

Groundwater Reserve Determination Study in the Thukela Catchment: Comprehensive Assessment

Project No: WP 9437/3

Ingrid Dennis and Rainier Dennis
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water & forestry

Department:
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Executive Summary

Introduction

The Thukela River is a principal river of the KwaZulu-Natal province in South Africa, and is ranked as the second largest river in the country by volume. It rises as a stream on the 3050 m high Mont-aux-Sources plateau near the merger point of the Lesotho – Free State Province borders. Its upper course lies within the Royal Natal National Park in the Northern Drakensberg. The river hurtles down a series of waterfalls as it drops a total of 948 m. The river cuts through the Thukela Gorge at the foot of the escarpment (approximately 1500 mamsl), passes through the Ladysmith Basin and becomes narrow and deep below Colenso. At Jameson’s Drift, it enters the wide open Thukela Trough and then the coastal plain. The 405 km Thukela River mouth lies midway between Durban and Richards Bay, 10 km to the east of the national road bridge, 14 km to the south-east of the town Mandini and 104 km from Durban.

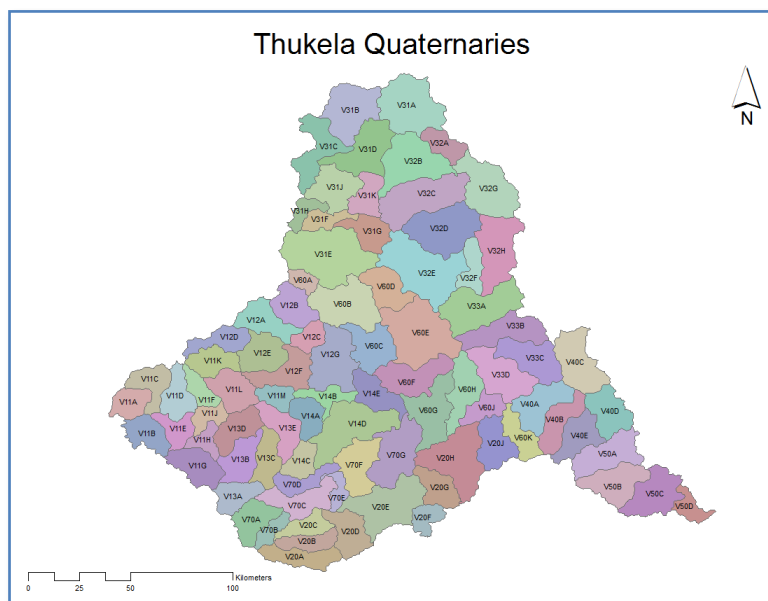
Major tributaries flowing into the Thukela River from the north are as follows:

- The Klip River, which passes through Ladysmith
- The Sundays River
- The Buffalo River, which rises above Newcastle

Major tributaries into the Thukela River from the south are as follows:

- The Little Thukela River
- The Bloukrans River
- The Bushmans River, passing though Escourt
- The Mooi River

The Thukela Water Management Area (WMA) consists of the entire catchment of the Thukela River, also referred to as the ‘V’ Hydrological Drainage Region (Midgeley *et al.*, 1994). The WMA contains 88 quaternary catchments.



The catchment experiences a wide range of climatic conditions, ranging from generally wet and cold in the Drakensberg Mountains to dry and hot in the Thukela Valley from Colenso towards the coast, and hot and humid at the coast. Summers are generally hot with temperatures often exceeding 35°C. Winters are cold,

particularly in the west and north, where temperatures fall below freezing and frost occurs regularly. Along the coast, conditions are generally more temperate. Rainfall varies significantly throughout the catchment and exhibits a strong correlation with relief. Rainfall is strongly seasonal, with in excess of 80% occurring as thunderstorms during the period from October to March. The peak rainfall months are December to February in the inland areas and November to March at the coast. Mean annual precipitation ranges from in excess of 1500 mm in the west to 750 mm, to over 1000 mm at the coast.

The Thukela River and some of its main tributaries rise in the west of the catchment in the high lying Drakensberg Mountain Range. These mountains attain elevations in excess of 2500 m. The river then winds its way through gently rolling hills before entering the steep sided gorges below Colenso. This rugged topography continues down to the river mouth, broken only occasionally by flatter, more densely populated floodplains (e.g. Tugela Estates and Tugela Ferry).

The natural vegetation types of the Thukela River Catchment follow a similar pattern to the geology. Montane grasslands covers the higher lying areas, giving way to Southern Tall Grassveld interspersed with invading *Acacia sieberiana* savanna and tilled agriculture in the lower parts of the Upper Thukela Sub-Catchment, between Bergville and Colenso. Moving downstream past Colenso, vegetation slowly changes to Valley Bushveld. Coastal grasslands and sugarcane farming characterise the lower part of the catchment. The Mooi River system is mainly modified by pastoral farming practices, with areas of indigenous subtropical forests along the steeper parts of this sub-catchment. Cattle farming bushveld dominates the Buffalo River Sub-Catchment, with the exception of montane grasslands in the upper part of this sub-catchment. The largest listed land use in this WMA is for nature reserves. A large portion of the Thukela Catchment is used for agriculture, comprising mainly subsistence farming, temporary commercial dryland agriculture, temporary commercial irrigated agriculture, and commercial forestry. Approximately 1% of the catchment is urban, comprising mostly residential, industrial and commercial development, as well as mines and quarries. This is mainly associated with the towns of Estcourt, Ladysmith, Dundee and Newcastle, situated in the upper catchment.

There are many important wetlands in the Thukela Basin. They are concentrated in three areas: the upper Buffalo Catchment, the upper Mooi/Bushmans Catchment and the upper Myamvubu Catchment upstream of Craigie Burn Dam. In the upper Buffalo Catchment, the Wakkerstroom Vlei, Groenvlei and the Blood River Vlei are important in themselves, but are also renowned for their bird life. There are several smaller vleis in the upper catchment of the Slang River. Boschoffsvlei is near Utrecht. Well-known vleis in the upper Mooi River Catchment are the Hlatikulu, Stillerust Vlei and the Highmoor Vlei.

The soil is a complex mixture of eroded rock, mineral nutrients, decaying organic matter, water, air and billions of organisms, most of which are microscopic decomposers. The following soil types occur in the Thukela WMA:

- Drakensberg Escarpment (western boundary): moderate to deep clays on steep slopes
- Drakensberg Escarpment (northern boundary): moderate to deep sandy loams on undulating terrain
- Central area: moderate to deep clays on undulating terrain and moderate to deep clayey loams on steep slopes and undulating terrain
- Coastal belt: moderate to deep clayey loams and sandy loams on undulating terrain

The study area is mostly underlain by the Karoo Supergroup and is either sub-horizontal or has a very gentle inland dip to the west, and a minor eastern coastal and coastal hinterland portion, wherein the structure comprises numerous south-easterly or seaward tilted fault blocks. These fault blocks play an important role in groundwater flow. In the low-standing east central portion of the basin, extending east to within about 20 km of the coast - 'Basement' rocks are exposed, comprising granite-gneiss, schists and amphibolites. Younger unconsolidated sands are limited to the coastal area and river beds.

Aquifers within the study area include:

- Weathered and fractured hard rock aquifer systems.
- Primary aquifers that are confined to a narrow strip along the coast and the middle reaches of the Thukela, Sundays and Buffalo Rivers. The primary aquifer in the immediate vicinity of the estuary provides a source of moderate quality water to the estuary during periods of low flow.

Project Objectives

Detailed determinations aim to produce high-confidence results, are based on site-specific data collected by specialists, and are used for all compulsory licensing exercises, as well as for individual license applications that could have a large impact on any catchment, or a relatively small impact on ecologically important and sensitive catchments. The primary objective of the study is to calculate the Groundwater Reserve for the study area with a satisfactory associated confidence level. Issues to be addressed during this investigation include:

- Water-related problems caused by mining (for example coal mines), power stations and heavy industry.
- Substantial inter-basin transfers from the Thukela.
- Agriculture (including forestry, sugarcane, stock and game farming) consumes large quantities of water and also contaminates groundwater resources in some locations.
- Localised pollution (e.g. sanitation, mining and agriculture).
- Quantification of surface water–groundwater interaction and the impacts thereof on aquatic ecosystems.
- More knowledge regarding the status of all natural habitats in the Thukela River Catchment is required.
- Soils in the Drakensberg Mountain Range are relatively shallow. Pressure from human activities outside of the protected areas, particularly in the subsistence agriculture areas, affects the groundwater resources within the study area.
- The wetlands and sponges in the upper and middle Drakensberg do not under face a major threat of destruction at present, due to their remoteness and the fact that the areas are protected. The resources need to be preserved as far as possible due to their critical role in supplying baseflows in all the rivers.

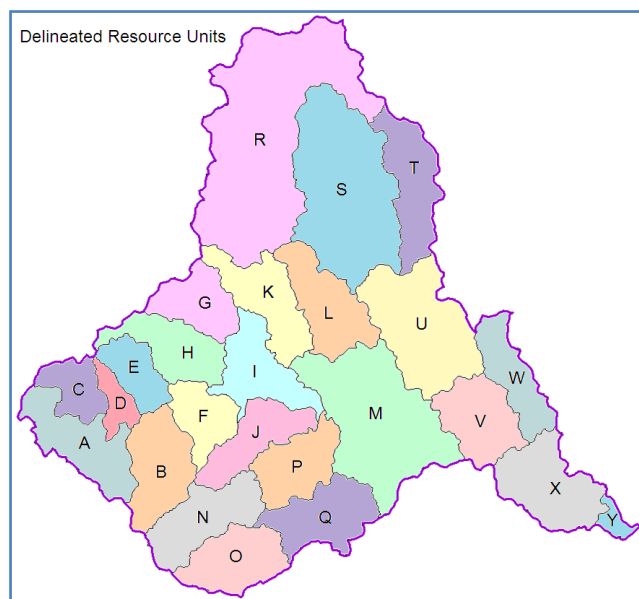
A secondary objective is training. The aim of this is to ensure the transfer of technical skills to historically disadvantaged individuals. The project team also involves regional DWAF officials in the Groundwater Reserve determination. The training component of the investigation is discussed in a separate document.

Delineation of Resource Units

As already mentioned, there are 88 quaternary catchments within the Thukela WMA, making delineation a complex process. In addition, as the surface water Reserve has already been completed for the WMA, the groundwater Reserve must take these results into account and the surface water RUs must therefore also be taken into account together with groundwater. The first step in the delineation process was to divide the study area into four sub-catchments, namely the Upper Thukela, Buffalo, Mooi/Sundays and Lower Thukela catchments. Each area is then divided into smaller and in most cases quaternary catchments. Other aspects taken into consideration are:

- Geology
- Topography
- Recharge
- Groundwater use (and stress)

The delineated resource units are shown in the Figure below.



Classification and the Reserve

The results of the classification and the Reserve are summarised in the Table below.

Resource Unit	Classification		Recharge			Reserve			Allocation	
	Present Status Category	Resource Category	Total Area km ²	Effective Area km ²	Recharge Mm ³ /a	Baseflow Mm ³ /a	BHN Mm ³ /a	Reserve % Recharge	Allocation Mm ³ /a	Current Use Mm ³ /a
TRU-A	B/C	Good/Fair	1098.5	715.2	109.275	58.880	0.108	54%	43.762	6.525
TRU-B	C	Fair	1064.5	827.9	69.597	19.210	0.122	28%	20.656	29.609
TRU-C	C	Good/Fair	518.3	505.3	44.273	15.890	0.130	36%	15.145	13.107
TRU-D	B/C	Good/Fair	304.7	304.7	15.498	4.070	0.031	26%	1.873	9.524
TRU-E	B/C	Good/Fair	558.5	520.7	25.694	5.960	0.030	23%	4.431	15.272
TRU-F	B/C	Good/Fair	659.1	659.1	24.195	5.030	0.017	21%	2.259	16.889
TRU-G	C	Fair	755.2	755.2	41.220	12.140	0.125	30%	19.950	9.005
TRU-H	B/C	Good/Fair	892.8	892.8	39.041	11.040	0.007	28%	6.864	21.130
TRU-I	C	Fair	962.6	962.6	47.506	8.420	0.279	18%	25.136	13.672
TRU-J	B/C	Good/Fair	827.0	794.0	50.633	12.274	0.034	24%	24.635	13.689
TRU-K	B/C	Good/Fair	1019.1	1019.1	41.252	13.360	0.072	33%	10.860	16.960
TRU-L	B/C	Good/Fair	1055.1	1055.1	36.900	11.100	0.170	31%	10.854	14.776
TRU-M	C	Fair	2553.6	2553.6	62.028	21.430	0.227	35%	40.191	0.180
TRU-N	B/C	Good/Fair	1046.6	597.1	80.922	29.340	0.262	37%	36.940	14.380
TRU-O	B/C	Good/Fair	944.5	763.2	69.793	26.450	0.005	38%	12.875	30.464
TRU-P	B/C	Good/Fair	869.0	852.6	28.148	5.870	0.034	21%	20.082	2.162
TRU-Q	C	Fair	1006.2	994.4	51.900	12.530	0.031	24%	18.338	21.000
TRU-R	C/D	Fair	4142.0	4062.8	295.926	47.170	0.595	16%	164.523	83.638
TRU-S	D	Fair	2761.4	2761.4	97.261	21.530	0.525	23%	3.096	72.110
TRU-T	C	Fair	1061.7	1041.4	41.378	8.040	0.084	20%	12.616	20.637
TRU-U	B/C	Good/Fair	1836.8	1825.1	67.968	14.860	0.173	22%	52.748	0.187
TRU-V	B/C	Good/Fair	965.4	928.5	52.764	11.490	0.051	22%	40.914	0.309
TRU-W	B/C	Good/Fair	788.2	755.8	26.065	10.380	0.038	40%	15.138	0.509
TRU-X	B/C	Good/Fair	1201.8	1198.3	87.847	31.700	0.144	36%	51.589	4.414
TRU-Y	C	Fair	146.8	144.2	8.822	5.590	0.022	64%	0.288	2.923

Resource Quality Objectives

Guidelines for Resource Quality Objectives were provided for the following:

- Borehole management
- Wetlands and estuaries
- Springs
- Basic human needs, strategic use and international obligations
- Protected areas
- Contaminated sites

Table of Contents

EXECUTIVE SUMMARY	III
LIST OF FIGURES	IX
LIST OF TABLES	XIV
LIST OF ABBREVIATIONS AND ACRONYMS	XVIII
UNITS OF MEASUREMENT	XIX
1. INTRODUCTION	1
2. GROUNDWATER RESOURCE DIRECTED MEASURES	6
3. SUMMARY OF SURFACE WATER RESERVE	23
4. DESCRIPTION OF THE STUDY AREA	35
5. DELINEATION OF RESOURCE UNITS	56
6. CLASSIFICATION AND THE RESERVE FOR RESOURCE UNIT A	63
7. CLASSIFICATION AND THE RESERVE FOR RESOURCE UNIT B	76
8. CLASSIFICATION AND THE RESERVE FOR RESOURCE UNIT C	88
9. CLASSIFICATION AND THE RESERVE FOR RESOURCE UNIT D	98
10. CLASSIFICATION AND THE RESERVE FOR RESOURCE UNIT E	107
11. CLASSIFICATION AND THE RESERVE FOR RESOURCE UNIT F	116
12. CLASSIFICATION AND THE RESERVE FOR RESOURCE UNIT G	125
13. CLASSIFICATION AND THE RESERVE FOR RESOURCE UNIT H	135
14. CLASSIFICATION AND THE RESERVE FOR RESOURCE UNIT I	145
15. CLASSIFICATION AND THE RESERVE FOR RESOURCE UNIT J	154
16. CLASSIFICATION AND THE RESERVE FOR RESOURCE UNIT K	163
17. CLASSIFICATION AND THE RESERVE FOR RESOURCE UNIT L	172
18. CLASSIFICATION AND THE RESERVE FOR RESOURCE UNIT M	182
19. CLASSIFICATION AND THE FOR RESOURCE UNIT N	194
20. CLASSIFICATION AND THE RESERVE FOR RESOURCE UNIT O	205
21. CLASSIFICATION AND THE FOR RESOURCE UNIT P	216
22. CLASSIFICATION AND THE FOR RESOURCE UNIT Q	226
23. CLASSIFICATION AND THE RESERVE FOR RESOURCE UNIT R	236
24. CLASSIFICATION AND THE RESERVE FOR RESOURCE UNIT S	251
25. CLASSIFICATION AND THE RESERVE FOR RESOURCE UNIT T	261
26. CLASSIFICATION AND THE RESERVE FOR RESOURCE UNIT U	271
27. CLASSIFICATION AND THE RESERVE FOR RESOURCE UNIT V	281
28. CLASSIFICATION AND THE RESERVE FOR RESOURCE UNIT W	290
29. CLASSIFICATION AND THE RESERVE FOR RESOURCE UNIT X	299
30. CLASSIFICATION AND THE RESERVE FOR RESOURCE UNIT Y	309
31. RESOURCE QUALITY OBJECTIVES	318
32. CONCLUSIONS	338
33. REFERENCES	341

List of Figures

Figure 1: Quaternary catchments making up the Thukela Water Management Area	2
Figure 2: Relationship between various classification systems (Parsons and Wentzel, 2007)	9
Figure 3: RUs in the Upper Thukela study area	24
Figure 4: RUs in the Lower Thukela study area	24
Figure 5: Population distribution in the Thukela WMA	28
Figure 6: Main towns, rivers and dams within the study area	37
Figure 7: Topography within the study area	41
Figure 8: Soils within WMA	49
Figure 9: Geology of study area	51
Figure 10: Spatial distribution of boreholes	53
Figure 11: Four sub-catchments of the Thukela WMA	57
Figure 12: Location of RUA	64
Figure 13: Landcover in RUA	66
Figure 14: Groundwater levels in RUA	69
Figure 15: Baseflow separation for quaternary catchment V11A	70
Figure 16: Baseflow separation for quaternary catchment V11B	71
Figure 17: Baseflow separation for quaternary catchment V11E	71
Figure 18: Baseflow separation for quaternary catchment V11G	72
Figure 19: Baseflow separation for quaternary catchment V11H	72
Figure 20: TDS values	73
Figure 21: Stochastic results	74
Figure 22: Expanded Durov diagram for RU	75
Figure 23: Location of RUB	76
Figure 24: Landcover within RUB	79
Figure 25: Groundwater levels in RUB	82
Figure 26: Baseflow separation for quaternary catchment V13A	83
Figure 27: Baseflow separation for quaternary catchment V13B	83
Figure 28: Baseflow separation for quaternary catchment V13C	84
Figure 29: Baseflow separation for quaternary catchment V13D	84
Figure 30: TDS values	85
Figure 31: Stochastic results	86
Figure 32: Expanded Durov diagram for RU	87
Figure 33: Location of RUC	88
Figure 34: Landcover with RUC	90
Figure 35: Groundwater levels in RUC	92
Figure 36: Baseflow separation for quaternary catchment V11C	93
Figure 37: Baseflow separation for quaternary catchment V11D	93
Figure 38: TDS values	94
Figure 39: Stochastic results	95
Figure 40: Expanded Durov diagram for RU	96
Figure 41: Location of RUD	98
Figure 42: Landcover within the study area	99
Figure 43: Groundwater levels in RUD	101
Figure 44: Baseflow separation for quaternary catchment V11F	102
Figure 45: Baseflow separation for quaternary catchment V11J	102
Figure 46: TDS values	103
Figure 47: Stochastic results	104
Figure 48: Expanded Durov diagram for RU	105
Figure 49: Location of RUE	107
Figure 50: Landcover within the study area	108
Figure 51: Groundwater levels in RUE	111

