	-2
Animals & Bird Life	Corridors	?	?	?	0
	Habitat Variety	-1	0	0	0
	Habitat Extent	-2	0	0	0
	Endangered Species	-3	0	0	0
Aquatic Life	Variety	0	0	0	0
Air Quality	Dust	-3	0	0	+3
	Radio-nuclides	-2	0	0	+3
Noise	Intensity	-2	0	-1	-1
	Duration >40 db	-2	0	-1	-1
Aesthetics	Landscape Diversity	-3	-1	0	0
	Scenic views	-3	-1	0	+1
Social	People at Home	0	0	0	0
	People at Work	0	0	0	0
	People at School	0	0	0	0
	People at Play	0	0	0	0
	Vehicle Occupants	0	0	0	0
	Pedestrians	0	0	0	0
Socio-economic	Regional Income	0	0	0	0
	Education Standard	0	0	0	0
	Demographic pattern	0	0	0	0
	Land values	0	0	0	0

1 = Waste rock dumps   2 = Sewage and refuse removal systems
3 = Industrial refuse   4 = Control of dust and radiation emission

Elevated noise levels in the vicinity of the waste rock dumps are accompanied by higher dust and radionuclide levels, due to the dumping technique. These dust and radiation levels are considered to pose a serious threat to plant and animal life in the area. In addition, the burial of large areas beneath piles of rock has had important negative impacts through reductions in the extent of plant and animal habitat. These would be particularly important in the case of any rare or endangered species present in the area. While the elevated noise and dust levels in these areas is sufficiently high to retard re-colonization of the new habitat created by the rock piles, it is possible that alien vegetation will colonize these disturbed areas. This would have a moderately negative impact.

The Rössing waste rock dumps have also altered surface drainage patterns in the gorges and have the potential to increase the levels of heavy metals, salts and radionuclides contributed to the groundwater. These are considered to be moderate negative impacts. Clearly, this impact will be most intense after rainfalls.

4.5.1 Sewage and Refuse Removal Systems

At the Rössing Uranium Mine, domestic sewage is treated in two activated sludge sewage treatment plants. The first of these is located some 2 kilometres north of the security offices,while the second is situated immediately west of the mine pond, near the pit superintendent's office. Theses two plant cover a total area of approximately 2 ha, with a combined maximum dry weather flow of 1 520 m^3 day^{-1}.

Perhaps the only significant negative impacts of these two treatment plants are their impact on aesthetic values. While the plants themselves do not contribute significant quantities of dust, a portion of the final chlorinated effluent is used for dust control on gravelled road surfaces in the open pit and near the ammonium nitrate store. This could have a very minor negative impact on the quality of seepage water. In addition, the dissolved nitrogen and phosphorus levels of this effluent will promote the growth of alien vegetation on disturbed road verges, a minor negative impact (Table 4.6).

4.5.2 Industrial Refuse

Approximately 13 000 m^3 of industrial rubbish are dumped per year at the Rössing Mine. This rubbish is collected weekly and then transported to whichever active waste rock dump has been designated and buried. Old engine oil is purified and re-used on site. The only impacts associated with disposal of industrial refuse consist of slight increases in noise levels, considered to be of minor negative importance (Table 4.6). In the longer term, these deposits of industrial refuse may contribute salts and heavy metals to any water which percolates through the waste rock dumps. The longer term impacts are therefore also considered to be of moderate negative importance.

4.5.3 Control of Dust and Radiation Emissions

Elevated dust and radiation levels are probably the two most important health hazards in uranium mining and all possible care is therefore taken to reduce needless personnel exposure. A wide variety of dust and radiation control actions have been implemented at the Rössing Uranium Mine; these vary with the different mining activities concerned.

Optimum use of recycled water and effluent forms the central thrust of dust control techniques at the Rössing open pit. All roads and haulways in the open pit are thoroughly watered down several times per day, while other gravelled roads are wetted at least twice per day. In these activities the water is delivered by tanker and applied while the vehicle is in motion, with a minor negative impact in elevated noise levels. Similarly, ore piles are watered with high pressure hoses. Wherever possible, recycled water is used instead of fresh water. These watering down activities are very effective in reducing airborne dust and radionuclide levels and thus have an important positive impact (Table 4.6). Nevertheless, whilst much of the water applied is lost through evaporation, a small proportion seeps downwards to contaminate the groundwater; this is considered to be a moderately important negative impact. In addition, evaporative water losses will contribute minimally to changes in microclimate in sheltered areas. Watering down of gravelled roads can also increase the erosion potential of these areas and sustain the growth of alien plants along road verges; both of these effects have minor negative impacts. The reduction in ambient dust levels also contributes marginally to improved visual aspects.

Within the mine works, recycled water is also used for dust control in the crusher and ore conveyor sections. Elsewhere in the works, dust control is effected through the use of covered or shrouded conveyor systems and exhaust ventilation. In combination, all of these processes have had a major positive impact on reducing ambient dust levels. In those areas such as the final product recovery plant, the use of protective clothing and respirators is mandatory for all personnel. Frequent checks have shown that careful attention to safety procedures and the use of protective equipment has contributed significantly to reducing the health risks to mine personnel.

At the tailings dam, the situation is much more complicated and under greater control of environmental factors such as wind and sporadic rainfalls. Tests with bittern and chemical sprays have shown these to be effective under conditions of low to moderate wind speeds, but ineffective during high velocity winds. Preliminary results of field measurements suggest that changes to the tailings disposal practice have also reduced dust losses from the surface of the tailings dam. Similarly, field tests with various thicknesses of alluvium cover have shown that radon exhalations from the tailings dam can be reduced to acceptable levels for decommissioning. Overall, dust control measures at the tailings dam have had a minor positive impact in reducing levels of airborne dust and radionuclides from this source.

