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ESKOM THYSPUNT TRANSMISSION LINE INTEGRATION PROJECT EIA: GEO-TECHNICAL SPECIALIST REPORT

Prepared for

SiVEST

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

SiVEST have been appointed by Eskom to undertake the Thyspunt Transmission Line Integration Project Environmental Impact Assessment (EIA). This EIA focuses on the servitudes that will accommodate the power lines and it has been recommended that at least two separate servitude corridors be identified due to Nuclear Safety regulations. Consequently, SiVEST approached Creo Design as one of a number of geo-technical advisors to give detailed descriptions, discussions and recommendations on the following aspects:

- Geology
- Land types (general characteristics)
- Soil characteristics (average soil depth and clay percentage)
- Slopes
- Geohydrology
- Potential quarry sites

This study relied on expert knowledge and literature sources to describe development restrictions within the planned corridors. Furthermore, an impact rating system, as requested by SiVEST, was applied to all the data layers, ensuring an objective approach. Additionally, the data layers were awarded different weights based on their relative importance. These weights were then combined to produce a compound impact rating across all corridors, highlighting restrictions and limitations.

In general, the northern alternative of the Northern Corridor shows more severe limitations due to steep slopes, shallow soils and a low clay percentage within the soils. The southern alternative of the Northern Corridor suffers, to a degree, from the same shortfalls, but the restrictions/limitations are less abundant. Effective mitigation practices, together with existing opportunities to avoid problematic sectors altogether, make this alternative more attractive.

The Southern Corridor, on the other hand, faces restrictions mainly from the presence of unconsolidated alluvial sand or aeolianite and low clay percentages rendering these soils dispersive and therefore prone to erosion. Soil depths and slopes are generally more forgiving, while severe limitations can be avoided to a certain extent. The following table provides a summary of the impact ratings for the different data layers and the essential findings of this study.

Both corridors would need to take the Coega fault into account, as well as localized, smaller faults which are fairly common in the Algoa and Gamtoos basins.

Comparison of summarized impacts on environmental parameters

Environmental parameter	Issues	Rating prior to mitigation	Rating post mitigation
Aeolianite, alluvium, Coega fault	Erosion, destabilization, unsightly scars	**-54**	**-30**
		Negative High impact	Negative Medium impact
Vegetation and topsoil	Erosion, siltation, compaction	**-63**	**-28**
		Negative High impact	Negative Low impact
Aquifers, Coega fault	Pollution	**-22**	**-7**
		Negative Low impact	Negative Low impact
Slope: 10-20%	Erosion, siltation	**-34**	**-13**
		Negative Medium impact	Negative Low impact
Slope: >20%	Erosion, siltation	**-54**	**-30**
		Negative High impact	Negative Medium impact

The impact rating system, weighting of parameters and the compound rating system proved effective to ensure a holistic, inclusive approach to address the challenges at hand. Development restrictions were also quantified and emphasized, which will allow more efficient planning to be undertaken. It should be noted, however, that mitigation measures would be needed on a wide scale to bring the sustainability of this project to fruition.

GLOSSARY OF TERMS

Apedal	Soil particles well aggregated although well formed structures are not visible.
Cations	Positively charged ions, e.g. Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}, H^{+}, Al^{3+}
Duplex soils	Refers to soils with relatively permeable topsoil abruptly overlying a very slowly permeable diagnostic horizon which is not a hardpan.
Dystrophic	Refers to soil that has suffered marked leaching, such that the sum of the exchangeable Ca, Mg, K and Na, expressed in me/100g clay, is less than 5. Such soil is said to have a low base status.
Eutrophic	Refers to soil that has suffered little or no leaching, such that the sum of the exchangeable Ca, Mg, K and Na, expressed in me/100g clay, is more than 15. Such soil is said to have a high base status. The term is normally confined to non-calcareous soils.
Hardpan	A massive material enriched with and strongly cemented by sesquioxides, chiefly iron oxides, silica (silcrete) or lime (calcrete).
Horizon	Unlike the layers in recent alluvium which are the result of simple deposition, horizons have developed through processes (e.g. fluctuating watertable) taking place within the soil. A horizon is bounded by air, hard rock or by soil material that has different characteristics.
Leaching	Removal of materials in solution from a part of or from the whole of the soil profile.
Margalitic	Refers to A horizons (top horizons) that are dark coloured with a high base status, Ca and Mg being the predominant exchangeable cations.
Mesotrophic	Refers to soil that has suffered moderate leaching, such that the sum of the exchangeable Ca, Mg, K and Na, expressed in me/100g clay, is 5-15. Such soils is said to have medium base status.
Permeability, soil	Generally, this refers to the east with which gases, plant roots or more usually, liquids penetrate or pass through a soil horizon.
Plinthic horizon	Accumulation of iron (and frequently also manganese) oxides and hydrates, and localization in the form of high-chroma mottles and concretions (often with black centres) is the predominating feature of this horizon. This takes place in a zone of periodic saturation with water, for example between the limits of fluctuation of a watertable. Accumulation of iron and manganese may have progressed from soft mottles to the formation of discrete concretions in all stage of hardening (also known as gravel ferricrete).
Sand	A soil separate consisting of particles 2.0-0.02mm in diameter.

1. TERMS OF REFERENCE

SiVEST have been appointed by Eskom to undertake the Thyspunt Transmission Line Integration Project Environmental Impact Assessment (EIA). The EIA is to be conducted for the servitudes for the required 400kV lines out of the HV yard at the proposed new Nuclear Power Station site, Thuyspunt. The servitudes are required to accommodate five 400kV lines. A new substation site is required in the Port Elizabeth area. Two of the 400kV lines head towards this substation site and a further two 400kV lines are required out of this new proposed substation. It has been recommended to identify at least two separate servitude corridors or to separate the lines as far as practicable, due to Nuclear Safety and reliability of supply considerations.

As part of the EIA process and report, a geo-technical assessment during the scoping phase is required. The Terms of Reference for this report is provided below:

- ❖ Conduct a desk-top geotechnical assessment;
- ❖ Undertake an Aerial Photographic Interpretations (API) to identify geotechnical features present in the study area;
- ❖ Make use of aerial photography (stereo pairs in particular) to conduct the assessment;
- ❖ Conduct a site walkover in order to confirm geotechnical features identified during the API where necessary only (within the budget provided);
- ❖ Apply the rating system provided for geotechnical features of each corridor, and substation site (for the proposed PE S/S) to establish the more favourable corridor and S/S site from a general geotechnical perspective in the Scoping Phase; and
- ❖ Include the following geotechnical characteristics in the assessment:
- geology and soil types
- depth to bedrock
- materials usage
- potential water seepage
- Potential quarry sites.
- ❖ Produce a draft geo-technical assessment for review by SiVEST and a final report incorporating SiVEST comments thereafter.

2. GEOLOGY

The lithotypes occurring in this study area has been described by following the convention by which the rocks are described from the oldest to the youngest. The geology comprises almost entirely of sedimentary units spanning a period of some 500 million years.

The area has been subjected to several phases of tectonic activity with the most conspicuous the compressive forces that resulted in the formation of the prominent Cape Fold mountains.
This event was followed in short succession by the rifting forces that resulted in the fragmentation of the Gondwana Super continent creating high sedimentation rates in basins along this southern margin of the newly formed continent. The geology within the proposed corridors is highlighted in Figure 1.

2.1 GAMTOOS GROUP

Inliers of the Late Proterozoic Gamtoos Group are exposed along a 110-km-long strip extending from the eastern end of the Baviaans Kloof to the coast south-west of Port Elizabeth. This group seems to be overturned as a whole with a faulted lower boundary and a paraconformable or unconformable upper contact.

Because of the structural complexity of the area and poor exposures, thicknesses for the group as a whole and for the four constituent formations are uncertain.

At least several hundred metres are probably present. The stratigraphy, initially established has since been modified.

2.1.1 LIME BANK FORMATION

This unit is essentially equivalent to the "Kleinfontein calcareous stage" although it also includes their "lower phyllite stage" which is of such a restricted occurrence that it may be more properly regarded as an intercalation within the former. It occurs as an apparently overfolded anticline along the southern boundary of the Gamtoos Valley inlier and consists of a limestone unit, 30 to 35 m thick, with underlying or intercalated contorted phyllite and carbonaceous pyritic shale. These rocks are best exposed in the limestone quarry on Lime Bank 174, Hankey District. The limestone is massive and bluish grey with numerous calcite veins and grades upward through calcareous grit and carbonaceous shale into the next unit.

2.1.2 KLEINRIVIER FORMATION

The Kleinrivier Formation consists predominantly of yellowish grey phyllite but also includes intercalations grit and arkose as well as minor quartzite and conglomerate layers. A strongly developed cleavage is characteristic. The phyllite is often conspicuously sericitic and the grit schistose in appearance. This formation grades through calcareous shale and thin siliceous limestone and grit layers into the next unit

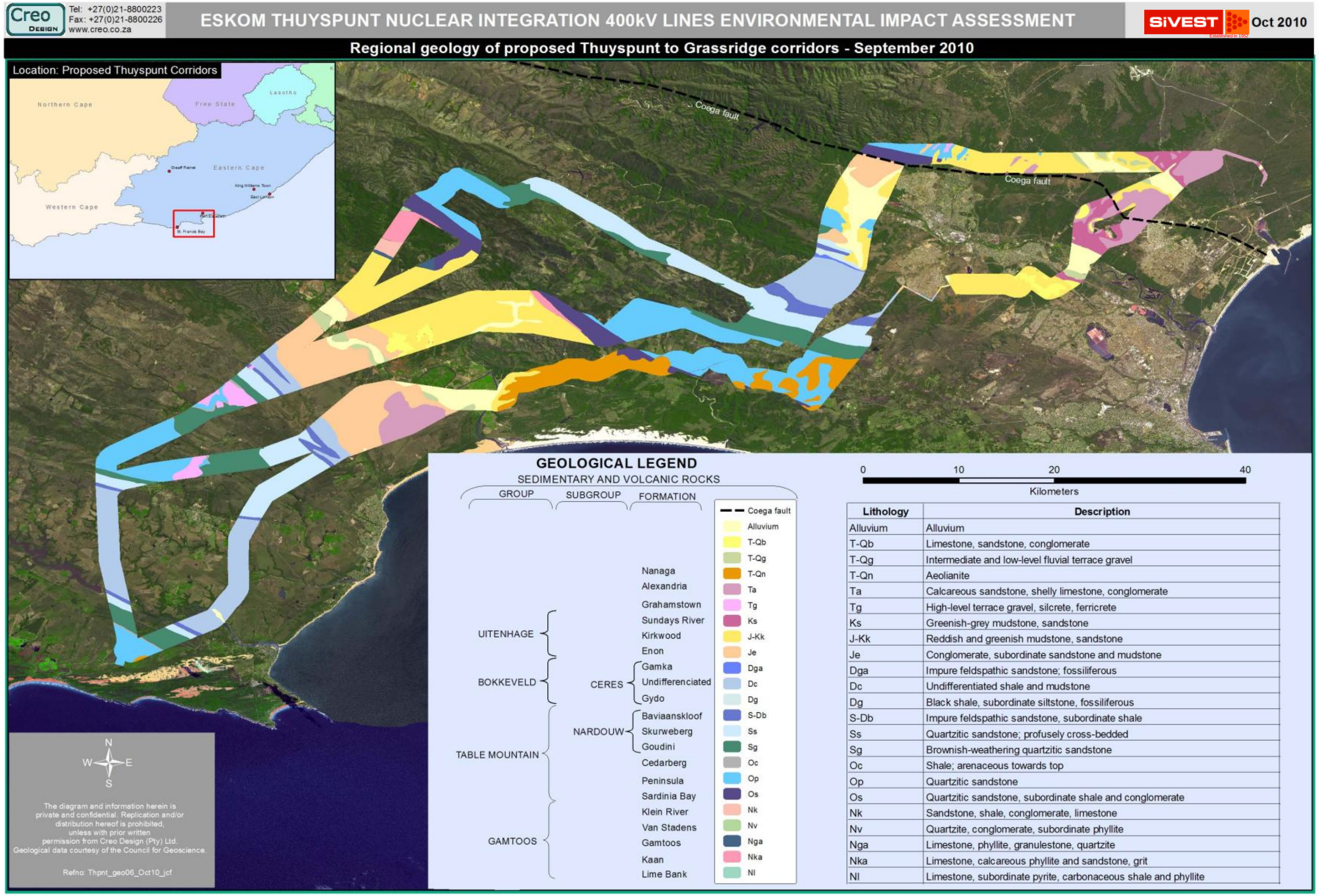


Figure 1: Geology within the proposed corridors

2.1.3 KAAN FORMATION

This formation consists characteristically of calcareous rocks, including bluish grey limestone, which may be dolomitic in places, and calcareous phyllite, sandstone and grit. In the Gamtoos Valley two prominent limestone horizons occur which are up to 30m thick each, the upper splitting eastward into a few impersistent thinner layers.

2.1.4 VAN STADENS FORMATION

Most of the arenaceous succession overlying the Kaan Formation and previously designated “upper pre-Cape” has since been assigned to the Sardinia Bay Formation of the Table Mountain Group.

The remainder, named Van Stadens Formation, comprises medium- to dark-grey cross-bedded quartzite, lenses of polymictic small-pebble conglomerate and subordinate phyllite Felspar is rather common in the two first-mentioned lithologies.

The upper contact is often paraconformable and then rather indistinct.