Figure 52: Baseflow separation for quaternary catchment V11K	111
Figure 53: Baseflow separation for quaternary catchment V11L	112
Figure 54: TDS values	113
Figure 55: Stochastic results	114
Figure 56: Expanded Durov diagram for RU.....	115
Figure 57: Location of RUF	116
Figure 58: Landcover within the study area.....	117
Figure 59: Groundwater levels in RUF	119
Figure 60: Baseflow separation for quaternary catchment V11M.....	120
Figure 61: Baseflow separation for quaternary catchment V13E	120
Figure 62: Baseflow separation for quaternary catchment V14A.....	121
Figure 63: TDS values	122
Figure 64: Stochastic results	123
Figure 65: Expanded Durov diagram for RU.....	124
Figure 66: Location of RUG	125
Figure 67: Landcover for RUG.....	127
Figure 68: Groundwater levels in RUG.....	129
Figure 69: Baseflow separation for quaternary catchment V12A	130
Figure 70: Baseflow separation for quaternary catchment V12B	130
Figure 71: Baseflow separation for quaternary catchment V12C	131
Figure 72: TDS values	132
Figure 73: Stochastic results	133
Figure 74: Expanded Durov diagram for RU.....	134
Figure 75: Location of RUH	135
Figure 76: Landcover within RU	137
Figure 77: Groundwater levels in RUH.....	139
Figure 78: Baseflow separation for quaternary catchment V12D.....	140
Figure 79: Baseflow separation for quaternary catchment V12E	140
Figure 80: Baseflow separation for quaternary catchment V12F	141
Figure 81: TDS values	142
Figure 82: Stochastic results	143
Figure 83: Expanded Durov diagram for RU.....	144
Figure 84: Location of RUI.....	145
Figure 85: Landcover within RUI.....	146
Figure 86: Groundwater levels in RUI	148
Figure 87: Baseflow separation for quaternary catchment V12G.....	149
Figure 88: Baseflow separation for quaternary catchment V14B	150
Figure 89: Baseflow separation for quaternary catchment V14E	150
Figure 90: TDS values	151
Figure 91: Stochastic results	152
Figure 92: Expanded Durov diagram for RU.....	153
Figure 93: Location of RUJ	154
Figure 94: Landcover within RUJ.....	155
Figure 95: Groundwater levels in RUJ	157
Figure 96: Baseflow separation for quaternary catchment V14C.....	158
Figure 97: Baseflow separation for quaternary catchment V14D.....	159
Figure 98: TDS values	160
Figure 99: Stochastic results	161
Figure 100: Expanded Durov diagram for RU.....	162
Figure 101: Location of RUK.....	163
Figure 102: Landcover in RUK	164
Figure 103: Groundwater levels in RUK	166
Figure 104: Baseflow separation for quaternary catchment V60A.....	167
Figure 105: Baseflow separation for quaternary catchment V60B.....	168
Figure 106: Baseflow separation for quaternary catchment V60C.....	168

Figure 107: TDS values	169
Figure 108: Stochastic results	170
Figure 109: Expanded Durov diagram for RU.....	171
Figure 110: Location of RUL	172
Figure 111: Landcover in RUL	173
Figure 112: Groundwater levels in RUL	176
Figure 113: Baseflow separation for quaternary catchment V60D.....	177
Figure 114: Baseflow separation for quaternary catchment V60E	177
Figure 115: TDS values	178
Figure 116: Stochastic results	179
Figure 117: Expanded Durov diagram for RU.....	180
Figure 118: Location of RUM	182
Figure 119: Landcover in RUM.....	183
Figure 120: Groundwater levels in RUM.....	186
Figure 121: Baseflow separation for quaternary catchment V20H.....	187
Figure 122: Baseflow separation for quaternary catchment V20J	187
Figure 123: Baseflow separation for quaternary catchment V60F	188
Figure 124: Baseflow separation for quaternary catchment V60G.....	188
Figure 125: Baseflow separation for quaternary catchment V60H.....	189
Figure 126: Baseflow separation for quaternary catchment V60J	189
Figure 127: Baseflow separation for quaternary catchment V60K	190
Figure 128: TDS values	191
Figure 129: Stochastic results	192
Figure 130: Expanded Durov diagram for RU.....	193
Figure 131: Location of RUN	194
Figure 132: Landcover within RUN	196
Figure 133: Groundwater levels in RUN.....	198
Figure 134: Baseflow separation for quaternary catchment V70A.....	199
Figure 135: Baseflow separation for quaternary catchment V70B	200
Figure 136: Baseflow separation for quaternary catchment V70C	200
Figure 137: Baseflow separation for quaternary catchment V70D.....	201
Figure 138: Baseflow separation for quaternary catchment V70E	201
Figure 139: TDS values	202
Figure 140: Stochastic results	203
Figure 141: Expanded Durov diagram for RU.....	204
Figure 142: Location of RO.....	205
Figure 143: Landcover for RUO.....	207
Figure 144: Groundwater levels in RUO.....	209
Figure 145: Baseflow separation for quaternary catchment V20A.....	210
Figure 146: Baseflow separation for quaternary catchment V20B	211
Figure 147: Baseflow separation for quaternary catchment V20C	211
Figure 148: Baseflow separation for quaternary catchment V20D.....	212
Figure 149: TDS values	213
Figure 150: Stochastic results	214
Figure 151: Expanded Durov diagram for RU.....	215
Figure 152: Location of RUP.....	216
Figure 153: Landcover for RUP	218
Figure 154: Groundwater levels in RUP	220
Figure 155: Baseflow separation for quaternary catchment V70F	221
Figure 156: Baseflow separation for quaternary catchment V70G.....	221
Figure 157: TDS values	222
Figure 158: Stochastic results	223
Figure 159: Expanded Durov diagram for RU.....	224
Figure 160: Location of RUQ.....	226
Figure 161: Landcover in RU	227

Figure 162: Groundwater levels in RUQ	230
Figure 163: Baseflow separation for quaternary catchment V20E	231
Figure 164: Baseflow separation for quaternary catchment V20F	231
Figure 165: Baseflow separation for quaternary catchment V20G.....	232
Figure 166: TDS values	233
Figure 167: Stochastic results	234
Figure 168: Expanded Durov diagram for RU.....	235
Figure 169: Location of RUR.....	236
Figure 170: Land use within RUR	238
Figure 171: Groundwater levels in RUR	241
Figure 172: Baseflow separation for quaternary catchment V31A.....	242
Figure 173: Baseflow separation for quaternary catchment V31B.....	242
Figure 174: Baseflow separation for quaternary catchment V31C.....	243
Figure 175: Baseflow separation for quaternary catchment V31D.....	243
Figure 176: Baseflow separation for quaternary catchment V31E.....	244
Figure 177: Baseflow separation for quaternary catchment V31F.....	244
Figure 178: Baseflow separation for quaternary catchment V31G.....	245
Figure 179: Baseflow separation for quaternary catchment V31H.....	245
Figure 180: Baseflow separation for quaternary catchment V31J.....	246
Figure 181: Baseflow separation for quaternary catchment V31K.....	246
Figure 182: Baseflow separation for quaternary catchment V32A.....	247
Figure 183: TDS values	248
Figure 184: Stochastic results	249
Figure 185: Expanded Durov diagram for RU.....	250
Figure 186: Location of RUS.....	251
Figure 187: Landcover within RUS	252
Figure 188: Groundwater levels in RUS	254
Figure 189: Baseflow separation for quaternary catchment V32B.....	255
Figure 190: Baseflow separation for quaternary catchment V32C.....	255
Figure 191: Baseflow separation for quaternary catchment V32D.....	256
Figure 192: Baseflow separation for quaternary catchment V32E.....	256
Figure 193: Baseflow separation for quaternary catchment V32F.....	257
Figure 194: TDS values.....	258
Figure 195: Stochastic results	259
Figure 196: Expanded Durov diagram for RU.....	260
Figure 197: Location of RUT.....	261
Figure 198: Landcover within RUT	263
Figure 199: Groundwater levels in RUT	265
Figure 200: Baseflow separation for quaternary catchment V32G.....	266
Figure 201: Baseflow separation for quaternary catchment V32H.....	266
Figure 202: TDS values	267
Figure 203: Stochastic results	268
Figure 204: Expanded Durov diagram for RU.....	269
Figure 205: Location of RUU	271
Figure 206: Landcover within the RU.....	272
Figure 207: Groundwater levels in RUU.....	274
Figure 208: Baseflow separation for quaternary catchment V33A.....	275
Figure 209: Baseflow separation for quaternary catchment V33B.....	276
Figure 210: Baseflow separation for quaternary catchment V33C.....	276
Figure 211: Baseflow separation for quaternary catchment V33D.....	276
Figure 212: TDS values	278
Figure 213: Stochastic results	279
Figure 214: Expanded Durov diagram for RU.....	280
Figure 215: Location of RUV	281
Figure 216: Landcover within RU	282

Figure 217: Groundwater levels in RUV	284
Figure 218: Baseflow separation for quaternary catchment V40A	285
Figure 219: Baseflow separation for quaternary catchment V40B	285
Figure 220: Baseflow separation for quaternary catchment V40E	286
Figure 221: TDS values	287
Figure 222: Stochastic results	288
Figure 223: Expanded Durov diagram for RU.....	289
Figure 224: Location of RUW	290
Figure 225: Landcover within the RU.....	291
Figure 226: Groundwater levels in RUW.....	293
Figure 227: Baseflow separation for quaternary catchment V40C	294
Figure 228: Baseflow separation for quaternary catchment V40D.....	294
Figure 229: TDS values	295
Figure 230: Stochastic results	296
Figure 231: Expanded Durov diagram for RU.....	297
Figure 232: Location of RUX.....	299
Figure 233: Landcover within RU	300
Figure 234: Groundwater levels in RUX	303
Figure 235: Baseflow separation for quaternary catchment V50A.....	304
Figure 236: Baseflow separation for quaternary catchment V50B	304
Figure 237: Baseflow separation for quaternary catchment V50D.....	305
Figure 238: TDS values	306
Figure 239: Stochastic results	307
Figure 240: Expanded Durov diagram for RU.....	308
Figure 241: Location of RUY.....	309
Figure 242: Landcover within RU	310
Figure 243: Groundwater levels in RUY	313
Figure 244: Baseflow separation for quaternary catchment V50D.....	314
Figure 245: TDS values	315
Figure 246: Stochastic results	316
Figure 247: Expanded Durov diagram for RU.....	317
Figure 248: Time series water levels of boreholes within the WMA	319
Figure 249: Setting RQOs for Rivers.....	333
Figure 250: Setting RQOs for wetlands and estuaries.....	333
Figure 251: Setting RQOs for springs	334
Figure 252: Protection zones for rivers.....	334
Figure 253: RQOs for BHNs, strategic use and international obligations.....	335
Figure 254: RQOs for protected areas	336

List of Tables

Table 1: Relationship between present status category, desired status category and management class (Parsons and Wentzel, 2007).....	9
Table 2: Resource Units, QRUs and information for the Upper Thukela catchment	25
Table 3: Resource Units, QRUs and information for the Lower Thukela catchment.....	26
Table 4: Annual potential BHNR in the entire catchment expressed in MCM	28
Table 5: Analysis of water demand by settlement type.....	29
Table 6: Water demand for 5 km buffer zone (expressed in MCM/a)	30
Table 7: Water quality classification	31
Table 8: Ecological classification	32
Table 9: IFR results.....	33
Table 10: Major dams within catchment	38
Table 11: Alien vegetation (Source: Knight Piesold, 2003)	45
Table 12: Resource units in the Upper Thukela	58
Table 13: Resource units in the Mooi/Sundays	60
Table 14: Resource units in the Buffalo	61
Table 15: Resource units in the Lower Thukela	62
Table 16: Protected areas	63
Table 17: Recharge values	70
Table 18: Basic human needs.....	70
Table 19: Groundwater contribution to baseflow	72
Table 20: Groundwater use	73
Table 21: Aquifer vulnerability.....	74
Table 22: Category for RU	75
Table 23: Reserve.....	76
Table 24: Recharge values	82
Table 25: Basic human needs.....	82
Table 26: Groundwater contribution to baseflow	84
Table 27: Groundwater use	85
Table 28: Aquifer vulnerability.....	85
Table 29: Category for RU	87
Table 30: Reserve.....	87
Table 31: Recharge values	92
Table 32: Basic human needs.....	92
Table 33: Groundwater contribution to baseflow	93
Table 34: Groundwater use	94
Table 35: Aquifer vulnerability.....	95
Table 36: Category for RU	96
Table 37: Reserve.....	97
Table 38: Recharge values	101
Table 39: Basic human needs.....	102
Table 40: Groundwater contribution to baseflow	103
Table 41: Groundwater use	103
Table 42: Aquifer vulnerability.....	104
Table 43: Category for RU	105
Table 44: Reserve.....	106
Table 45: Recharge values	111
Table 46: Basic human needs.....	111
Table 47: Groundwater contribution to baseflow	112
Table 48: Groundwater use	112
Table 49: Aquifer vulnerability.....	113
Table 50: Category for RU	115

Table 51: Reserve.....	115
Table 52: Recharge values	119
Table 53: Basic human needs.....	120
Table 54: Groundwater contribution to baseflow	121
Table 55: Groundwater use	121
Table 56: Aquifer vulnerability.....	122
Table 57: Category for RU	124
Table 58: Reserve.....	124
Table 59: Recharge values	129
Table 60: Basic human needs.....	129
Table 61: Groundwater contribution to baseflow	131
Table 62: Groundwater use	131
Table 63: Aquifer vulnerability.....	132
Table 64: Category for RU	134
Table 65: Reserve.....	134
Table 66: Recharge values	139
Table 67: Basic human needs.....	139
Table 68: Groundwater contribution to baseflow	141
Table 69: Groundwater use	141
Table 70: Aquifer vulnerability.....	142
Table 71: Category for RU	144
Table 72: Reserve.....	144
Table 73: Recharge values	149
Table 74: Basic human needs.....	149
Table 75: Groundwater contribution to baseflow	150
Table 76: Groundwater use	151
Table 77: Aquifer vulnerability.....	152
Table 78: Category for RU	153
Table 79: Reserve.....	153
Table 80: Recharge values	158
Table 81: Basic human needs.....	158
Table 82: Groundwater contribution to baseflow	159
Table 83: Groundwater use	159
Table 84: Aquifer vulnerability.....	160
Table 85: Category for RU	162
Table 86: Reserve.....	162
Table 87: Recharge values	167
Table 88: Basic human needs.....	167
Table 89: Groundwater contribution to baseflow	168
Table 90: Groundwater use	169
Table 91: Aquifer vulnerability.....	170
Table 92: Category for RU	171
Table 93: Reserve.....	171
Table 94: Recharge values	176
Table 95: Basic human needs.....	176
Table 96: Groundwater contribution to baseflow	177
Table 97: Groundwater use	178
Table 98: Aquifer vulnerability.....	179
Table 99: Category for RU	180
Table 100: Reserve.....	181
Table 101: Recharge values	186
Table 102: Basic human needs.....	186
Table 103: Groundwater contribution to baseflow	190
Table 104: Groundwater use	190
Table 105: Aquifer vulnerability.....	191

Table 106: Category for RU	193
Table 107: Reserve.....	193
Table 108: Recharge values	198
Table 109: Basic human needs.....	199
Table 110: Groundwater contribution to baseflow	201
Table 111: Groundwater use	202
Table 112: Aquifer vulnerability.....	203
Table 113: Category for RU.....	204
Table 114: Reserve.....	204
Table 115: Recharge values	210
Table 116: Basic human needs.....	210
Table 117: Groundwater contribution to baseflow	212
Table 118: Groundwater use	212
Table 119: Aquifer vulnerability.....	213
Table 120: Category for RU.....	215
Table 121: Reserve.....	215
Table 122: Recharge values	220
Table 123: Basic human needs.....	221
Table 124: Groundwater contribution to baseflow	222
Table 125: Groundwater use	222
Table 126: Aquifer vulnerability.....	223
Table 127: Category for RU.....	224
Table 128: Reserve.....	225
Table 129: Recharge values	230
Table 130: Basic human needs.....	230
Table 131: Groundwater contribution to baseflow	232
Table 132: Groundwater use	232
Table 133: Aquifer vulnerability.....	233
Table 134: Category for RU.....	235
Table 135: Reserve.....	235
Table 136: Recharge values	241
Table 137: Basic human needs.....	241
Table 138: Groundwater contribution to baseflow	247
Table 139: Groundwater use	247
Table 140: Aquifer vulnerability.....	248
Table 141: Category for RU.....	250
Table 142: Reserve.....	250
Table 143: Recharge values	254
Table 144: Basic human needs.....	255
Table 145: Groundwater contribution to baseflow	257
Table 146: Groundwater use	257
Table 147: Aquifer vulnerability.....	258
Table 148: Category for RU.....	260
Table 149: Reserve.....	260
Table 150: Recharge values	265
Table 151: Basic human needs.....	265
Table 152: Groundwater contribution to baseflow	266
Table 153: Groundwater use	267
Table 154: Aquifer vulnerability.....	268
Table 155: Category for RU.....	269
Table 156: Reserve.....	270
Table 157: Recharge values	275
Table 158: Basic human needs.....	275
Table 159: Groundwater contribution to baseflow	277
Table 160: Groundwater use	277

Table 161: Aquifer vulnerability.....	278
Table 162: Category for RU.....	280
Table 163: Reserve.....	280
Table 164: Recharge values	284
Table 165: Basic human needs.....	285
Table 166: Groundwater contribution to baseflow	286
Table 167: Groundwater use	286
Table 168: Aquifer vulnerability.....	287
Table 169: Category for RU.....	289
Table 170: Reserve.....	289
Table 171: Recharge values	293
Table 172: Basic human needs.....	294
Table 173: Groundwater contribution to baseflow	295
Table 174: Groundwater use	295
Table 175: Aquifer vulnerability.....	296
Table 176: Category for RU.....	297
Table 177: Reserve.....	298
Table 178: Recharge values	303
Table 179: Basic human needs.....	303
Table 180: Groundwater contribution to baseflow	305
Table 181: Groundwater use	305
Table 182: Aquifer vulnerability.....	306
Table 183: Category for RU.....	308
Table 184: Reserve.....	308
Table 185: Recharge values	313
Table 186: Basic human needs.....	313
Table 187: Groundwater contribution to baseflow	314
Table 188: Groundwater use	314
Table 189: Aquifer vulnerability.....	315
Table 190: Category for RU.....	317
Table 191: Reserve.....	317
Table 192: Groundwater parameters	336
Table 193: Results of Study.....	340