Information collected from the network of dust and radiation monitoring stations described in Section 4.3.6 is used to evaluate dust and radiation controls at all parts of the mine and at Arandis. Detailed studies are conducted in all areas where results are found to be higher than expected and remedial actions are implemented as soon as possible. These features contribute an important positive impact.

4.6 Ground and Surface Water Protection Measures

A variety of measures are undertaken at the Rössing Uranium Mine to protect the local ground and surface water resources. The environmental impacts of these measures are summarized in Table 4.7 and are described in detail below.

4.6.1 Seepage Dam

The seepage dam is located down slope from the tailings dam and, with its associated reedbeds, covers a total area of approximately 2 hectares (Table 4.2). This dam traps up to 5000 to 6000 m^3 of tailings seepage per day and also receives seepage water pumped from the open pit and from de-watering wells at the head of Panner Gorge (Figure 3.11).

Whilst the seepage dam is very effective at collecting seepage from the tailings dam, it has also had an important negative impact by sustaining the development of a dense Phragmites reedbed. High evapotranspiration rates from this reedbed has undoubtedly led to a considerable loss of water, over and above that lost by evaporation from the water surface. This would have had a minor negative impact on the microclimate of the area (Table 4.7). Although Phragmites is often considered to be a cosmopolitan species, it would not normally occur in the Namib Desert, and is therefore considered

to be an alien species in the Rössing environment. In addition, Oreochromis mossambicus, a fish species which is indigenous to other parts of Namibia, has been introduced into the seepage dam and appears to be surviving. The introduction of this alien species must also be considered to have had a minor negative impact on any aquatic life in the dam.

Small amounts of water that have leaked from the seepage dam have entered the groundwater, contributing to the pollutant load flowing down Pinnacle Gorge, and are therefore considered to have had a moderate negative impact.

On the positive side, the seepage dam and its reedbeds has a pleasing visual appearance and is considered to have a minor positive impact on aesthetic values. In addition, the reedbeds provide refuge for several animal and bird species and thus have a minor positive impact through provision of habitat. The seepage dam also acts as a sediment trap for eroded tailings and therefore has an additional minor positive impact on the erosion status of the area (Table 4.7).

4.6.2 Cutoff Trenches and De-watering Wells

The positions of the various cut-off trenches and de-watering wells at Rössing are shown in Figure 3.11. These trenches and wells with their associated pumps play an important role in preventing contamination of the Khan River groundwater with seepage from the Rössing mine and therefore have had an important positive impact. However, whilst this system is effective in reducing the movement of contaminant plumes into the Khan River, they also reduce the low natural flow of groundwater in the gorges and thereby reduce the total flow in the Khan River. This negative impact is, however, considered to be minor.

The trench and well system has also had a number of minor negative impacts (Table 4.7). These include slight impacts on natural vegetation in their immediate vicinity and the promotion of alien plant growth on areas disturbed by trampling and vehicles. Additional features with minor negative impacts include temporary elevations in noise and dust levels during construction, maintenance and sampling of the wells and trenches, together with adverse visual impacts.

4.6.3 Monitoring Programme

The groundwater monitoring programme undertaken by Rössing has greatly improved the understanding of the groundwater characteristics of the area and has facilitated the evaluation of remedial actions designed to conserve water on the mine and protect the environment; this is considered to be an important positive impact (Table 4.7). On the negative side, the groundwater monitoring programme has had minor negative impacts through vegetation removal at well and borehole sites, together with temporarily elevated noise and dust levels from vehicles. The disturbance of the natural vegetation has reduced the aesthetic appeal of small areas and has created conditions suitable for colonization by alien vegetation, additional minor negative impacts.

The Khan River monitoring programme has provided basic ecological information on the condition of the perennial vegetation and supplements the data on water quality and quantity obtained from boreholes in the river bed. An improved understanding of seasonal variations in the Khan River vegetation and the provision of information for the management of water abstraction from the river are considered to have had minor positive impacts.

TABLE 4.7: Matrix of environmental impacts resulting from groundwater and seepage control measures implemented at the Rössing Uranium Mine.

Environmental Characteristics		Activities causing environmental impact (See list of activities in footnote)			
Category	Element	1	2	3	4
Geology	Regional System	0	0	0	0
	Local System	0	0	0	0
	Special Features	0	0	0	0
Geomorphology	Soil Quality/Type	0	0	0	0
	Erosion Status	+1	0	-1	0
Climate	Climatic Pattern	0	0	0	0
	Microclimate	-1	0	0	0
Hydrology	Surface Waters				
	(Perennial)	0	0	0	0
	(Temporary)	-1	0	0	0
	Underground Water	-2	+3	+3	+1
Vegetation	Regional Zonation	0	0	0	0
	Local Patterns	-2	-1	-1	+1
	Variations (season)	0	0	0	0
	Endangered Species	-2	?	?	0
	Alien Vegetation	-3	-1	-1	0
Animals & Bird Life	Corridors	?	?	?	0
	Habitat Variety	+1	0	0	0
	Habitat Extent	+1	0	-1	0
	Endangered Species	+1	-1	-1	0
Aquatic Life	Variety	-1	0	0	0
Air Quality	Dust	0	-1	-1	0
	Radio-nuclides	0	0	0	0
Noise	Intensity	0	-1	-1	0
	Duration >40 db	0	0	0	0
Aesthetics	Landscape Diversity	+1	-1	-1	0
	Scenic views	+1	-1	-1	0
Social	People at Home	?	0	0	0
	People at Work	0	0	0	0
	People at School	0	0	0	0
	People at Play	0	0	0	0
	Vehicle Occupants	0	0	0	0
	Pedestrians	0	0	0	0
Socio-economic	Regional Income	0	0	0	0
	Education Standard	0	0	0	0
	Demographic pattern	0	0	0	0
	Land values	0	0	0	0

1 = Seepage dam
2 = Cut-off trenches and de-watering wells
3 = Groundwater monitoring wells
4 = Khan River vegetation monitoring

Disturbance caused by elevated dust and vehicle noise during six-monthly sampling is considered to have negligible impact on the area. The movement of vehicles along the bed of the Khan River disturbs the surface alluvium layers and can promote the growth of alien plant species. However, it appears that most of the vehicle traffic along the bed of the Khan River can be attributed to casual week-end visitors who cannot easily be controlled.

