Geohydrological Assessment for the Proposed new Development at Northgate, Kimberley

Report Prepared for

NCPIH
209 PINEHURST OFFICE PARK
SOMERSETLINKS
SOMERSET WEST
7130

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March 2008

SRK Consulting
Engineers and Scientists

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Glossary of Terms

Aeolian: Relating to or arising from the action of wind.

Aquifer: A geological formation capable of supplying economic volumes of groundwater (*Also see Non-Aquifer*).

Aquifer system: A heterogeneous body of interlayered permeable and less permeable material that acts as a water-yielding hydraulic unit covering a region.

Anthropogenic: Effects derived from human activities.

Beach well: A shallow, 10 – 15 m deep well constructed /drilled in the beach sediments just above the high water mark for the abstraction or injection of water.

Borehole: Includes a well, excavation, or any other artificially constructed or improved groundwater cavity which can be used for the purpose of intercepting, collecting or storing water from an aquifer; observing or collecting data and information on water in an aquifer; or recharging an aquifer [from the National Water Act (Act No. 36 of 1998)].

Catchment: The area from which any rainfall will drain into the watercourse, contributing to the runoff at a particular point in a river system, synonymous with the term *river basin*.

Cenozoic Era: Cenozoic, meaning "new life", is the most recent of the three classic geological eras. It covers the 65.5 million years since the Cretaceous–Tertiary extinction event at the end of the Cretaceous that marked the demise of the last non-avian dinosaurs and the end of the Mesozoic Era. The Cenozoic era is ongoing.

Contamination: is the introduction of pollutants (whether chemical substances, or energy such as noise, heat, or light) into the environment to such a point that its effects become harmful to human health, other living organisms, or the environment.

Discharge area: An area in which subsurface water, including water in the unsaturated and saturated zones, is discharged at the land surface.

Electrical conductivity: Is a measurement of the ease with which water conducts electricity. Distilled water conducts electricity poorly, while sea water, with its very high salt content, is a very good conductor of electricity.

Fault: A zone of displacement in rock formations resulting from forces of tension or compression in the earth's crust.

Formation: A general term used to describe a sequence of rock layers.

Fracture: Cracks, joints or breaks in the rock that can enhance water movement.

Geohydrology: The study of the properties, circulation and distribution of groundwater, in practise used interchangeably with hydrogeology; but in theory *hydrogeology* is the study of geology from the perspective of its role and influence in hydrology, while *geohydrology* is the study of hydrology from the perspective of the influence on geology.

Groundwater: Water found in the subsurface in the saturated zone below the water table or piezometric surface, i.e. the water table marks the upper surface of groundwater systems.

Groundwater flow: The movement of water through openings and pore spaces in rocks below the water table, i.e. in the saturated zone. Groundwater naturally drains from higher lying areas to low lying areas such as rivers, lakes and the oceans. The rate of flow depends on the slope of the water table and the transmissivity of the geological formations.

Groundwater resource: All groundwater available for beneficial use, including by man, aquatic ecosystems and the greater environment.

Heavy metals: Those elements with atomic numbers greater than 36 in Group III through V of the Periodic Table.

Hydraulic gradient: Change in hydraulic head per unit of horizontal distance in a given direction, i.e. the difference in hydraulic head divided by the distance along the groundwater flow path. Groundwater flows from points of high elevation and pressure to points of low elevation and pressure.

Leachate: Any liquid, including any suspended components in the liquid that has percolated through or drained from human-emplaced materials.

Lineaments: A major, linear, topographic feature of regional extent of structural or volcanic origin, most easily appreciated from remote sensing data, e.g. a fault system.

Lithostratigraphy: Referring to the variation in composition of the different geological formations

Major aquifer system: Highly permeable formations, usually with a known or probable presence of significant fracturing, may be highly productive and able to support large abstractions for public supply and other purposes, water quality is generally very good.

Non-aquifer system: Formations with negligible permeability that are generally regarded as not containing groundwater in exploitable quantities, water quality may also be such that it renders the aquifer as unusable, groundwater flow through such rocks does take place and needs to be considered when assessing the risk associated with persistent contaminants.

Perched water table: Localised, unconfined groundwater separated from the underlying main body of groundwater by an unsaturated zone, i.e. the local water table is not in hydraulic continuity with the regional groundwater system.

Permeability: The ease with which a fluid can pass through a porous medium and is defined as the volume of fluid discharged from a unit area of an aquifer under unit hydraulic gradient in unit time (expressed as $m^3/m^2/d$ or m/d); it is an intrinsic property of the porous medium and is independent of the properties of the saturating fluid; not to be confused with *hydraulic conductivity* which relates specifically to the movement of water.

Poor aquifer system: *see non-aquifer system*.

Recharge: The addition of water to the zone of saturation, either by the downward percolation of precipitation or surface water and / or the lateral migration of groundwater from adjacent aquifers.

Recharge area: An area over which recharge occurs.