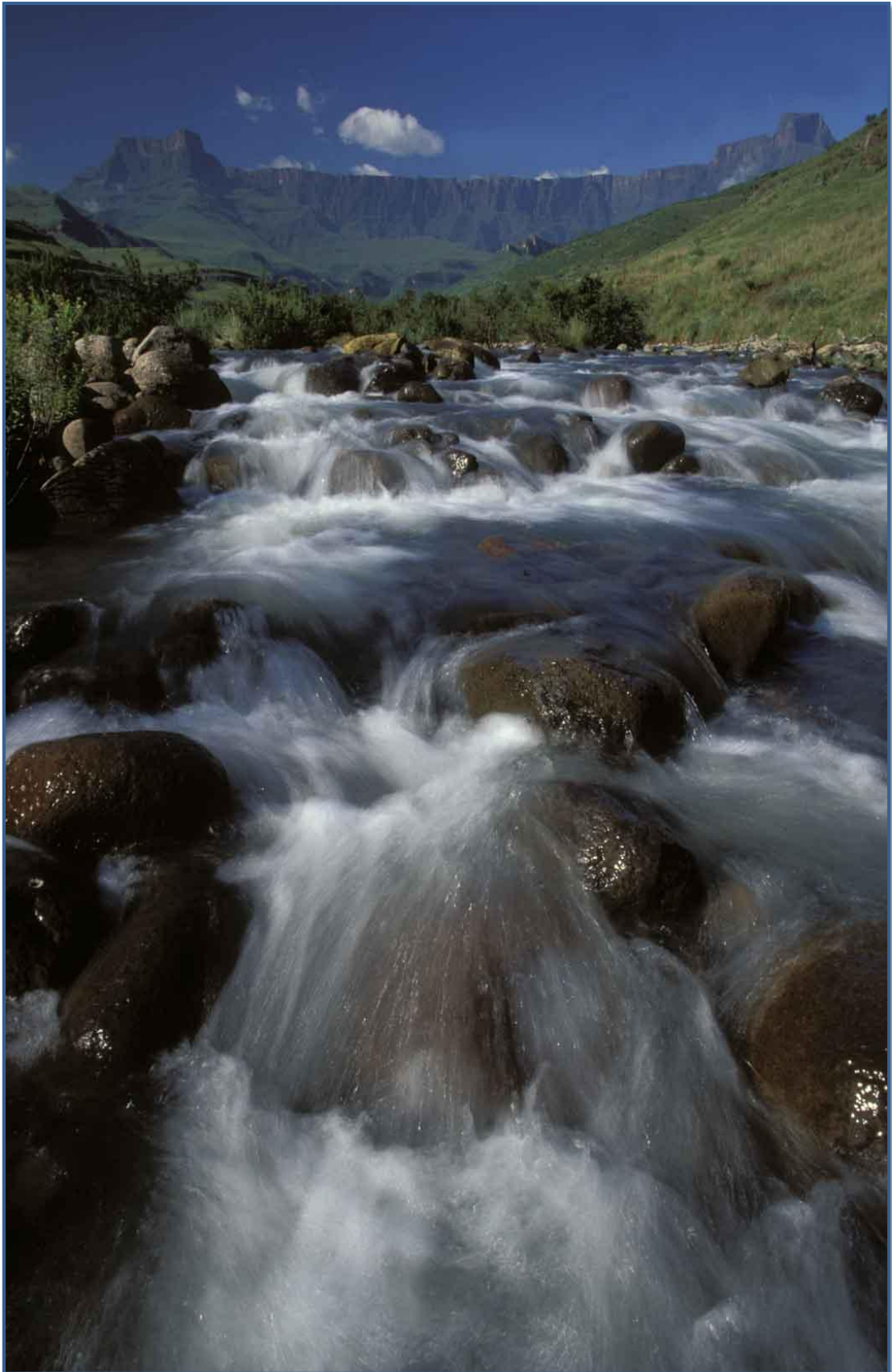
List of Abbreviations and Acronyms

BHN	Basic Human Needs
BHNR	Basic Human Needs Reserve
CMA	Catchment Management Agency
CRD	Cumulative Rainfall Departure
DSS	Decision Support System
DWAF	Department of Water Affairs and Forestry
EARTH	Extended Model for Aquifer Recharge and Soil Moisture Transport through the Saturated Hardrock
EC	Electrical Conductivity
EIS	Ecological Importance and Sensitivity
EMC	Ecological Management Category
ER	Ecological Reserve
EWR	Ecological Water Requirements
GMU	Groundwater Management Unit
GRDM	Groundwater Resource Directed Measures
GRU	Groundwater Resource Unit
HDI	Historically Disadvantaged Individual
ICM	Integrated Catchment Management
IFR	Instream Flow Requirements
IWRM	Integrated Water Resource Management
K	Hydraulic Conductivity
KZN	KwaZulu Natal
MAP	Mean Annual Precipitation
MAR	Mean Annual Run-off
MLF	Maintenance Low Flow
MSL	Mean Sea Level
NGDB	National Groundwater Data Base
NWA	National Water Act (Act 36 of 1998)
NWRS	National Water Resource Strategy
PES	Present Ecological State
PESC	Present Ecological State Category
QRU	Quality Resource Unit
RDM	Resource Directed Measures
RQO	Resource Quality Objectives
RU	Resource Unit
S	Storativity
T	Transmissivity

TDS	Total Dissolved Soilds
WMA	Water Management Area
WMS	Water Management System

Units of Measurement

a	annum
cm	centimetre
d	day
ha	hectare
km ²	square kilometre
ℓ	litre
ℓ/cap·d	litres per person per day
m	metre
Ma	million years
m ²	square metre
m ³	cubic metre
mamsl	metres above mean sea level
mbgl	metres below ground level
mbs	metres below sea level
MCM	million cubic metre
mg	milligram
mm	millimetre
mS	milliSiemen
s	second



“A river that acts with frightening suddenness...” (Stayt 1971)

Photographer: Nigel Dennis

1. Introduction

1.1 Preamble

The Thukela River is a principal river of the KwaZulu-Natal province in South Africa, and is ranked as the second largest river in the country by volume. The Thukela catchment of 29000 km² produces around 8.5% of South Africa's stream flow from 2.5% of its area. It rises as a stream on the 3050 m high Mont-aux-Sources plateau near the merger point of the Lesotho – Free State Province borders. Its upper course lies within the Royal Natal National Park in the Northern Drakensberg. The river hurtles down a series of waterfalls as it drops a total of 948 m. The river cuts through the Thukela Gorge at the foot of the escarpment (approximately 1500 mamsl), passes through the Ladysmith Basin and becomes narrow and deep below Colenso. At Jameson's Drift, it enters the wide open Thukela Trough and then the coastal plain. The 405 km Thukela River mouth lies midway between Durban and Richards Bay, 10 km to the east of the national road bridge, 14 km to the south-east of the town Mandini and 104 km from Durban.

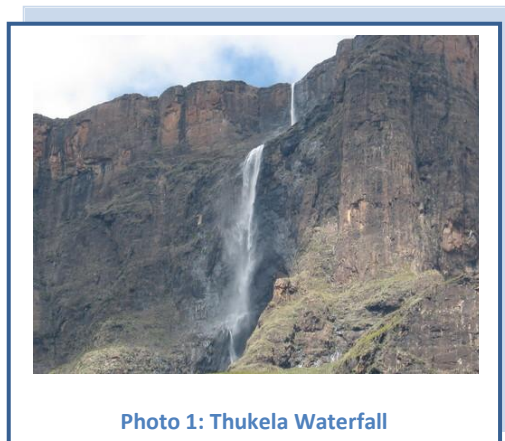


Photo 1: Thukela Waterfall

Major tributaries flowing into the Thukela River from the north are as follows:

- The Klip River, which passes through Ladysmith
- The Sundays River
- The Buffalo River, which rises above Newcastle

Major tributaries into the Thukela River from the south are as follows:

- The Little Thukela River
- The Bloukrans River
- The Bushmans River, passing through Escourt
- The Mooi River

The Thukela Water Management Area (WMA) consists of the entire catchment of the Thukela River, also referred to as the 'V' Hydrological Drainage Region (Midgeley *et al.*, 1994). The WMA contains 88 quaternary catchments (Figure 1).

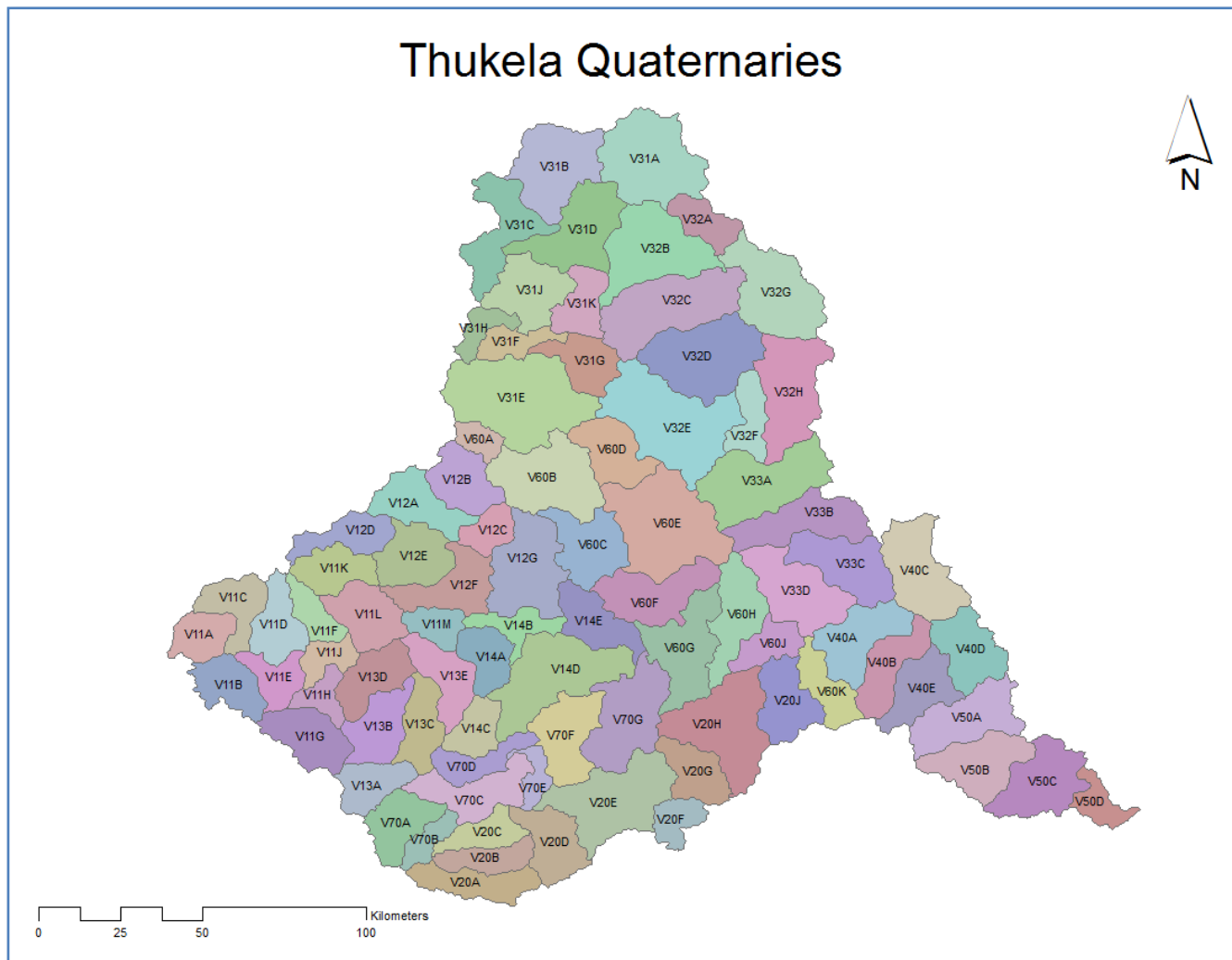


Figure 1: Quaternary catchments making up the Thukela Water Management Area

1.2 Project Objectives

Detailed determinations aim to produce high-confidence results, are based on site-specific data collected by specialists, and are used for all compulsory licensing exercises, as well as for individual license applications that could have a large impact on any catchment, or a relatively small impact on ecologically important and sensitive catchments. The primary objective of the study is to calculate the Groundwater Reserve for the study area with a satisfactory associated confidence level. Issues to be addressed during this investigation include:

- Water-related problems caused by mining (for example coal mines), power stations (Photo 2) and heavy industry.



Photo 2: Power Station just outside Newcastle

- Substantial inter-basin transfers from the Thukela system to the north (the Johannesburg/Pretoria complex) and the south (the Durban/Pietermaritzburg complex) exacerbate these problems. Consequently, the hydrological (and hydro-geological) characteristics of downstream natural flow regimes have been altered. In 2001, 23 m³/s of water was transferred from the catchment. Plans are in place to transfer an additional 15 m³/s to the Vaal River system.
- Agriculture (including forestry, sugarcane, stock and game farming) consumes large quantities of water and also contaminates groundwater resources in some locations.
- Localised pollution (e.g. sanitation, mining and agriculture).
- Quantification of surface water–groundwater interaction and the impacts thereof on aquatic ecosystems.

- More knowledge regarding the status of all natural habitats in the Thukela River Catchment is required.
- Soils in the Drakensberg Mountain Range are relatively shallow. Pressure from human activities outside of the protected areas, particularly in the subsistence agriculture areas, affects the groundwater resources within the study area.
- The wetlands and sponges in the upper and middle Drakensberg do not under face a major threat of destruction at present, due to their remoteness and the fact that the areas are protected. The resources need to be preserved as far as possible due to their critical role in supplying baseflows in all the rivers.

A secondary objective is training. The aim of this is to ensure the transfer of technical skills to historically disadvantaged individuals. The project team also involves regional DWAF officials in the Groundwater Reserve determination. The training component of the investigation is discussed in a separate document.

1.3 Level of Reserve Determinations

Ideally, all water resources in South Africa should be assessed to the same degree and the results of the assessment should be of a high confidence. However, the country does not have the manpower or financial resources to carry out Groundwater Resource Directed Measures (GRDM) assessments countrywide in the short term. To overcome this problem, different levels of GRDM assessments are used.

Four levels of GRDM determination are recognised, with each expected to yield a greater level of confidence in the results. The following general features characterise the differences between the four levels (taken from Parsons and Wentzel, 2007):

- Desktop: these determinations are created by means of readily available data and information; usually the first step in any GRDM process, and a useful planning tool.
- Rapid: includes a short field trip to assess present state; typically used to assess individual licence applications with low impact in unstressed catchments and/or catchments of low ecological importance and sensitivity; should take less than two weeks to complete.
- Intermediate: these determinations yield results of medium confidence; require field investigations by experienced specialists and should take about two months (but <6 months) to complete; used to assess individual licences for moderate impacts in relatively stressed catchments.
- Comprehensive: comprehensive GRDM determinations aim to produce high confidence results and are based on site-specific data collected by a team of specialists; used for all compulsory licensing exercises, as well as for individual licence applications that could have a large impact in any catchment, or a relatively small impact in ecologically important and sensitive catchments. It should take less

than two years to complete. Due to a lack of long-term geohydrological data sets, GRDM assessments will only rarely be done at this level.

The main difference between intermediate and comprehensive assessments is the nature and extent of data used. As far as possible, comprehensive assessments have been conducted throughout the study area. However, where there are data shortages, intermediate assessments had to be conducted.

2. Groundwater Resource Directed Measures

2.1 Groundwater Resource Directed Measures Steps (summarised from Parsons and Wentzel, 2007)

The objective of Resource Directed Measures (RDM) is to facilitate the proactive protection (for use) of the country's water resources, in line with sustainability principles. The National Water Act (NWA) recognises the need to develop and use the country's water resources to grow. RDM hence strives to ensure that the water resources are afforded a level of protection that will assure a sustainable level of development for the future. To this end, RDM comprises three main interrelated components, namely:

- Classification
- Reserve
- Resource Quality Objectives

Six steps are included in the GRDM methodology in this document:

1. Description of study area: This phase is probably the longest in the GRDM determination process, as it entails the collection of data and information on which the GRDM assessment is based. The collected information is then analysed and a conceptual understanding of the geohydrology of the study area developed.
2. Delineation of units: Based on the description of the study area, areas of similar character are demarcated. Resource units are areas of similar physical or ecological properties that are grouped or typed to simplify the Reserve determination process. For intermediate and comprehensive GRDM assessments, a more detailed delineation may be required and could be based on factors such as geology, topography, groundwater dependence and use.
3. Resource Classification: The key outcome of this phase is to define the water resource category for each groundwater resource unit (natural, good, fair, poor). The difference between reference conditions and present status is used to assess the sustainability of current groundwater use and the stress status of the groundwater resource. A single present status category is assigned to each groundwater response unit, which in turn is used to determine the water resource category of each unit.
4. Quantification of the Reserve: The only right to water in the NWA is water for basic human needs and for aquatic ecosystems. Basic human needs include water for cooking, drinking and personal hygiene, currently set at 25 l/d.
5. Setting Resource Quality Objectives: These are clear goals that balance the need to protect and sustain a water resource with the need to develop and use it. These objectives will tell managers how much water is needed to keep a water resource healthy, what the quality of the water should be and what the condition of the

animals and plants should be. The outcome from this phase is a list of goals – either numeric or descriptive – that can be used to set aquifer management criteria.

6. Review: DWAF (1999) proposed that each assessment of the groundwater allocation of a significant water resource be reviewed by a panel of experts prior to setting the Reserve.

2.2 Delineation of Resource Units

A three-tier system of delineation is used. By definition, quaternary catchments are used as the primary delineation of water resource units in RDM assessments. Secondary delineation takes into account surface water, when it is necessary to delineate zones of similar ecology within the study area. Groundwater resource units specifically relate to geohydrological characteristics, but may coincide with other significant water resource units, ecoregions, or parts thereof.

No formal methodology exists for delineating groundwater resource units beyond the second level of delineation. Until formal tools are available for this, expert judgement and local knowledge will be required. In the case of this investigation, tertiary delineation will be conducted in areas where groundwater is highly impacted. Unique classification and resource quality objectives must be determined and assigned to protect the groundwater resource.