4.7 Infrastructure

The enormous scale of operations undertaken at Rössing and the mine's location in a remote desert environment has accentuated the importance of a sound infrastructure. The location of the major infrastructure components at the Rössing Uranium Mine are shown in Figure 3.1; their environmental impacts are summarized in Table 4.8. and described in greater detail below.

4.7.1 Water Supplies

Assured supplies of good quality water are critical factors in the operation of any mining venture; Rössing is no exception. However, the scarcity of water in the desert environment required the construction of a 65 km long pipeline from Swakopmund, four intermediate pumping stations and three reservoirs at Rössing. These facilities cover an area of some 70 hectares (Table 4.2), though an additional area alongside the pipeline was disturbed during construction.

The most important negative aspects of the freshwater pipeline, pumping stations and reservoirs is the loss of scenic diversity and their visual intrusion on the landscape (Table 4.8). Similarly, the areas of disturbed ground alongside the pipeline and pumping stations promote the growth of alien vegetation and thus also have a moderately important negative impact. In addition, the surveying, grading and vegetation clearing of the pipeline route has disturbed local vegetation patterns and has had a moderately important negative impact on habitat variety and local vegetation patterns. This will also have had a minor negative impact on any fauna in the area.

Construction activities caused temporary increases in noise and dust levels and contribute a minor negative impact to the freshwater supply pipeline. This feature would also have accentuated any disturbance to the fauna.

The freshwater supplies from Swakopmund are supplemented by the abstraction of groundwater from three boreholes in the Khan River, which can provide some 3000 m^3 of saline water each day. However, the development of these boreholes and their associated pipelines is estimated to have affected an area of approximately 2 hectares. This has been accentuated by the construction of three temporary alluvium dams in the Khan River which has disturbed an additional 3 hectares of river bed (Table 4.8).

The disturbance to soils and indigenous vegetation in and around the bed of the Khan River has promoted the development of alien vegetation. However, the alien plants colonizing these areas are predominantly annual plants; the negative impacts are therefore considered to be minor. Temporarily elevated noise and dust levels during the drilling of boreholes and bull-dozing of dam walls have had minor negative impacts. Similarly, the increased erosion potential of cleared areas is considered to be a minor negative impact.

TABLE 4.8: Matrix of environmental impacts resulting from infrastructure at the Rössing Uranium Mine.

Environmental Characteristics		Activities causing environmental impact (See list of activities in footnote)						
Category	Element	1	2	3	4	5	6	7
Geology	Regional System	0	0	0	0	0	0	0
	Local System	0	0	0	0	0	0	0
	Special Features	0	0	0	0	0	0	0
Geomorphology	Soil Quality/Type	0	0	0	0	0	0	0
	Erosion Status	0	-1	-1	-1	0	-1	0
Climate	Climatic Pattern	0	0	0	0	0	0	0
	Microclimate	0	0	0	0	0	0	0
Hydrology	Surface Waters							
	(Perennial)	0	0	0	0	0	0	0
	(Temporary)	0	0	0	0	0	0	0
	Underground Water	+3	+3	0	-1	0	0	0
Vegetation	Regional Zonation	0	0	0	0	0	0	0
	Local Patterns	-1	-1	-1	-2	-1	-1	0
	Variations (season)	0	0	0	0	0	0	0
	Endangered Species	?	?	?	-1	0	-1	0
	Alien Vegetation	-2	-1	-1	-1	-1	-2	0
Animals & Bird Life	Corridors	0	0	0	0	0	0	0
	Habitat Variety	0	0	0	-1	-1	-1	0
	Habitat Extent	-1	0	-1	-1	-1	-1	0
	Endangered Species	-1	-1	-1	-1	-1	-1	0
Aquatic Life	Variety	0	0	0	0	0	0	0
Air Quality	Dust	-1	+2	-1	0	0	-1	0
	Radio-nuclides	0	+1	0	0	0	0	0
Noise	Intensity	-1	-1	-1	-1	-1	-1	0
	Duration >40 db	0	0	0	0	0	0	0
Aesthetics	Landscape Diversity	-3	-1	-1	-1	-1	-1	0
	Scenic views	-3	-1	-3	-2	-1	-1	-1
Social	People at Home	0	0	0	0	0	0	+1
	People at Work	0	0	0	+1	0	+1	+2
	People at School	0	0	0	0	0	0	0
	People at Play	0	0	0	0	0	0	0
	Vehicle Occupants	0	0	0	+1	0	0	0
	Pedestrians	0	0	0	+1	0	0	0
Socio-economic	Regional Income	0	0	0	+2	+2	0	+1
	Education Standard	0	0	0	0	0	0	+1
	Demographic pattern	0	0	0	0	0	0	0
	Land values	0	0	0	+2	+2	0	+1

1 = Water supplies from Swakopmund
2 = Recycled water and Khan River water
2 = Power supplies
4 = Roads
5 = Railway
6 = Airfield
7 = Telecommunications

The installation of additional pipelines to return seepage and tailings dam water to the mine workings has affected an additional 2 hectares (Table 4.2). This activity has also resulted in slightly increased noise and dust levels and promoted the growth of alien plants. These are considered to have had minor negative impacts (Table 4.8).

