NUCLEAR POWER STATION ('NUCLEAR 1') AND ASSOCIATED INFRASTRUCTURE

Addendum to Dune Geomorphology Impact Assessment: debris flows in the Sand River and potential for flood damage to the R330

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DECLARATION OF INDEPENDENCE

I, Werner Kurt Illenberger as principal of Illenberger & Associates, hereby confirm my independence as a specialist and declare that I do not have any interest, be it business, financial, personal or other, in any proposed activity, application or appeal in respect of which Arcus GIBB was appointed as environmental assessment practitioner in terms of the National Environmental Management Act, 1998 (Act No. 107 of 1998), other than fair remuneration for worked performed, specifically in connection with the Environmental Impact Assessment for the proposed conventional nuclear power station ('Nuclear 1'). I further declare that I am confident in the results of the studies undertaken and conclusions drawn as a result of it – as is described in my attached report.

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EXECUTIVE SUMMARY

This specialist study investigates alleged debris flows and debris flow deposits in the Sand River, quicksands and liquefaction of sand, the November 2007 flood that damaged the R330 at St Francis Bay Village and potential for flood damage where the R330 crosses the Sand River. These issues were raised at a key stakeholder workshop held at St. Francis Bay on 25 May 2010 as part of the EIA for a nuclear power station ('Nuclear-1') that Eskom proposes to build.

The possible threats that such events could have on the possible nuclear power station and its associated infrastructure at the Thyspunt site are assessed. The findings are presented in this Addendum Report to the Dune Geomorphology Report.

Available literature on the subject was perused, including diverse reports prepared for Eskom. Various local residents and environmental specialists were consulted. Detailed contour maps and aerial photographs from 1942 to 2007 were analyzed to investigate the behaviour of the Sand River and floodwater flow paths.

Debris flows and debris flow deposits

There are no debris flows or debris flow deposits in the Sand River. There are no other environmental conditions in the Cape St. Francis area that are conducive to the formation of debris flows. Thus debris flows cannot pose a threat to a possible nuclear power station and its associated infrastructure at the Thyspunt site.

Quicksands and liquefaction of sand

Quicksands often occur in the Oyster Bay dunefield. They are usually formed when loosely consolidated sand is inundated. Vehicles would not be engulfed in quicksands in the Oyster Bay dunefield unless they drive on the bed of the Sand River or around interdune ponds. Vehicles travelling on the R330 are not in any danger of being engulfed in quicksands.

The proposed "eastern access route" that would cross vegetated dunes and wetlands would be built to correct engineering specifications to accommodate any poor foundation conditions so that vehicles can safely use the road. The possible nuclear power station would be founded on solid rock and so quicksands or liquefaction of sand could not have any effect on it.

The November 2007 flood

The November 2007 flood that damaged the R330 is estimated to be a 1:200 year event. The main erosional damage resulted from erosion of sediments by floodwaters flowing down the steep V-drain along the R330. Damage was also caused by the deposition of sediment in the area from the R330 along Lyme Road into the adjacent part of the St. Francis Bay Golf Course. The deposit is an alluvial fan, not a debris flow deposit.

Ninham Shand has proposed improvements to stormwater drainage that would considerably reduce the chances of such damage occurring again. Some of these improvements have been undertaken.

Potential for flood damage where the R330 crosses the Sand River

The R330 crosses the Sand River via a box culvert constructed when the road was rebuilt to its current standard in 1989/1990. The most extensive damage to the R330 since then was in the flood of November 1996, when the wing walls on either side of the culvert were damaged and there was some erosion of the tarred surface by water flowing over the road. The road was still wide enough to accommodate two directions of traffic flow. Other floods caused less or no damage.

Thus the R330 has been damaged by some of the numerous floods of the Sand River but damage was minor in that vehicular access was never interrupted. It is recommended that the culvert be strengthened if necessary, be well-maintained, be checked regularly to see that it is not blocked by sand; and any debris that is caught across it during floods be removed.

ENVIRONMENTAL IMPACT ASSESSMENT FOR THE PROPOSED NUCLEAR POWER STATION ('NUCLEAR-1') and ASSOCIATED INFRASTRUCTURE

Addendum to Dune Geomorphology Impact Assessment: debris flows in the Sand River and potential for flood damage to the R330

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1 INTRODUCTION

1.1 Background

Eskom Holdings (Ltd) has proposed the construction of a nuclear power station on one of five alternative sites, located in the Northern, Eastern and Western Cape Provinces of South Africa. GIBB (Pty) Ltd (GIBB) was appointed by Eskom Holdings (Pty) Ltd (referred to hereafter as Eskom) to undertake the Environmental Impact Assessment (EIA) for the proposed nuclear power station and its associated infrastructure at each site.

As part of this EIA, a key stakeholder workshop was held at St. Francis Bay on 25 May 2010. Subsequent to this workshop Dr Werner Illenberger, the author of the Dune Geomorphology Report, was asked to investigate the alleged debris flows and debris flow deposits in the Sand River that were identified as such by Prof. Fred Ellery and colleagues, as well as the November 2007 flood that damaged the R330. The possible threats that such events could have on the possible nuclear power station and its associated infrastructure at the Thyspunt site were then to be assessed.