2.2 CAPE SUPERGROUP

2.2.1 TABLE MOUNTAIN GROUP

In the south-eastern Cape this group, comprising six conformable formations, is a predominantly medium-grained arenaceous succession, some 4 500m thick. The uppermost three formations together constitute the Nardouw Subgroup.

2.2.1.1 SARDINIA BAY FORMATION

The Sardinia Bay Formation is a predominantly arenaceous sequence of rocks comprising thin-to medium-bedded, often cross-bedded, quartzite sandstone with intercalated olive-grey to greenish black phyllitic shale and minor small-pebble conglomerates consisting mainly of vein-quartz clasts. The sandstone is usually fine to medium grained, light grey when fresh, and felspathic. Trace fossils are fairly common.

In its type area immediately east of Sardinia Bay – about 10km south-west of Port Elizabeth used the term “Sardinia Bay Formation” to describe outcrops of some 180m of the succession. All rocks younger than the Gamtoos Group and underlying the Peninsula Formation within this area in the Sardinia Bay Formation. Its upper boundary is gradational, being taken where bedding becomes thicker and shale very subordinate.

Its lower boundary, though sometimes indistinct, is often marked by a basal conglomerate and grit unit, up to 50m thick, which is best exposed along the coast west of Sardinia Bay.

The formation has a total thickness of 950 m along the coast south-west of Port Elizabeth and a thickness of less that 700m north-east of Loerie.
The Sardinia Bay Formation could be a stratigraphic equivalent of the Graafwater Formation in the Western Cape.

2.2.1.2 PENINSULA SANDSTONE FORMATION

This is areally, stratigraphically and topographically the most prominent formation of the group and consists of medium- to coarse-grained supermature sandstone, becoming quartzitic in places. Scattered well-rounded pebbles of vein quartz are rather common. Lenticular shale layers, less that a metre thick, are very subordinate. Toward the top this formation is generally more coarse grained and gritty, with lenses of matrix-supported, small-pebble conglomerate fairly common in places.

Although generally massive in appearance, flat-bedding and low-angle cross-bedding are not uncommon. Its maximum thickness probably does not exceed 3 000m.

2.2.1.3 CEDARBERG SHALE FORMATION

The Cedarberg shale is somewhat carbonaceous and black when fresh but grey to greenish grey and even yellowish in outcrop depending upon the degree of weathering. Intercalated thinly bedded, lenticular, silty and sandy beds become more evident and relatively coarser grained towards the top. In the extreme west sporadically developed diamictite is present within the lowermost 10m of this unit. It is best exposed on the north-easternmost corner of Farm 764 (Draaiklip), Humansdorp District, on the south bank of the Kouga River. This is thought to be the equivalent of the Pakhuis Formation of the Western Cape.

The Cedarberg shale peters out eastwards due to a gradation from shale to comparatively thin-bedded argillaceous sandstone. Its absence in places may be due to pinching as a result of folding and thrusting.

The formation is up to 55m thick. In the field its presence is readily recognised by the smooth slopes between the Peninsula and Goudini sandstones or by linear depressions when dips are high. The contact with the underlying Peninsula Formation is sharp, but the upper contact is gradational.

2.2.1.4 NARDOUW SUBGROUP

2.2.1.4.1 GOUDINI SANDSTONE FORMATION

The medium-grained quartzose sandstone comprising this formation is characterised in the field by its general brownish colour, thinner bedding and less pronounced topography compared with the underlying Peninsula and overlying Skurweberg sandstones.

Where it forms krantzes, it commonly develops numerous shallow caves. Cross-bedding is common though generally inconspicuous.
The very subordinate shale layers are generally less than 1m thick. The unit has a total thickness of some 260m as measured in the Baviaans Kloof.

2.2.1.4.2 SKURWEBERG SANDSTONE FORMATION

The Skurweberg Formation consists of white, resistant, medium- to coarse-grained quartzose sandstone which is rather quartzitic. It also features prominently in the mountains and builds the highest mountain peak in the area (Cockscomb, 1 758m).

A characteristic feature is the profuse and conspicuous cross-bedding. Shale is very subordinate. The formation has a total thickness of some 420m at the Paul Sauer Dam in the Hankey District. Both its lower and upper contacts are usually transitional.

2.2.1.4.3 BAVIAANSKLOOF FORMATION

This formation consists of “dirty”, fine-grained, massive-looking sandstone and sub-ordinate greyish black, carbonaceous and micaceous shale. A prominent light-grey, medium-grained, felspathic sandstone unit which occurs about halfway in the formation is known as the Kareedouw Member.

The formation attains a total thickness of almost 200m at the Paul Sauer Dam. Wave ripple marks occur occasionally in its lower portion. The 50-m-thick Kareedouw Member is usually thick-bedded and also cross-bedded in places. Bioturbation is common above the Kareedouw Member, while fossils of brachiopods and gastropods also occur. Alternating shale and sandstone beds characterise the transitional upper boundary.

2.3 BOKKEVELD GROUP

In contrast to the Table Mountain Group the Bokkeveld Group consists of dark-grey shales with intervening sandstone units.

It is subdivided into a lower Ceres Subgroup, characterised by marine invertebrate fossils and lateral continuity of its six formations, and an upper Traka Subgroup consisting of three formations in the Eastern Cape.

2.3.1 CERES SUBGROUP

This subgroup consists of an alternation of three thick shale, and three appreciably thinner sandstone formations, with transitional boundaries.

Thicknesses of roughly 500m, 300m and 300m have been recorded for the Gydo, Voorstehoek, and Tra-tra shales respectively, while the Gamka, Hexriver and Boplaas sandstones have thicknesses in the order 200m, 50m and 80m respectively. The shales are somewhat carbonaceous and virtually black when fresh. The sandstones form prominent ridges. They are generally fine grained, impure, felspathic and dark grey. Flat bedding, inclined bedding, micro cross-lamination and bioturbation are common features.

Marine invertebrates abound at certain horizons in this subgroup. The fossils are generally distorted and include brachiopods, pelecypods, gastropods, cephalopods, trilobites and crinoids.

2.3.2 DEPOSITIONAL ASPECTS AND AGE

The sandstone formations of the Ceres Subgroup are interpreted as having been deposited along the margin of an epicontinental sea and the shale formations in the off-shore area. Depositional environments of the Traka Subgroup ranged from outer offshore to lower shoreface for the Karies, pro-delta slope for the Adolphspoort and sub aqueous delta-front platform for the Sandpoort Formation.

The Bokkeveld Group ranges in age from Early to Late Devonian, the lower age limit being established by invertebrate fossils which occur fairly abundantly in the older units.

2.4 UITENHAGE GROUP

Deposits of this group cover an area of approximately 4 000km^2 in the 600 km^2 in the Gamtoos Basin. These Late Jurassic-Early Cretaceous deposits, which are not confined to the land only, area partly, fault controlled, and seismic work and drilling proved the Algoa Basin to consist of two structural sub-basins onshore, namely the Sundays River Trough and Uitenhage Trough. The main faults follow the trend of the underlying Palaeozoic Cape rocks.

Deposition of the predominantly clastic succession commenced with coarse fanglomerates of the Enon Formation and distal sandstones and mudstones of the Kirkwood Formation and terminated with deposition of the marine sediment of the Sundays River Formation.

These deposits straddle the Jurassic-Cretaceous boundary.

2.4.1 ENON CONGLOMERATE FORMATION

In the Gamtoos Basin it outcrops along the south-western and in the Algoa Basin mainly along the western and northern margin. The lithology is rather similar in all three areas, and the deposit is regarded as being a piedmont fanglomerate although there is also evidence – such as clast imbrication and limited cross-bedding in finer lithologies for fluvial depositional agents.

The formation consists of whitish grey to red-brown conglomerate with subordinate interbedded lenticular light-reddish to greenish sandstone and reddish brown mudstone. The conglomerate is made up almost exclusively of quartzitic sandstone clasts of the Cape Supergroup and is characteristically reddish in the Baviaans Kloof and in the Algoa Basin due to iron oxide in the sandy matrix, often also forming a thin veneer around clasts.

The Enon often carries large boulders at the base and sorting is generally poor. Along the southern margin of the Algoa panhandle thinly bedded sandstone and mudstone, up to 200 m thick, occur below the conglomerate. At the type area near Enon Mission Station in the Algoa Basin a total thickness of 300m was estimated for this formation. In the Gamtoos Basin a borehole near the coast, on Mauritskraal 501, penetrated 1 980m Enon conglomerate without reaching its base.

Silicified wood has been the only fossil material found to date.

The upper contact of the formation in the Anglo Basin is taken at the top of the massive conglomerates. This contact is transitional and lateral gradation into the Kirkwood Formation and interfingering with the latter are known to occur.

2.4.2 KIRKWOOD FORMATION

This formation is regarded as representative of a mainly fluvial environment of deposition. Whilst overlying the Enon conformably at most places, its interfingering with the conglomerate locally is interpreted as contemporaneous deposition of the Enon near the point of entry of sediments into the basin.

The formation consists mainly of silty mudstone and sandstone. The pelites are variegated reddish brown, pinkish or greenish grey, and the sandstones are whitish, yellowish or pale grey.

Coarser sandstones are either massive or cross-bedded. In the Gamtoos Valley conglomerates appear towards the top of the formation, which may be related to proximity of high-relief Cape Group rocks and the Gamtoos fault which might already have been active then.

Deep drilling in the Algoa Basin encountered two relatively important subsurface members of the Kirkwood Formation, named the Swartkops Sandstone Member (fluvial to estuarine) and the Colchester Shale Member (estuarine to shallow marine). A maximum thickness of 2 210 m for the Kirkwood Formation was obtained in borehole AL 1/69, drilled by the Southern Oil Exploration Corporation (SOEKOR) near the coast east of the Sunday River mouth.

Plant fossils are rather common in the Kirkwood Formation and remains of reptiles and invertebrates (fresh-water, estuarine and marine types) also occur. Thin beds of lignite occur west of Loerie in the Gamtoos Valley and on Welbedachtsfontein 300, Port Elizabeth District.

In the Algoa Basin the upper contact of the formation is taken at the top of the uppermost red-brown mudstone. The transition to the overlying Sundays River Formation may be gradational but local unconformities have also been deduced.

2.4.3 SUNDAYS RIVER FORMATION

The Sundays River Formation consists of grey to bluish mudstone, siltstone and sandstone which are interpreted as cyclic trangressive-regressive sequences of shallow marine and estuarine origin. In outcrop, rocks of the Sunday River Formation are greenish grey and contain some secondary limestone and gypsum. The top is truncated by erosion and the thickest intersection, encountered in borehole CK 1/68 near Addo, amounted to 1 863m. The formation is extensively covered by Tertiary to Recent deposits.

Invertebrate fossils, including ammonites, belemnites, bivalves and gastropods, are rather common in the Sunday River Formation and indicate a Neocomian (Lower Cretaceous) age for this unit. Vertebrate remains are scarce. Plant remains and lignite are also known to occur.

2.5. TERTIARY TO RECENT DEPOSITS

2.5.1 GRAHAMSTOWN FORMATION

Scattered high-level terrace deposits which border the mountain ranges are probably partly coeval with the Alexandria Formation as they lie on remnants of formerly extensive peneplains regarded as inland equivalents of the floor of the Alexandria Formation.

These deposits are tentatively correlated with the Grahamstown Formation.

Where they abut against the mountains the terrace deposits consist of angular sandstone and quartzite blocks cemented by siliceous material. They are generally less than 6m thick, although thicker deposits, such as the exceptionally 40-m-thick silcrete on Zwartbosch Plaat 278 north-west of Uitenhage, are known. Downslope, boulder size and angularity decrease rapidly with an increase of fluviatile gravel and sand.

The terraces are generally capped by silcrete which often grades laterally and vertically into ferruginous sandstone and ferricrete. Increasing iron content, sometimes associated with manganese, can probably be related to the proximity of springs at the time of depositions as is the case with two large patches of ferricrete overlying the Peninsula Formation on the Tertiary peneplain immediately north of Humansdorp.

2.5.2 ALEXANDRIA FORMATION

As a result of marine transgressions during the Tertiary Period, Uitenhage and Cape rocks were bevelled for several tens of kilometres inland. On this wave-cut platform the marine Alexandria Formation was deposited during Neogene times, resting as a thin unconformable veneer on a remarkably level surface which displays at least three steps. The landward margin of the sediments occurs at approximately 300m above sea level north of Uitenhage and at Paterson, some 30km from the present coastline.

In the lower Gamtoos Valley a few small outcrops – not shown on the map – appear on high ground east of that river. West of the river the pre-Alexandria peneplain, cut into rocks of the more resistant Cape Supergroup, displays two prominent steps which are devoid of marine deposits. Humansdorp is situated on the landward margin of the lower one.

The Alexandria Formation reaches a thickness of approximately 13m in its type area near Colchester, but usually it is thinner.

It consists of calcareous sandstone, sandy limestone – more correctly coquinite – and conglomerate, the latter mostly occurring at its base.

Well-rounded cobbles and pebbles of variously coloured quartzitic sandstone, derived from the Cape Supergroup predominate, but some vein quartz and dark-grey to black chert or hornfels clasts are also present. Most beds carry marine shells and/or shell fragments, mostly of gastropods and pelecypods. The Alexandria Formation is regarded as mainly a littoral deposit.

2.5.3 NANAGA FORMATION

This formation, with a maximum thickness of 250m, overlies the Alexandria Formation and other rocks north and east of the Sundays River and south-west of Port Elizabeth. It consists of whitish to yellowish, mainly fine-to medium-grained, partly or wholly consolidated aeolian sand or dune rock, which is calcareous due to the presence of numerous shell fragments.