However, the use of recycled water and saline water from the Khan River in dust control measures on the mine has had important positive effects through reduced dust and airborne radionuclide levels (Table 4.8). Similarly, the interception and recycling of groundwater contaminant plumes for dust control has had a very important positive impact on local groundwater.

4.7.2 Power Supplies

The 220 kV SWAWEK overhead transmission line supplying electrical power to Rössing traverses the mine property on its way from Omburu to Swakopmund and Walvis Bay. Erection of this powerline and its continued maintenance is estimated to have affected a total of 15 hectares (Table 4.2), while the Rössing sub-stations have disturbed an additional area of approximately 1 hectare. The powerlines are visually intrusive and have had a major negative impact on the scenic diversity of the area. The areas of disturbance have reduced the availability of plant and animal habitat and increased the erosion status of soils, while the growth of alien plants has been promoted on the disturbed areas; these are considered to be minor negative impacts (Table 4.8). The slight increase in dust levels due to the erection and maintenance of the powerlines has had a negligible impact.

4.7.3 Transportation Systems

Efficient and reliable transportation systems are a vital part of the Rössing infrastructure. The construction and maintenance of transportation networks has had inevitable environmental impacts on the Rössing Mine property. The individual impacts of the transportation components, namely: the road network, railway and the airfield, on the mine property are considered separately.

A well-maintained network of tarred and gravelled-surface roads has been constructed at the Rössing Mine. The total area of disturbance amounts to some 26 hectares in the case of tarred roads with an additional 43 hectares for gravelled roads (Table 4.2). The roads are considered to have had moderately important positive impacts on regional income and land values through improved communications and transport. The clear layout and display of road safety notices along the roads has also had minor positive impacts on pedestrians, vehicle occupants and workers (Table 4.8).

On the negative side, several sections of road have a low aesthetic appeal or are visually intrusive on the stark scenic beauty of the countryside. The movement of heavy vehicles particularly on unsurfaced roads has raised dust levels in the vicinity and disturbs nearby plant, animal and bird habitat. These are considered to be moderately important negative impacts. Dust control measures on the unsurfaced roads around the mine workings have proved to be very effective in reducing ambient dust levels.

The roads also act as collection surfaces for the infrequent rainfalls and focus runoff into shallow washes and gulleys. This increases the erosion potential of these areas and promotes the growth of alien weed species. Both of these aspects are considered to have minor negative impacts (Table 4.8).

The spur railway line linking the Rössing Mine with the main Usakos - Swakopmund railway line at Arandis is an essential component of the transportation network at the mine. This line is estimated to have affected an area of some 7 hectares (Table 4.2).

As in the case of the road network, the railway's vital role in the transport of goods and services is considered to have a moderately positive impact on regional income levels and land values. This is offset to some extent by the moderate negative impact due to the visual intrusion of the railway on the landscape. Increased noise levels are usually of short duration and, together with a slight loss of plant and animal habitat and promotion of alien plant growth along the railway verges, have had minor negative impacts (Table 4.8).

The Arandis airport and its associated facilities are located on the mine property and are estimated to have affected a total area of some 15 hectares (Table 4.2). The location of this airfield on flat, poorly vegetated terrain has limited its effect on plant, bird and animal habitat such that it is considered to have had only a minor negative impact. However, the layout of gardens at the hangers, while improving the aesthetic value of the site, has increased the potential for colonization by alien plants. This is therefore considered to be a moderately important negative impact (Table 4.8).

Due to the flat terrain, the airfield has had only a minor negative impact on the scenic value of the countryside and on the erosion potential of the surrounding area. The convenience afforded to mine personnel by the airfield is considered to have contributed a minor positive impact.

The good telecommunications systems at the Rössing Mine have contributed moderately important positive impacts to the residents of Arandis and to mine personnel (Table 4.8). These have also had minor positive impacts through contributions to increased land values, educational standards and regional income. The only minor negative impact has been the visual intrusion of telephone poles and cables on the scenic beauty of the region.

4.8 Housing and Recreational Facilities

The provision of good housing, social amenities and recreational facilities for Rössing Mine personnel forms an important part of the remuneration package of each employee (Sections 3.7.7 and 3.7.8). The different housing and recreational facilities cover a total area of approximately 314 hectares (Table 4.2). The environmental impacts of each component of these projects are summarized in Table 4.9 and are described in more detail below.

4.8.1 Arandis

The town of Arandis covers an area of approximately 135 hectares and accommodates Rössing's less skilled workers (Section 3.7.7.2). The town is virtually self-contained, and has very important positive impacts on every social and socio-economic feature of the community (Table 4.9). The provision of schooling, medical facilities and skills training has had strongly positive impacts at all levels of the community. The local and regional educational standards have been raised and there have been strong positive effects on demographic patterns and land values.

The location of Arandis contrasts sharply with the arid surrounding countryside and detracts somewhat from the scenic beauty of the region, though the negative impacts on landscape diversity are minor. The contrast between Arandis and its surroundings has been accentuated by the development of well-watered gardens, sports fields and park areas. Inevitably, the importation of alien plants for gardens has to be considered as an important negative impact, though improvements to the local soils have had a minor positive impact.

TABLE 4.9: Matrix of environmental impacts resulting from housing and recreational facilities associated with the Rössing Uranium Mine.