Three criteria are recognised for potential use as a basis for delineation, namely physical, management or functional criteria. It is necessary to specify which criterion or characteristics were used in the delineation process, and motivate why that particular characteristic was considered the most appropriate.

- Typically, delineation based on physical criteria would consider one or more of the following:
 - ✓ Geology
 - ✓ Climate
 - ✓ Topography and geomorphology
 - ✓ Recharge
 - ✓ Groundwater levels and flow directions
 - ✓ Temporal hydrostatic response patterns
 - ✓ Groundwater quality
 - ✓ Groundwater use (and stress)
 - ✓ Groundwater-dependent ecosystems.
- Management criteria: The outcome of a GRDM assessment and aquifer management goals are key components of the National Water Resource Strategy. In some cases, it may be difficult to manage an aquifer on the basis of physical delineation considerations, and it may be more practical and meaningful to use

management criteria for delineation. Examples could include property, water user association, catchment management, water management and political boundaries.

- Functional criteria: It may be useful to type areas in terms of the role groundwater plays in sustaining the environment. The purpose of this sort of typing is to identify components within the study area that play a unique role in the hydrological and ecological functioning of a water resource.

In this Assessment . . .

As already mentioned, there are 88 quaternary catchments within the WMA, making delineation a complex process. In addition, as the surface water Reserve has already been completed for the WMA, the groundwater Reserve must take these results into account and the surface water RUs must therefore also be taken into account together with groundwater. The first step in the delineation process was to divide the study area into four sub-catchments, namely the Upper Thukela, Buffalo, Mooi/Sundays and Lower Thukela catchments. Each area is then divided into smaller resource units. Other aspects taken into consideration are:

- Geology
- Climate
- Recharge
- Surface water and groundwater stresses

“Hot spots” were identified during the classification process. A hot spot can be defined as an area within a RU that is severely stressed.

2.3 Classification

The overall objective of classifying a water resource is to define its water resource class (in terms of natural, good, fair and poor) and its management class (in terms of excellent, good and fair), as explicated in Figure 2. The management class is set to ensure both long-term protection and management of groundwater resources, as well as to promote the development and use of the resource. The management class is also used to define the level at which the Reserve and RQOs must be set.

Classification of groundwater resources will occur at two levels, namely a regional scale for each resource unit, and also a local scale where problem areas might occur and more rigorous constraints (classification and RQOs) might be necessary. The reason for including two scales of classification and RQOs is that groundwater-related problems (contamination and over-abstraction) are usually localised and do not affect the whole area for which the Reserve is calculated. This process also allows the RQOs to be site-specific and more accurate.

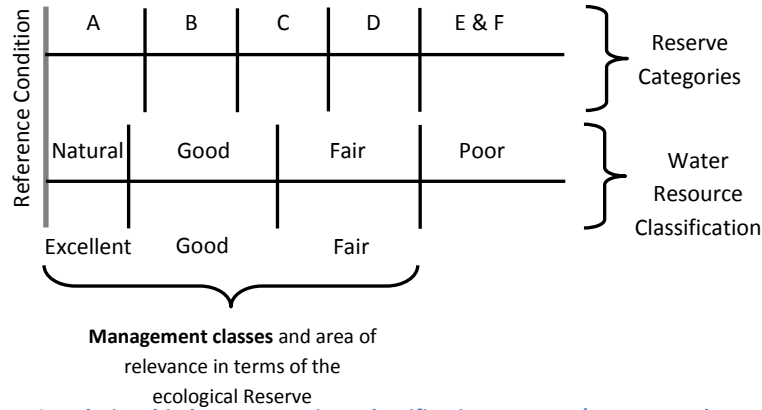


Figure 2: Relationship between various classification systems (Parsons and Wentzel, 2007)

In terms of the overall groundwater categorisation process, and in order to be able to determine the class of a water resource, reference conditions need to be identified and present status assessed. A single present status category is assigned to each groundwater resource unit, which is then used to assign a water resource category to each unit.

Reference conditions refer to the natural or ambient state of the groundwater system, while present status (also referred to as present ecological status category or PESC) relates to the current state of the groundwater system. A significant difference between reference conditions and present state implies that a resource is in a degraded state and hence assigned a lower category.

Once a single present status category is assigned to each resource unit, then the groundwater resource category can be determined using Table 1. It must be remembered that the desired status of the resource and management class is not addressed here, but rather in the public participation and catchment visioning processes.

Table 1: Relationship between present status category, desired status category and management class (Parsons and Wentzel, 2007)

Present Status Category	Water Resource Category	Desired Status * Category	Management * Class
A – unmodified natural	Natural	A – Highly sensitive systems, negligible risk allowed	Excellent
B – largely natural	Good	B – Sensitive systems, small risk allowed	Good
C – moderately modified		C – Moderately sensitive systems, moderate risk allowed	
D – largely modified	Fair	D – Resilient systems, large risk allowed	Fair
E – seriously modified	Poor		
F – critically modified			

Note: *only considered during public participation and catchment visioning processes

In this Assessment . . .

Defining Quantitative Stress

To provide a quantitative means of defining stress, a groundwater stress index was developed by dividing the volume of groundwater abstracted from a groundwater unit by the estimated recharge to that unit. The PESI is then calculated as:

PRESENT STATUS CATEGORY	DESCRIPTION	STRESS INDEX (abstraction / recharge)
A	Unstressed or slightly stressed	< 0.05
B		0.05–0.20
C	Moderately stressed	0.20–0.40
D		0.40–0.65
E	Highly stressed	0.65–0.95
F	Critically stressed	> 0.95

Abstraction takes into account all groundwater use including aquatic ecosystems and basic human needs.

- ***Calculating Basic Human Needs***

The 2001 census data was used with an annual growth rate of 1.5%. The groundwater dependence from the population in the study area is an estimated 18%, which correlates with figures presented in the surface water Reserve for the same area. The basic human need contribution to the water balance becomes negligible when a large study area is considered, but remains an important component to quantify according to the water law. When the area becomes small e.g. the extent of a village, the BHN component represents a significant amount of the water balance. The reason for this is that, in the Reserve, determination a uniform population distribution is assumed for the study area, which results in a low population density over a large extent. In the case of a village, the population total is known and the area is small, resulting in a dense population distribution.

- ***Calculating Aquatic Ecosystem Use (Groundwater Contribution to Baseflow)***

Groundwater contribution to baseflow was estimated through the baseflow separation technique proposed by Herold. The Herold method is used in the GRDM Assessment Software to determine the groundwater contribution to flow in a river. Vegter used the Herold method to separate monthly river flows into a surface runoff component and a groundwater contribution. The Herold method can be explained as follows:

$$Q_i = Q_{Gi} + Q_{Si}$$

where: Q_i = total flow during month i
 Q_{Gi} = groundwater contribution
 Q_{Si} = surface runoff

The assumption is that all flow below a certain value (called $GGMAX$) is groundwater flow, hence:

$$Q_{Si} = Q_i - GGMAX \quad (\text{for } Q_i > GGMAX)$$

or $Q_{Si} = 0 \quad (\text{for } Q_i \leq GGMAX)$

and hence $Q_{Gi} = Q_i - Q_{Si}$

The value of $GGMAX$ is adjusted each month according to the surface runoff during the preceding month and is assumed to decay with time, hence

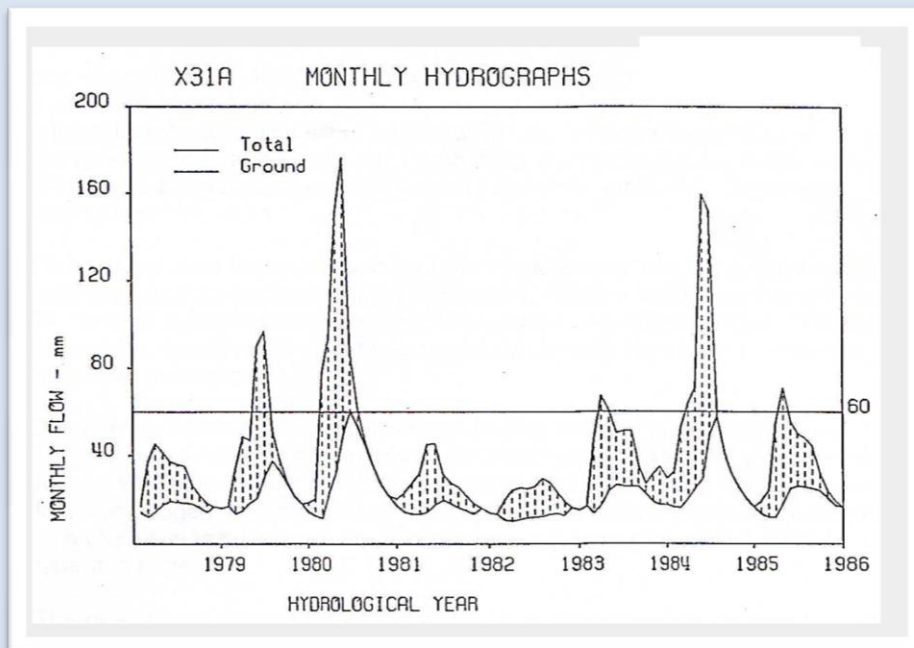
$$GGMAX_i = DECAFY \cdot GGMAX_{i-1} + PG \cdot QS_{i-1} / 100$$

where: subscripts i and $i-1$ refer to the current and preceding month.

$DECAFY$ = groundwater decay factor ($0 < DECAFY < 1$)

PG = groundwater growth factor ($0 < PG > 1$)

An added constraint is that $GGMAX$ may not fall below a specified value, $QGMAX$. Calibration of this model is achieved by selecting an appropriate value of $DECAFY$, PG and $QGMAX$ so that a realistic division between surface runoff and groundwater is obtained, as shown in below:



Monthly flow data are required for the separation process. Naturalised monthly flow data for each quaternary catchment can be obtained from WR2005, while flow data can be downloaded from the DWAF website (www.dwaf.gov.za). The method was included in the GRDM Assessment Software and is easy to use. However, the fitting of the separation curve is subjective, and the user has to decide which is the most appropriate fit when attempting to quantify the groundwater contribution to river flow. When doing the separation, the following should be borne in mind:

- ✓ Groundwater will contribute very little to the flow in those rivers with a low baseflow index, ephemeral or strongly seasonal rivers. Consequently, the modelled groundwater contribution to flow should be small.
- ✓ Given that annual groundwater level fluctuations in a catchment are small in relation to the length or width of the catchment (and consequently that the hydraulic gradient varies very little), it is conceptualised that the groundwater contribution to flow in a river remains fairly constant. It is hence not possible that the groundwater contribution to flow will vary by orders of magnitude, as suggested by conventional approaches to baseflow separation.

The groundwater contribution to baseflow values were validated with:

- ✓ Comparing them to Pitman's baseflow values
- ✓ Comparing them to Hughes's baseflow values
- ✓ Comparing them to Van Tonder's baseflow values
- ✓ Performing simple models to confirm results

- ***Calculating Groundwater Use***

When considering the water balance equation used in the groundwater Reserve determination process, the groundwater use component is singled out as the parameter with the highest uncertainty. This is mainly due to groundwater use that is not registered and when a hydrocensus is done, most of the production boreholes are locked and no accurate record of abstraction rates exist.

The approach adopted for this study was to compare abstraction rates available from hydrocensus data with the WARMS database and the existing use figures available in the GRDM software package. It was evident from the available data that the WARMS database does not reflect all the groundwater use in the area and that the existing groundwater use figure in the GRDM software is also too small.

An estimation was made on how much of the study area is under irrigation and plantations. The ratio between surface and groundwater use in each of the identified resource units were used to calculate the percentage of irrigation dependent on groundwater. What was evident from comparison of aerial photos and existing land use maps, is that the land use in terms of irrigation is much higher than indicated on the maps.

Crop water use was determined using the BEWAP crop water model. BEWAP is a water balance model for irrigation based upon profile available water capacity crop need. BEWAP was developed by the Department of Soil Sciences at the University of the Free State. Simulations were run for various crop types and an average use was included in the groundwater use calculations.

The average tree density was estimated for both natural and planted forests with an average groundwater use of 10 l/tree/day. The Table below shows typical water use of selected trees types which are associated with high groundwater use.

Tree Type	Daily Water Use (l)
Blue Gum (Eucalyptus family)	100
Citrus Trees	20 - 50
Eucalyptus	25
Oak	25
Pine	25
Wattle	50

Forestry has a major impact on the water use in an area. A monitoring programme from SAEON (South African Environmental Observation Network) that started in 1938, showed the following trends:

- ✓ The onset of streamflow reductions was evident at ~5 years.
- ✓ Streamflow is strongly associated with plantation age.
- ✓ Peak streamflow reduction occurs at ~15 years.
- ✓ A rule of thumb is 30-40 mm streamflow reduction per 10% of catchment planted, at peak water use.

Furthermore, clearing invasive trees along rivers, during relatively low-flow conditions, typically results in streamflow increases of 8 000 to 12 000 litres/ha per day in the winter rainfall region, and up to 34 000 litres/ha per day in the summer rainfall region, regardless of location and species. It is therefore critical to include water use from trees in the Reserve determination, especially in areas where forestry is dominant.

Due to the uncertainty associated with the calculation of the groundwater use, a stochastic approach was applied in the reserve calculation. A normal distribution curve with a specified standard deviation was applied to the groundwater use to account for the uncertainty in that component. The result is a range of the reserve with a specified confidence rather than a single value.

- **Calculating Recharge**

Numerous methods were used to calculate groundwater recharge, including:

- ✓ **Chloride Mass Balance**

Aquifer systems are mainly recharged via preferential pathways such as fractures, dykes, bedding planes and highly weathered zones. The recharge from rainfall was estimated using the Chloride Mass Balance (CMB) method and is expressed as a percentage of the Mean Annual Precipitation (MAP). The method is based on the following equation:

$$\% \text{ Recharge} = \frac{\text{Chloride concentration in rainfall}}{\text{Chloride concentration in groundwater}} * 100$$

The assumptions necessary for the successful application of the chloride method are as follows (Van Tonder & Xu, 2001):

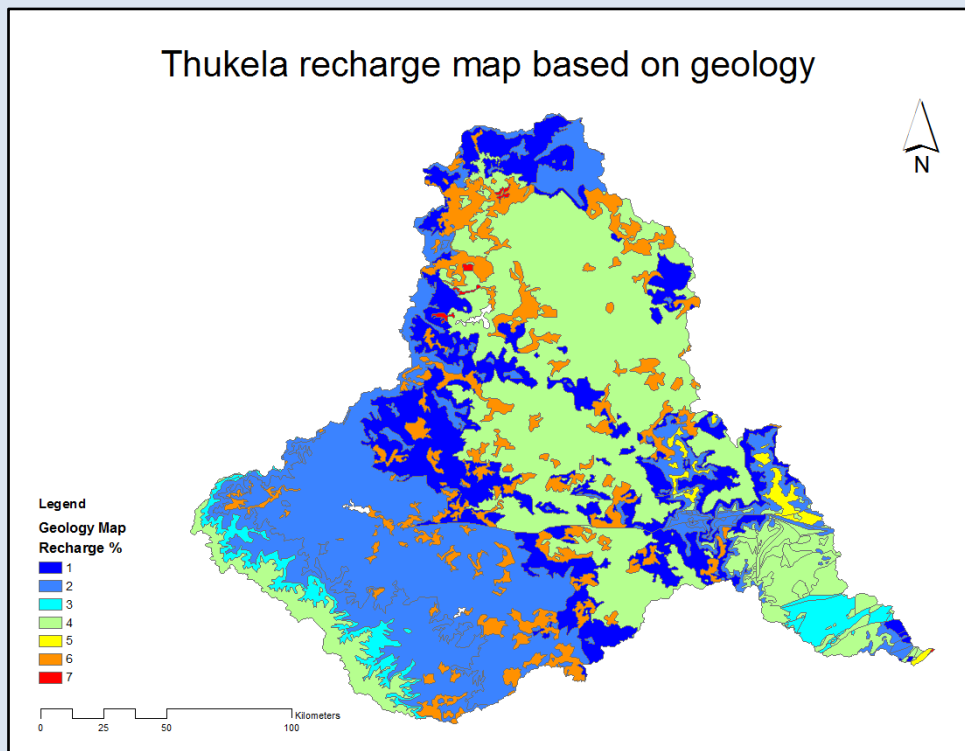
- There is no source of chloride in the soil water or groundwater other than precipitation.
- Chloride is conservative in the system.
- Steady state conditions are maintained with respect to long term precipitation and chloride concentration in that precipitation, and in the case of the unsaturated zone.
- A piston flow regime, which is defined as downward vertical diffuse flow of soil moisture, is assumed. However this assumption may be invalidated if the flow through the unsaturated zone is along preferred pathways.

The CMB method is the only analytical method that could be applied to the recharge calculation due to the lack of time series monitoring data across the study area. Ecca formations are known for their high chloride values, which will result in a lower recharge estimation than the actual value. Previous studies have shown that a dilution factor of 2.0 is sufficient to correct the CMB method in Ecca rich areas.

- ✓ **Geology Recharge Estimate**

Various recharge percentages are associated with specific lithologies. The individual resource units were delineated on the basis of the underlying lithology, and a recharge estimate was made using the associated recharge of the identified lithologies proportional to their area. The recharge map of the Thukela based on the geology is shown below.

Thukela recharge map based on geology



✓ Qualified Guess

A qualified guess on recharge per resource unit was made taking into account the landcover and soil types (Van Tonder, 2001). Although not an analytical approach, the method could be applied as a first attempt in the recharge estimation when little data are available. The qualified guess is presented in this document for comparison purposes.

Defining Quality Stress

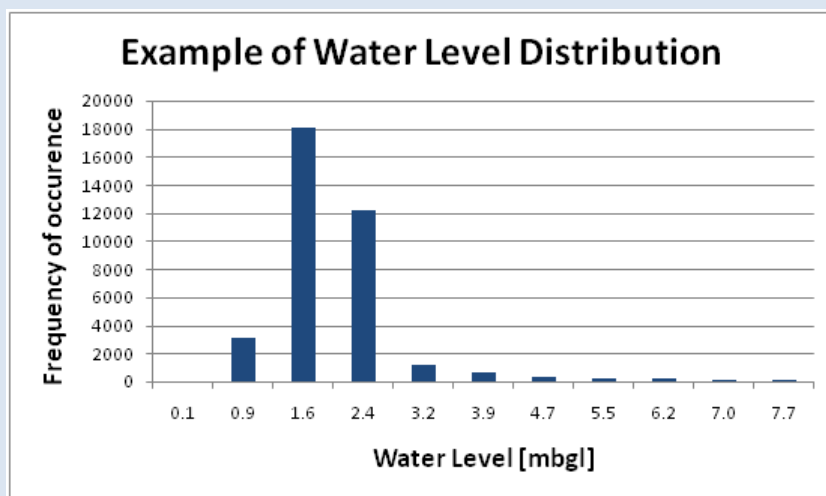
- ***Aquifer Vulnerability and Land Use***

The aquifer vulnerability assessment technique relies on readily available information for a study area. Utilising the hydrogeological setting, inferences are made as to the soil's geochemical nature and the potential for contaminants to migrate from the soil surface to the groundwater table. The term hydrogeological setting refers to a composite description of all the major geologic and hydrologic factors. These types of analyses apply to areas on the order of 0.5 km² and more (Delleur, 1999).