It is profusely cross-bedded in places and shown signs of local weathering and redistribution. A cover of surface limestone is widespread which in turn may be overlain by grey to reddish brown soil, which does not form part of the formation.

The aeolianites obviously accumulated as the coastline receded and are therefore progressively younger from the inland margin to the coast. They are regarded as being of Pliocene to Pleistocene age.

2.5.4 FLUVIAL TERRACE DEPOSITS

Well-developed fluvial terraces, which to some extent reflect changing sea levels in the Quaternary, characterise the valleys of major drainage systems in the coastal area, including the Gamtoos, Swartkops and Sundays Rivers. These terraces area generally covered by gravel and soil which may be cemented by lime and occasionally by silica and iron oxide, and sometimes carry a calcrete cover. Similar terraces also occur inland along major rivers like the Fish River in the north-eastern portion of the map area.

2.5.5 CALCRETE

Thin discontinuous layers of calcrete of various ages occur rather commonly in the map area. Only some thicker and more extensive occurrences are shown in the north-eastern corner of the map. They have not been assigned formal stratigraphic status as yet.

2.5.6 SCREE

Patches of scree are commonly seen along the steeper mountain slopes. Most of these merge downslope through piedmont gravels into terrace deposits and sheet wash. Only the larger patches are depicted on the map.

2.5.7 ALLUVIUM

Deposits shown as alluvium on the map area either flood-plain soils along major rivers, or other transported soils which may merge into sheet wash in the upper reaches of tributaries. Alluvium is particularly well developed in the valley of the Gamtoos and Sundays Rivers where irrigation schemes take advantage of the fertile soils, which in places exceed 20 m in thickness. Coarser-grained terrestrial alluvium makes way for finer-grained "estuarine alluvium" as the coast is approached, but this distinction is not shown on the map.

2.5.8 AEOLIAN SAND

Shifting sand dunes are present along much of the coastline. They occur as far inland as 4 km and may be up to 30m high. Along most of the coast they are predominantly longitudinal with a north-north-easterly strike, their orientation being directed mainly by the prevailing south-westerly winds. East of the Sundays Rivers mouth, however, interference by strong northerly and north-easterly winds complicates the pattern in the very extensive dune field developed there. The primary source of the sand is evidently sandstones of the Cape Supergroup.

Inland a fairly extensive body of light reddish brown sand, south of Glenconnor, appears to be of mixed aeolian and alluvial origin. Another sizable occurrence of blown sand is found in the vicinity of Paterson where sand, derived from the Nanaga Formation to the south, has accumulated at the foot of the Suurberg range.

3. STRUCTURAL GEOLOGY

The outcrop pattern and corresponding topography on the map disclose a dominant regional structure of east-south-east-trending folds and mountain chains.

Post-Cape lateral compression produced zones of intense folding with south-ward-dipping axial planes in the Cape and lower Karoo rocks. The folds are mainly confined to the Cape depositional basin, their intensity, and apparently also age, decreasing northwards. They were placed in the Permian to Triassic Periods.

The more competent quartzitic sandstones of the Table Mountain and Witteberg Groups constitute the cores of major anticlines, forming mountain chains due to resistance to weathering. Relatively incompetent formations overlying the quartzites suffered more intense deformation into disharmonic parasitic folds.

Tensional stresses which followed the Cape folding facilitated surface access for the Jurassic Suurberg volcanics of the Algoa Basin and initiated large south-ward-throwing strike faults which border the major fold zones on their southern sides. These faults are suggested to be reversals of those which triggered the Cape folding.

Displacements measure up to a few kilometres and it is against some of these fault scarps that the Late Mesozoic Uitenhage deposits accumulated. Their swing toward the south-east and the development of the graben-like Algoa and Gamtoos Basins are evidently related to the break-up of Gondwanaland.

Post-Cretaceous epeirogenic movements caused upward warping of the continent, gentle east-north-east-trending folds, and periodic seaward tilting of the coastal belt.

Neotectonic activity along the major fault zones, in particular those bordering the Cretaceous basins (Gamtoos and Algoa Basins and the Swartkops Sub-basin) are well documented (Hattingh & Goedhart 1997). They observed that local compressional faulting occurs along the Coega fault due to possible reactivation of the Agulhas Fracture Zone.

4. GEOHYDROLOGY

The study area is underlain by a wide range of rock types as described in the previous section with equally diverse ability to store groundwater and a large variation in groundwater quality. In general the rocks of the Table Mountain Group have the highest ground water yield potential and the best ground water quality with electrical conductivity of less than 100 mS/m.

The Bokkeveld Group rocks, with exception of the Sandstone units with characteristics similar to the Table Mountain Group rocks are known for much poorer yield values and groundwater quality at 100-1000 mS/m.

Rocks of the Gamtoos Group have slightly better groundwater yield and quality than the Bokkeveld Group shales and are similar to the Bokkeveld Group. Sandstones are inferior to the Table Mountain Group rocks.

The Uitenhage Group rocks display low yield values (less than 0.5l/sec.) and very poor water quality values of 100-1000 mS/m.

The Algoa Group rocks springs issuing from the basal Alexandria Formation conglomerate, occur sporadically along the coast.

Groundwater can be obtained from the discontinuous basal Alexandria Formation conglomerate of the Algoa Group.

Joint structures in subordinate sandstone lithozones, interbedded in largely incompetent Bokkeveld Group shales can be utilised for groundwater development.

Numerous springs in the Table Mountain Group rocks issue due to presence of groundwater-impeding shale layers such as the shale of the Cedarberg Formation.

The competent quartzitic sandstones of the Table Mountain Group contain numerous faults, other fractures and joints, which can be targeted for groundwater.

Regardless of the groundwater exploitation potential of alluvium, it also often acts as a storage and recharge medium to underlying jointed hard rocks.

Interbedded, often porous sandstone lenses in conglomerate and shale beds of the Uitenhage Group, do possess limited groundwater development potential.

Grit, limestone, joint and fault structures in the Gamtoos Group can be aimed at for groundwater development.

Overfolding and thrust faulting are common and often impede the movement and development of groundwater.

Subordinate sandstone lithozones in anticlines, backed by favourable recharge conditions, can be used to obtain groundwater in the largely argillaceous beds of the Bokkeveld.

Numerous smaller faults occurring in the Bokkeveld Group possess groundwater potential.

Joints and fractures on crests of anticlines can be targeted for groundwater development.

The Uitenhage Subterranean Government Water Control Area is essentially a two-layer, partially fractured aquifer in the eastern portion. The topmost, mostly non-artesian aquifer is formed by the predominantly argillaceous strata of the Uitenhage Group, which mostly acts as an aquiclude. The groundwater occurrence of this unit has been depicted on the map. The strata of the Uitenhage Group overlie the more productive, often artesian to subartesian Table Mountain quartzitic sandstone aquifer.

No groundwater or at best insignificant groundwater can be obtained from the Coastal Sands in this area. Groundwater might however be procured from the underlying bedrock.

Figure 2 depicts the geohydrology within the proposed corridors and potential areas that should be further investigated.

5. LAND TYPES AND SOIL INVENTORY

During the compilation of the land types and soil inventory, extensive use was made of the land type dataset. This dataset was compiled by the ARC-Institute for Soil, Climate and Water and contains the most comprehensive soil database for the whole of South Africa (Land Type Survey Staff 1972-2006).

Because the inventory was completed on a 1:250 000 scale, it outlines individual land types, rather than individual soil units. Land types are compiled by grouping similar soils together, taking into account soil characteristics such as soil horizons, permeability, degree of leaching, average depth, average clay percentage and other structural limitations that might be of interest to the user.

Terminology and classification was based on the official soil classification system for South Africa (Soil Classification Working Group 1977). The land type units are seen as areas with a fairly homogeneous character where similar management practices can be applied across the unit. Although a compilation of the soil types within a land type unit is present, the precise distribution thereof is not.

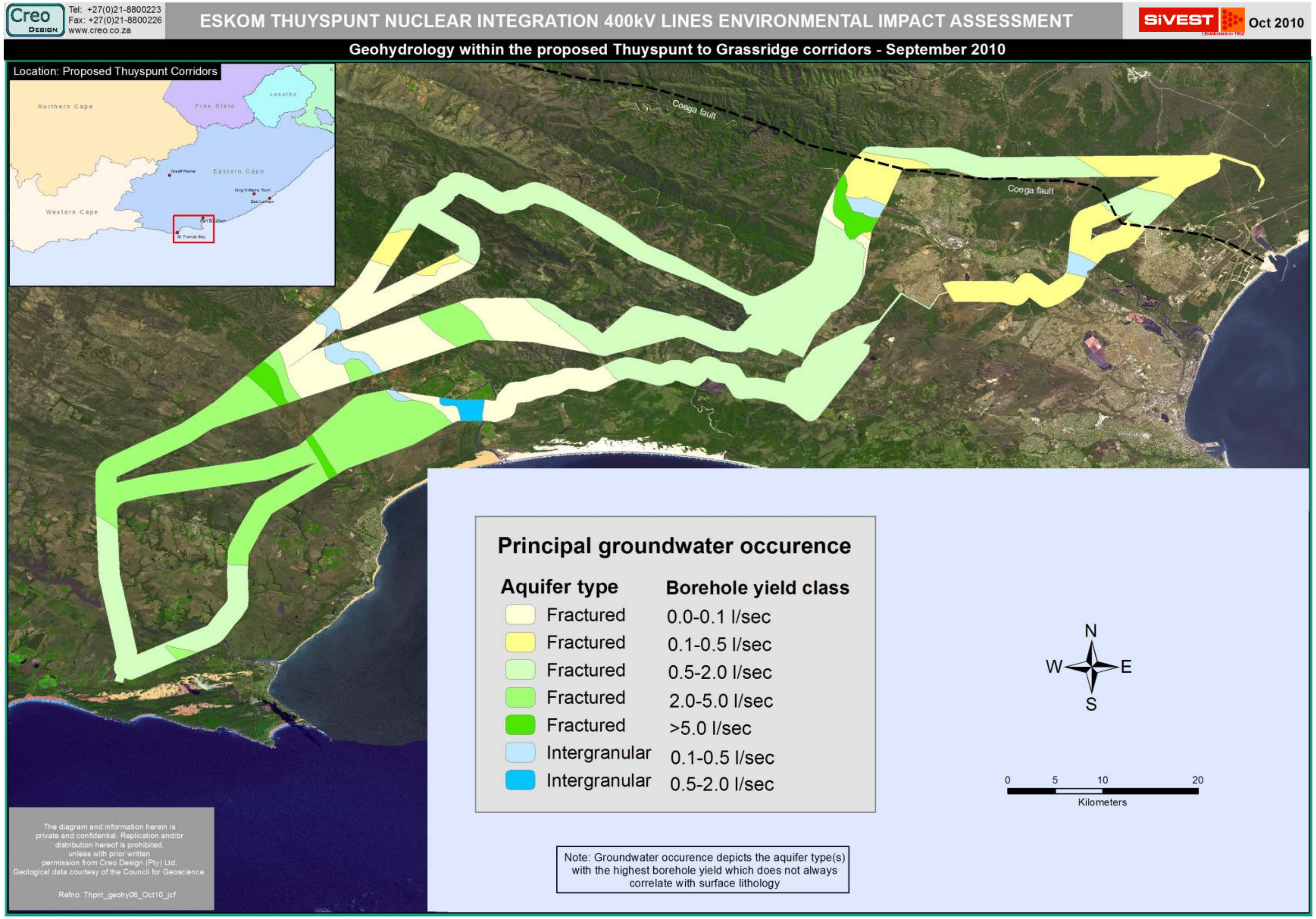


Figure 2: Geohydrology within the proposed corridors

The dataset contains individual land type unit polygons, each linked to a number of attributes in the accompanying attribute table. The following attributes is listed in the dataset:

LANDTYPE	Land type number, forms link with spatial information
Broad	Broad soil pattern code
Avr_Depth	Average depth in mm
Depth_Clas	Average depth class
D1	Percentage of land type with depth class D1, <= 300mm
D2	Percentage of land type with depth class D2, 301 - 600mm
D3	Percentage of land type with depth class D3, 601 - 900mm
D4	Percentage of land type with depth class D4, 901 - 1200mm
D5	Percentage of land type with depth class D5, >1200mm
Avr_Clay	Average topsoil clay %
Clay_Class	Average topsoil clay content class
C1	Percentage of land type with Clay class C1, <= 6%
C2	Percentage of land type with Clay class C2, 6.1 - 15%
C3	Percentage of land type with Clay class C3, 15.1 - 25%
C4	Percentage of land type with Clay class C4, 25.1 - 35%
C5	Percentage of land type with Clay class C5, 35.1 - 55%
C6	Percentage of land type with Clay class C6, >55
S1	Percentage of land type with category 1 soils*
S2	Percentage of land type with category 2 soils*
S3	Percentage of land type with category 3 soils*
S4	Percentage of land type with category 4 soils*
S5	Percentage of land type with category 5 soils*
S6	Percentage of land type with category 6 soils*
S7	Percentage of land type with category 7 soils*
S8	Percentage of land type with category 8 soils*
S9	Percentage of land type with category 9 soils*
S10	Percentage of land type with category 10 soils*
S11	Percentage of land type with category 11 soils*
S12	Percentage of land type with category 12 soils*
S13	Percentage of land type with category 13 soils*
S14	Percentage of land type with category 14 soils*
S15	Percentage of land type with category 15 soils*
S16	Percentage of land type with category 16 soils*
S17	Percentage of land type with category 17 soils*

Where soil category classes are

S1 Soils with humic topsoil horizons
S2 Freely drained, structureless soils
S3 Red or yellow structureless soils with a plinthic horizon
S4 Excessively drained sandy soils
S5 Dark clay soils which are not strongly swelling
S6 Swelling clay soils
S7 Soils with a pedocutanic (blocky structured) horizon
S8 Imperfectly drained soils, often shallow and often with a plinthic horizon
S9 Podzols
S10 Poorly drained dark clay soils which are not strongly swelling
S11 Poorly drained swelling clay soils
S12 Dark clay soils, often shallow, on hard or weathering rock
S13 Lithosols (shallow soils on hard of weathering rock)
S14 Duplex soils (a sandy topsoil abruptly overlying a clayey, structured subsoil), often poorly drained
S15 Wetlands
S16 Non soil land classes
S17 Rock

The 'Broad' attribute refers to a general description of the overall character of the soils present in the land type unit. Table 1 provides a list of the broad soil pattern codes, as well as accompanying descriptions.