These matters do not form part of the original Terms of Reference of the dune geomorphology investigation, and are thus presented in this Addendum Report to the Dune Geomorphology Report.

This Addendum Report is also referred to in responses to comments submitted by I&APs regarding the EIA.

Further background information is in the Dune Geomorphology Report.

1.2 Study Approach

Relevant literature on the subject was perused. These are listed in the References Section, and are referred to in the text where relevant.

Detailed contour maps and aerial photographs from 1942 to 2007 were analyzed to investigate the behaviour of the Sand River and floodwater flow paths.

Local residents were consulted to collect information about flood events, damage that resulted from floods, and other relevant information.

Various specialists familiar with the sites were consulted. These specialists include:

Specialists on the EIA team:

- Koos Reddering: geology and seismic hazard. Koos Reddering mapped the geology of the area under investigation in detail. His PhD thesis was on the Robberg Formation, which consists largely of debris flow deposits.

Acknowledged academic specialists:

- Jenny Burkinshaw, Izak Rust, Koos Reddering, Pete Illgner: physical coastal environment. All three specialists have extensive experience of coastal dunes, including inter alia the dunes in the area under investigation. Jenny Burkinshaw studied morphodynamics of headland-bypass dunefields, concentrating on the Cape St. Francis dunefields, in her PhD thesis.

Civil engineers:

Chris Roberts and Geoff Roberts of Aurecon (formerly Ninham Shand Consulting Engineers), the consulting engineers approached by Eskom to do exploratory studies of the roads that would be necessary for the construction and operation of the possible nuclear power station at Thyspunt. Their brief includes assessing existing roads such as the R330 and proposed modifications and improvements that may be needed.

2 SUPPOSED DEBRIS FLOWS AND DEBRIS FLOW DEPOSITS

2.1 Information supplied by Prof. Ellery

In various e-mails during June and July 2010, Prof. Ellery supplied his definition of debris flows, a locality map (Figure 2.1) and a description and photographs of the deposits he observed in the field (Figures 2.2 to 2.4). The photographs were taken by Pete Illgner who was on one of the field trips undertaken by Prof. Ellery and his colleagues.

Figure 2.1. Locality map of the supposed debris deposits Prof. Ellery observed in the field.

Prof. Ellery defined debris flows as follows:

> “I would describe a debris flow as a liquefied mass of unconsolidated, saturated debris made up primarily of clastic sediment, but also including biological material, which is entrained by water and flows down a slope. Typically, there is an appreciable fraction of biological material, and there may be a wide range of particle sizes present due to the sudden and indiscriminate nature of these events in both entraining debris (mainly sediment) as well as depositing it. These features differ from landslides, that, although often triggered by hydraulic processes, are made up primarily of clastic sediment. Landslides are not entrained by flowing water - they simply involve the flow of clastic material (and vegetation) down a slope.

Figure 2.2. Overall view of the deposits. Photograph by Pete Illgner.

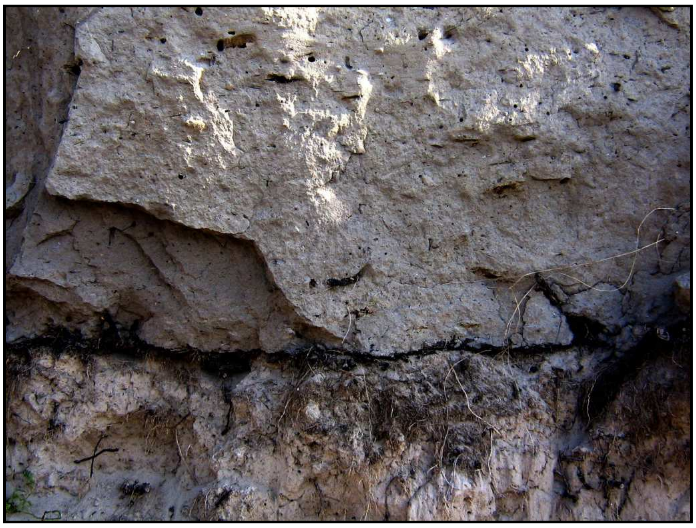

Figure 2.4. Base of the deposit. Photograph by Pete Illgner.

Figure 2.3. Complete vertical section through the deposit. Photograph by Pete Illgner.

> "Obviously, the grade of material transported and deposited in a debris flow will depend on the nature of the sediment in the catchment. Mudflows are a special form of debris flow where material is mainly mud (silt and clay material). I must be honest and say that the mode of entrainment is not central to the definition of a debris flow - it is more about the nature of the material entrained and deposited during an event that is important."