Runoff: All surface and subsurface flow from a catchment, but in practise refers to the flow in a river, i.e. excludes groundwater not discharged into a river.

Saline intrusion: Replacement of freshwater by saline water in an aquifer, usually as a result of groundwater abstraction.

Saline water: Water that is generally considered unsuitable for human consumption or for irrigation because of its high content of dissolved solids.

Saturated zone: The subsurface zone below the water table where interstices are filled with water under pressure greater than that of the atmosphere.

Storativity: The ratio of the volume of water that drains by gravity to the total volume of rock.

Syntectonic: A geological event, process, rock or feature / structure formed during tectonism.

Tectonism: The deformation of the lithosphere, i.e. the uppermost shell of the earth, broken into a number of tectonic plates.

Transmissivity: the rate at which a volume of water is transmitted through a unit width of aquifer under a unit hydraulic head (m^2/d); product of the thickness and average hydraulic conductivity of an aquifer.

Unsaturated zone: That part of the geological stratum above the water table where interstices and voids contain a combination of air and water; synonymous with the *zone of aeration* and *vadose zone*.

List of Abbreviations

amsl:	***above mean sea level***
DEAT:	Department of Environmental Affairs and Tourism
DWAF:	Department of Water Affairs and Forestry
EC:	Electrical conductivity
EIA:	Environmental Impact Assessment
ID:	Internal diameter
K:	Hydraulic conductivity
Ma:	Million years ago
mamsl:	metres above mean sea level
MAP:	Mean annual precipitation
MAR:	Mean annual runoff
mbgl:	metres below ground level
mS/m:	milli-Siemens per metre
m^3/a:	cubic metres per annum
m/d:	metres per day
m^2/d:	square metres per day
m^3/d:	cubic metres per day
MTPA:	Million Tons per Annum
NGDB:	National Groundwater Database
NWA:	National Water Act (Act No. 36 of 1998)
OD:	Outside diameter
S:	Storativity (dimensionless)
SRK:	SRK Consulting Engineers and Scientists
T:	Transmissivity
TDS:	Total Dissolved Solids

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SRK Report No. **March 2008**

Geohydrological Assessment for the Proposed New Residential Development at Northgate, Kimberley.

1 Introduction

An enquiry was received on 18 February 2008 from Mr. Joe Loedolff on behalf of NCPIH regarding a groundwater assessment study at a proposed new development site near Roodepan, ~8 km north of Kimberley. The proposed development will include approximately 6,400 units with sizes varying from 250 m^2 to 750 m^2. It is located immediately west of Kamfers Dam and most of the storm water from this development will drain towards the dam (**see Figure 1**). An outline of the proposed work to be carried out and a cost estimate was forwarded to Mr. Loedolff on 26 February 2008. A letter of appointment was received from Group 1 on 27 February 2008.

2 Terms of Reference (ToR)

The following ToR was proposed by SRK Consulting in the cost estimate and has been accepted by NCPIH:

1. Collate all available groundwater data and reports for the study area from the National Groundwater Database (NGDB) and the Department of Water Affairs and Forestry (DWAF).

2. Conduct a local hydrocensus of the surrounding area.
3. Use the data from (1) and (2) to assess the aquifer potential.
4. Compile a final report.

Figure 1: Google Earth locality map of the proposed Northgate development.

3 Geography and Climate

The study area comprises a flat terrain with a general gentle slope towards Kamfers Dam. Elevations vary between 1180 m.amsl. in the north-west of the area and 1160 m.amsl. at Kamfers Dam. Most of the area falls within Quaternary Catchment C91E (Kamfers Dam drainage) with a small area falling in Quaternary Catchment C91F. The general drainage is towards the Vaal River.

Rainfall occurs mainly during the summer months with the wetter months being October to April. Based on the rainfall data the average rainfall is approximately 420 mm per annum, with the maximum mean occurring in March and the minimum mean in July (**Figure 2**).

The climate around Kimberley is essentially a continental one with warm, wet summers and relatively mild winters. The average summer maximum is 32.6^{o}C and the average winter minimum 2.7^{o}C (**Figure 3**). Summer rains tend to take the form of occasional, severe thunderstorms rather than prolonged soft showers. It is not unusual for winter night-time temperatures to drop below freezing.

The average A-pan evaporation rate is >2,600 mm/annum with the highest average in January and lowest average in June.