Table 1: Broad soil pattern codes and descriptions

Broad soil pattern code	Description*
Ae	Freely drained, red, eutrophic, apedal soils comprise >40% of the land type (yellow soils comprise <10%)
Ah	Freely drained, red and yellow, eutrophic, apedal soils comprise >40% of the land type (red and yellow soils each comprise >10%)
Bb	Red and yellow, dystrophic/mesotrophic, apedal soils with plinthic subsoils (plinthic soils comprise >10% of land type, red soils comprise <33% of land type)
Ca	Land type qualifies as Ba-Bd, but >10% occupied by upland duplex/margalitic soils
Db	Duplex soils (sandier topsoil abruptly overlying more clayey subsoil) comprise >50% of land type; <50% of duplex soils have non-red B horizons
Fa	Shallow soils (Mispah & Glenrosa forms) predominate; little or no lime in landscape
Fc	Shallow soils (Mispah & Glenrosa forms) predominate; usually lime throughout much of landscape
Ha	Deep grey sands dominant (comprise >80% of land type)
Hb	Deep grey sands sub dominant (comprise >20% of land type)
Ia	Deep alluvial soils comprise >60% of land type
Ib	Rock outcrops comprise >60% of land type

* Please refer to the 'Glossary of Terms' for a comprehensive explanation.

Figure 3 illustrate the land types present in the proposed corridors earmarked for the construction of the ESKOM 400kV lines, as provided by SiVEST.

The Southern Corridor consists mostly of freely-drained, deeper soils (Ae, Ah, Bb, la) with a fair amount of sandier topsoils (Db) and deep grey sands (Ha, Hb). The depth of these soils range from just over 0.5 meter to well over 1m, with clay percentage varying from just over 4%, up to 22% in other sections.

In contrast with the above, the northern and eastern section of the corridors consist mostly of shallower soils (Fa, Fc), as well as large sections occupied by rock outcrops (lb). Average depth of the soils in these regions rarely surpasses the 0.5m mark, with clay percentage from as low as 1% to over 22%.

The western, south-western limbs of the corridors are characterized by apedal topsoils with a low to medium base status, overlying plinthic subsoils. Plinthic subsoils refer to soil horizons where iron (and often manganese) oxides and hydroxides have accumulated in a zone of temporary wetness, e.g. fluctuation of water levels. These soils are relatively shallow, mostly between 0.25-0.5m, with highly variable clay percentage.

6. DIGITAL ELEVATION MODEL AND SLOPE

The Digital Elevation Model with 20m spatial resolution was used in the slope analysis study. The DEM was used to calculate slope (in percentage). To aid visualization and further processing, slope was reclassified into 3 broad classes *viz.* less than 10%, between 10 and 20%, and greater than 20%. These classes are broadly based on specifications for soil types where slope might be a restriction, and were obtained from the Conservation of Agricultural Resources Act (DOA 1984). Figure 4 illustrates the slope classes within the proposed corridors.

7. POTENTIAL QUARRY SITES

Potential quarry sites were selected on the basis of suitable geology and are illustrated in Figure 5. The geology's suitability was subdivided into areas suitable for aggregate, concrete sand, plaster sand, road-building material, and unsuitable for any of the above.