He described the debris flow deposits illustrated in the photographs:

> "Biological material has been buried by a 1.5 to 2 m thick debris deposit. The debris deposit includes mainly fine sand (the material in the source area that is well known to you) together with coarse fragments and vegetation. There are no small-scale sedimentary features that result from gradual movement and

> burial of bed forms - throughout the sequence the material that was entrained has simply been dumped. There are some minor features present that indicate the turbulent nature of the flow."

He provided further information as follows:

> "Attached is a Google Earth image that shows the location of the debris flow deposits that we saw in the Oyster Bay dunefield. But they are almost certainly more widespread than the location shown! I think that they are likely to be present over a broad front in low-lying ground east of the elevated ground that marks the highest point of the dunefield. I suspect that they arise in settings with a slope of 1% or more. There is no doubt in my mind that a slope on the land surface of something like 1% represents a geomorphic threshold in the Oyster Bay system. Slopes approaching 1% or greater than that, are likely to be vulnerable to debris flows."

In his comments on the EIA in a letter dated early June 2010, he notes:

> "The dunefield has an asymmetric longitudinal morphology in that it slopes gently upwards from west to east to the crest of the dunefield with a slope of 1:135 (0.74%). The dunefield has a central portion that is relatively flat over a distance of 1km. Eastwards of the flat central section the dunefield slopes downwards towards the east with a slope of 1:85 (1.2%)."

The slopes of 1:135 and 1:85 he mentions are quoted from the Dune Geomorphology Report. Converting to degrees (a unit commonly used for slope), 1:135 is 0.42º and 1:85 is 0.67º.

Prof. Ellery considers debris flows to pose a threat to infrastructure that will provide vehicular access to the possible nuclear power station. He cites examples such as the damage recently done by mudflows in China.

2.2 Debris flows and debris flow deposits as defined in the literature

Debris flows and debris flow deposits are defined, discussed and theorised about in numerous scientific textbooks and articles (e.g. Hsu 2004, Iverson, 1997, Reddering, 2000). Numerous more readable definitions and descriptions can be found on the internet, e.g. "Natural Hazards in Switzerland (2010)" "State of California Dept of Conservation" (2010), California Geological Survey (2010), USGS (2010). Figure 2.5 illustrates a typical debris flow, and Figure 2.6 illustrates damage caused by a landslide that falls in the debris flow category.

The pertinent characteristics relevant to the Sand River are:

- Debris flows initiate on steep slopes, typically 30º or more, with a minimum of 15º. Gravity is the driving force that creates the flows, not entrainment (i.e. picking up and carrying along) of sediment by moving water.
- Debris flows that cause significant destruction are mostly those that are initiated on steeper slopes: 20º and above.
- Debris flows can continue flowing on shallow slopes, at least 1º, until friction dissipates their inertia.

- Water often initiates a debris flow by lubricating the sediment, enabling it to start sliding; extreme rainfall events trigger most debris flows, e.g. Figure 2.6.

- Debris flows stop flowing after a short while and end abruptly: they are “frozen” when they run out of inertia. There are consequently no sedimentary structures like cross-bedding, soft-sediment deformation, etc.

- It is not necessary for biologic material to be a constituent of debris flows.

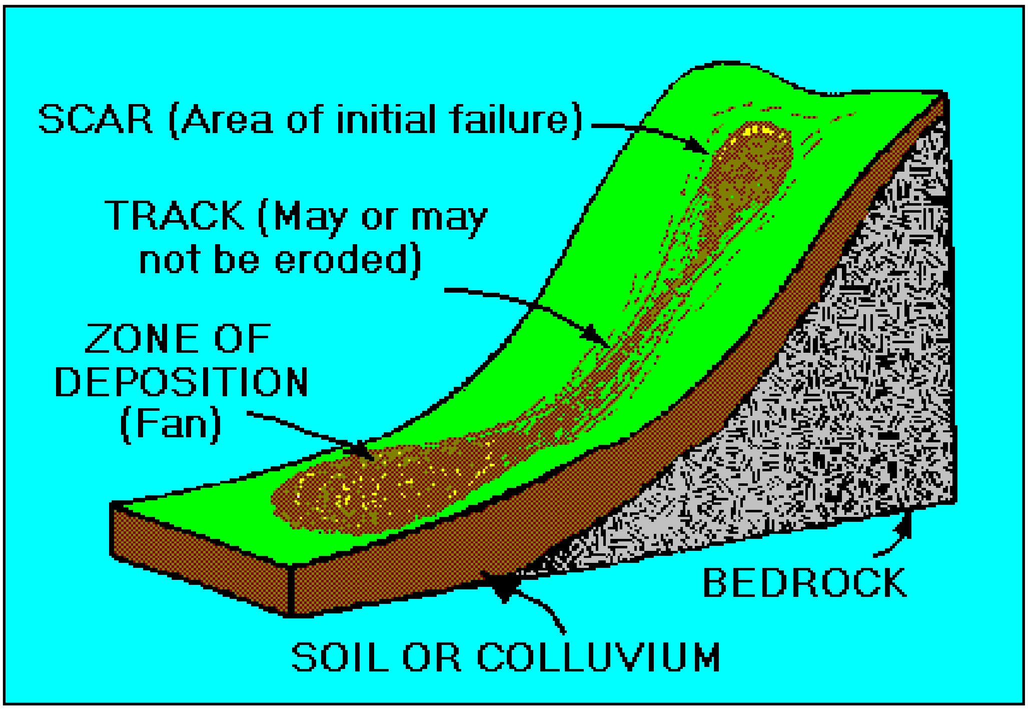

Figure 2.5. Sketch of a typical debris flow. From California Geological Survey (2010).