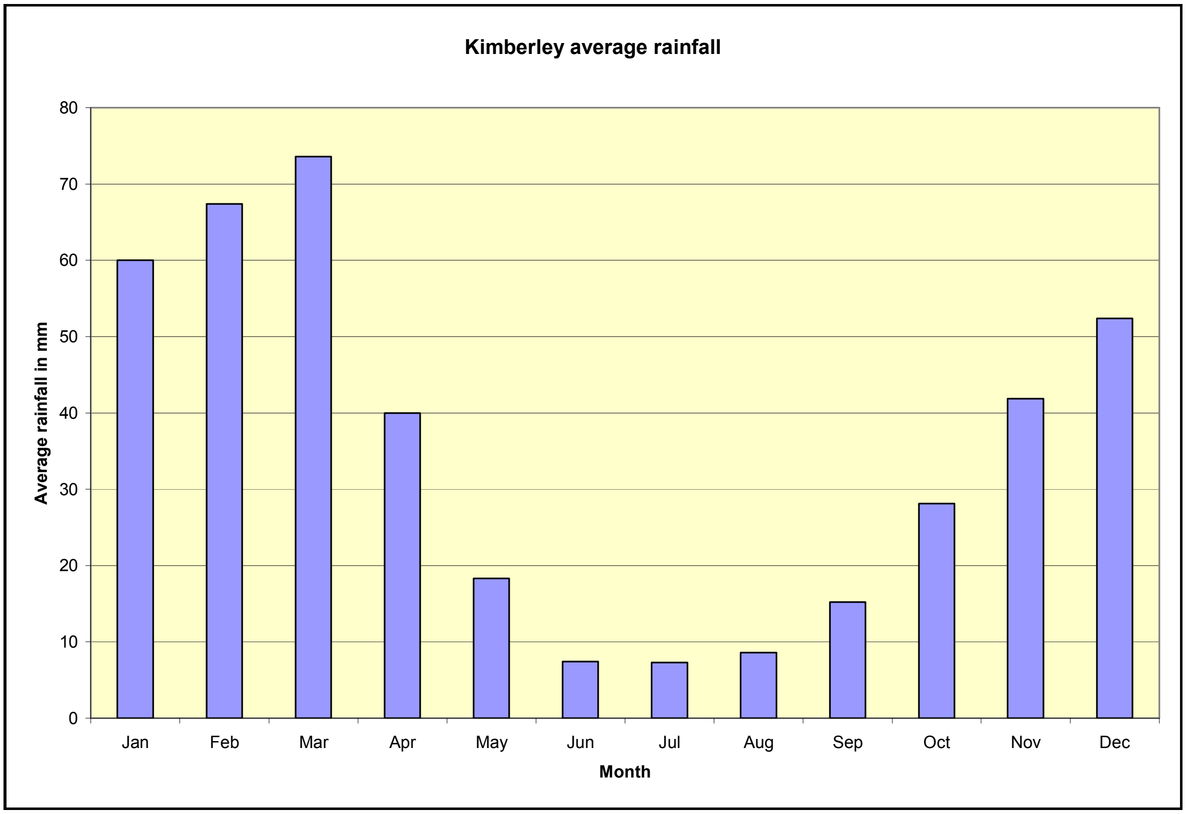

Figure 2: Kimberley average rainfall.