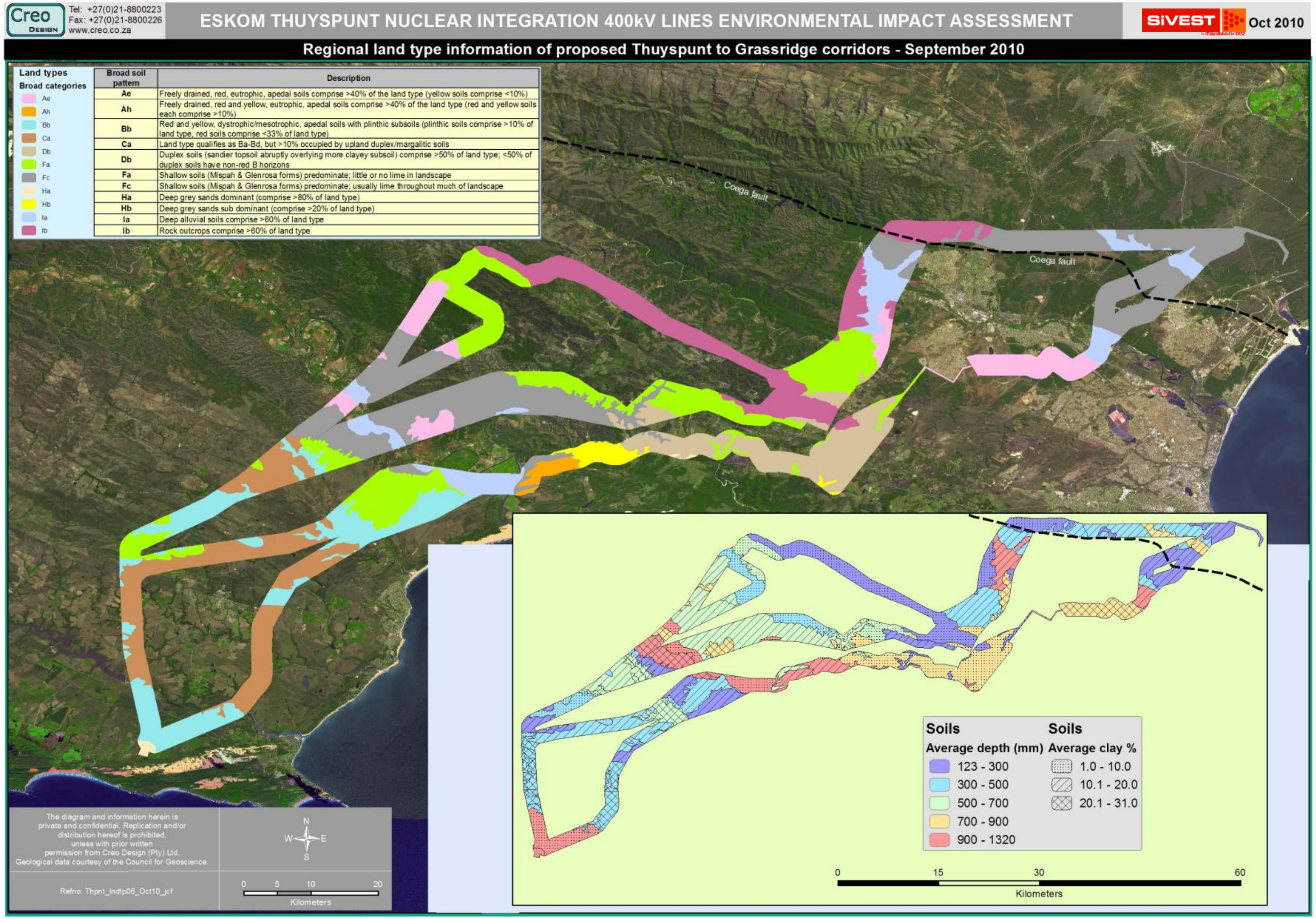


Figure 3: Land type information present in proposed corridors

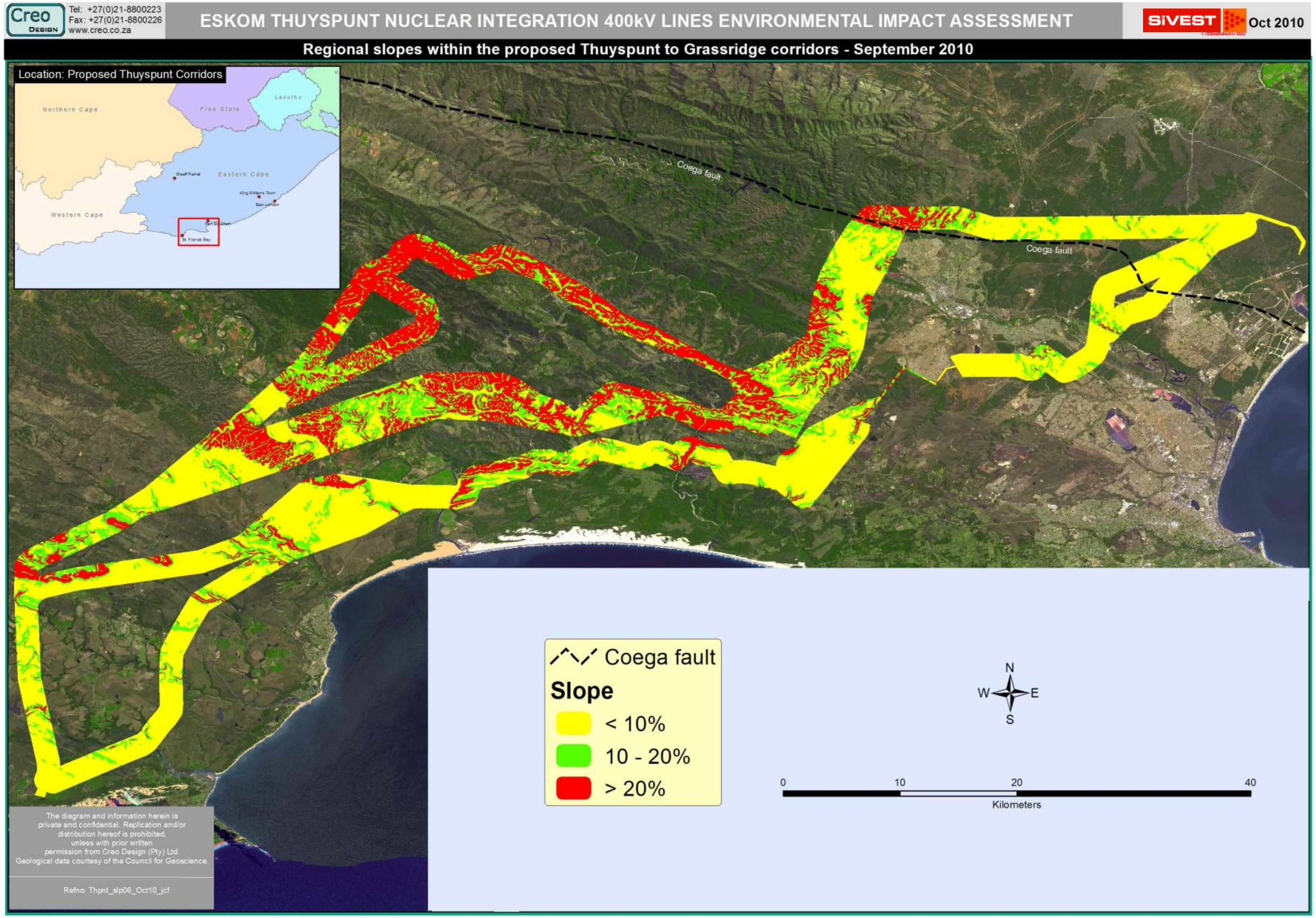


Figure 4: Slope classes in proposed corridors

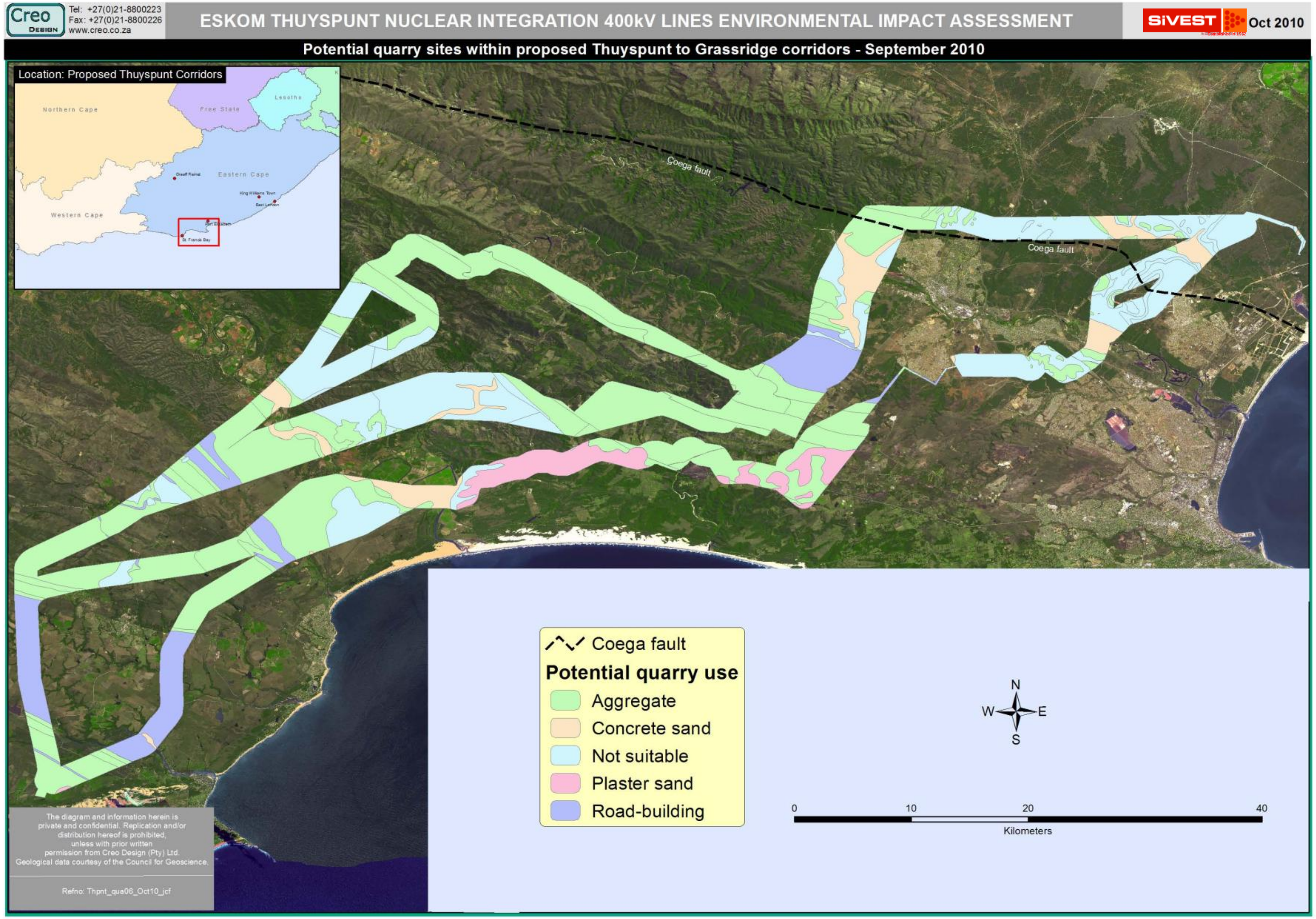


Figure 5: Potential quarry sites within the proposed corridors

8. IMPACT RATING WITHIN CORRIDORS

The aim of this exercise was to provide the relevant data layers requested by SiVEST and highlight their attributes, specifically those that could pose as potential obstacles during the development of the proposed 400kV power lines. The vulnerabilities of the different data layers within the development servitudes had to be highlighted, graphically displayed and rated according to the impact rating system provided by SiVEST. This methodology assists in evaluating the overall effect and impact of a proposed activity on the environment. It must take into account the nature, scale and duration of effects on the environment, and are also assessed according to the following project stages: planning, construction, operation, decommissioning.

Consequently, vulnerabilities and possible impacts on the environment will be discussed separately for each of the following layers:

- Geology;
- Hydrogeology;
- Landtypes;
- Soil depth;
- Clay percentage;
- Quarry potential;
- Slope.

In order to remain objective throughout the exercise, a system developed by Zhang (1989) and used by Triantafilis, Ward & McBratney (2001) was used whereby restriction terms with accompanying parametric scores were assigned to the attributes of the data layers. The restriction terms and their assigned parametric scores are shown in Table 2. This system was applied to every dataset so that the datasets could be compared to one another at a later stage.

Table 2: Qualitative restriction terms and the corresponding quantitative scores

Qualitative term	Quantitative score
No limitation	0
Low limitation	1
Moderate limitation	3
Moderately strong limitation	6
Severe limitation	9

The terms and scores outlined in Table 2 were assigned to attributes of the data layers. The total scores for each attribute were then calculated, with lower scores indicating lower limitations while higher scores would indicate higher limitations. The end result is relative figures which would discriminate between areas with higher and lower limitations objectively.

8.1 GEOLOGY

The geology of the area, as shown in Figure 1, consists of mostly quartzitic sandstones, sandstones, mudstones, conglomerates, shales and siltstones, with appreciable amounts of terrace gravel, silcrete, ferricrete and aeolianite. Since the hardness, thickness, porosity, composition, density and specific gravity of these layers vary considerably; some layers are more susceptible for impacts than others.

The restriction terms and scores for geology are shown in Figure 6.

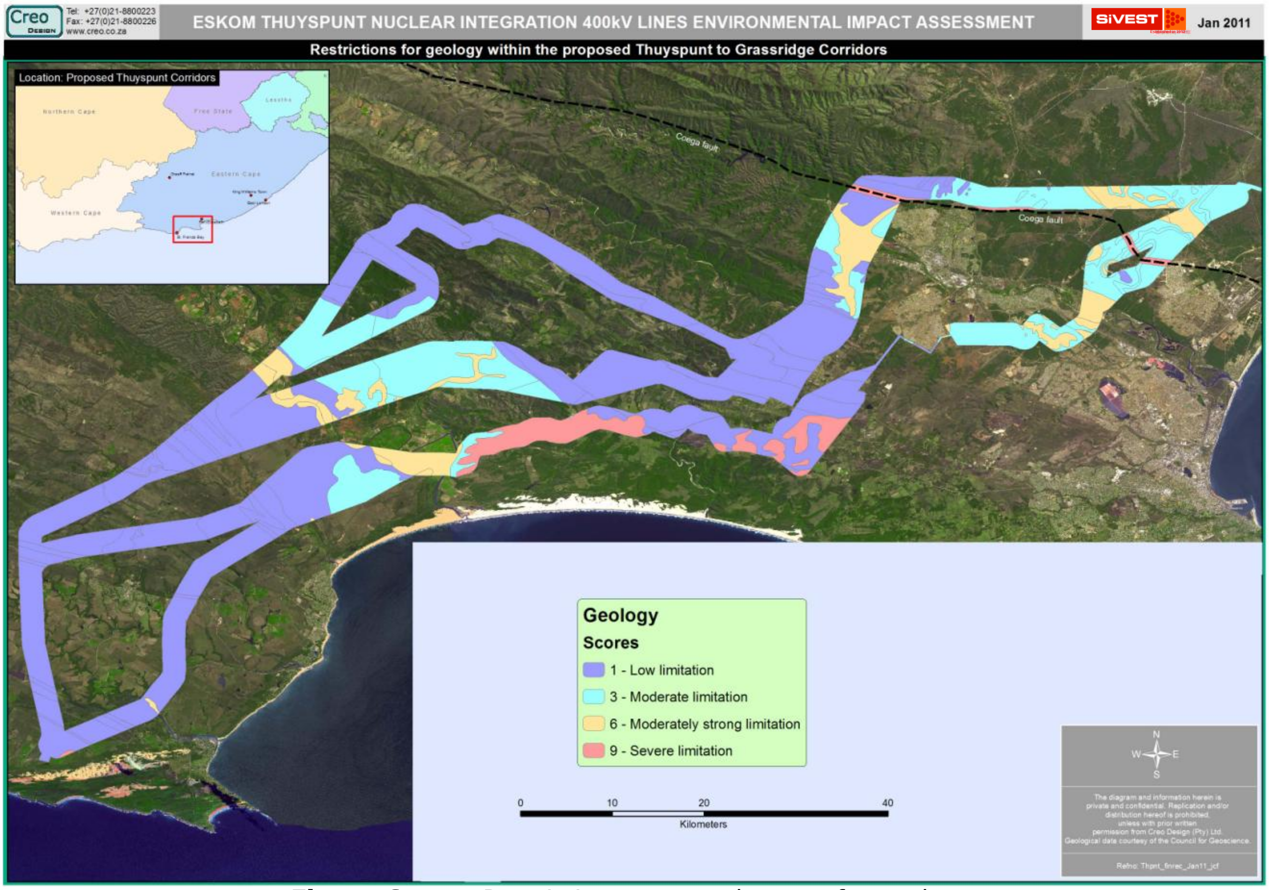


Figure 6: Restriction terms and scores for geology

Severe limitations are caused mainly by the presence of aeolianite, which can be described as lithified sediment which was deposited by aeolian processes (wind). Typically, the aeolianite of this region is characterized by overlying unconsolidated sands, with lithified sediments occurring deeper down. The immediate vicinity of the Coega fault is also seen as a severe limitation, since neotectonic activity has been noted. The latter could be hazardous for erected power lines. Therefore, a buffer of 300m on each side of the fault has been incorporated as precautionary measure. Moderately strong limitations are mainly caused by the presence of alluvium, but also intermediate and low-level fluvial terrace gravel to a lesser extent. The above lithologies are susceptible mainly from an erosion and stability point of view during the construction phases. The rating system for the severe and moderately strong limitations is outlined in the following tables, as requested by SiVEST. The focus will be on the more important limitations as identified by Creo Design.

Table 3: Impact rating for geology

IMPACT TABLE		
Environmental Parameter	Aeolianite, alluvium, intermediate and low-level fluvial terrace gravel, Coega fault	
Issue/Impact/Environmental Effect/Nature	Erosion of the above layers during the construction/operation phases due to excavation. Destabilization of the country rock during construction phase that could cause unsightly scars and rock slides. Neotectonic activity could destabilize power lines	
Extent	Site (1)	
Probability	Probable (3)	
Reversibility	Irreversible (4)	
Irreplaceable loss of resources	Significant loss of resource (3)	
Duration	Permanent (4)	
Cumulative effect	Medium cumulative impact (3)	
Intensity/magnitude	Medium (3)	
Significance Rating	-54	
	Pre-mitigation impact rating	Post mitigation impact rating
Extent	1	1
Probability	3	3
Reversibility	4	4
Irreplaceable loss	3	2
Duration	3	2
Cumulative effect	4	3
Intensity/magnitude	3	2
Significance rating	-54 (Negative High impact)	-30 (Negative Medium impact)
Mitigation measures	• Both erosion and destabilization can, to a degree, be addressed by minimizing disturbance of natural vegetation on the sites. • Access routes should ideally be planned on areas less susceptible to erosion/destabilization/compaction or appropriate action should be taken to minimize impact, e.g. planning of new access routes along contour lines and minimizing of cutting and filling operations. • Zones directly adjacent to Coega fault should be avoided.	

8.2 LAND TYPES, SOIL DEPTH AND CLAY PERCENTAGE

Three factors were considered in this category, *viz.* the properties of the individual land types, average soil depth, and average clay percentage. Since these three factors are intertwined, impacts on all will be described in this section.
With regards to the individual land types, freely drained, consolidated soil types without signs of wetness were deemed ideal. Limitations were usually encountered on shallow soils, unconsolidated sands, deep alluvial soils and rock outcrops. The restriction terms and scores for the land types are shown in Figure 7.

Generally, the land types show limited areas where severe and moderately strong limitations are found. Isolated patches are dominated by deep grey sands and the proposed actions in this area should take this limitation into account. Moderately strong limitations are, similar to the geology layer, dominated by deep alluvial soils, characteristic of valleys in this area. Rock outcrops and shallow soils tend to be restrictive in the northern corridor, while duplex soils and deep grey sands pose as obstacles in the southern corridor.

Given that the parameters, average soil depth and clay percentage, did not coincide well with the land types, these attributes have been plotted on their own. The restriction terms and scores for the average soil depths are shown in Figure 8.