Environmental Characteristics		Activities causing environmental impact (See list of activities in footnote)			
Category	Element	1	2	3	4
Geology	Regional System	0	0	0	0
	Local System	0	0	0	0
	Special Features	0	0	0	0
Geomorphology	Soil Quality/Type	+1	+1	0	0
	Erosion Status	-1	0	-1	0
Climate	Climatic Pattern	0	0	0	0
	Microclimate	?	?	0	+1
Hydrology	Surface Waters				
	(Perennial)	0	0	0	0
	(Temporary)	-1	0	0	0
	Underground Water	-2	0	?	+1
Vegetation	Regional Zonation	0	0	0	0
	Local Patterns	-2	0	-1	-2
	Variations (season)	0	0	0	-1
	Endangered Species	?	0	0	?
	Alien Vegetation	-3	-1	-1	-2
Animals & Bird Life	Corridors	?	?	?	0
	Habitat Variety	-1	0	0	+1
	Habitat Extent	-1	0	0	0
	Endangered Species	-1	0	0	0
Aquatic Life	Variety	0	0	0	0
Air Quality	Dust	-1	0	-1	0
	Radio-nuclides	0	0	0	0
Noise	Intensity	-1	-1	-1	0
	Duration >40 db	0	0	0	0
Aesthetics	Landscape Diversity	-1	-1	-1	+1
	Scenic views	-1	-1	-1	+2
Social	People at Home	+3	+3	0	+2
	People at Work	+3	+3	+2	+2
	People at School	+3	+3	0	0
	People at Play	+3	+3	+2	+2
	Vehicle Occupants	+2	+2	+1	0
	Pedestrians	+2	+2	+1	0
Socio-economic	Regional Income	+3	+3	+2	0
	Education Standard	+3	+3	+1	+1
	Demographic pattern	+2	+2	0	0
	Land values	+2	+3	0	+2

1 = Arandis
2 = Swakopmund suburbs (Tamariskia & Vineta)
3 = Contractor housing
4 = Rössing Country Club

The relative abundance of alien plants in Arandis emphasizes the disruption to local vegetation patterns though the loss of plant and animal habitat in the area is considered to have had a minor negative impact. The increased noise and dust levels that are always associated with towns are considered to have minor negative impacts.

The tarred roads and roofs of houses form an almost continuous rain collection area. Rainfall is directed away from Arandis by drainage ditches which have had a minor negative impact on the erosion potential of local soils. In combination, these features have had a moderate negative impact on the patterns of groundwater recharge by rainfall.

4.8.2 Swakopmund

Rössing has provided 746 staff houses in two Swakopmund suburbs, namely Vineta and Tamariskia, covering a total area of 75 hectares (Table 4.2). The development of these two suburbs has had an enormous positive impact on the social and economic features of the community (Table 4.9). Particularly important are the strong positive impacts on the regional and national economy, local land values and demographic patterns, as well as development of a coherent community structure and identity. The high safety standards at Rössing are reflected in the levels of awareness shown by pedestrians and vehicle occupants, together with a very positive attitude to household safety measures. The extensive and intensive on-the-job training at Rössing has also contributed to raising the education level of all its employees.

In contrast to Arandis, the Swakopmund suburbs were added to an existing town. Thus, there was minimal disturbance of indigenous plant and animal habitat though there is minor visual intrusion. The development of gardens has had a minor positive impact on soil quality in the area though this is countered by the minor negative impact caused by the planting of alien vegetation.

4.8.3 Contractor Housing

The accommodation and facilities provided for temporary contract workers at Rössing are located at Namib Lodge and Rossec Lodge (Figure 3.1). These units and their associated mess facilities and recreational amenities are estimated to cover an area of 20 hectares (Table 4.2).

These facilities have a moderately positive impact in terms of improved working conditions and recreational facilities. In addition, the individual firms of contractors working at Rössing benefit from increased job opportunities in the region and thereby contribute to raising the regional income. The requirement for all contractors to adhere to the high standards of safety at Rössing provides additional minor positive impacts through improved education and safety training.

The areas around both Namib Lodge and Rossec Lodge have been affected by clearing and construction activities. This has caused minor negative impacts through slight increases in dust and noise levels, a slight increase in the erosion potential of the area, the disruption of existing vegetation patterns and the introduction of alien plants. These all combine to increase the visual intrusion which is considered to have had a minor negative impact.

4.8.4 Rössing Country Club

The amenities offered by the Rössing Country Club (RCC) cover an area of approximately 100

hectares (Table 4.2), a large proportion of which is contributed by the 18 hole golf course. The well-designed facilities have an attractive visual impact and add to the scenic diversity of the area. The wide range of activities and amenities offered by the RCC has made a significant positive contribution to the social life of all mine personnel and has had positive impacts on educational standards and land values in Swakopmund (Table 4.9).

The extent of disturbance to local vegetation patterns and the extensive areas of alien vegetation must be considered to have had a moderate negative impact. However, this feature is to some extent counteracted by the abundance of vegetation which will have had a minor positive impact on vegetation diversity in the area. In addition, the regular irrigation of bowling greens and the golf course will probably have minor positive impacts on the groundwater and on the local microclimate.

4.9 Overall Impressions of Environmental Impacts at Rössing

Previous sections of this chapter have detailed the extent and significance of environmental impacts resulting from the variety of activities undertaken at the Rössing Uranium Mine since site exploration began. It is clear from this analysis that the large scale of operations at Rössing has largely dictated the extent and severity of the recorded impacts. However, the analysis is complicated by the fact that several different processes and operations at Rössing can contribute to, and accentuate, the impacts on a single component of the environment. Therefore, it is appropriate to draw together those contributors to impacts of concern and evaluate their overall impact on the environment. The following sections represent a cross-impact evaluation of the Rössing Mine operations to obtain an overall impression of the processes and operations that have had, and will continue to have, impacts on mine personnel and the surrounding environment.