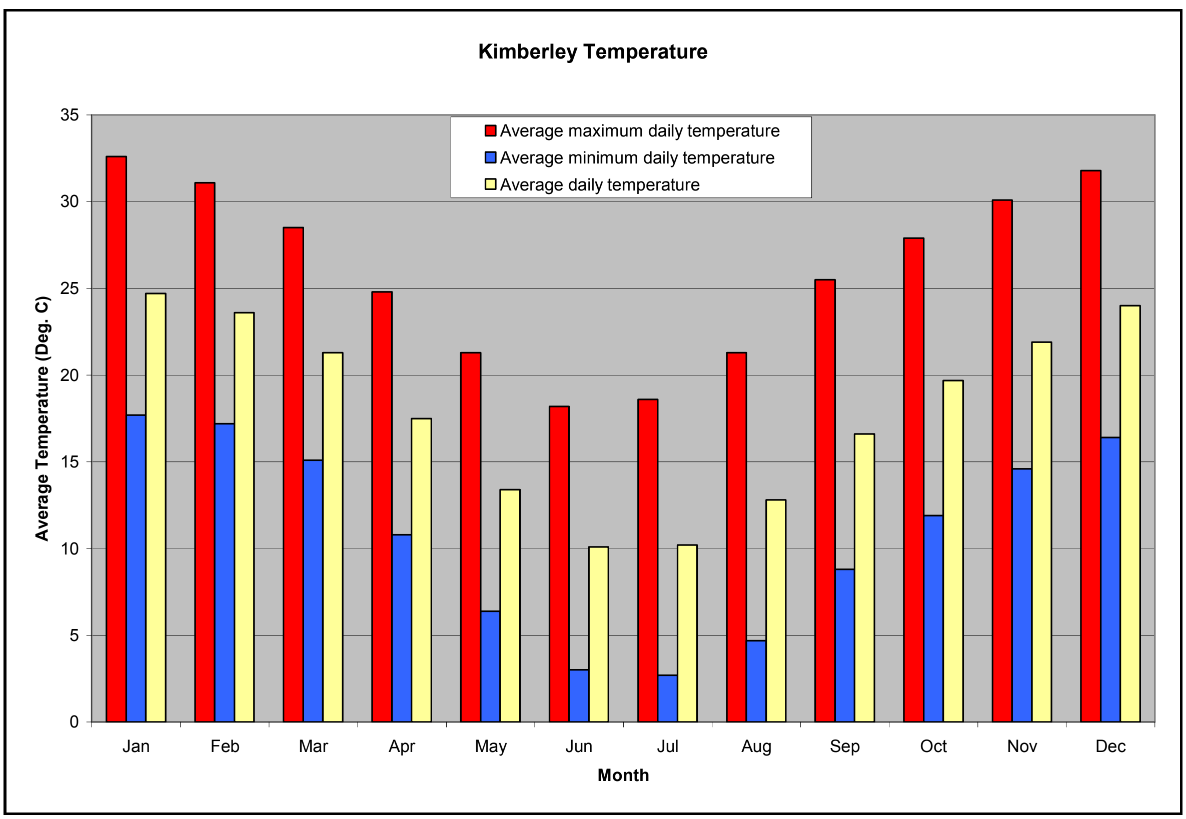

Figure 3: Kimberley average temperatures.

4 Geology and Geohydrology

The geology of the area is represented in **Figure 4** over page. Outcrops of Karoo dolerite occur in the western, central and south-eastern parts of the development area. Minor outcrops of the Prince Albert Shale Formation occur in the central and eastern parts of the area. The far north-east of the area is underlain by recent deposits of windblown sand, which covers the above-mentioned Formations. Groundwater in this area is mainly associated with fissures, joints and fractures in the otherwise impermeable rock types, and is called fractured-rock or secondary aquifers. These structures are normally associated with faults and kimberlite and dolerite intrusions. Due to the soft nature of the shale it deforms rather than fracture under stress and strain resulting in very few openings for infiltration of groundwater. Borehole yields in the shale are therefore generally low (<1 L/s). Furthermore, the shale weathers to dense clay which restricts groundwater infiltration and flow even further. In contrast to this the dolerite intrusions are much harder and fractures readily during the cooling process and under stress and strain, resulting in much more openings for infiltration and movement of groundwater. The contact zones of kimberlite and dolerite intrusions are usually fractured and representing good targets for groundwater development.

DWAF's groundwater maps indicate that the area is underlain by a fractured-rock aquifer with a potential dry season recharge of 5,570 m^3/km^2/annum. Average borehole yields range between 0.5 and 2.0 L/s.

The groundwater quality, expressed as Total Dissolved Solids (TDS), ranges between 500 and 2,000 mg/L. This is marginally acceptable for long term human consumption (SABS 241:2006 recommended operational limit (Class 1) = < 1,000 mg/L).

DWAF's groundwater vulnerability map indicates that this area is the least vulnerable to groundwater pollution (**Figure 5**). This is a result of the argillaceous nature of the Prince Albert shale.

Based on the available groundwater maps compiled by DWAF, the aquifer can be classified as a non-important aquifer because of the marginal groundwater quality (for human consumption) and the low average yields thereof.