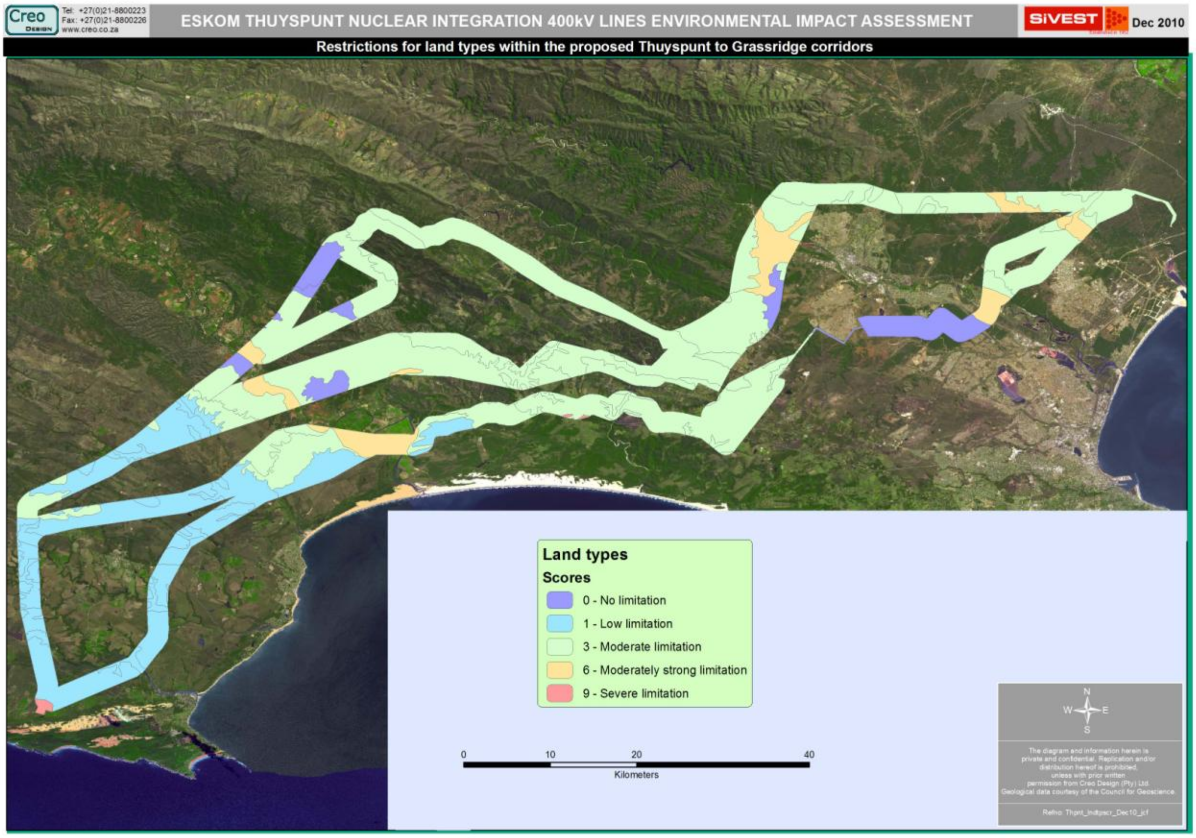


Figure 7: Restriction terms and scores for land types

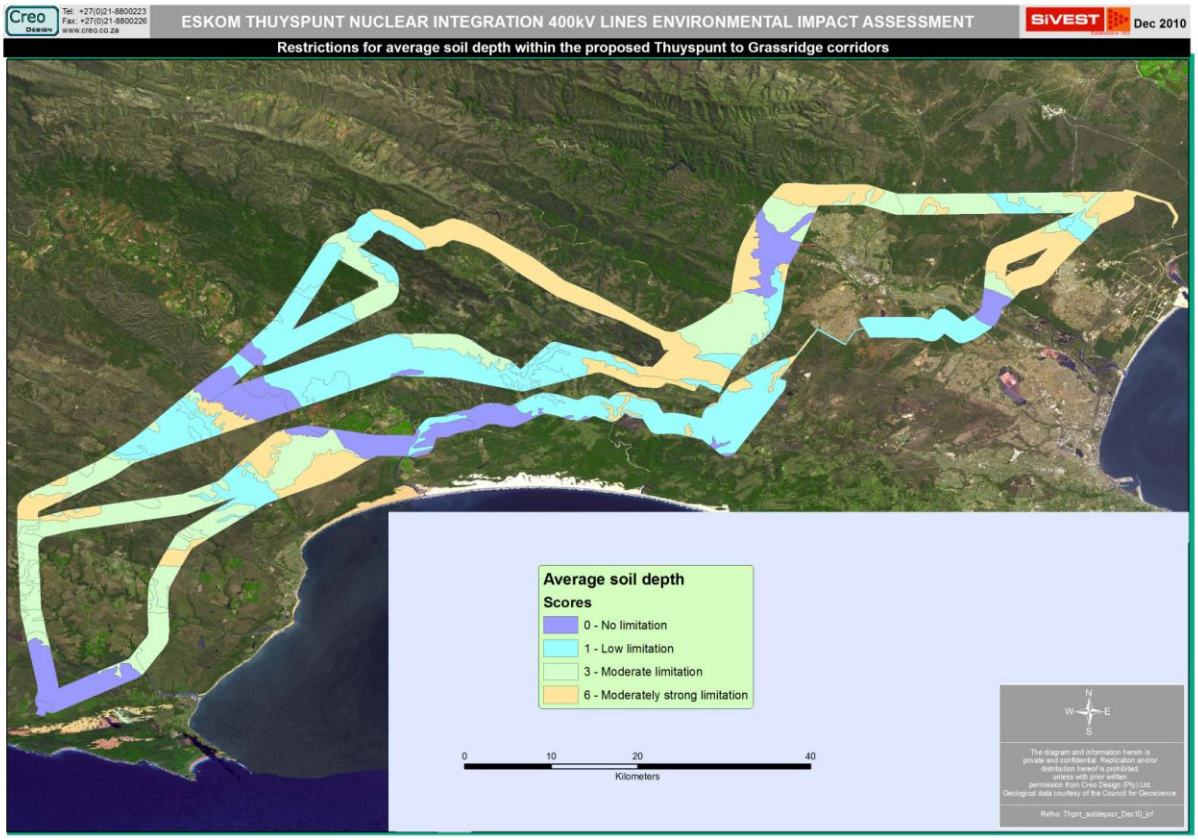


Figure 8: Restriction terms and scores for average soil depth

It is noticeable that the northern corridor has larger areas restricted by shallower soils, defined as soils shallower than 500mm, while the southern corridor shows low to no limitations in this regard. Shallow soil depths would not only contribute more towards erosion hazards, but could also be problematic during the construction phase. Clay percentage, as shown in Figure 9, is another factor of importance.

Figure 9: Restriction terms and scores for average clay percentage

Large areas within the development corridors suffer from clay percentages below 10%, as shown by the moderately strong limitation class. Clay content is important to stabilize soils and impede soil erosion. The abundance of unconsolidated sands with low clay percentages are also shown in Figure 9. Soils with clay percentages between 20-30% were considered to have a moderate limitation, since difficulty during the construction and operational stages could be encountered.

Soils with high clay content have a high degree of shrinkage/swelling during drier and wetter times respectively. This trait is seen as not conducive during the construction and operational phases of the project. Soils containing clay content of 10-20% were considered not posing any limitations.

The importance of soil conservation, together with the significant impact that actions within these corridors could have on soils, necessitated the use of a number of parameters contained within the dataset. Of these, general land type information, average soil depth and average clay percentage were used in this exercise. However, the interaction between these attributes is of paramount importance and all three parameters were considered in a holistic approach during the final impact rating evaluation.

Noticeable impacts on the soils within the corridors would be the removal of vegetation and topsoil, and compaction of the topsoil, affecting soil formation processes, erosion and the siltation of lower-lying waterways and dams. These impacts are rated in Table 4.

Table 4: Impact rating for soils

<table>
<tr><td colspan="3">IMPACT TABLE</td></tr>
<tr><td>Environmental Parameter</td><td colspan="2">Vegetation and topsoil removal</td></tr>
<tr><td>Issue/Impact/Environmental Effect/Nature</td><td colspan="2">Removal of vegetation and topsoil during the construction phase leading to erosion, siltation, affecting soil formation processes, and soil compaction</td></tr>
<tr><td>Extent</td><td colspan="2">Local (2)</td></tr>
<tr><td>Probability</td><td colspan="2">Definite (4)</td></tr>
<tr><td>Reversibility</td><td colspan="2">Irreversible (4)</td></tr>
<tr><td>Irreplaceable loss of resources</td><td colspan="2">Significant loss of resource (3)</td></tr>
<tr><td>Duration</td><td colspan="2">Permanent (4)</td></tr>
<tr><td>Cumulative effect</td><td colspan="2">High cumulative impact (4)</td></tr>
<tr><td>Intensity/magnitude</td><td colspan="2">High (3)</td></tr>
<tr><td>Significance Rating</td><td colspan="2">-63</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td></td><td>Pre-mitigation impact rating</td><td>Post mitigation impact rating</td></tr>
<tr><td>Extent</td><td>2</td><td>2</td></tr>
<tr><td>Probability</td><td>4</td><td>3</td></tr>
<tr><td>Reversibility</td><td>4</td><td>2</td></tr>
<tr><td>Irreplaceable loss</td><td>3</td><td>2</td></tr>
<tr><td>Duration</td><td>4</td><td>2</td></tr>
<tr><td>Cumulative effect</td><td>4</td><td>3</td></tr>
<tr><td>Intensity/magnitude</td><td>3</td><td>2</td></tr>
<tr><td>Significance rating</td><td>-63 (Negative High impact)</td><td>-28 (Negative Low impact)</td></tr>
<tr><td>Mitigation measures</td><td colspan="2">• Keep disturbance sites to a minimum
• Rehabilitate soil and vegetation
• Implement effective erosion control measures
• Install silt fences
• Access routes should follow contour lines, avoid unconsolidated sands or sands with a low clay percentage, and steer clear of densely vegetated areas</td></tr>
</table>

8.3 GEOHYDROLOGY

The geology of the area has been described in previous sections with the geohydrology described in more detail in Section 5. The main concern with regards to geohydrology would be pollution of the underlying aquifers due to activities in the area. Furthermore, presence of the Coega fault warrants special attention since the risk for pollution of the underlying fractured aquifers is increased. Lasting impacts from the proposed actions on the aquifers were seen as minimal. Still, a number of considerations should be taken into account during the planning phase of the project:

- Depth to the aquifer is of importance since pollution would become more of a reality in shallower aquifers. Average soil depth should also be used as an indicator since shallower soils are often underlain by host rock. This could prove more problematic should the host rock have favourable attributes for good aquifer potential.
- Composition of the overlying soil would be essential to determine its buffering capacity in preventing pollutants entering an underlying aquifer. In this regard, unconsolidated sands and soils showing extensive signs of wetness would pose a greater limitation since their ability to prevent the movement of pollutants is low.
- Areas within the buffer of 300m surrounding the Coega fault should be avoided if possible.

Considering the above aspects, special care should be taken during the planning and construction phases of the project. The restriction terms and scores for geohydrology are shown in Figure 10.

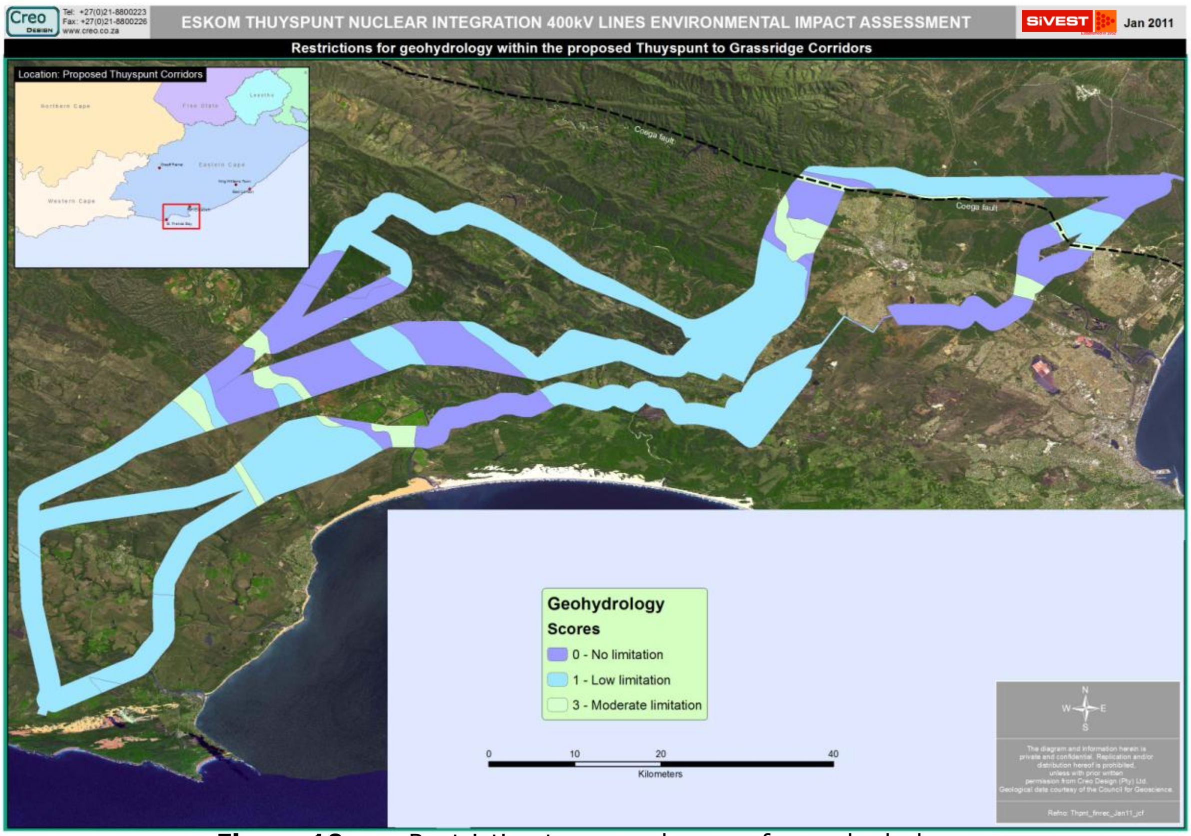


Figure 10: Restriction terms and scores for geohydrology

Higher yielding fractured and intergranular aquifers are seen as moderate limitations for the project. The impact rating system on geohydrology is depicted in Table 5.

Table 5: Impact rating for geohydrology

IMPACT TABLE		
Environmental Parameter	Aquifers	
Issue/Impact/Environmental Effect/Nature	Pollution of underlying aquifers during the construction phase	
Extent	District (2)	
Probability	Possible (2)	
Reversibility	Completely reversible (1)	
Irreplaceable loss of resources	Marginal loss of resource (2)	
Duration	Medium term (2)	
Cumulative effect	Low cumulative impact (2)	
Intensity/magnitude	Medium (2)	
Significance Rating	-22	
	Pre-mitigation impact rating	Post mitigation impact rating
Extent	2	2
Probability	2	1
Reversibility	1	1
Irreplaceable loss	2	1
Duration	2	1
Cumulative effect	2	1
Intensity/magnitude	2	1
Significance rating	-22 (Negative Low impact)	-7 (Negative Low impact)
Mitigation measures	Avoid higher yielding aquifers and shallow soils, underlain by rock types with favorable aquifer attributes. Avoid areas in 300m buffer surrounding the Coega fault	

8.4 SLOPE

Slope was considered one of the more important limitations during this exercise, mainly because of the potential erosion hazard it presented. Therefore, slopes above 20% were seen as a severe limitation, while slopes between 10-20% were considered moderate. As mentioned earlier, these guidelines were obtained from the Conservation of Agricultural Resources Act (DOA 1984). The restriction terms and scores for slope are shown in Figure 11.