Figure 2.6. Damage caused by a landslide in California. This landslide falls in the debris flow category. From USGS (2010).

2.3 Assessment of the supposed debris flows and debris flow deposits in the Sand River

The following observations are pertinent to the deposits in the Sand River found by Prof. Ellery:

- Slopes in the area that are steep enough to initiate debris flows are ridges formed by arms of parabolic dunes and sidewalls of previously mobile dunefields. However, these ridges are composed entirely of sand, and debris flows cannot form in pure sand because water soaks away rapidly into sand (Hsu, 2004).
- The Sand River slopes at 0.67º, too shallow to form or sustain debris flows.
- Koos Reddering has studied the photographs of the deposits using image enhancement, and has identified features that could be cross-bedding and soft-sediment deformation, although these are vague, and cannot be positively indentified without a field visit.

- Jenny Burkinshaw, Izak Rust, Pete Illgner and Werner Illenberger have never seen any debris flows or debris flow deposits in many field visits to the area, including some visits made shortly after flood events of the Sand River.

- Koos Reddering has mapped the geology of the area in detail and has never seen any debris flow deposits.

The opinion of the above specialists is that the supposed debris flow deposits are river flood deposits of sand, some mud, a few pebbles, and some plant debris, that were entrained and later deposited by the Sand River when in flood. The Sand River carries a high sediment load ("hyperconcentrated flow"), so sedimentary structures are often poorly developed. The sediments portrayed in Figures 2.2, 2.3 & 2.4 were probably deposited by a flood event of the Sand River like the one illustrated in Figure 2.7.

It is concluded that there are no debris flows or debris flow deposits in the Sand River. There are no other environmental conditions in the Cape St. Francis area that are conducive to the formation of debris flows. Thus debris flows cannot pose a threat to a possible nuclear power station and its associated infrastructure at the Thyspunt site.

Figure 2.7. View up the Sand River from the R330 after the flood event of 3 August 2006. The front-end loader at the top right that has settled into the bed of the river is discussed in Chapter 3. Photographed 19 August 2006.

3 QUICKSANDS AND LIQUEFACTION OF SAND

Mr Chris Barratt submitted comments as chairman of the St Francis Kromme Trust in an I&AP letter dated 29 June 2010. One of the concerns was that liquefaction of sand could take place within the mobile dunefields, and amongst vegetated dunes and wetlands that the “eastern access route” would traverse, resulting in quicksand that could engulf vehicles, hence making access routes to the possible nuclear power station and its associated infrastructure at the Thyspunt site unsafe. Ms Renee Royal of the Thyspunt Alliance raised similar concerns, as did some other I&APs.

Quicksands often occur in the mobile dunes of the Oyster Bay dunefield: many people have experienced all terrain vehicles being bogged down while driving through the dunefield during wet periods. The quicksands are mostly formed when loosely consolidated sand is inundated (e.g. Figure 3.1).

The front-end loader that settled into the bed of the Sand River during the flood event of 3 August 2006 is a spectacular example of quicksand formed during a flood event (Figure 3.2). What is significant is that the vehicle was not moved or engulfed in the sand, but settled down in the sand, as water flow was obstructed by the vehicle, causing erosion and liquefaction of sand around the vehicle.

It is concluded that vehicles would not be engulfed in quicksands in the Oyster Bay dunefield unless they drive on the bed of the Sand River or around interdune ponds. Vehicles travelling on the R330 are not in any danger of being engulfed in quicksands.

The proposed “eastern access route” that would cross vegetated dunes and wetlands would be built to correct engineering specifications including geotechnical surveys with boreholes, etc. It would be designed with suitable foundations to accommodate any poor founding conditions, so that vehicles can safely use the road.

The possible nuclear power station would be founded on solid rock and so quicksands or liquefaction of sand could not have any effect on it.

Figure 3.1. Quicksand next to an interdune hollow formed when loosely consolidated sand was inundated during the flood event of 3 August 2006. Photographed 19 August 2006.

Figure 3.2. The front-end loader used for sand mining just upstream of the R330, which settled into the bed of the Sand River during the flood event of 3 August 2006. Photographed 19 August 2006.

4 THE NOVEMBER 2007 FLOOD THAT DAMAGED THE R330

This flood is described in detail in Ninham Shand (2008). The catchment area and flow path of the flood-water as best the author has been able to ascertain are as shown in Figure 4.1. What is known for certain is that these floodwaters did not originate from the Sand River (which is situated to the north of where the flooding occurred), as a large elongate east-west trending dune ridge separates the Sand River catchment from catchments to the south (Figure 4.1). The catchments to the south are separated by similar but lower dune ridges that are mostly closely spaced. Consequently these catchments are long and narrow.