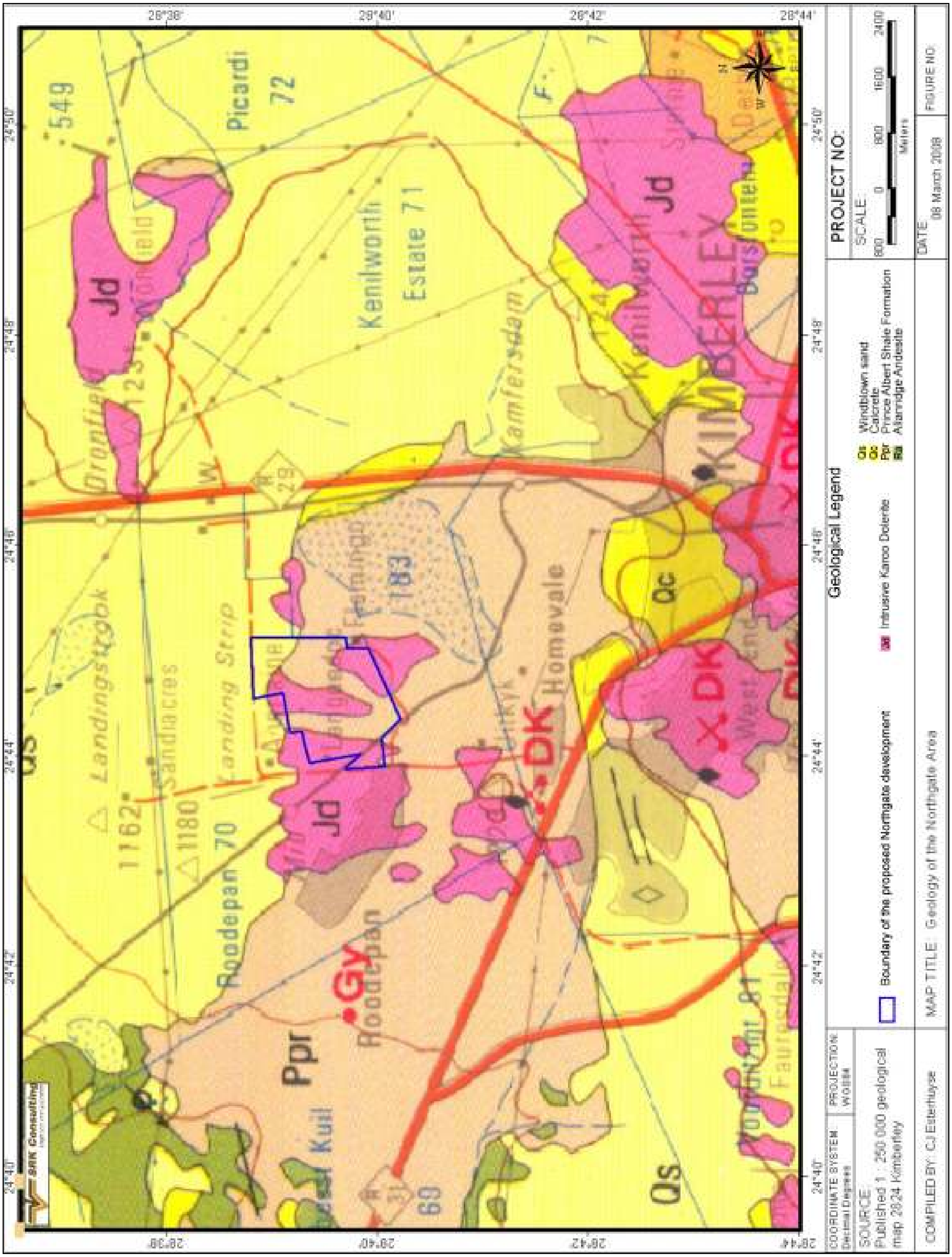

Figure 4: Geology of the Northgate area

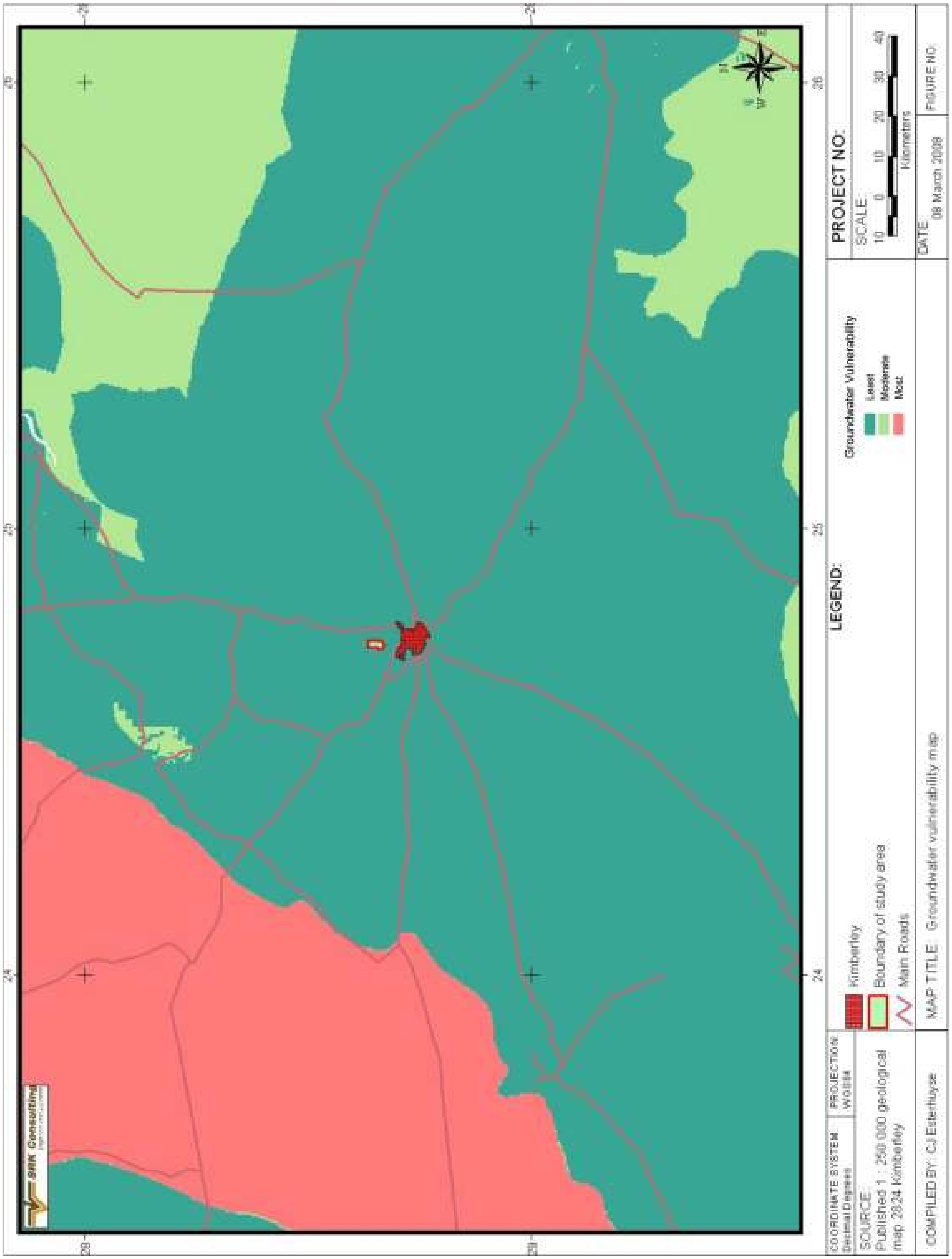

Figure 5: Groundwater vulnerability map of the Kimberley area

5 Hydrocensus

The area was visited on 5 March 2008 and a limited hydrocensus of the area and surroundings conducted. The hydrocensus data is summarized in **Table 1** below with the localities of the boreholes relative to the geology indicated in **Figure 6** over page.

Table 1: Summary of hydrocensus results obtained at Northgate

Bh No	Lattitude	Longitude	Elevation (m.bgl.)	SiteType	Date Visited	Current Use	Abstrac-tion (m^3/a)	Bh Yield (L/s)	Depth (mbgl)	Equipment	Groundwater Level Comment	Ground-water Level (mbgl)	EC (mS/m)	pH	Other Comment
RP1	-28.65853	24.73429	1175.0	Borehole	05-Mar-08	Domestic, stock	2,050	1.2	40.00	WP 75mm Cylinder	Windpump pumping	6.38	115	7.93	
RP2	-28.66410	24.74367	1156.0	Borehole	05-Mar-08	None				None	Blocked				Was pumped for small scale irrigation
RP3	-28.66239	24.74330	1170.0	Borehole	05-Mar-08	None				None	Blocked				Was pumped for small scale irrigation
RP4	-28.66314	24.74300	1162.0	Borehole	05-Mar-08	None				None	Blocked				Was pumped for small scale irrigation
RP5	-28.66044	24.74108	1170.0	Borehole	05-Mar-08	None				None	Blocked				Borehole intersected mainly shale with little dolerite
RP6	-28.66098	24.73047	1180.0	Borehole	05-Mar-08	Domestic, stock	3,942	2.0	39.00	50mm Submersible	Pumping water level	6.38	66	7.64	
RP7	-28.65984	24.73042	1180.0	Borehole	05-Mar-08	None		1.5	39.00	None		5.03			Pipes dropped in borehole
RP8	-28.66108	24.73116	1181.0	Borehole	05-Mar-08	None		1.0	40.00	None	Blocked				Was used for gardening
RP9	-28.64657	24.73517	1184.0	Borehole	05-Mar-08	Domestic, stock	2,050	0.5	45.00	WP 75mm Cylinder	Windpump pumping slowly	13.70	91	8.28	
RP10	-28.64662	24.73525	1183.0	Borehole	05-Mar-08	None		0.1	40.00	None		13.24			Borehole open - no casing - very low yield
RP11	-28.64642	24.73533	1185.0	Borehole	05-Mar-08	None		0.1	40.00	None	Borehole collapsed				Borehole open - no casing - very low yield