First impressions from Figure 11 reveal that the central section of the Northern Corridor (affecting all alternatives within it) is severely limited by slopes exceeding the allowable 20% restriction, making soil conservation measures of paramount importance. Large sections of these areas also suffer limitations in terms of shallow soils and low clay percentages, as shown by Figures 8 and 9 respectively. The impact rating system for slope is depicted in Table 10.

Distinction is made between slopes steeper than 20% (severe limitation) and slopes of 10-20% (moderate limitation). Carefully planned soil conservation practices on moderately limited slopes could still provide feasible solutions, while very steep slopes would offer little to no potential for any activities.

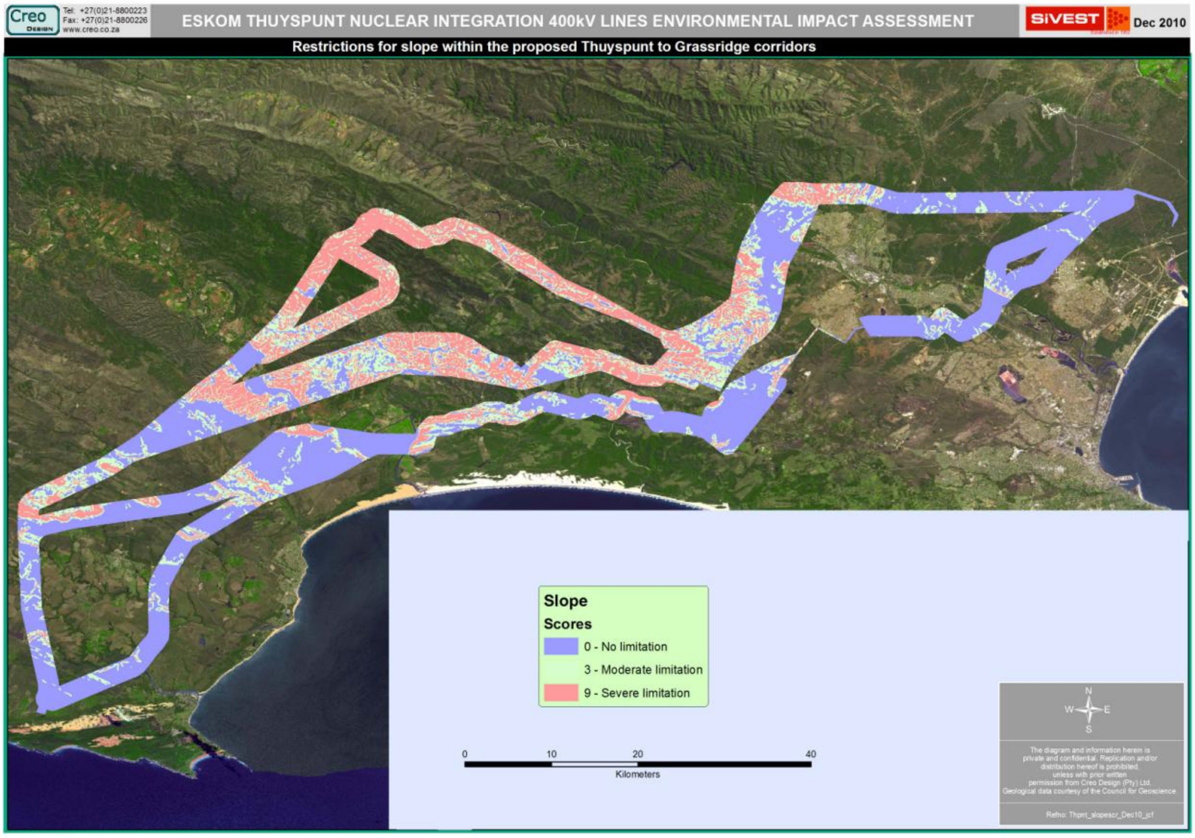


Figure 11: Restriction terms and scores for slope

Table 6: Impact rating for slope

IMPACT TABLE	
Environmental Parameter	Slope: 10-20%
Issue/Impact/Environmental Effect/Nature	Erosion of topsoil; siltation
Extent	Local (2)
Probability	Probable (3)
Reversibility	Irreversible (4)
Irreplaceable loss of resources	Significant loss of resources (3)
Duration	Medium term (2)
Cumulative effect	Medium cumulative impact (3)
Intensity/magnitude	Medium (2)
Significance Rating	-34

	Pre-mitigation impact rating	Post mitigation impact rating
Extent	2	2
Probability	3	2
Reversibility	4	4
Irreplaceable loss	3	2
Duration	2	1
Cumulative effect	3	2
Intensity/magnitude	2	1
Significance rating	-34 (Negative Medium impact)	-13 (Negative Low impact)
Mitigation measures	Keep disturbance sites to a minimum Rehabilitate soil and vegetation Implement effective erosion control measures Install silt fences Access routes should follow contour lines, avoid unconsolidated sands or sands with a low clay percentage, and steer clear of densely vegetated areas	

IMPACT TABLE	
Environmental Parameter	Slope: >20%
Issue/Impact/Environmental Effect/Nature	Erosion of topsoil; siltation
Extent	Local (2)
Probability	Probable (4)
Reversibility	Irreversible (4)
Irreplaceable loss of resources	Significant loss of resources (3)
Duration	Medium term (2)
Cumulative effect	Medium cumulative impact (3)
Intensity/magnitude	High (3)
Significance Rating	-54

	Pre-mitigation impact rating	Post mitigation impact rating
Extent	2	2
Probability	4	3
Reversibility	4	4
Irreplaceable loss	3	2
Duration	2	2
Cumulative effect	3	2
Intensity/magnitude	3	2
Significance rating	-54 (Negative High impact)	-30 (Negative Medium impact)
Mitigation measures	Avoid slopes >20% where possible Keep disturbance sites to a minimum Rehabilitate soil and vegetation Implement effective erosion control measures Install silt fences Access routes should follow contour lines, avoid unconsolidated sands or sands with a low clay percentage, and steer clear of densely vegetated areas	

8.5 QUARRY SITES

The potential of underlying geological formations to produce material for different uses has been assessed, and the following uses were identified:

- Aggregate
- Concrete sand

- Plaster sand
- Road-building
- Not suitable

Although of importance from a logistical viewpoint, the quarry potential of the different lithologies was of lesser importance in the overall picture. Consequently, areas with no quarry potential were only regarded as having a moderate restriction for development within the corridors. Furthermore, since this feature was only of logistical importance and would not have an impact on the natural state of the environment, it was not rated by the impact rating system. However, should a quarry site be identified, a thorough investigation would be needed to determine the impact on the surrounding environment by considering all the data layers discussed so far. The restriction terms and scores for quarry sites are shown in Figure 12.

Figure 12: Restriction terms and scores for potential quarry sites

8.6 COMPOUND IMPACT RATING AND PAIR-WISE COMPARISON

Although discussion of the above data sets separately is undoubtedly insightful, it should be noted that certain data sets would be more critical than others. Given that a holistic, all-encompassing approach is necessary to address the problem, none of these data sets can be considered in complete isolation. From this it follows that certain data sets would be more sensitive to impacts on the environment, and therefore should be awarded a heavier weight. One example would be the comparison of slopes to potential quarry sites. In this study, the slope-factor would have a more profound influence on the state of the environment than the site's potential to host a quarry. To assign equal weights to these two data sets would not produce a realistic account of the relative importance of each. Hence, different weights were assigned to the individual parameters to determine their relative importance.

One system used regularly in the literature is Saaty's (1980) analytical hierarchy procedure as described in Ahamed, Rao & Murthy (2000). An importance scale is used for the pair-wise comparison of parameters. After the parameters have been pair-wise compared to each other, the eigenvector is calculated and the weights of the parameters are estimated. Thus, different weights are assigned to the different parameters. The overall membership score of the pixel for the landuse can then be determined as:

$$\mu_A(x)_{overall} = w1.\mu_A(x)_{geology} + w2.\mu_A(x)_{land\ type} + w3.\mu_A(x)_{slope} + \ldots$$

where $\mu_A(x)_{overall}$ represent the final membership score for the corridors and the elements at the right-hand side of the equation are the individual membership scores summing to unity. Table 7 shows an example of the pair-wise comparison matrix used in this exercise.

Table 7: Pair-wise comparison matrix for the corridors

	Geo	Geohydro	Land type	Soil depth	Clay %	Quarry	Slope
Geo	1						
Geohydro	3	1					
Land type	5	3	1				
Soil depth	5	3	1	1			
Clay %	5	3	1	1	1		
Quarry	1/5	1/7	1/7	1/7	1/7	1	
Slope	5	3	1	1	1	7	1

The weights can be explained as follow:

1 = Both parameters are equally important

3 = In comparison with the column variable, the row variable is slightly more important

5 = In comparison with the column variable, the row variable is moderately more important
7 = In comparison with the column variable, the row variable is significantly more important
9 = In comparison with the column variable, the row variable is overwhelmingly more important
1/3 = In comparison with the column variable, the row variable is slightly less important
1/5 = In comparison with the column variable, the row variable is moderately less important
1/7 = In comparison with the column variable, the row variable is significantly less important
1/9 = In comparison with the column variable, the row variable is overwhelmingly less important

Consider row 4, where the relative importance of the average soil depth is compared to the relative importance of the geology. The score of '5' indicates that, compared to the column variable (geology), the row variable (soil depth) is moderately more important. This can be attributed to the fact that topsoil is more likely to be negatively influenced by any activity than the underlying geology.

To ensure the matrix is not biased or any mistakes have been made in the reasoning, a consistency index (CI) be calculated. A CI ≤ 0.1 is considered acceptable. The CI for this exercise was 0.06 indicating that the matrix is consistent and unbiased.

This matrix also produced the necessary relative weights for the layers and they are displayed in Table 8.

Table 8: Weights assigned to the different layers

Geology	0.04
Geohydrology	0.07
Land type	0.21
Average soil depth	0.21
Average clay percentage	0.21
Quarry potential	0.02
Slope	0.21

After the weighting process, all the layers were compared to produce a compound impact rating, shown in Figure 13.

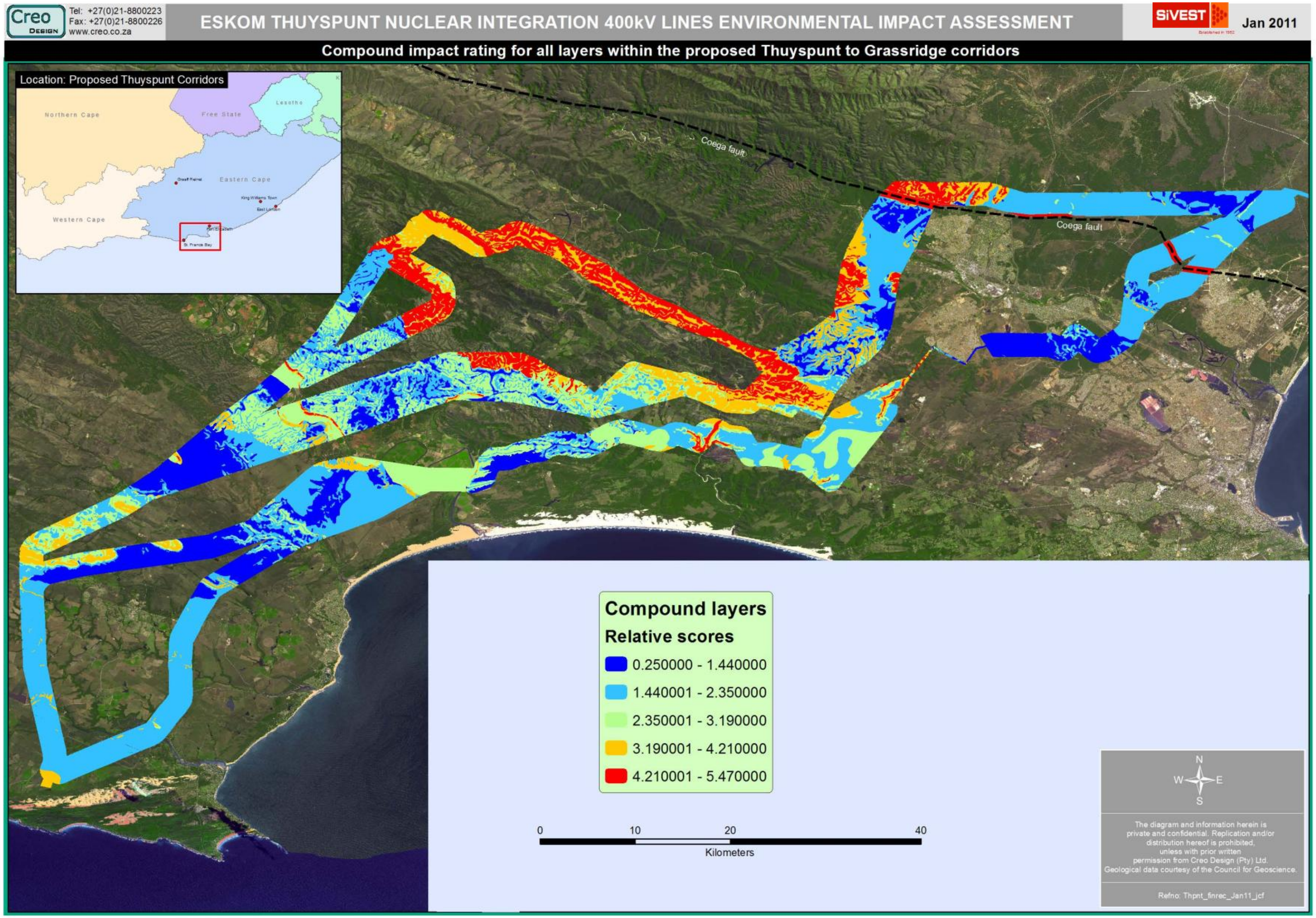


Figure 13: Compound impact rating for all layers within the proposed corridors

Although the limitations of all the layers have been discussed already, it is useful to summarize which layers contribute more towards limitations within the corridors. Figure 13 show that the northern part of the Northern corridor shows heavy restrictions which can mostly be attributed to severe limitations in slope, shallow soils and a low clay percentage. On the other hand, the southern part of the Northern Corridor appears less restrictive and a more attractive option for development if the steep slopes and unconsolidated/shallow soils can be avoided and/or effective mitigation measures be applied.
Unlike the Northern Corridor, the Southern Corridor faces limited restrictions from steep slopes. Restrictions occur mainly due to the presence of alluvial sand or aeolianite, and low clay percentages. Soil depths in this corridor are generally satisfactory. In both corridors the Coega fault presents a heavy limitation – fortunately the areas restricted to development are small.