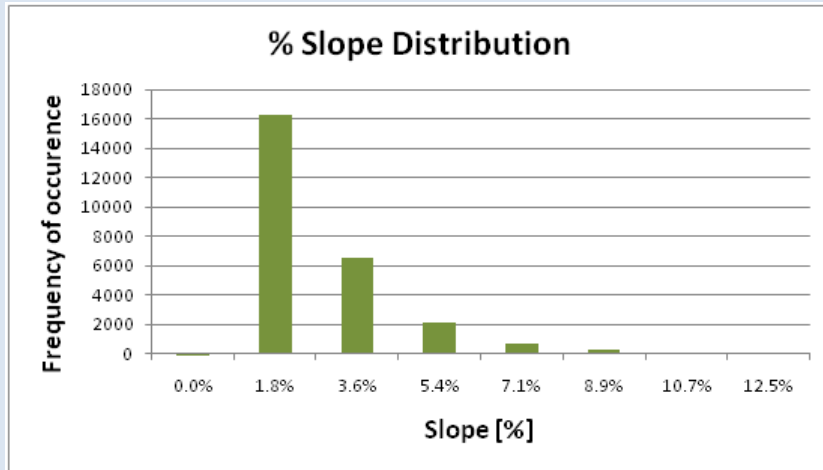
The DRASTIC method is classified as an overlay technique and provides a simple and straightforward means of assessing the susceptibility of certain areas to contaminants. The acronym DRASTIC refers to the seven factors utilised in the rating system — depth to groundwater, recharge rate (net), aquifer media, soil media, topography, impact on vadose zone, and hydraulic conductivity.

Each of these is assigned a value based on a rating. These factors are adjusted by a weighting factor and summed to calculate the pollution potential or DRASTIC index (Delleur, 1999). The aquifer vulnerability for this study was calculated using the SAGDT (South African Groundwater Decision Tool), which utilises a modified DRASTIC approach based on a fuzzy logic rule set. Hydraulic conductivities are seldom available and hence the method SAGDT aquifer vulnerability calculation is reduced to only use the following parameters:

- ✓ Groundwater Level [mbgl] - The water levels across the area are presented as a histogram and the bin with the highest frequency is chosen as a representative water level. An example is shown in the Figure below. When more than one dominant water level exists, the shallower level is used to obtain a conservative vulnerability estimate.



- ✓ Slope of the area [%] – Random elevation samples taken over the area are used to produce a distribution of representative slopes over the area. An example is shown in the Figure below. When more than one dominant slope exists, the smaller one is used to obtain a conservative vulnerability estimate.
- ✓ Recharge [%] – The recharge percentage is the calculated value from all existing recharge data.
- ✓ Soil Media – Soil media information is obtained from soil covers available for the area.
- ✓ Aquifer Media – Aquifer media are associated with geology in the area, and can also be confirmed by borehole logs that are available for some of the boreholes.
- ✓ Vadose Zone – The Vadose zone types for most of the county are available and associated with the soils and geology present in the area.



The calculated aquifer vulnerability is expressed as a percentage rather than the traditional DRASTIC index. Note that the aquifer vulnerability is determined from natural parameters that are not likely to change with time. The only parameter that is prone to change is the water levels, but due to the large aerial extent these should not have an influence if water levels were to change drastically in a specific area.

The land use is defined as a low, moderate or high impact, according to the Table below:

EXPECTED IMPACT	LAND USE
Low impact	natural veld industrial area – (not chemical) pastures rural area – farms abattoirs irrigation – limited chemicals kraals rural area – low density
Moderate impact	sewage works – small (less than 1 Mℓ/d) spills – hazardous waste site – small industrial area – food processing irrigation – chemicals rural area – high density feedlots sewage works – medium waste site – medium (between 1 and 20 Mℓ/d)
High impact	industrial area – chemical mine dumps urban area waste site – large sewage works – large (greater than 20 Mℓ/d) underground storage tanks industrial area – metal processing power generation waste site – hazardous

The land use and vulnerability are combined to give a category as follows:

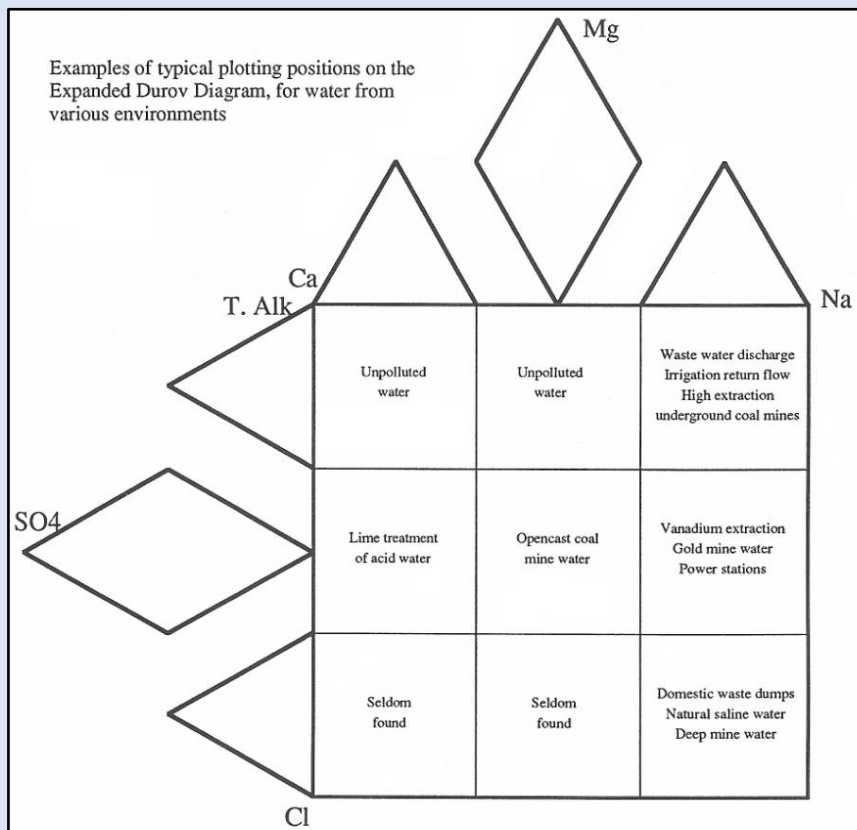
LAND USE	VULNERABILITY				
	20	40	60	80	100
Low	A	A	B	B	C
Medium	B	B	C	C	D
High	C	C	D	D	E

- **Groundwater quality**

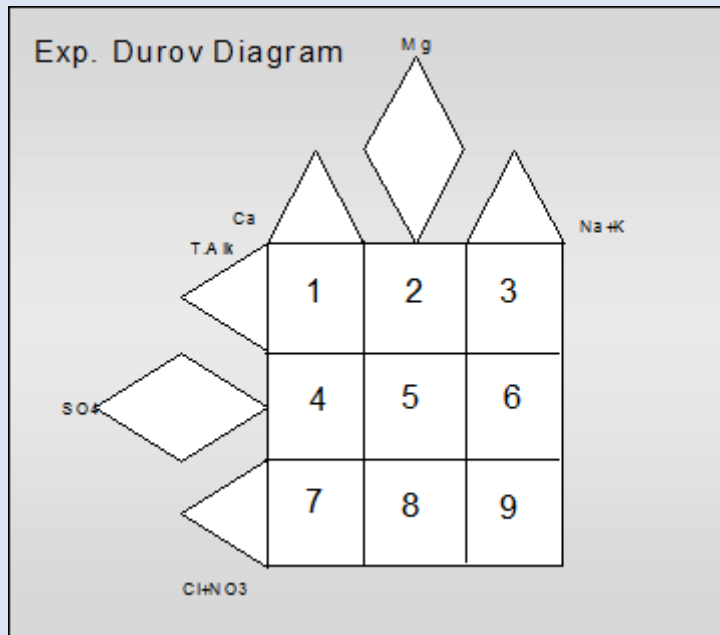
With the available hydrocensus data and chemical analysis done during the Reserve determination at selected sites, enough information is available to produce expanded Durov diagrams of selected boreholes. The expanded Durov diagrams allow the plotting of eight chemical parameters for a single water sample. Either surface or groundwater chemistries may be plotted. The procedure is as follows:

- ✓ Calculate concentrations for Ca, Mg, Na, K, Cl, SO₄, NO₃, T.Alk in units of milliequivalents per liter.
- ✓ Calculate relative percentages for the cations and anions.
- ✓ Plot the percentages cations in the top triangle (see Figure below).
- ✓ Plot the percentages anions in the bottom triangle (see Figure below).
- ✓ Project the two points to the central block on the diagram and make a mark where the two projections cross.

A very general interpretation is given in the Figure below.

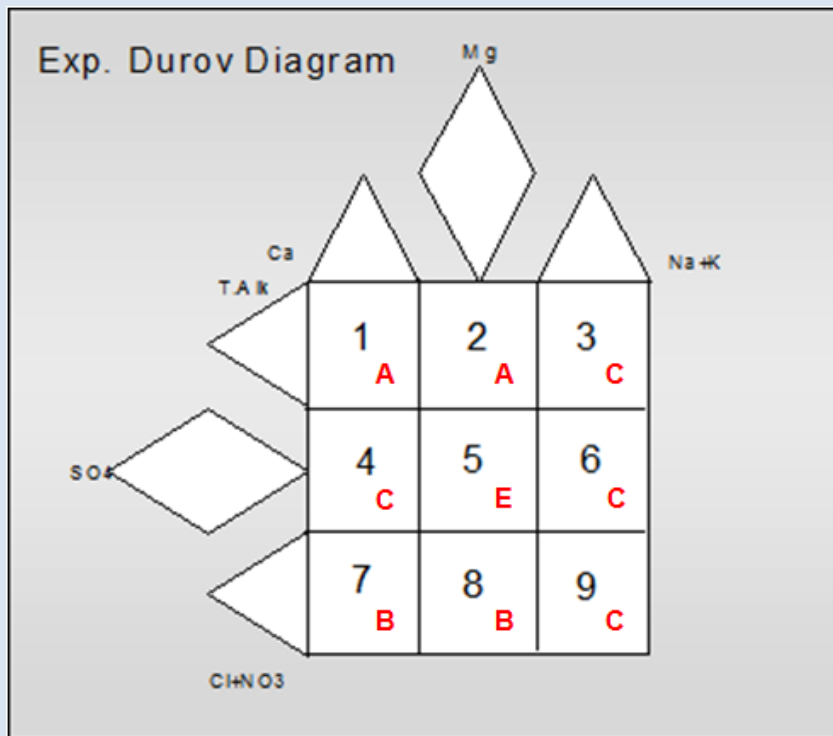


A more detailed description of each of the fields is summarised below, with reference to the Figure below.



1. Fresh, very clean recently recharged groundwater with HCO_3^- and CO_3 dominated ions.
2. Field 2 represents fresh, clean, relatively young groundwater that has started to undergo Mg ion exchange, often found in dolomitic terrain.
3. This field indicates fresh, clean, relatively young groundwater that has undergone Na ion exchange (sometimes in Na-rich granites or other felsic rocks), or because of contamination effects from a source rich in Na.
4. Fresh, recently recharged groundwater with HCO_3^- and CO_3 dominated ions that has been in contact with a source of SO_4 contamination, or that has moved through SO_4 enriched bedrock.
5. Groundwater that is usually a mix of different types – either clean water from Fields 1 and 2 that has undergone SO_4 and NaCl mixing / contamination, or old stagnant NaCl dominated water that has mixed with clean water.
6. Groundwater from Field 5 that has been in contact with a source rich in Na, or old stagnant NaCl dominated water that resides in Na-rich host rock / material.
7. Water rarely plots in this field, which indicates NO_3 or Cl enrichment, or dissolution.
8. Groundwater that is usually a mix of different types - either clean water from Fields 1 and 2 that has undergone SO_4 , but especially Cl mixing / contamination, or old stagnant NaCl dominated water that has mixed with water richer in Mg.
9. Very old, stagnant water that has reached the end of the geohydrological cycle (deserts, salty pans, etc.); or water that has moved a long time and / or distance through the aquifer and has undergone significant ion exchange.

For the purpose of this reserve study the expanded Durov fields was related to the classification system as presented at the beginning of this section. The relation between the Durov fields and the present status classification system are shown in the Figure below.



The available TDS (Total Dissolved Solids) values are also displayed in the resource units to give an indication of possible pollution. The boreholes rated against the TDS drinking standards are also displayed on the expanded Durov diagrams for each resource unit to highlight the dominating constituents.

2.4 Reserve

The groundwater component of the Reserve is the part of the groundwater resource that sustains basic human needs and aquatic ecosystems. Groundwater can only be allocated to users and potential users once the volume of groundwater that contributes to sustaining the Reserve has been quantified and RQOs met. To be able to quantify the groundwater component of the Reserve, the following equation has to be solved:

$$GW_{\text{allocate}} = (Re + GW_{\text{in}} - GW_{\text{out}}) - BHN - GW_{\text{Bf}}$$

where: GW_{allocate} = groundwater allocation
 Re = recharge
 GW_{in} = groundwater inflow
 GW_{out} = groundwater outflow

BHN	=	basic human needs
GW _{Bf}	=	groundwater contribution to baseflow

2.5 Resource Quality Objectives

The purpose of the Resource Quality Objectives is to establish clear goals relating to the quality of the relevant water resource. When setting Resource Quality Objectives (RQOs), a balance must be obtained between the need to protect and sustain water resources on the one hand, and the need to develop and use them on the other. Resource quality may relate to critical flows, groundwater levels, and quality to be maintained. RQOs are considered powerful tools for implementing groundwater protection for sustainable use. At present, these are non formal guidelines with respect to setting RQOs.

2.6 Assumptions related to GRDM

Understanding the role of groundwater in sustaining the environment is still in its infancy. To be able to undertake GRDM assessments and quantify the volume of groundwater required to meet Classification requirements and sustain the Reserve, a number of assumptions are made:

- Groundwater systems are generally resilient and can normally recover from most perturbations. However, it is accepted that groundwater contamination can persist over decades and centuries.
- Groundwater resources can be developed and used to some point, without significantly impacting the ability of groundwater resources to sustain the Reserve or meet the RQOs.
- The ability of a geohydrological system to satisfy basic human needs, RQOs and the ecological Reserve is not impacted if regional groundwater levels do not decline significantly over the long term and ambient groundwater quality remains within natural limits.
- The sustainable rate at which groundwater can be abstracted is a function of the average long-term annual recharge, while the volume of groundwater held in storage acts as a buffer during dry periods.
- It is assumed that recharge and groundwater abstraction are distributed relatively evenly throughout significant water resources.
- The validity of each GRDM assessment will be reviewed at least every five years using monitored data from the study area.
- The GRDM assessment will be carried out by persons qualified and experienced in the field of groundwater hydrology who, in turn, will collaborate with other specialist hydrologists and ecologists. The GRDM assessment will also be subject to formal review.

2.7 Sources of information

The following sources were accessed during this study:

- Numerous reports documented in the reference list documented in Chapter 32 of this report.
- Data from the following databases/institutions were obtained and included in the study:
 - ✓ National Groundwater Archive (NGA)/National Groundwater Database (NGDB)
 - ✓ Groundwater Resource Information Project (GRIP) from DWAF, Durban
 - ✓ Field investigations (hydrocensus data)
 - ✓ Geohydrological reports reports obtained from consultants and DWAF officials
 - ✓ WARMS database from DWAF, Durban
 - ✓ Local monitoring data from DWAF, Durban
 - ✓ Local and regional municipalities

3. Summary of Surface Water Reserve

3.1 Background

The IWR Source-to-Sea was responsible for the surface water Reserve in the Thukela River Catchment. This Chapter contains extracts of the reports generated by IWR Source-to-Sea in 2004.

3.2 Delineation of Resource Units

The Thukela system is the second largest South African river (in terms of Mean Annual Run-off (MAR)), and the main stem of the Thukela River alone is approximately 500km long. In order to study this extensive system, it is necessary to divide it into manageable units on the basis of physical and biological criteria. The major units are termed Resource Units (RUs) and are measured on a scale of kilometres. Each RU is delineated on the basis of having sufficiently unique physical or biological characteristics to set it apart from the other RUs and to warrant its own RD. Within the Resource Units, IFR sites are selected, and these form the study sites at which the quantity component of the Ecological Reserve is determined. These are measured at a scale of metres.

The breakdown of a catchment into RUs for the purpose of determining the Reserve for rivers is primarily determined on a biophysical basis, according to the occurrence of different ecological regions (eco-regions) within the catchment, as supplied by DWAF. Since the endpoint of an RD is an ecological one, the idea is to divide the catchment into individual units that are relatively homogenous (from end to end) on an ecological basis.

The RUs are shown in Figure 3 and Figure 4.

The river sections are homogenous in terms of water quality, and form water quality sub-units. Each RU may have more than one Quality Resource Unit (QRU). The selection of QRUs is influenced by activities in the catchment, the availability of water quality data, and the length of the data series.