The census data indicate that only small scale groundwater abstraction occurs in the area, i.e. for domestic and stock use only (Total estimated abstraction < 10,000 m^3/annum). No irrigation occurs in the surveyed area except for small gardens at the homesteads of the local farmers. Boreholes RP2, RP3 and RP4 were previously used for small scale irrigation (<1 ha), but have been abandoned since. The groundwater quality in this locality is expected to be poor as it is located in shale and along a drainage channel. Boreholes RP5, RP10 and RP11 are drilled in a dolerite sill, but intersected only a thin layer of dolerite above the Prince Albert shale. The reported blow out yield of these boreholes was very low (pers. comm. owners). Little is known about borehole RP9, which is located close to boreholes RP10 and RP11, but it seems as if this borehole has intersected some groundwater in a fracture zone in the shale. The reported yield is, however, still relatively low at approximately 0.5 L/s.

Field measured Electrical Conductivity (EC) values range from 66 to 115 mS/m which is (based on the EC) fit for human consumption (Class 1 or better). The better than expected groundwater quality (as indicated by field electrical conductivity measurements compared to DWAF's groundwater maps) obtained from the sampled boreholes can be attributed to two factors, namely:

- Boreholes intersected groundwater in and immediately below a dolerite sill. Dolerite sills are known to yield groundwater of a better quality than shale.
- The sampled boreholes are located on relative high ground, i.e. outside drainage channels. Groundwater recharge occurs on the high laying areas and as it moves down hill salts from the adjacent rock types are dissolved in the groundwater. Thus the groundwater quality deteriorates with increased distance from the recharge zones. Therefore the sampled boreholes are expected to yield a good quality of groundwater.