The table below summarises recent flood events at St. Francis Bay (Ninham Shand, 2008). Rainfall was above average, with numerous medium-sized flood events that caused an increase in groundwater level. The November 2007 flood is estimated to be a 1:200 year event that was very localized.

Date	Total amount	Peak
August 2006	248 mm	165 mm over 3 days
March 2007	176 mm	175 mm over 3 days
May 2007	179 mm	161 mm over 3 days
August 2007	142 mm	56 mm over 3 days
23 November 2007	184 mm over 1 day	120 mm in 4 hours – over very small area

The recent removal of alien vegetation in the catchment of the November 2007 also caused an increase in groundwater level. Groundwater level was thus very high during the last quarter of 2007, so infiltration was reduced and runoff increased proportionally. There was a fire in the catchment in early November 2007 which would have further reduced infiltration rates and increased runoff. All these factors compounded to cause an unusually high amount of runoff. The factors are largely natural.

The catchment for the November 2007 floodwater is formed by the narrow Eastern Valley Bottom wetland that is confined by the aforementioned low east-west trending dune ridges. The floodwater then flowed across the Links Golf Course (Figure 4.2). Runoff from the Links Golf Course augmented the flow, but apparently not to a great extent (Ninham Shand, 2008). The flow path used to follow a natural course across the R330, as shown in Figure 4.1, before St. Francis Bay Village was built. Although stormwater pipes had been built under the R330 at this point, the development of St. Francis Bay Village blocked this natural course. Hence the floodwater turned and ran down the R330 and then turned again to cross the R330 to run into the St. Francis Bay Golf Course (Figures 4.1 & 4.4). Some of the floodwater ponded here and soaked away slowly, and some flowed down the length of the Golf Course to eventually discharge into the sea.

The main erosional damage caused by the November 2007 flood resulted from erosion of sediments by floodwaters flowing down the steep V-drain along the R330, that ultimately eroded away the whole width of the R330 (Figure 4.3). Damage due to the deposition of sediment occurred in the area from the R330 along Lyme Road into the adjacent part of the St. Francis Bay Golf Course (Figure 4.4). The sediment was deposited here because the gradient of the flow path flattens, so the flow speed dropped and the sediment-transporting capacity of the floodwater diminished. The deposit is an alluvial fan, not a debris flow deposit.

As far as can be ascertained, the rainfall that made this flood was very restricted: as explained above the catchment for the floodwater is long and narrow, and there was minimal flooding down adjacent catchments.

The above information is as best the author has been able to ascertain. The author would be grateful if anyone who has further information would let the author know (please e-mail werner@illenberger.biz).

The question that arises is how likely a similar flood with associated damage could happen again. The flood is estimated to be a 1:200 year event, and stormwater drainage is normally designed to handle a 1:50 year event. It is recommended that road engineers check that stormwater drainage is adequate along this section of the R330. Ninham Shand (2008) and Chris Roberts (personal communication 2010) proposed improvements to stormwater drainage that would considerably reduce the chances of such damage occurring again:

- A cut-off drain along the western boundary of the Links Golf Course to divert floodwater originating in the Eastern Valley Bottom wetland into a large natural depression that will act as a soak-away for floodwaters. This will considerably reduce the volume of floodwater that would discharge across the Links Golf Course onto the R330.

- A large diameter pipe down the R330 underneath the side drain, together with a collector intake at the exit from the Links Golf Course, just upstream of the single 600mm diameter pipe that currently crosses under the R330 on the original line of the water course as shown in Fig 4.1. This new pipe will go down the hill into a box culvert crossing under the R330 at the entrance to St. Francis Bay Village. This will carry floodwater safely onto the St. Francis Bay Golf Course.

- A box culvert under St. Francis Drive to take floodwater to the eastern part of the St. Francis Bay Golf Course before it enters the original watercourse to the sea.

- Some re-shaping of the St. Francis Bay Golf Course to allow clear passage for this water down to the sea.

Some of these improvements have been undertaken:

- A cut-off drain has been built along the western boundary of the Links Golf Course.

- Some re-shaping of the St. Francis Bay Golf Course has been done.