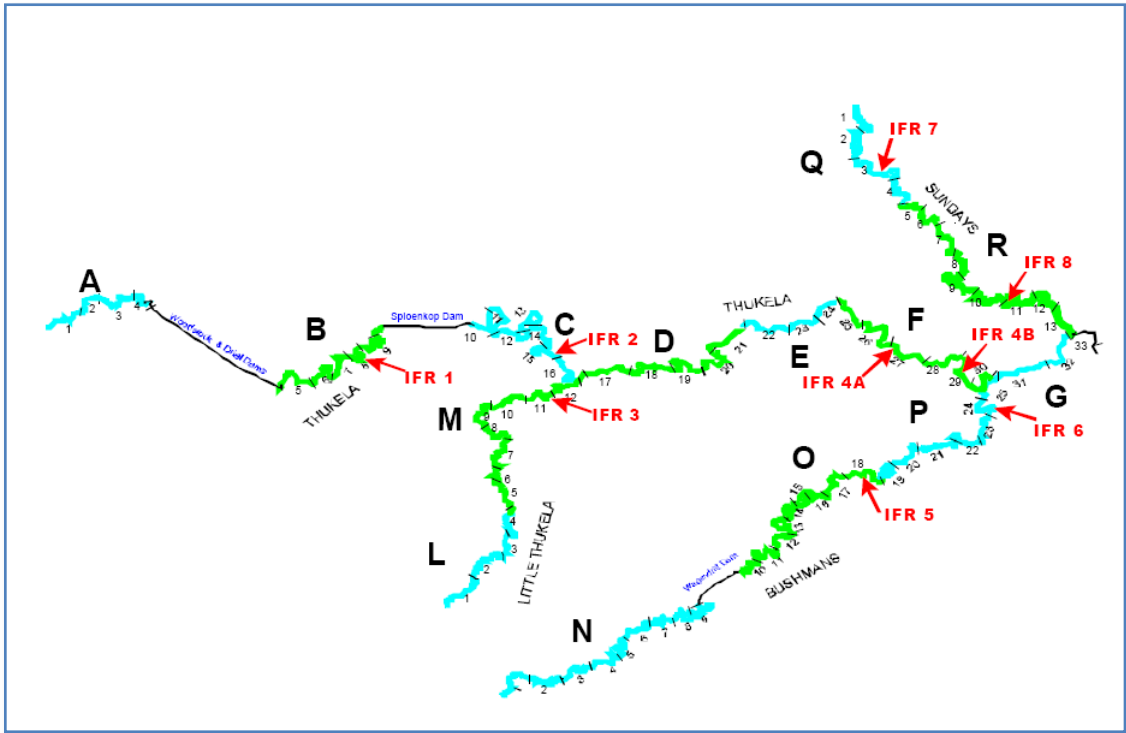


Figure 3: RUs in the Upper Thukela study area

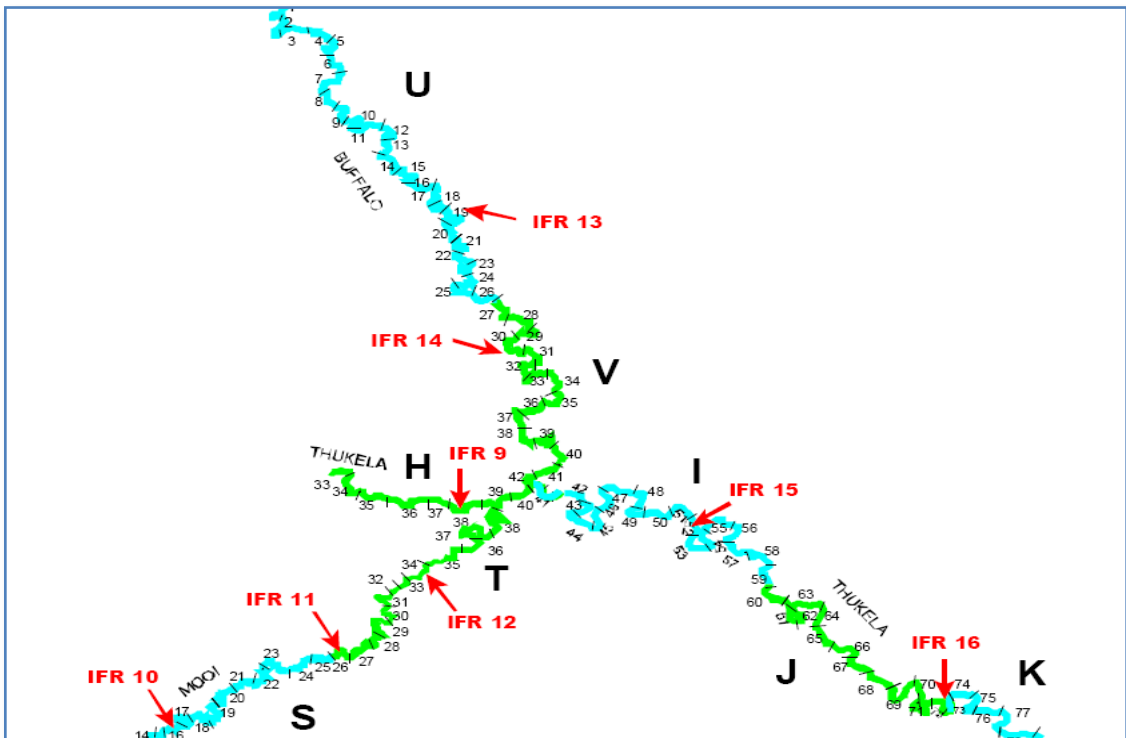


Figure 4: RUs in the Lower Thukela study area

The QRUs identified are documented in Table 2 and Table 3.

Table 2: Resource Units, QRUs and information for the Upper Thukela catchment

Upper Thukela River Catchment: Thukela River			
QRU no.	Segment no. (RU)	Description	Monitoring point data available and used for assessing RC + PES
Q1	1 – 4 (A)	Rugged Glen to upstream of Woodstock and Driel Dams	DWAF mon. points V1H035 (RC) and V1H036 (PES)
Q2	5 – 7 (B)	Woodstock and Driel Dams to upstream of Bergville.	DWAF mon. points V1H058 (data no suitable).
Q3	7 – 9 (B)	Bergville to upstream of Spioenkop Dam .	DWAF mon. points V1H026 (PES) and V1H031. <i>Combine QRUs 2 and 3, and use V1H035 from QRU 1 for RC.</i>
Q4	10 – 16 (C)	Spioenkop Dam to upstream of Thukela – Little Thukela confluence	DWAF mon. points V1H035 (RC) and V1H036 (PES)
Q5	17 – 20 (D)	Thukela – Little Thukela confluence to upstream of Colenso.	No water quality data. <i>Combine QRUs 5 and 6.</i>
Q6	21 – 24 (D, E)	Colenso to upstream of Thukela – Klip River confluence near Ladysmith.	DWAF mon. point V1H001 (RC and PES) at Colenso
Q7	25 – 29 (F)	Thukela – Klip River confluence to upstream of the Thukela – Bloukrans confluence.	There are no DWAF mon. points in the segment. DWAF data on the Klip River will therefore be used, i.e. V1H038 just upstream of Thukela – Klip River confluence. It is important to acknowledge the dilution effects when the Klip and Thukela Rivers join. WQ site 5 data (PES) is also available for the stretch below the Klip confluence and above the Bloukrans confluence with the Thukela River.
Q8	29 – 30 (F)	Thukela – Bloukrans confluence to upstream of the Thukela – Bushmans confluence.	No water quality dat. <i>Combine QRUs 7 and 8.</i>
Q9	31 -33 (G)	Thukela – Bushmans confluence to upstream of Thukela – Sundays confluence.	No water quality data. <i>Combine with QRU 10.</i> There is also a significant short tributary called the Sikhehlengeni River in this reach.
Upper Thukela River Catchment: Little Thukela River			
QRU no.	Segment no. (RU)	Description	Monitoring point data available and used for assessing RC + PES
Q14	1-9 (L, M)	Wonder Valley to upstream of Winterton.	No water quality data. <i>Combine with QRU 15.</i>
Q15	10-12 (M)	Winterton to the confluence of the Little Thukela and Thukela Rivers.	DWAF mon. point V1H010 (RC and PES).
Upper Thukela River Catchment: Bushmans River			
Q16	1-9 (N)	Elands Park to upstream of Wagendrift Dam.	DWAF mon. points V7H016 on the Ncibidwane River (a tributary of the Bushmans, joining it at segment 2), and V7H017 (RC and PES) on the Bushmans River, at the confluence with the Ncibidwane.
Q17	10-11 (O)	Wagendrift Dam to upstream of the Little Bushmans River – Bushmans River confluence (including Estcourt).	DWAF mon. points V7H018 and V1H012 (at Estcourt, PES) on the Little Bushmans River. V7R001 at the outlet of Wagendrift Dam (RC due to setting in dam).
Q18	12-20 (O, P)	Little Bushmans River – Bushmans River confluence to upstream of Weenen.	No water quality data. <i>Combine with QRU 19.</i>
Q19	21-25 (P)	Weenen to the confluence of the Bushmans and Thukela Rivers.	There are no DWAF monitoring points in this segment. Use WQ site 4 (PES) data.
Upper Thukela River Catchment: Sundays River			
Q20	1-6 (Q, R)	Sundays River from the Ladysmith/Newcasle road to upstream	DWAF mon. point V6H006 (above study area, RC) and V6H004 (segment 2, PES).

		of the Wasbank – Sundays River confluence.	
Q21	7-13 (R)	Wasbank – Sundays River confluence to the confluence of the Sundays and Thukela Rivers.	DWAF mon. point V6H003 on the Wasbank River, WQ site 3 (PES) on the lower Sundays River (around IFR 8). Use V6H006 or RC (as for QRU 20).

Table 3: Resource Units, QRUs and information for the Lower Thukela catchment

Lower Thukela River Catchment: Thukela River			
QRU no.	Segment no. (RU)	Description	Monitoring point data available and used for assessing RC + PES
Q10	34 -39 (H)	Thukela – Sundays confluence to upstream of Thukela – Mooi River confluence.	DWAF mon. point V6H002 (RC and PES) at Tugela Ferry.
Q11	39-41 (H, I)	Thukela – Mooi River confluence to upstream of Thukela – Buffalo river confluence.	No water quality data. <i>Combine with QRU 12.</i> Use WQ site 1 (PES) at Jameson’s Drift.
Q12	42-73 (I,J)	Thukela – Buffalo River confluence to upstream of the Mandini/Sundumbili industrial complex.	DWAF mon. point V5H002 (RC and PES) (Segments 52 – 73).
Q13	74 – estuary at 78 (K)	Mandini/Sundumbii industrial complex to the Thukela estuary	DWAF mon. point V5H002 (segment 73-74) and water quality data from Sappi Tugela. Note: This QRU is not covered in the water quality section, as dealt with as part of the estuarine assessment.
Q22	1-15 (S)	Beginning of study area to upstream of Mooi River town	DWAF mon. point V2H006 on the Little Mooi River and V2H005 (RC and PES on the Mooi River.
Q23	16-30 (S, T)	Mooii River Town to upstream of Muden.	DWAF mon. point V2H004 (PES) at Mooi River town, and V2H04 on segment 26 (around IFR 11). Use V2H005 for RC (as for QRU 22).
Q24	30-38 (S, T)	Muden to the confluence of the Mooi and Thukela Rivers.	DWAF mon. point V2H008 (PES) at Keate’s Drift. Use V2H005 for RC (as for QRU 22 and 23).
Lower Thukela River Catchment: Mooi River			
Q25		Above the study area, including the Newcastle industrial area, the Ncandu and Ngagane tributaries of the Buffalo River Osizweni and Madendeni.	DWAF mon. point V3 h009 on the Hom River, a tributary of the Ngagane River and V3H027 on the Ngagane River. No RC point, therefore default to benchmark tables. Use V3H011 (blood River) for PES.
Q26	1-42 (U, V)	From the Utrecht – Osizweni road bridge to the confluence of the Buffalo and Thukela Rivers (area includes IFR 13 and 14).	No DWAF monitoring data available; use WQ site 2 (PES), around IFR 14. Use V3H011 for RC.

3.3 Determination of IFR sites

IFR sites are critical points within individual RUs, and must meet certain criteria. A sequential process is followed to determine the IFR sites. The sites were selected on the basis of the aerial habitat assessment video and groundtruthed through site visits. Seventeen sites were selected; nine in the Upper Thukela and eight in the lower Thukela (Figure 3 and Figure 4).

3.4 Basic Human Need Requirements (BHNRS)

The BHNRS has been generated by following a number of steps. The first step was to use demographic data supplied by the Directorate Water Services: DWAF as a basis for analysis. The base information supplied by DWAF was adjusted data from the 1996 census. This data

source utilised information collected at an enumerator area (EA) level. The EA is the most fine-grained demographic information available. The EA data for the purposes of this study were further broken down to reflect the likely direct users of the surface water resources of the Thukela. This involved demarcating a 5 km buffer zone on either side of the Thukela and its major tributaries. For the purpose of this exercise, and in keeping with the Thukela Reserve Determination Study, the relevant river reaches were those defined as the Thukela, Little Thukela (Injasuthi), Bushmans (Mchezi), Buffalo (Mzinyathi), Sundays and Mooi Rivers. It was assumed that people outside of this area, although they might be making use of water from the rivers via a formal urban supply or a community water supply scheme, would mainly be using springs, minor streams or groundwater.

The analysed data are presented in Table 4 and Table 5. These tables are based on the entire population of the Thukela catchment, i.e. in an area greater than the 5km buffer zone already discussed. Table 4 and Table 5 consider the likely water needs of the population of the catchment in its entirety. Scenarios are presented for the currently accepted RDP norm of 25l per capita per day, as well as more liberal allowances of 60l and 100l per day. In addition, the population growth is projected up to 2020. It should be noted that accurately projecting population growth is problematic, given the uncertainty around the impact of HIV/AIDS. Figure 5 illustrates the population within the Thukela Catchment. In order to err on the side of caution, a 1.5% per annum population growth rate was allowed for. Current estimates are that many rural areas, and the Thukela catchment is predominately rural, will have a zero or even a negative growth rate over the medium term.

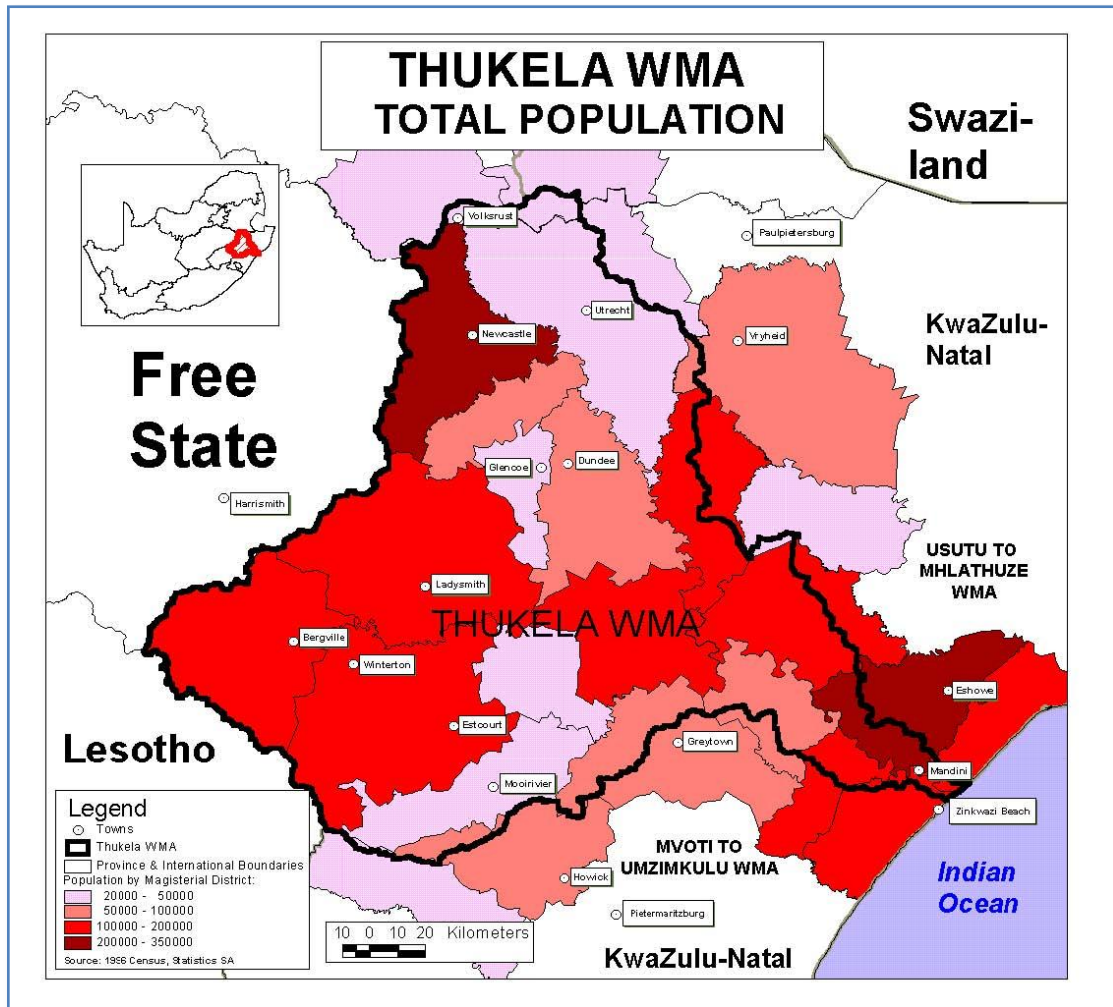


Figure 5: Population distribution in the Thukela WMA

Table 4: Annual potential BHNR in the entire catchment expressed in MCM

Year Population	2001 1 567 246	2005 1 663 418	2010 1 791 973	2015 1 930 464	2020 2 079 658
Water use at 25l per capita per day	14.30	15.17	16.35	17.61	18.97
Water use at 25l per capita per day	34.32	36.42	39.24	42.27	45.54
Water use at 25l per capita per day	57.20	60.71	65.40	70.46	75.90

Table 5: Analysis of water demand by settlement type

Year	2001	Water need in MCM per annum	2010	Water need in MCM per annum	2020	Water need in MCM per annum
Settlement	Population		Population		Population	
Rural village	291214	2.66	329723	6.02	338049	12.34
Scattered rural	876548	8.00	944524	8.62	944524	8.62
Urban	312478	22.81	380909	27.81	464326	33.90
Peri-urban	87066	3.18	106133	5.81	129375	9.44
Total population	1567306		1761289		1876274	
Total water needs		36.64		48.25		64.30

Table 5 examines the total population of the catchment in more detail. In Table 6, the population in the catchment is disaggregated into four logical categories of settlement. These are rural villages (18.6% of the population of the catchment), scattered rural settlement (55.9%), urban (19.9%) and peri-urban (5.6%). Growth rates are applied to each category, based on current, settlement-based projections. These projections consider a fairly high growth rate of 2% for the urban and peri-urban areas over the next 20 years. A lower growth rate starting at 1.5% and declining to nil is considered for rural areas. This is in keeping with trends towards urbanisation, and taking into account the expected impacts of AIDS. Figures for the total catchment differ fairly substantially from those presented in Table 4. By the year 2020, a more fine-grained analysis predicts a population of 1.87 million people, whereas the coarse-grained analysis, as summarised in Table 4, predicts a population of 2.07 million.

Table 5 allows for different water demand and consumption levels. A per capita allowance of 200l/c/d has been allocated for urban areas. The peri-urban areas start with an allowance of 100l/c/d at present, growing to 200l/c/d per person per day by the year 2020. This would be consistent with a “high road” scenario, assuming electrification and increasing in prosperity in these areas, leading to the purchase of appliances using larger volumes of water, such as washing machines. Rural villages start with 25l/c/d, increasing to 50l/c/d per person per day by the year 2010, and 100l/c/d by 2015. This again assumes a growth in prosperity and village electrification. Scattered rural areas retain a 25l/c/d allocation for the entire period under consideration. This is based on the assumption that they will probably never have house connections, and experience shows that the effort involved in transporting water from stand pipes or protected springs caps consumption at about 25l/c/d.