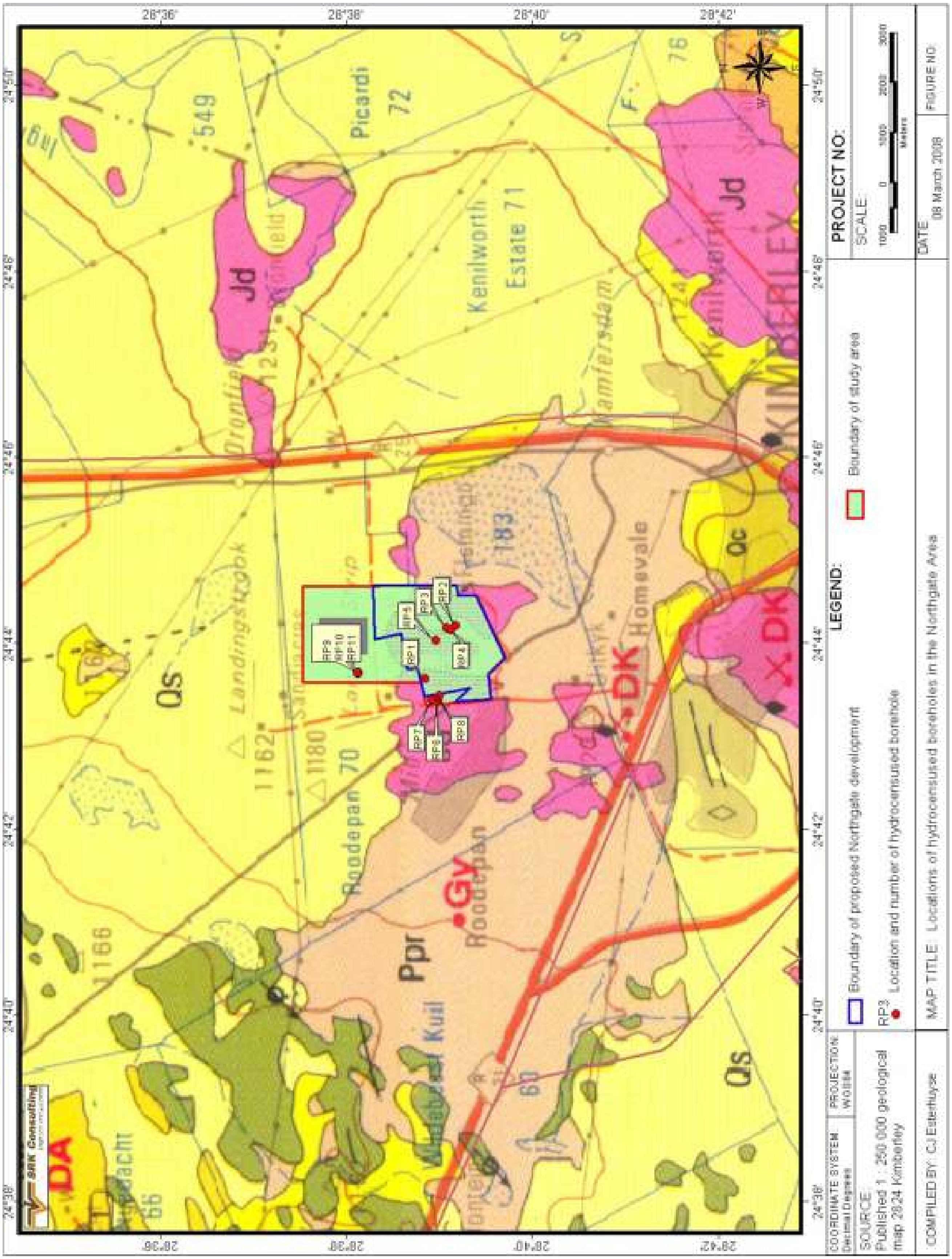

Figure 6: Locations of hydrocensused boreholes in the Northgate area

6 Potential Environmental Impacts

As the proposed development will use treated surface water from the Riverton pipeline and make use of the existing Sol Plaatjie Municipal sewage works, the impact on groundwater will be diminutive. A groundwater assessment is, however, required as the groundwater recharge of the immediate area may change (less in the urban area with compacted and paved surfaces and more downstream in the valley where the stormwater runoff concentrates). In the areas with increased recharge the groundwater level may become very shallow with springs and seeps day lighting during wet seasons. This can result in a deterioration of the groundwater quality due to increased evapo-transpiration. Fortunately a large part the low laying area is underlain by clay which restricts groundwater movement and thus recharge from the increased surface runoff.