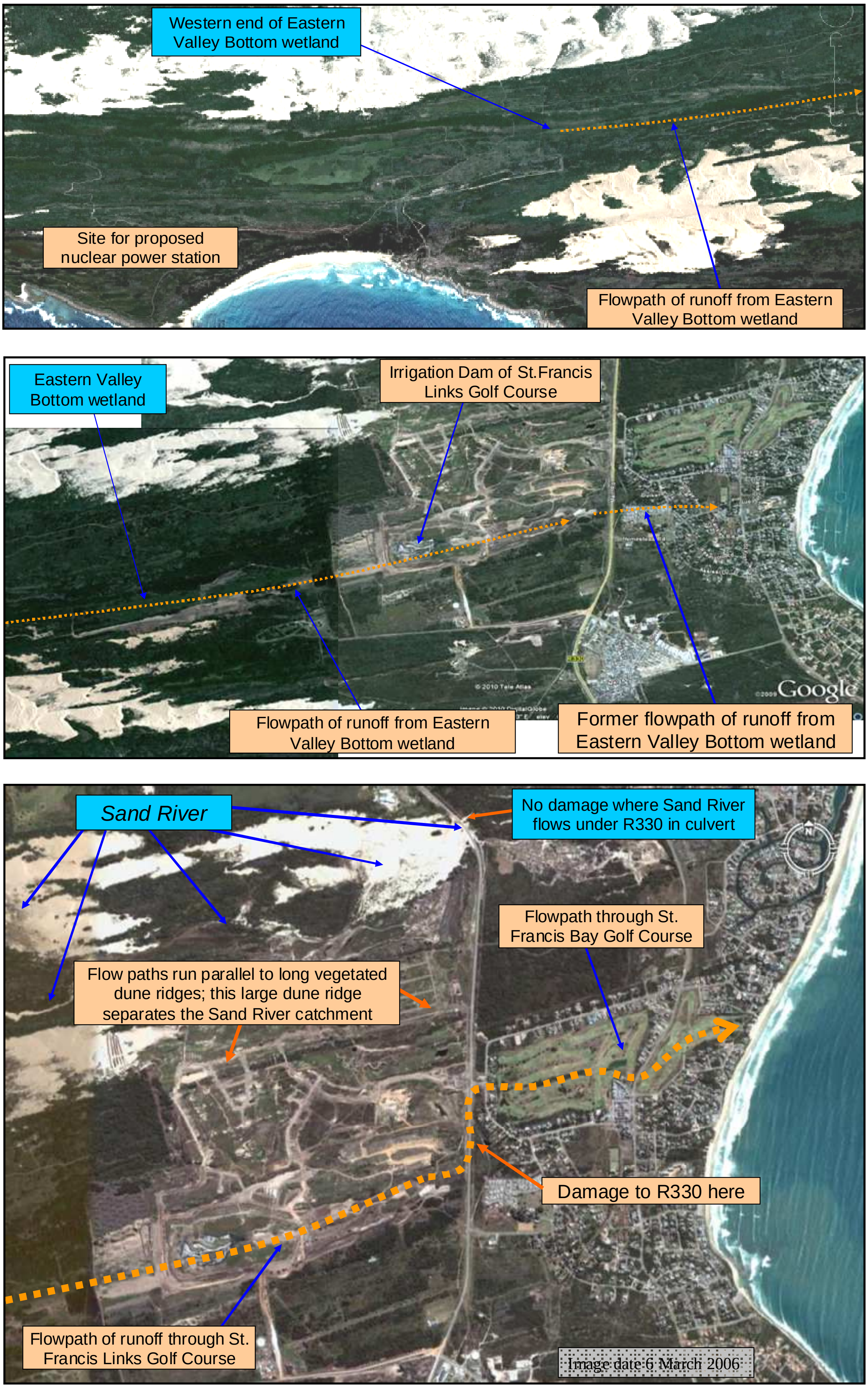

Figure 4.1. Flow path of floodwater that damaged the R330 on 23-24 November 2007. The map is in three parts, top to bottom is from west to east.

Figure 4.2. Floodwater as it approached the R330 off the Links Golf Course. Photograph taken by Keith Simon on 24 November 2007.

Figure 4.3. Flood damage to the R330. Photograph taken by Frank Silberbauer on 24 November 2007.

Figure 4.4. Oblique aerial view looking east, showing flow path of floodwater and areas where sediment was deposited in the St. Francis Bay Golf Course. Photograph taken by Frank Silberbauer on 28 November 2007.

5 POTENTIAL FOR FLOOD DAMAGE WHERE THE R330 CROSSES THE SAND RIVER

The R330 needs to be able to handle floods without significant damage so that access to the possible nuclear power station is not interrupted. The following information has been assembled to assess the R330 where it crosses the Sand River in a box culvert (Figures 5.1 & 5.2).

The bridge over the Kromme River was constructed from 1975 to 1985 and the culvert was built when the road to Cape St. Francis was tarred in 1989/1990. (Marius Keyser, District Roads Engineer, Provincial Roads Dept, personal communication, October 2010).

The most extensive damage to the R330 was in the flood of November 1996, when the wing walls on either side of the culvert were damaged and there was some erosion of the tarred surface by water flowing over the road. The road was still wide enough to accommodate two directions of traffic flow (Owen Putzier, former Town Clerk, personal communication, September 2010).

Chris Roberts, civil engineer at Ninham Shand, supplied the following information (partly paraphrased personal communication, September 2010).

> "I have been to St Francis Bay fairly often since about 1985 for various jobs and haven't seen any major damage.
>
> The wing walls on either side of the actual culvert have been damaged. The wing walls on the downstream side are severely damaged. These wing walls got damaged prior to the 2006 & 2007 floods; the Sand River didn't flow that strongly during these events. The bottom line is that the culvert itself is adequate, although the road may have overtopped once or twice.
>
> The sand mining upstream of the bridge will reduce the risk of the culvert being blocked."