Table 6 presents the summarised estimates for the areas within the 5km buffer zone, as already defined. The total population living within the 5km buffer zone in 2001 is calculated at 715281 or 45.6% of the total population at the catchment. A per capita allowance of 200l/c/d has been allocated for urban areas. The peri-urban areas start with an allowance of 100l/c/d at present, increasing to 200l/c/d per person per day by the year 2020. Rural

villages start with 25l/c/d, increasing to 50l/c/d per person per day by the year 2010, and 100l/c/d by 2015. Scattered rural areas retain a 25l/c/d allocation for the entire period under consideration.

Table 6 reflects the probable demand pattern for those living within the buffer zone and dependent upon river flow. It is not, however, necessarily a BHNR, as the amounts applied to some of the settlement types probably exceed the amounts that could be defined as making up a basic human need.

For those living outside the buffer zone, it is assumed that groundwater is probably of great importance. It is estimated that the current groundwater abstraction for BHNR is in the region of 18 MCM/a. According to this estimate, the population outside the buffer zone uses approximately 57l/c/d.

Table 6: Water demand for 5 km buffer zone (expressed in MCM/a)

Year	2001	Annual water need	2010	Annual water need	2020	Annual water need
Settlement	Population		Population		Population	
Rural village	87364	0.80	99741	1.82	101415	3.70
Scattered rural	316989	2.89	323169	2.95	323169	2.95
Urban	249982	18.25	304727	22.25	352968	25.77
Peri-urban	60946	2.22	90208	4.94	103500	7.56
TOTAL	715281	24.16	817845	31.95	881051	39.97

3.5 Classification of the Resource

This section documents the results of the water quality and ecological classification. It follows the classification system documented in Section 2.3. Table 7 documents the water quality classification for each Quality Resource Unit (QRU) evaluated during the study.

The objective of the ecological classification step is to create an understanding of the Present Ecological State (PES) and the ecological functioning of the river in each of the Resource Units (RUs) and, based on this, to set realistic ecological aims/objectives for the river. The PES is derived from, or described as, deterioration from a described reference condition (that ideally relates to an A category condition). The degree of change is indicated by assigning a PES category to the RU from the range of categories provided in DWAF's present classification system (i.e. A to F). The PES of the river is assessed for each of the following components: habitat (habitat integrity), biophysical (fish, riparian vegetation, aquatic invertebrates and geomorphology) and water quality (chemistry) integrity. Each component is assigned a category level (A -F).

Table 7: Water quality classification

QRU	Overall site classification for water quality	
	A – F system	Descriptive system
Resource Unit A <i>Thukela River (QRU 1)</i>	B	Good
Resource Unit B <i>Thukela River (QRU 2 & 3)</i>	B/C	Lower Good
Resource Unit C <i>Thukela River (QRU 4)</i>	B	Good
Resource Unit D - E <i>Thukela River (QRU 5 & 6)</i>	B	Good
Resource Unit F <i>Thukela River (QRU 7 & 8)</i>	C	Upper Fair
Resource Unit G - H <i>Thukela River (QRU 9 & 10)</i>	C	Upper Fair
Resource Unit I <i>Thukela River (QRU 11 & 12)</i>	B/C	Lower Good
Resource Unit J <i>Thukela River (QRU 13)</i>	C	Upper Fair
Resource Unit L - M <i>Little Thukela River (QRU 14 & 15)</i>	B/C	Lower Good
Resource Unit N <i>Bushmans River (QRU 16)</i>	B	Good
Resource Unit O <i>Bushmans River (QRU 17)</i>	B/C	Lower Good
Resource Unit P <i>Bushmans River (QRU 18 & 19)</i>	B	Good
Resource Unit Q <i>Sundays River (QRU 20)</i>	C	Upper Fair
Resource Unit R <i>Sundays River (QRU 21)</i>	C	Upper Fair
Resource Unit R <i>Wasbank River (QRU -)</i>	C - C/D	Upper Fair - Fair
Resource Unit S <i>Mooi River (QRU 22)</i>	B	Good
Resource Unit S - T <i>Mooi River (QRU 23)</i>	B	Good
Resource Unit T <i>Mooi River (QRU 24)</i>	C	Upper Fair
Resource Unit U <i>Buffalo River (QRU 25)</i>	D	Lower Fair
Resource Unit V <i>Buffalo River (QRU 26)</i>	C/D	Fair

The ecological importance and sensitivity (EIS) of a river is an expression of its importance to the maintenance of ecological diversity and functioning on local and wider scales. The Socio importance (SI) is also taken into account to recommend a final ecological category (EC) for the management of a system. The results of the ecological classification are documented in Table 8.

Table 8: Ecological classification

Dark blue = B; dark blue to light green = B/C; light green = C; light green to dark green = C/D; dark green = D

RU	PES	EIS	SI	EC
THUKELA				
A	B/C	Moderate	Moderate	B/C
B	D	Moderate	Low	D
C	C	Moderate	Moderate	C
D	C	Moderate	Moderate	C
E	B	Moderate	High	B
F	B/C	High	High	B (B/C)
G	C/D	Moderate/High	Moderate	C/D
H	D	Moderate	Moderate	D
I	C	High	High	C (C/D)
J	C/D	Moderate	Moderate	C/D (D)
Estuary	C	High	Moderate	C

RU	PES	EIS	SI	EC
LITTLE THUKELA				
L	C	Moderate	Moderate	C (C/D)
M	C/D	Moderate	Moderate	C/D (D)

RU	PES	EIS	SI	EC
BUSHMANS				
N	B/C	Moderate	Moderate	B/C
O	D	Moderate	Moderate	D
P	B/C	High	Moderate	B/C

RU	PES	EIS	SI	EC
SUNDAYS				
Q	C/D	High	High	C/D
R	D	Moderate	High	D

RU	PES	EIS	SI	EC
MOOI				
S	C	Moderate	Moderate	C
T	B/C	Moderate	High	B/C

RU	PES	EIS	SI	EC
BUFFALO				
U	D	Moderate	Moderate	D (D/E)
V	B/C	High	High	B (B/C)

3.6 Inflow Stream Requirements

The objective of this task was to provide flow regimes (IFR) for different sites in the rivers, to achieve a specific ecological state as described in Table 8. The IFR results are documented in Table 9.

Please note:

- % Long (Long-term percentage): This refers to the % of the natural MAR required to match the IFR time series generated by the IFR rules, i.e. including periods of drought, maintenance, between drought and maintenance and above maintenance flows.
- %Tot: the total maintenance IFR a percentage of natural MAR.
- % Low: This refers to the maintenance low flow IFR as a percentage of the natural MAR.

Table 9: IFR results

RU	IFR	LOWER SCENARIO				RECOMMENDED SCENARIO				UPPER SCENARIO				CONFIDENCE
		ERC	% Long	% tot	% low	ERC	% Long	% tot	% low	ERC	% Long	% tot	% low	
THUKELA RIVER														
A		C/D	-	22	9.2	B/C	-	35.5	19.1	B	-	40.84	24.4	Low, extrapolated
B	1	-	-	-	-	D	22.3	17.3	7	C	31.7	29.9	14.9	IFR components: Med-high to high Hydraulics: Med-high MED-HIGH
C	2	D	22	18.2	4.2	C	29	27.4	11.1	B	37.5	38.5	19.2	IFR components: Med-low (low flow), med-high (high flow). Hydraulics: High. MED-LOW (low flow), MED-High (high flow)
D		D	-	19.1	6.1	C	-	24.8	10.5	B	-	35.1	18	Low, extrapolated
E		C	-	25.4	10.1	B	-	35.3	18	-	-	-	-	Low, extrapolated
F	4 **	B/C	29	28.4	12.4	B	31.8	31.8	14.7	-	-	-	-	IFR components: Med-high Hydraulics: Med-high MED-HIGH
G		D	-	18.94	-	C/D	-	22.1	9	B/C	-	30.8	14	Low, extrapolated
H	9	-	-	-	-	D	24.3	20.3	6.1	C	28.2	27.8	12	IFR components: Med-low Hydraulics: Med-high MED-HIGH**
I	15	D	22.7	18.2	6.2	C	27	25.5	12.6	-	-	-	-	IFR components: Med-high Hydraulics: Low (low flow), med-high (high flow) LOW (low flow), MED-HIGH (high flow)
J	16	D	29.6	23.7	8.4	C/D	32.6	28.4	11.4	B/C	36	36.1	18	IFR components: Med (low flow), med-high (high flow) Hydraulics: Med (drought), med-high (rest) MED (low flow) MED-HIGH (high flow)

RU	IFR	LOWER SCENARIO				RECOMMENDED SCENARIO				UPPER SCENARIO				CONFIDENCE
		ERC	% Long	% tot	% low	ERC	% Long	% tot	% low	ERC	% Long	% tot	% low	
LITTLE THUKELA RIVER														
L		D				C				B				Low, extrapolated
M	3	D		18.6	6.1	C/D		24.7	11.1	B/C		42.8	21.4	IFR components: Med (low flow), med-high (high flow) Hydraulics: High MED (low flow), MED-HIGH (high flow)
BUSHMENS RIVER														
N		C/D	-	31.3	13.1	B/C	-	44.3	22	B	-	49.8	27.5	Low, extrapolated
O	5	C/D	37.5	32.7	13.3	B/C	47.4	45.4	22.4	-	-	-	-	IFR components: Med (low flow), med-high (high flow) Hydraulics: High MED (low flow), MED-HIGH (high flow)
P	6	C/D	-	32.1	13.1	B/C	-	44.7	22.2	-	-	-	-	Low, extrapolated
SUNDAYS RIVER														
Q	7	C/D	29.3	25.6	10.9	B/C	35.8	36.7	28.6	-	-	-	-	IFR components: Med Hydraulics: Med MED
R	8	-	-	-	-	D	24.1	19.6	6.8	C	29.5	28.7	13.1	IFR components: Med Hydraulics: High MED-HIGH (low flow), MED (high flow)
MOOI RIVER														
S	10	D	24.9	18.6	9	C	32.4	29.9	17.2	B	41.9	43.6	28.04	IFR components: Low-med to Med-high Hydraulics: Low (droughts), Med-high (low flow) LOW (droughts), MED (high flow)
T	11	C/D	27.2	23.5	12.4	B/C	35.4	36.3	22.1	B	39.5	42	27.7	IFR components: Med-high Hydraulics: Med-high MED-HIGH

RU	IFR	LOWER SCENARIO				RECOMMENDED SCENARIO				UPPER SCENARIO				CONFIDENCE
		ERC	% Long	% tot	% low	ERC	% Long	% tot	% low	ERC	% Long	% tot	% low	
BUFFALO RIVER														
U	13	-	-	-	-	D	18.1	16	3.9	C	23.1	22.2	9.2	IFR components: Med-high Hydraulics: Low-med (low), med-high (intermediate) LOW-MEDIUM (low flow), MEDIUM (>1.8)
V	14	C/D	20	18.1	5	B/C	24.1	24.8	10.2	-	-	-	-	IFR components: Med-high Hydraulics: High MED-HIGH

*1 Even though the IFR component evaluation is med-low, flows should be managed from Spioenkop to cater for IFR 4 which is a higher REC than IFR 9. IFR 9 should therefore get more flows than recommended and the confidence in achieving the REC is therefore linked to the hydraulics, i.e. med-high.

*2 IFR 4: 3 scenarios were supplied, B (recommended), B/C (alternative and PES), C/D (lower than PES). Only the B and B/C scenario fit into the table and C/D information needs to be used within the design of additional scenarios if necessary.

4. Description of the Study Area

4.1 Background

The Thukela River is a major river of the KwaZulu-Natal province in South Africa. The word Thukela means "something that startles". The total drainage basin is more than 29000 km². The total population of the catchment is approximately 1.56 million. This includes several hinterland towns serving farming areas, such as Estcourt, Bergville, Mooi River and Dundee. The largest urban area is the Newcastle/Madadeni conurbation, which has a population of nearly 300000. The second largest is Ladysmith/Ezakeni, with 105000. The catchment also includes the districts of Msinga, Nkandla and Nquthu which, despite being predominantly rural, are nevertheless heavily settled, having a combined population of close to 500000 people.



Photo 3: Sugar cane fields within the study area
(Source: www.ewisa.co.za)

The majority of land is used for agriculture, with relatively large areas of grassland. There is a small amount of forestry in this catchment, as found in the southern and eastern areas. The agriculture includes large areas of beef and dairy pastures, some sugar cane (Photo 3) near the coast and around Weenen (both dry land and irrigated), vegetables and nuts, and some citrus farming on the coast near

Mandini. The majority of irrigation uses sprinkler irrigation systems, but centre-pivot irrigation is also used in the western areas (especially around the Thukela River).

The objective of GRDM is to facilitate the proactive protection of the country's water resources, in line with sustainability and equity principles. The NWA recognises the need to develop and use water resources for growth. However, the NWA also recognises that water resources should not be used to the detriment of future users. RDM hence strives to ensure that water resources are afforded a level of protection that will assure a sustainable level of development for the future. However, before a detailed assessment of the study area is undertaken, this section is used to introduce the reader to the study area and provide some background to the area. Detailed discussions concerning the area will be undertaken in the following Chapters of this document.

4.2 Towns, Rivers and Dams within the Study Area

The study area is located in the Kwa-Zulu Natal Province of South Africa. The main towns (Figure 6) included in the study are: Wakkerstroom, Volksrust, Charlestown, Groenvlei, Ingogo, Utrecht, New Castle, Madadeni, Ozizweni, Ballengeich, Bloedrivier, Kinsley, Normandien, Dannhauser, Hattingspruit, Ntabebomvu, Van Rooyen, Dundee, Cundycleugh, Fort Mistake, Glencoe, Van't Drift, Biggarsberg, Criagsforth, Wasbank, Van Reenen, Wyford, Drifontein, Rorke's Drift, Elandslaagte, Besters, Pepworth, Helpmekaar, Elandskraal, Pomeroy, Ladysmith, Roosboom, Geluksburg, Bergville, Winterton, Zunckels, Chieveley, Weenen, Frere, Cathedral Peak, Ntabamhlope, Rockmount, South Downs, Redcliffe, Rosetta, Nottingham Road, Mooirivier, Rietvlei, Escourt, Tugela Ferry, Mangeni, Qudeni, Dlolowana, Keate's Drift, Muden, The Ranch, Ntunjambiti, Kranskop, Sizabantu, Mtombeni, Mapumulo, Otimati, Mandini and Tugela Mouth (Photo 4).



Photo 4: Thukela River Mouth
(Source: www.panoramio.com)

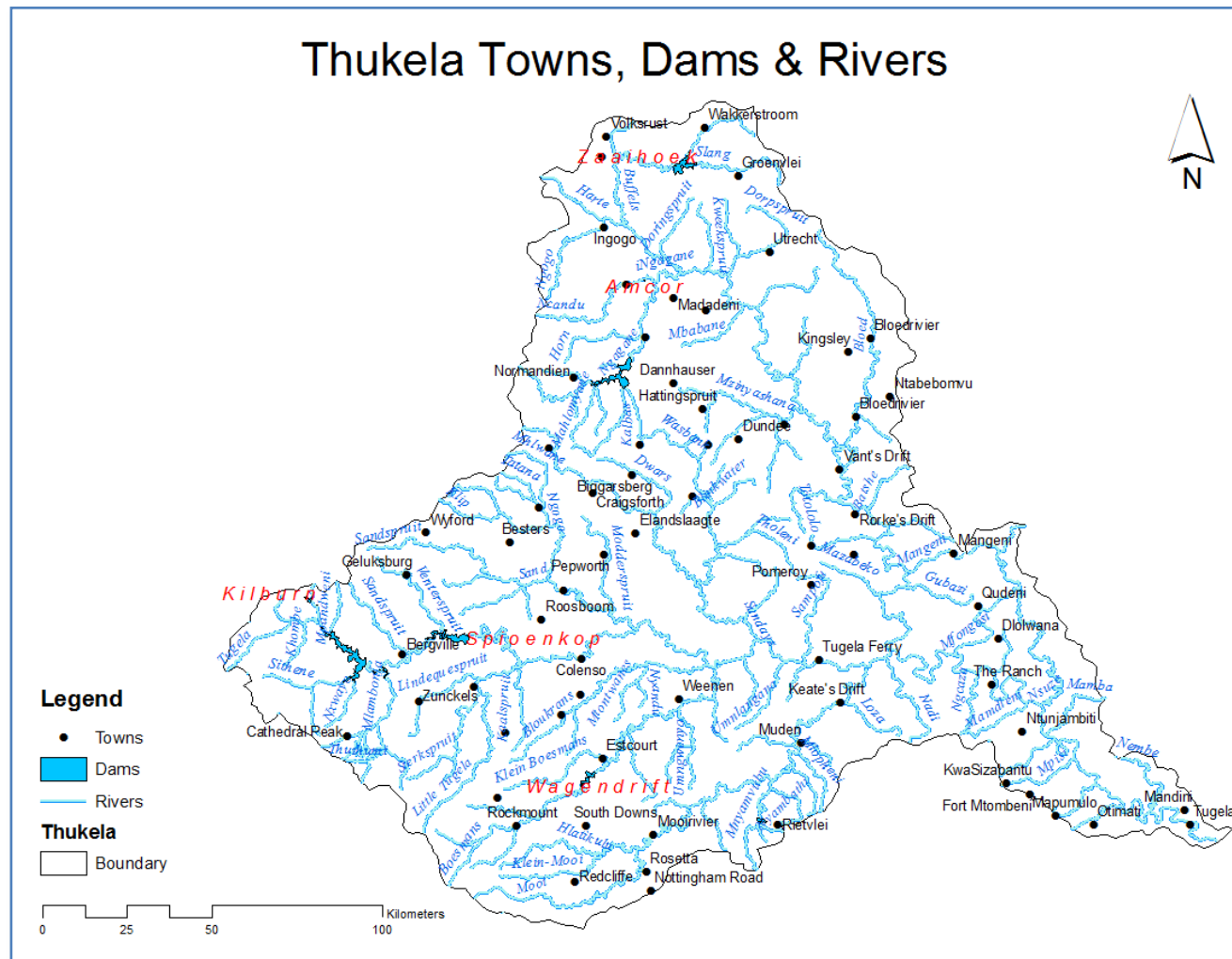


Figure 6: Main towns, rivers and dams within the study area

Major tributaries flowing into the Thukela River from the north are as follows:

- The Klip River, which passes through Ladysmith
- The Sundays River
- The Buffalo River, which rises above Newcastle

Major tributaries into the Thukela River from the south are as follows:

- The Little Thukela River
- The Bloukrans River
- The Bushmans River, passing through Estcourt
- The Mooi River

The major dams within the study area are listed in Table 10.