The increased surface runoff will as well result in a rise of the water level in Kamfers Dam. However, three small dams are planned in the clay covered valley that drains towards the dam. Here a significant part of the runoff will evaporate, thereby decreasing the surface runoff into the dam. The study of this falls outside a geohydrologist's scope of work, but assuming each of these dams has a surface area of 10,000 m^2 (the same as the existing dam) and a potential evaporation of 2.60m/annum the water loss as a result of evaporation can be as much as 78,000m^3/annum.

Sewage water will have to be pumped to the existing sewage pipelines and works. A contingency plan must be formulated to ensure that generators would be available to operate the pumps at the sewage pump station(s) in the event of an extended power outage. Alternatively the booster dam(s) at the sewage pump station(s) can be designed to store the excess sewage during such incidents. Once the power supply is restored the excess sewage can be pumped to the municipal sewage works.

Table 2: Impact of Northgate Development on the groundwater resources

	Source of impact	Nature of impact	Scale	Duration	Intensity	Probability	Confidence	Significance	
								Without mitigation	With mitigation
Construction	Fuel, oil and grease spillages during construction	High concentrations will contaminate local groundwater system which may be detrimental to other water users. This risk can be mitigated by applying good house keeping rules and by quick containment and cleaning-up of spillages.	Local	Short term	Low	Possible	High	Very low	Insignificant
	Disturbance of the natural groundwater system conditions	Dewatering of excavations in low laying areas might alter natural groundwater movement.	Local	Short term	Low	Possible	High	Low	Insignificant
Operation	Spillage and leakage of sewage	Leakage or accidental spillage of sewage could contaminate the groundwater system which eventually will discharge into Kamfers Dam where it may have a negative impact on the local water biota. This risk can be mitigated by applying good house keeping rules and by quick containment and cleaning-up of spillages.	Local	Short term	Low	Possible	High	Low	Insignificant
	Increase in salinity of the local groundwater system	Increased recharge from the increased runoff could cause more evapo-transpiration in low laying areas which in turn can result in more saline groundwater	Local	Long term	Medium	Possible	High	Low	Insignificant

7 Conclusions

Based on the hydrocensus results the following can be concluded for the Northgate area:

- Groundwater occurrence is limited to secondary aquifers associated with fractured zones in shale and Karoo dolerite
- Groundwater use in the area is limited to domestic use for farmsteads and stock watering.
- It is estimated that < 10,000 m^3/annum is being abstracted from boreholes in the area.
- The average groundwater level in the area ranges between 5 and 6 m.bgl, except for the high laying area to the north where it is > 10 m.bgl.
- A clay layer exists in the central part of the area which indicates that this part is underlain by shale. This clay restricts groundwater movement and the infiltration rate in this area will be slow.
- Groundwater quality in the area is relatively good and fit for human consumption, based on the field measured EC values. The field measured EC's vary between 66 and 115 mS/m.
- The occurrence of relatively good quality of groundwater can be linked to dolerite outcrops and the higher laying recharge area.
- Maximum immediate borehole yields are generally < 2.0 L/s.
- The secondary aquifer in this area can be classified as minor aquifer.

8 Recommendations

Based on the discussions and conclusions of this report the following is recommended:

1. In order to guarantee that the proposed development does not have an unacceptably negative impact on the surrounding groundwater users, the surface runoff should be channelled to the low laying clay covered area where infiltration is limited.

2. A contingency plan must be formulated to ensure that generators would be available to operate the pumps at the sewage pump station(s) in the event of an extended power outage. Alternatively and if feasible, the booster dam(s) at the sewage pump station(s) can be designed to store the excess sewage during such incidents.

3. The proposed dams that will collect some storm water runoff are a plausible effort to reduce storm water runoff to Kamfers Dam and should be implemented as part of the construction plan.

4. A groundwater monitoring network should be established prior to construction in order to monitor the effect of the development on local groundwater resources. Boreholes RP1 and/or RP9 can be incorporated into this network for background monitoring. Another borehole downstream of the proposed development will have to be identified or drilled, if necessary, where the downstream effect of the expected increased groundwater recharge caused by the development can be monitored. This borehole can also be used to detect the effect of possible sewage leakage or spilling on the downstream groundwater quality.

5. Automatic recorders measuring water level, EC and temperature on a continual basis should preferably be installed in the monitoring boreholes. The data can then be downloaded on a six monthly basis during the water quality sampling run. Although automatic recorders are preferred, water levels can also be recorded on a monthly basis by using a handheld electrical contact water level meter and EC meter. A local operator(s) can be trained to do regular and accurate monitoring.

6. Groundwater samples should be collected at the monitoring boreholes every six months and send to an accredited laboratory for selective constituent analysis (N, K, Cl, Na, NH4, PO4, SO4 and COD).

7. The accumulated monitoring data should be entered in a groundwater monitoring program such as Aquimon3, which will enable the water manager to identify the development of "red flag" situations timeously and to take preventative action.

8. Monitoring data should be analysed and reported on by a qualified hydrogeologist on at least an annual basis.

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