An unusual incident occurred in June 1992, when a large transverse dune had completely blocked the Sand River, causing the Sand River to dam up to create a large body of water (Figures 5.3, 5.4 & 5.5). This natural dam was breached during a high rainfall event sometime before November 1992. The flowing water eroded a channel through the dune, and a large volume of water flowed down to the R330 and then ran down along the west side of the R330 to the Kromme estuary, because the culvert was blocked with sand (Owen Putzier, personal communication, September 2010). The road was not damaged.

The Sand River again dammed up against a large transverse dune 50 m from the road in 1998. A bulldozer was used to breach this dam, because it was feared that if the dam breached naturally due to a flood event, parts of St Francis Bay Village might be inundated as happened in the 1996 flood (Owen Putzier, personal communication, September 2010). Note that this inundation was due to the Sand River overflowing its channel downstream of the culvert.

The sand that is transported by the Sand River passes through the culvert under the road during normal flow and flood events. Figures 5.1 and 5.2 illustrate typical scenes after a flood.

Thus the R330 has been damaged by some of the numerous floods of the Sand River since the road was rebuilt to its current standard in 1989/1990, but damage was minor in that vehicular access was never interrupted. It is however recommended that:

- The wing walls on either side of the culvert be repaired;
- Road engineers should check what flood recurrence interval the culvert can handle, and improvements should be made if necessary;
- The culvert should be checked regularly to see that it is not blocked by sand; and
- The culvert should be checked during floods and any debris that is caught across it should be removed.

Figure 5.1. Oblique aerial view looking south, showing typical situation where the Sand River crosses the R330. About one third of the large transverse dune that had blocked the dunefield had been eroded away (see text and Figures 5.3, 5.4 & 5.5). Photograph taken by Jenny Burkinshaw on 15 June 1993.