4.9.1 Noise and Vibration

Noise and vibration are inescapable features of any mining operation. Clearly, the extent and severity of any impacts resulting from these two stimuli tend to diminish with distance from the source. Thus, it is to be expected that the most significant impacts of noise and vibration are likely to be those experienced by mine personnel. Direct measurements of noise and vibration levels at Rössing show very clearly that personnel employed in and around the open pit and in the crusher circuits and ore processing facilities experience the highest noise and vibration levels. Rössing studies have also shown that the use of appropriate protective equipment reduces noise levels appreciably and thereby lessens its impact on personnel. Therefore, while excessive noise does pose an extremely important hazard to the health and well-being of mine personnel, its effects are controllable.

However, these solutions are neither practicable nor possible in the case of the natural environment around the mine. Noise measurements made at different points on the mine property have shown that continuous noise levels average between 30 and 45 dB, with temporary higher values up to 90 dB during blasting. Very high noise levels, for example during blasting, cause immediate disturbance to birds and animals. Their immediate reaction is to vacate those areas where noise and vibration levels are intolerable. This is in accordance with the assessment that Namib Desert animals would be accustomed to the low levels of background noise that are found in most areas of the Namib Desert. The low numbers of small and large animals around the Rössing Mine suggest that noise levels have had a serious effect on animal populations in the area. However, the presence of Klipspringer and Baboon in Panner Gorge and the several species of birds found throughout the mine property, indicate that many species are able to achieve some degree of "acclimatization" to moderate levels of continuous noise. Therefore, while this does not reduce the harmful effects of noise, the animal and bird populations around Rössing appear to be able to tolerate much of the noise that is generated by mining operations.

4.9.2 Dispersion of Particulates

The dispersion of particulate material by air and water is of prime concern to all mining operations and is particularly acute in uranium mines where radionuclides are also dispersed. Whilst respirable dust, (that fraction of particles with diameters less than 5 μm), can pose severe health hazards to humans, there is seldom any size limit placed on the particles that have an impact on ecological systems and processes.

Rössing's geographical location in a desert environment with frequent high winds predisposes the mine works to wind erosion and dust dispersion. Indeed, dust storms are a frequent occurrence throughout the Namib Desert and its ecological communities are specially adapted for survival in this environment. In contrast, the low and infrequent rainfalls recorded in the Namib Desert reduce the extent of particle dispersion by water erosion. Nevertheless, the episodic rainfalls recorded at Rössing generate considerable runoff in a short period of time and water erosion is therefore still regarded as an important process for the dispersion of particulates in this area.

At Rössing, direct measurements have shown that wind dispersion of tailings from the tailings dam and ore dust from the open pit, crushers, conveyors and ore stockpiles is responsible for the largest amounts of radionuclides and dust dispersed into the surrounding environment. These sites are therefore of prime concern as sources of particulates likely to cause health hazards and contaminate the environment. Mine employees working in close proximity to any of the major sources listed above are therefore at greatest risk. Once again, regular measurements have shown that thorough watering-down procedures and the use of appropriate protective equipment and procedures in the mine workings has reduced levels of airborne particulates to such an extent that employee exposures to dust and radionuclides are within accepted safety limits.

Ongoing optimization of tailings deposition practices at Rössing is designed to maximize water savings, particularly through reduced evaporation losses. An important negative result has been the increased area of dry tailings which now have a lower cohesivity and the finer particles are dispersed readily even by light winds. The remaining coarser particles require much higher wind speeds before they are transported from the tailings dam. The strong east winds that are so characteristic of the winter months provide suitable conditions for transport of these larger particles. The particularly strong winds on 20-21 July 1989 where peak wind speeds exceeded 125 km hr^{-1} are estimated to have removed over 1000 tonnes of tailings from the tailings dam. This wind caused considerable erosion of the exposed tailings dam beaches and berm walls, depositing large quantities of tailings dust in the shallow gullies and water courses to the west of the tailings dam. The extent of the visible depositions of wind-blown tailings is shown in Figure 4.1.

Observations in Pinnacle, Panner, Khan and Ostrich Gorges, and an extensive area to the west of the tailings dam have shown that the quantities of deposited tailings dust diminish dramatically with increasing distance from the tailings dam. Surface accumulations of fine tailings dust are visible up to 2.5 kilometres to the west of the tailings dam, where dust has accumulated on the sheltered lee side of rocks, bushes and small trees. Several plants growing in exposed situations near to the tailings dam also show clear signs of sand blasting on their lower portions, whilst low-growing species are often covered with sand after periods of strong wind. These observations and the routine measurements made by Rössing personnel indicate that dust and radionuclides blown from the tailings dam have affected a considerable area.