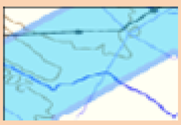
To conclude this section it can be stated that the followed approach produced insightful results and the combination of layers through the weighting system generated a more accurate representation of the holistic picture. Moreover, more problematic restrictions were highlighted and can be addressed during the planning stage of the project. Still, low relative scores do not propose that mitigation measures should be disregarded – for final decisions the separate layers should be consulted.

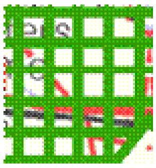
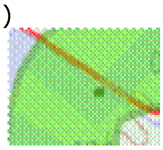
8.7 CORRIDOR ALTERNATIVES

SiVEST requested that all the routes and their alternatives be compared in tabular format with preferred routes highlighted by specialists. Additionally, corridors with fatal flaws (scores of 74-96) should be highlighted and elaborated on. This exercise was undertaken and Table 9 gives a summary of the routes and their alternatives, and the preferred route from a geotechnical perspective. Preferred alternatives are highlighted. None of the corridors showed any fatal flaws in any of the parameters.

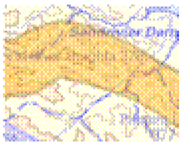
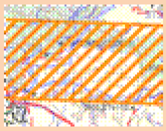
Table 9: Corridor alternatives comparison

Southern Corridor:

Area (Section of Route)	Route Alternative	Route Alternative	Geotechnical basis
HV Yard to Gamtoos River	Southern Corridor at start of EIA phase (aligned to north-west of St. Francis Bay, to east of Humansdorp) 	Located in the Northern Corridor (i.e. 5 lines in Northern Corridor, running to the north of Humansdorp to join Southern Corridor west of the Gamtoos River Valley) 	**Preference:** Southern Corridor **Reasons:** Marginal edge due to lower restrictions on slope and average soil depth. Other aspects not significantly more or less favourable than Northern Corridor alternative.

Fitches Corner / Geduld Rivier	Southern Corridor at start of EIA phase (running through Fitches Corner and through Rocklands) 	Alternative to the east to avoid Fitches Corner and La Rochelle smallholdings 	**Preference:** Fitches Corner **Reasons:** Both routes have similar attributes, but Fitches Corner is not hampered by severe limitation of aeolianite.
Between Despatch and Motherwell	Southern Corridor at start of EIA phase (running north of Despatch) 	Alternative to the east (closer to Motherwell) 	**Preference:** Motherwell alternative **Reasons:** Slightly more advantageous since no/little limestone, sandstone, conglomerate layers exist here. However, both share the Coega fault limitation

Northern Corridor:

Area (Section of Route)	Route Alternative	Route Alternative	Geotechnical basis
Longmore / Elands River Area	Longmore Northern Firebreak (past Hankey and through the Elands River Valley) 	Longmore Southern Firebreak (running just north of Loerie and running through the southern part of the Longmore property) 	**Preference:** Longmore Southern Firebreak **Reasons:** Limitations of slope, average soil depth and clay percentage significantly less than Northern Firebreak. Geological constraints slightly more than Northern Firebreak. Both share the Coega fault limitation

Final corridor recommendations are shown in Figure 14, with explanations in Table 9. For the Northern Corridor, the Longmore Southern Firebreak was chosen since it is less limited in terms of slope, average soil depth and clay percentage than the Northern Firebreak.

The first section chosen for the Southern Corridor is the alternative stretching north-west of St Francis Bay to east of Humansdorp. This route was marginally less restrictive than the northern alternative due to lower restrictions on slope and soil depth. The second preferred section runs through Fitches Corner and Rocklands and was chosen because the Fitches Corner alternative is not hampered by the severe limitation of aeolianite, characteristic of the alternative to the east of Fitches Corner. Since this section is also an alternative to host the PE substation, it is important that the geology, geohydrology and soils exhibit low limitations. These aspects are highlighted in Figures 6, 8, and 10 respectively, and in all parameters only low limitations exist. The latter is important from a pollution point of view, since the substations contain oils that could pose a threat.

The final recommended section follows the Motherwell alternative route since it's slightly more advantageous than the Despatch alternative because of little to no limestone, sandstone and conglomerate layers. However, the Coega fault poses a sizeable limitation to development, both from a stability and aquifer pollution point of view.

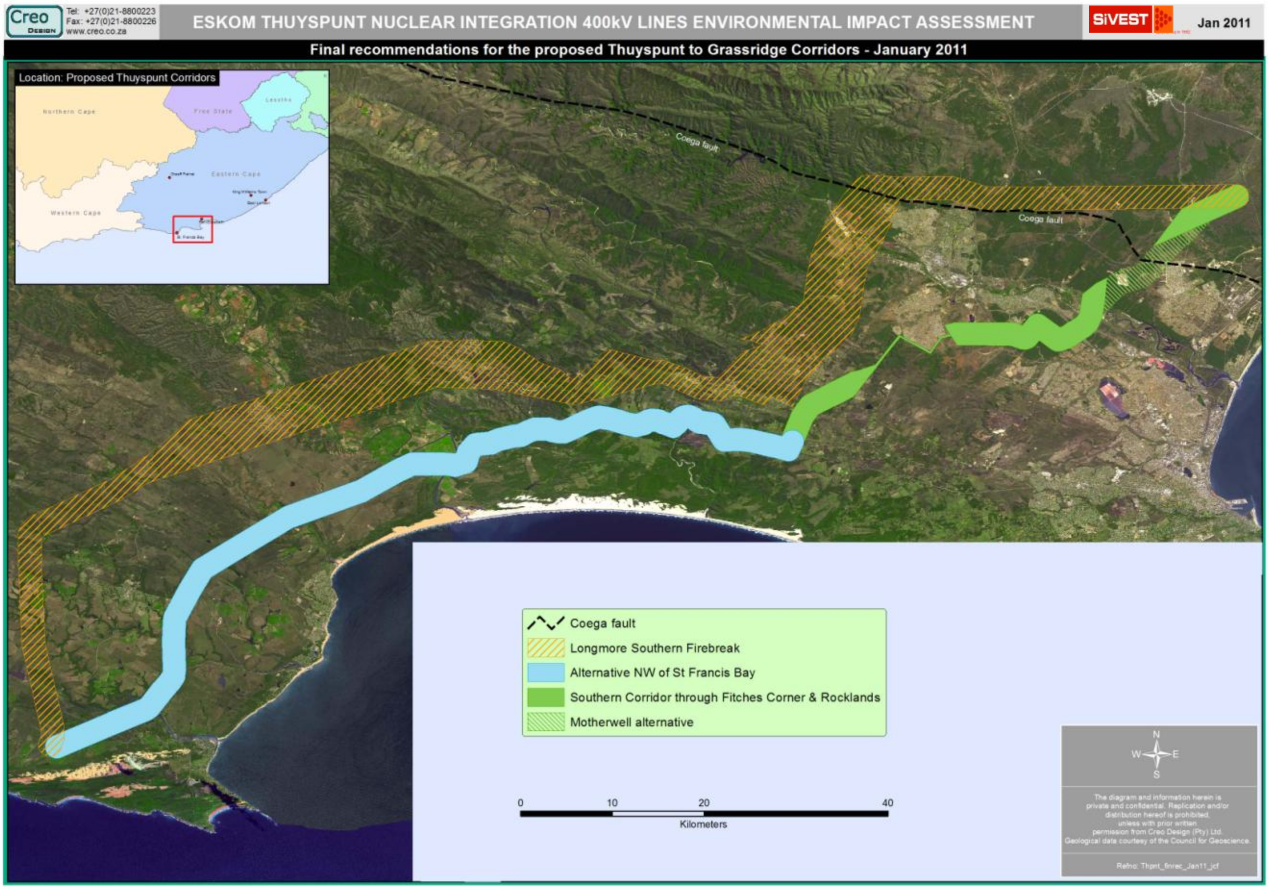


Figure 14: Final recommendations based on geotechnical parameters

9. CONCLUSIONS AND RECOMMENDATIONS

SiVEST have appointed Creo Design to perform a geo-technical assessment of the servitudes identified by Eskom to accommodate five 400kV lines as part of the Thyspunt Transmission Line Integration Project EIA. It has been recommended to identify at least two separate servitude corridors or to separate the lines as far as practicable, due to Nuclear Safety and reliability of supply considerations. This scoping phase included detailed descriptions, discussions and recommendations of the following characteristics:

- Geology
- Land types (general characteristics)
- Soil characteristics (average soil depth and clay percentage)
- Slopes
- Geohydrology
- Potential quarry sites

This study incorporated expert knowledge of the above-mentioned parameters as well as literature sources, and all the information was plotted graphically to allow easy observation of restrictions/limitations within the corridors. Furthermore, the impact rating system, as requested by SiVEST, was applied to all the data layers. This approach ensured that layers could be compared to each other in an objective manner. Additionally, the weighted ratings of all the layers were combined to produce a compound impact rating for the corridors, highlighting restrictions within the corridors.

Table 10 provides a summary of the impact ratings for the different data layers and the essential findings of this study. In general, the northern alternative of the Northern Corridor shows severe limitations that can be attributed to steep slopes, shallow soils and a low clay percentage. While, the southern alternative of the Northern Corridor suffers, to a degree, from the same shortfalls than the northern section, the limitations for development are more restricted spatially. Effective mitigation practices to curb the steep slopes and unconsolidated/shallow soils, would certainly make this southern alternative more attractive. Moreover, due to the restrictive spatial distribution of the problematic sections, opportunities exist to avoid these sectors altogether.

The Southern Corridor, on the other hand, faces restrictions mainly from the presence of alluvial sand or aeolianite and low clay percentages. Soil depths and slopes are generally more forgiving, while more opportunities exist to avoid severe limitations.
Both corridors would need to take the Coega fault into account, as well as localized, smaller faults which are fairly common in the Algoa and Gamtoos basins.

Table 10: Comparison of summarized impacts on environmental parameters

Environmental parameter	Issues	Rating prior to mitigation	Rating post mitigation
Aeolianite, alluvium, Coega fault	Erosion, destabilization, unsightly scars	**-54**	**-30**
		Negative High impact	Negative Medium impact
Vegetation and topsoil	Erosion, siltation, compaction	**-63**	**-28**
		Negative High impact	Negative Low impact
Aquifers, Coega fault	Pollution	**-22**	**-7**
		Negative Low impact	Negative Low impact
Slope: 10-20%	Erosion, siltation	**-34**	**-13**
		Negative Medium impact	Negative Low impact

Slope: >20%	Erosion, siltation	**-54**	**-30**
		Negative High impact	Negative Medium impact

The impact rating system, weighting of parameters and the compound rating system proved effective to ensure a holistic, inclusive approach to address the challenges at hand. Development restrictions were also quantified and emphasized, which will allow more efficient planning to be undertaken. It should be noted, however, that mitigation measures would be needed on a wide scale to bring the sustainability of this project to fruition.

Finally, it is highly recommended that the spatial distribution of land use/land cover within the corridors is captured from a recent satellite image, such as SPOT 5. The spatial resolution of SPOT 5 would allow detailed planning to a scale of 1:8 000. This data would be invaluable from a detailed planning point of view, since many information classes can be extracted from the image. This data can then also be used in more comprehensive studies on the corridors in the future.

10. REFERENCES

Ahamed TRN, Rao KG & Murthy JSR 2000. GIS-based fuzzy membership model for crop-land suitability analysis. *Agricultural Systems* 63:75-95.

Hattingh J & Goedhart ML 1997. Neotectonic control on drainage evolution in the Algoa basin, southeastern Cape Province. *South African Journal of Geology 100:43-52.*

Soil Classification Working Group 1977. *Soil classification: a binomial system for South Africa*. Pretoria: Department of Agriculture.

South Africa (Republic of) 1984. *Conservation of agricultural resources act, Act 43 of 1983.* Government Gazette 3707, 9238.

Triantafilis J, Ward WT & McBratney AB 2001. Land suitability assessment in the Namoi Valley of Australia, using a continuous model. *Australian Journal of Soil Science* 39:273-290.