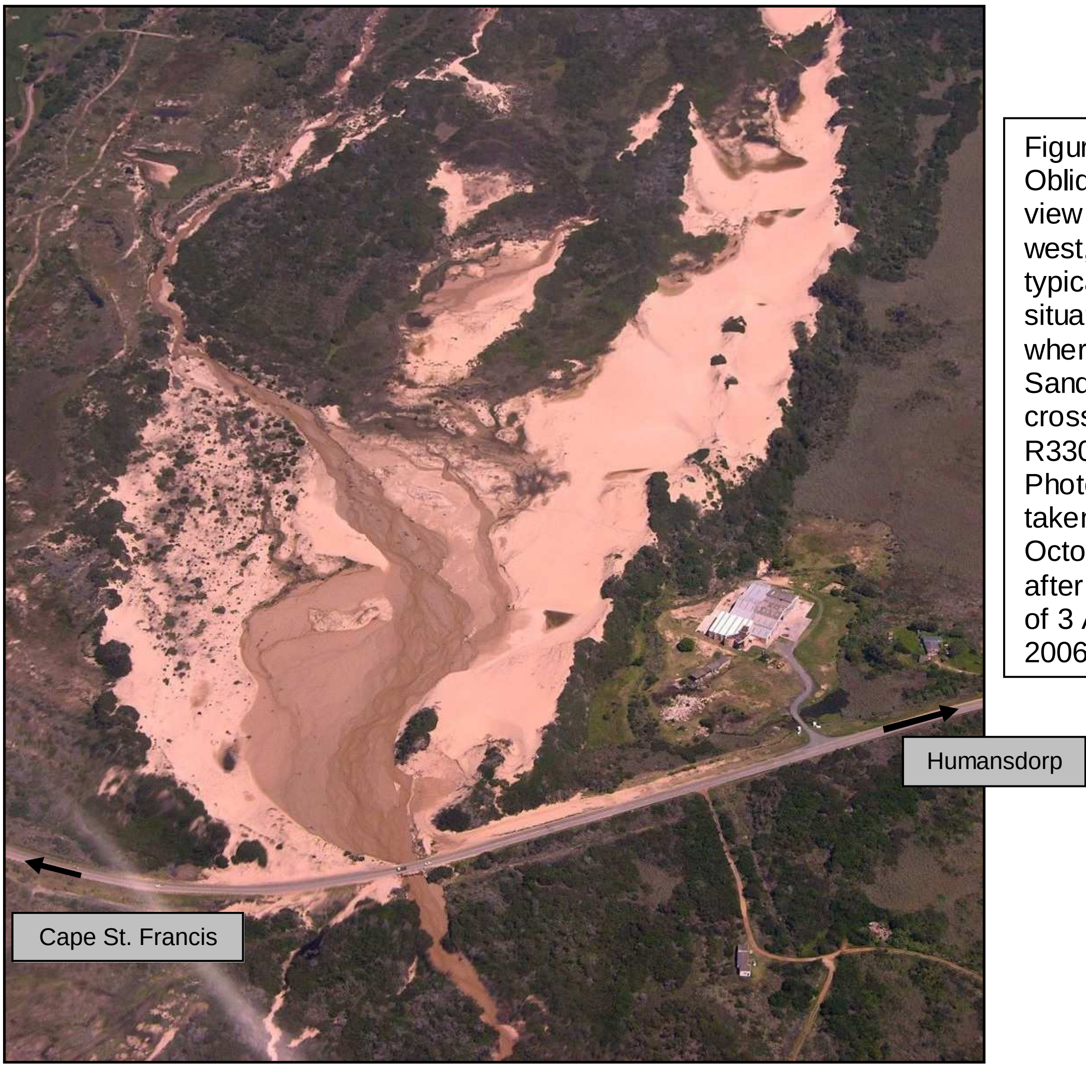

Figure 5.2. Oblique aerial view looking west, showing typical situation where the Sand River crosses the R330. Photograph taken on 6 October 2006 after the flood of 3 August 2006

Figure 5.3. View up the Sand River from the R330 showing the large transverse dune that had completely blocked the Sand River. Photograph taken by Jenny Burkinshaw on 28 July 1992.

Figure 5.4. The large body of water that dammed up against the large transverse dune, looking southeast. Photograph taken by Jenny Burkinshaw on 28 July 1992.

Figure 5.5. The large body of water that dammed up against the large transverse dune, looking south. Photograph taken by Jenny Burkinshaw on 28 July 1992.

6 CONCLUSIONS AND RECOMMENDATIONS

6.1 Debris flows and debris flow deposits

There are no debris flows or debris flow deposits in the Sand River. There are no other environmental conditions in the Cape St. Francis area that are conducive to the formation of debris flows. Thus debris flows cannot pose a threat to a possible nuclear power station and its associated infrastructure at the Thyspunt site.

6.2 Quicksands and liquefaction of sand

Quicksands often occur in the mobile dunes of the Oyster Bay dunefield. They are usually formed when loosely consolidated sand is inundated.

Vehicles would not be engulfed in quicksands in the Oyster Bay dunefield unless they drive on the bed of the Sand River or around interdune ponds. Vehicles travelling on the R330 are not in any danger of being engulfed in quicksands.

The proposed “eastern access route” that would cross vegetated dunes and wetlands would be built to correct engineering specifications to accommodate any poor foundation conditions so that vehicles can safely use the road.

The possible nuclear power station would be founded on solid rock and so quicksands or liquefaction of sand could not have any effect on it.

6.3 The November 2007 flood

The November 2007 flood that damaged the R330 is estimated to be a 1:200 year event that was exacerbated by high rainfall in the period before the flood and the recent removal of alien vegetation in the catchment that caused an increase in groundwater level, so infiltration was reduced and runoff increased proportionally. There was a fire in the catchment in early November 2007 which would have further reduced infiltration rates and increased runoff.

The main erosional damage resulted from erosion of sediments by floodwaters flowing down the steep V-drain along the R330. Damage was also caused by the deposition of sediment in the area from the R330 along Lyme Road into the adjacent part of the St. Francis Bay Golf Course. The deposit is an alluvial fan, not a debris flow deposit.

Ninham Shand has proposed improvements to stormwater drainage that would considerably reduce the chances of such damage occurring again:

- A cut-off drain along the western boundary of the Links Golf Course to divert floodwater originating in the Eastern Valley Bottom wetland into a large natural depression that will act as a soak-away for floodwaters. This will considerably reduce the volume of floodwater that would discharge across the Links Golf Course onto the R330.

- A large diameter pipe down the R330 underneath the side drain, together with a collector intake at the exit from the Links Golf Course. This new pipe will go down the hill into a box culvert crossing under the R330 at the entrance to St. Francis Bay Village. This will carry floodwater safely onto the St. Francis Bay Golf Course.

- A box culvert under St. Francis Drive to take the floodwater onto the eastern part of the St. Francis Bay Golf Course before it enters the original watercourse to the sea.

- Some re-shaping of the St. Francis Bay Golf Course to allow clear passage for this water down to the sea.

Some of these improvements have been undertaken.

6.4 Potential for flood damage where the R330 crosses the Sand River

The R330 crosses the Sand River via a box culvert constructed when the road was rebuilt to its current standard in 1989/1990. The most extensive damage to the R330 since then was in the flood of November 1996, when the wing walls on either side of the culvert were damaged and there was some erosion of the tarred surface by water flowing over the road. The road was still wide enough to accommodate two directions of traffic flow. Other floods caused less or no damage.

Thus the R330 has been damaged by some of the numerous floods of the Sand River but damage was minor in that vehicular access was never interrupted. It is recommended that:

- The wing walls on either side of the culvert be repaired;

- Road engineers should check what flood recurrence interval the culvert can handle, and improvements should be made if necessary;

- The culvert should be checked regularly to see that it is not blocked by sand; and

- The culvert should be checked during floods and any debris that is caught across it should be removed.

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