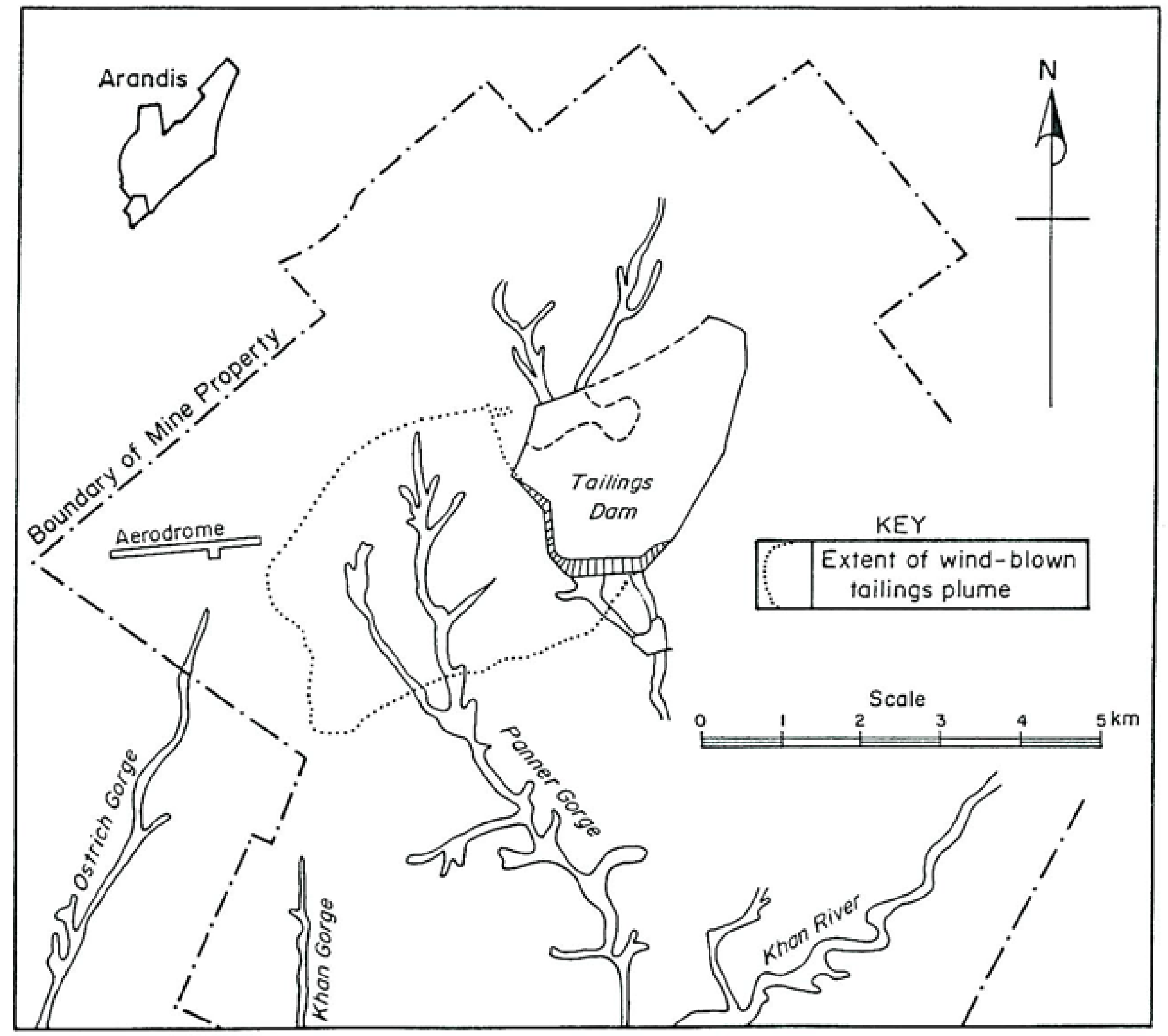

Plate 4.1: Map showing the extent of visible deposits of wind-blown tailings from the Rössing Uranium Mine tailings impoundment. (Drawn from information provided by A. Abrahams, Rössing Uranium Mine).

In exposed desert areas further away from the Rössing Mine, the ground surface has formed an armoured layer of so-called "desert pavement" due to the ablation of fine material over a considerable period of time. This desert pavement consists largely of coarse and fine gravel particles with diameters greater than 0.5cm. These particles form a protective layer on the surface and are only transported by the strongest winds. Similar sorting of tailings particles occurs on the surface of the tailings dam and a surface layer of coarser tailings particles or alluvium has been shown to provide a significant degree of protection against wind erosion. Concerted remedial action will be required to reduce further tailings erosion and to clean up affected areas.

4.9.3 Radiation

Natural background levels of radiation in the area around the Rössing mine are considered to be low (Figure 2.6), no doubt due in part to the low uranium grade of the Rössing orebody (average U_3O_8 content = 0.035 %). Gamma radiation dose measurements at Arandis vary between 1.6 - 1.7 mSv $year^{-1}$. This value can be regarded as representative of external background radiation levels. Within the final product recovery section, dose measurements indicate that personnel receive between 1.0 and 2.5 mSv $year^{-1}$ of radiation above the external background levels.

Rössing have adopted the ICRP (International Commission on Radiological Protection) guidelines for exposure to radiation. The ICRP makes a distinction between two groups, namely radiation workers and the general public, and recommends different limits of exposure to radiation over and above the natural radiation for each group. The occupational radiation exposure of radiation workers must be below 20 mSv $year^{-1}$. The exposure for a member of the public must be below 5 mSv $year^{-1}$ for any one year, and below 1 mSv $year^{-1}$ taken over a lifelong exposure. Not all workers on the mine are classed as radiation workers and are therefore considered as part of the general public. Measurements at all work stations on the mine have shown that no personnel have been exposed to radiation doses that exceed the ICRP guideline. Therefore, despite the risks of harmful radiation, the current safety precautions appear to be adequate for the protection of radiation workers as well as the general public.

Radon exhalation measurements at the tailings dam have shown exhalation rates on dry beaches to average 0.8 Bq m^{-2} sec^{-1}, compared with an average background value of 0.02 Bq m^{-2} sec^{-1}. Similar measurements at the open pit, waste rock dumps and ore stockpiles have values that average 0.5, 0.6 and 0.9 Bq m^{-2} sec^{-1} (Strydom *et al.*, 1989), respectively. Radon concentrations associated with mining activities were calculated as 14 Bq m^{-3} at Arandis (Grundling & Leuschner, 1990). Again, this value is considered to indicate a low contribution from mining-related activities (Grundling & Leuschner, 1990). The estimated annual average dose equivalent of radon attributable to mining-related activities amounts to some 0.5 mSv $year^{-1}$. Again, this is lower than any dose that might be received from the natural environment (de Beer, 1990).

Detailed measurements of the natural radon concentrations in the area around the Rössing Uranium Mine were collected by the Atomic Energy Corporation over a 1-year period, from October 1987 to September 1988. These measurements show clearly that the highest concentrations of radon in the natural environment are recorded in the vicinity of the Rössing open pit and the tailings impoundment. In contrast, the town of Arandis is located in a region of low radon concentrations (Figure 4.2; Grundling *et al.*, 1988).

The dispersion of radionuclides with wind-blown tailings and ore dust would certainly increase the levels of radiation to which plant and animal communities are exposed. This problem is particularly acute since wind-blown dust accumulated in the lee of stones, rocks and shrubs. These sites form the most important habitats for the fauna around the Rössing Uranium Mine. The short- and long-term consequences of this additional radiation for plants and animals are not known but are considered to be harmful. Nevertheless, the remoteness of the Rössing Mine site, coupled with the short half-life of radon and its rapid dilution in air, are mitigating factors. The implementation of effective dust control measures at the tailings dam would also contribute substantially to reducing environmental radiation.

The available data suggest that there is very little human health risk associated with wind-blown tailings to the west of the tailings impoundment. This aspect should, however, be confirmed by additional direct measurements.

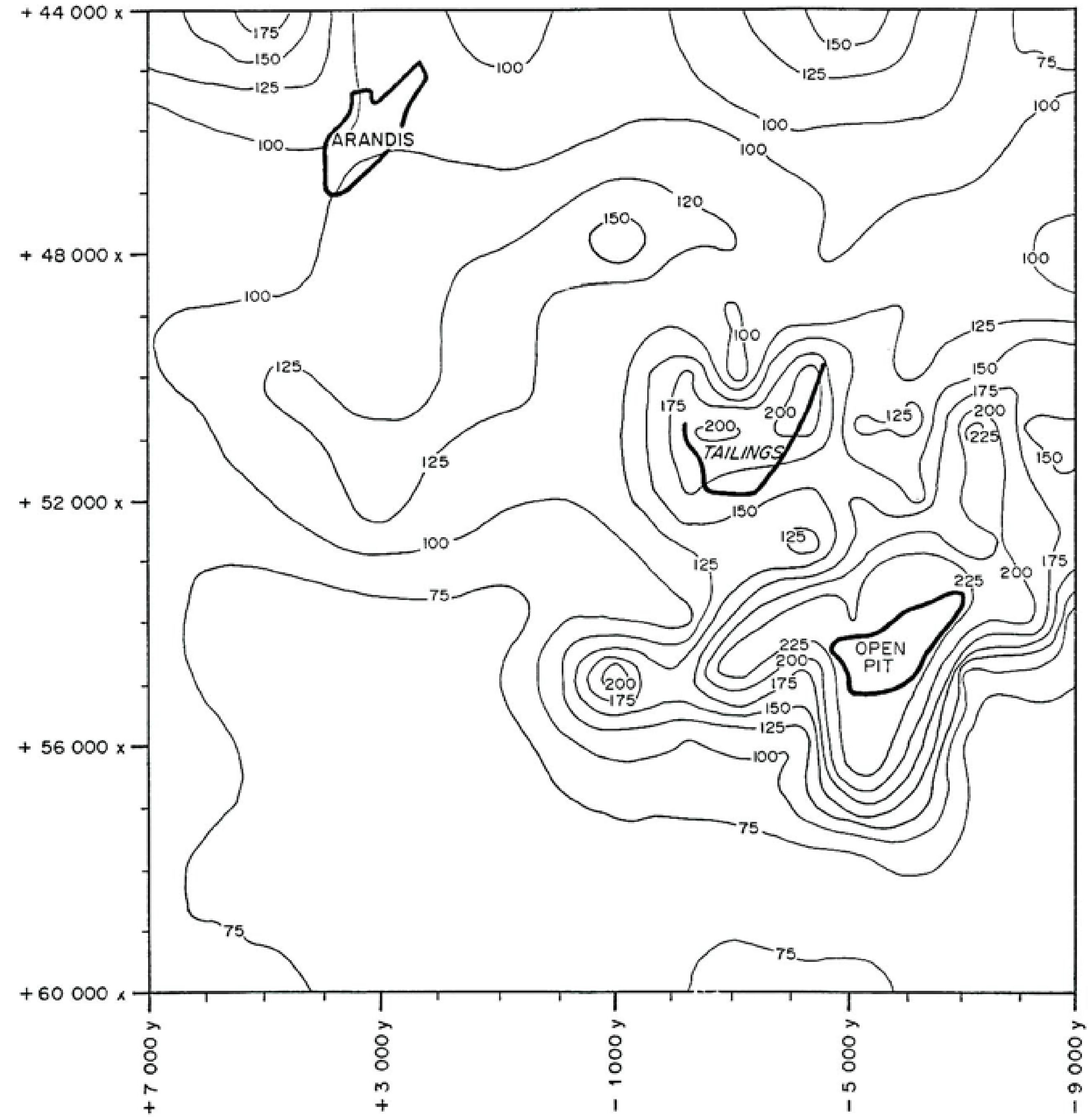

Figure 4.2: Contour map of measured average environmental radon concentrations in the vicinity of the Rössing Uranium Mine, for the period October 1987 to September 1988. The positions of Arandis, and the Rössing open pit and tailings impoundment are shown to indicate their locations in relation to regions of high radon concentrations. (All values are given in Bq m^{-3}; data obtained from Grundling *et al.*, 1988).

4.9.4 Seepage Control and Groundwater Contamination

The three major gorges in the vicinity of the Rössing Mine (Dome, Pinnacle and Panner Gorges) appear to be incised into the regional bedrock groundwater table at several locations, forming a network of drainage channels leading towards the Khan River. The tailings dam at the head of