Table 10: Major dams within catchment

Dam Name	Quaternary catchment	River	Purpose	Natural MAR Million m ³ /a
Bell Park	V13B	Little Thukela	Irrigation	75.6
Ntshigwago/Chelmsford	V31E	Ingagane	Domestic	110.8
Craigie Burn	V20F	Mnyamvubu	Irrigation	23.6
Donald McHardy	V32E	Uithoekspruit	Domestic	720.8
Driel Barrage	V11J	Thukela	Domestic	710.7
Hattingspruit	V31G	Hattingspruit	Domestic	156.0
Shamrock	V11F	Sandspruit	Irrigation	23.5
Spioenkop	V11L	Thukela	Domestic	791.4
Tom Worthington	V32E	Ngobiya	Domestic	720.8
Wagendrift	V70C	Boesmans	Irrigation	233.3
Woodstock	V11J	Thukela	Domestic	433.2
Kilburn	V11C	Majaneni	Irrigation	35.7
Slangdraai	V60A	Sundays	Irrigation	10.3
Zaaihoek	V31A	Slang	Domestic	100.0

The dams and rivers within the study area are shown in Figure 6.

4.3 Climate

The catchment experiences a wide range of climatic conditions, ranging from generally wet and cold in the Drakensberg Mountains to dry and hot in the Thukela Valley from Colenso towards the coast, and hot and humid at the coast. Summers are generally hot with temperatures often exceeding 35°C. Winters are cold, particularly in the west and north, where temperatures fall below freezing and frost occurs regularly. Along the coast, conditions are generally more temperate.

Rainfall varies significantly throughout the catchment and exhibits a strong correlation with relief. Rainfall is strongly seasonal, with in excess of 80% occurring as thunderstorms (Photo 5) during the period from October to March. The peak rainfall months are December to February in the inland areas and November to March at the coast. Mean annual precipitation ranges from in excess of 1500 mm in the west to 750 mm, to over 1000 mm at the coast. Corresponding mean annual run-off figures are in excess of 600 mm in the west (40% of MAP), 80 mm (11% of MAP) in the central (Ladysmith) area and 180 mm (18% of MAP) at the coast. In general, the MAP is about 840 mm, and the corresponding MAR 131 mm (16% of MAP). The MAR of the Thukela is estimated at 3799 million cubic metres per annum.



Photo 5: Thunderstorm in Royal Natal National Park

(Source: www.panoramio.com)

Snowfall on the Drakensberg mountains (Photo 6) between April and September has a significant influence on the climate of the WMA. Frost occurs inland from May to August. The average number of heavy frost days per annum range from one to thirty days for the inland areas, to zero for the eastern coastal area.

Evaporation increases from the coast westwards. At the coast, evaporation amounts to about 1300 mm/a, and increases to 1600 mm/a in the central part of the study area. Evaporation along the escarpment ranges between 1300 and 1400 mm/a.



4.4 Topography

The Thukela River and some of its main tributaries rise in the west of the catchment in the high lying Drakensberg Mountain Range. The source of the Thukela River is near Bergville. These mountains attain elevations in excess of 2500 m. The river then winds its way through gently rolling hills before entering the steep sided gorges below Colenso. This rugged topography continues down to the river mouth, broken only occasionally by flatter, more densely populated floodplains (e.g. Tugela Estates and Tugela Ferry). The Little Thukela, Bushmans, Sundays and Mooi Rivers meander through the mountains, through relatively undulating terrain, before joining the Thukela River. The source of the Buffalo River is also reasonably high lying, but flows through more rugged topography and gorges in the lower half of its trajectory. The topography flattens eastwards toward the coast. The topography for the WMA is shown in Figure 12.

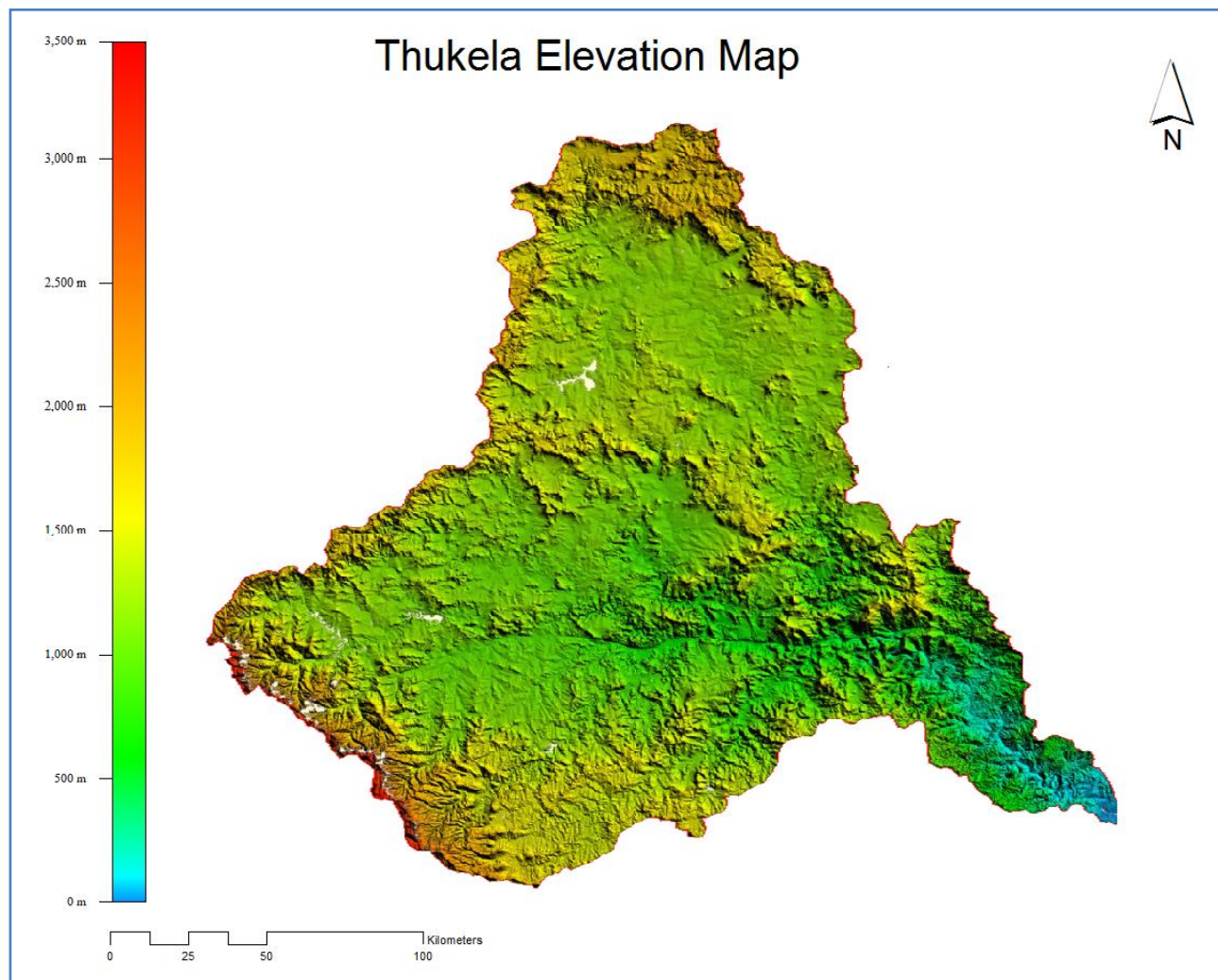


Figure 7: Topography within the study area

4.5 Flora and fauna

The natural vegetation types of the Thukela River Catchment follow a similar pattern to the geology. The simplified vegetation types prevailing within the Thukela WMA are as follows:

- Western (Drakensberg Escarpment) and northern boundary: highland sourveld changing to southern tall grassveld (west to east and north to south)
- Central area: grassveld, changing to valley bushveld (west to east) and Natal sour sandveld (north to south). These two vegetation types cover the bulk of the Thukela WMA.
- Coastal area: coastal forest

The environment in the upper parts of the catchment still has naturally occurring small game and predators, reptiles and a wealth of bird species.

The conservation importance of aquatic ecosystems of the Thukela WMA lies in the fact that the Thukela mudfish, *Labeo rubromaculatus*, only occurs naturally in the Thukela River and its tributaries. The mayfly species diversity in the Mooi River is particularly high, with one unusual species of burrowing mayfly apparently found only in this river.

The Thukela Estuary is an important feeding ground for Palearctic waders. The Thukela River, and in particular its silt load, plays a major role in sustaining the marine Thukela Banks, which is an offshore area supporting a rich prawn fishery.

The large conservation areas in the Thukela WMA lie along the high Drakensberg and have been consolidated into the Ukhahlamba Drakensberg Park. The park, which incorporates several other conservation areas along the Drakensberg escarpment with Lesotho, including the Royal Natal National Park, is also the most recently declared World Heritage site in South Africa, recognised as a natural and culturally mixed site. It includes magnificent mountain scenery, exceptional biodiversity (numerous plant, bird, mammal, reptile and frog species) and some of the finest rock art (Photo 7) in the world. The Weenen biosphere reserve adjoins the Weenen Nature Reserve. Elephant have been re-introduced to this area. The Nkandla Nature Reserve (V40D) embraces the Nkandla Forest and the Mome Gorge. The Qudeni (V40A), Hlatikulu (V40A), Normandien (V31H) and Ncandu (V31F) Reserves are small and do not have major rivers flowing through them.

Unprotected areas of ecological importance and ecological sensitivity in the Thukela WMA are the waterfalls, and the major gorges in the Thukela River valley downstream of Colenso and in the Buffalo River valley from Fugitives Drift to the Thukela confluence. The gorges below waterfalls and in the rivers usually support flora, which is protected by the steepness of the terrain and therefore includes many rare and threatened species.



Photo 7: Rock art in the Drakensberg

(Source: www.panoramio.com)

4.6 Land use and land cover

The natural vegetation types of the Thukela River Catchment follow a similar pattern to the geology. Montane grasslands covers the higher lying areas, giving way to Southern Tall Grassveld interspersed with invading *Acacia sieberiana* savanna and tilled agriculture in the lower parts of the Upper Thukela Sub-Catchment, between Bergville and Colenso. Moving downstream past Colenso, vegetation slowly changes to Valley Bushveld. Coastal grasslands and sugar cane farming characterise the lower part of the catchment. The Mooi River system is mainly modified by pastoral farming practices, with areas of indigenous subtropical forests along the steeper parts of this sub-catchment. Cattle farming (Photo 8) bushveld



Photo 8: Cattle farm close to Nottingham Road

(Source: www.panoramio.com)

dominates the Buffalo River Sub-Catchment, with the exception of montane grasslands in the upper part of this sub-catchment. The largest listed land use in this WMA is for nature reserves. A large portion of the Thukela Catchment is used for agriculture, comprising mainly subsistence farming, temporary commercial dryland agriculture, temporary commercial irrigated agriculture, and commercial forestry. Some sugar cane and improved grasslands are also present. Roughly 8% of the Thukela Catchment comprises degraded grassland, bushland and forest, with some erosion. A low proportion of the catchment is natural and consists mostly of grassland and bushland, with some forest. Approximately 1% of the catchment is urban, comprising mostly residential, industrial and commercial development, as well as mines and quarries. This is mainly associated with the towns of Estcourt, Ladysmith, Dundee and Newcastle, situated in the upper catchment.

Manufacturing makes the largest contribution to gross geographical product (GGP). Agriculture contributes a relatively small amount to the GGP (8.1%), while mining and quarrying are insignificant (0.4%).

The main manufacturing centres are in the Thukela WMA are Newcastle, Estcourt and Ladysmith/Ezakheni. The Iscor iron and steel plant at Newcastle is an important contributor to the manufacturing sector. The manufacturing of textiles, clothing, footwear and leather are some of the main industries in the area.

Agriculture includes forestry, sugar cane plantations, stock farming and game farming. The predominant irrigated crops are maize, wheat and pasture for dairy farming. With timber only developed to a limited extent, 29400 ha have been identified as suitable for afforestation. Mining activities in the Thukela WMA do not consume significant amounts of water, but do impact on the water quality, especially in the Buffalo River and Sundays River Catchments. The main product of the mining industry in the Thukela WMA is coal (Photo 9). A number of other commodities such as sand and dolerite are also mined. The Vryheid Formation of the Ecca Group contains coal seams, which have been extensively mined in the past. The coal mines, scattered over the northern parts of the Thukela River Catchment, have either been closed for a number of years, or are in the process of closing down. Many of the older mines were never rehabilitated adequately. Consequently, these mines produce acid mine decant that enters the Thukela River system. The worst affected areas occur around Newcastle (Buffalo and Ngagane Rivers).

Commercial afforestation has been one of the major sources of alien vegetation in South Africa, largely as a result of poor forestry management practices in the past. About 44% of the area invaded by plantation trees (pine, eucalyptus and black wattle), overlaps with areas affected by commercial afforestation practices. Estimates of the reduction



Photo 9: Polluted waters due to coal discard dump outside Newcastle

in run-off caused by alien vegetation show that this may be in the order of 55 million m³/a. Active intervention of the National Working for Water Programme and local resident organisations have been very successful in controlling invasive alien vegetation in parts of this catchment. The Upper Thukela River Catchment has been cleared of much of the Black and Silver Wattle infestations. Aquatic weeds have not been noted as a problem in the Thukela River Catchment. Table 11 summarises the area infested by alien vegetation.

Table 11: Alien vegetation (Source: Knight Piesold, 2003)

PRIMARY		CATCHMENT				CONDENSED AREA OF ALIEN VEGETATION (km ²)		
No.	Description	SECONDARY		KEY AREA				
No.	Description	No.	Description	No.	Description			
V	THUKELA	V1		V11	Driel Weir	31.3		
					V11	Spioenkop Dam	5.8	
					V14	Jana Dam	142.4	
			Sub-total Upper Thukela				179.5	
		V2	Mooi			55.3		
		V3				V31	Upper Buffalo	38.9
						V31	Ngagane Dorings	10.2
						V32	Middle Buffalo	6.1
						V33	Lower Buffalo	6.1
		Sub-total Buffalo				61.3		
		V4&V5	Lower Thukela				36.4	
		V6	Sundays				40.6	
		V7	Bushmans				248.5	
TOTAL IN THUKELA WMA						621.5		

4.7 Surface water

The Thukela water management area represents the single river catchment with the largest mean annual run-off from South African territory of all the rivers in the country. As a result of the rainfall distribution and topography, most of the run-off originates in the vicinity of the escarpment and in the upper reaches of tributary streams, where waterfalls are a significant feature. Because of the steep topography, there are no natural lakes in the water

management area. The rivers in the catchment are steeply graded and flow from west to east. The Thukela River is the major river that drains the study area. The highest surface run-off occurs along the steep sloped escarpment and generally decreases eastwards towards the coast.

The construction of a number of water supply and farm dams in the catchment has modified surface flows. Major dams in the catchment include the Wagendrift Dam (Photo 10) (Bushmans River), Spioenkop Dam (Thukela River), the Chelmsford Dam (Buffalo River) and Woodstock Dam (Thukela River). Dams



Photo 10: Wagendrift dam wall

proposed as part of the Thukela Water Project are the Jana Dam on the Thukela River south-west of Ladysmith and the Lelietuin Dam of the Bushmans River between Weenen and Estcourt.

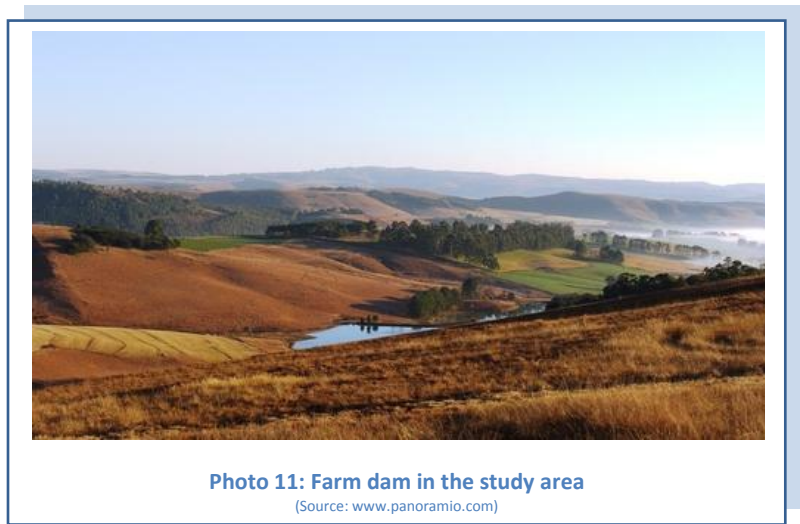


Photo 11: Farm dam in the study area

(Source: www.panoramio.com)

DWAF have permitted a large number of smaller farm dams (Photo 11), most of which are found in the upper reaches of main rivers. The Thukela Basin Consultants (2000) estimated that the total storage of farm dams may be in the order of 3389 Mm³, which is sufficient to have a

significant impact on flow regimes, particularly on the upper parts of the catchment.

There are many important wetlands in the Thukela Basin. They are concentrated in three areas: the upper Buffalo Catchment, the upper Mooi/Bushmans Catchment and the upper Myamvubu Catchment upstream of Craigie Burn Dam. In the upper Buffalo Catchment, the Wakkerstroom Vlei (Photo 12), Groenvlei and the Blood River Vlei are important in themselves,



Photo 12: Wakkerstroom Vlei

but are also renowned for their bird life. There are several smaller vleis in the upper catchment of the Slang River. Boschoffsvlei is near Utrecht. Well-known vleis in the upper Mooi River Catchment are the Hlatikulu, Stillerust Vlei and the Highmoor Vlei.

4.8 Soils

The soil (Photo 13) is a complex mixture of eroded rock, mineral nutrients, decaying organic matter, water, air and billions of organisms, most of which are microscopic decomposers. To see the soil characteristics of the study area, refer to Figure 13.



Photo 13: Soil erosion
(Source: www.ewisa.co.za)

The average size of the spaces or pores in a soil determines soil permeability, i.e. the rate at which water and air move from upper to lower soil layers. Soil

permeability is also influenced by soil structure: how soil particles are organised and clumped together. Soils vary in their contents of clay (very fine particles), silt (fine particles), sand (medium-sized particles), and gravel (coarse to very coarse particles). The proportion of

the different sizes and types of mineral particles determines the soil texture. Loam soils are comprised of roughly equal mixtures of clay, sand silt and humus, which are the best soils for growing most crops.

The following soil types occur in the Thukela WMA:

- Drakensberg Escarpment (western boundary): moderate to deep clays on steep slopes
- Drakensberg Escarpment (northern boundary): moderate to deep sandy loams on undulating terrain
- Central area: moderate to deep clays on undulating terrain and moderate to deep clayey loams on steep slopes and undulating terrain
- Coastal belt: moderate to deep clayey loams and sandy loams on undulating terrain

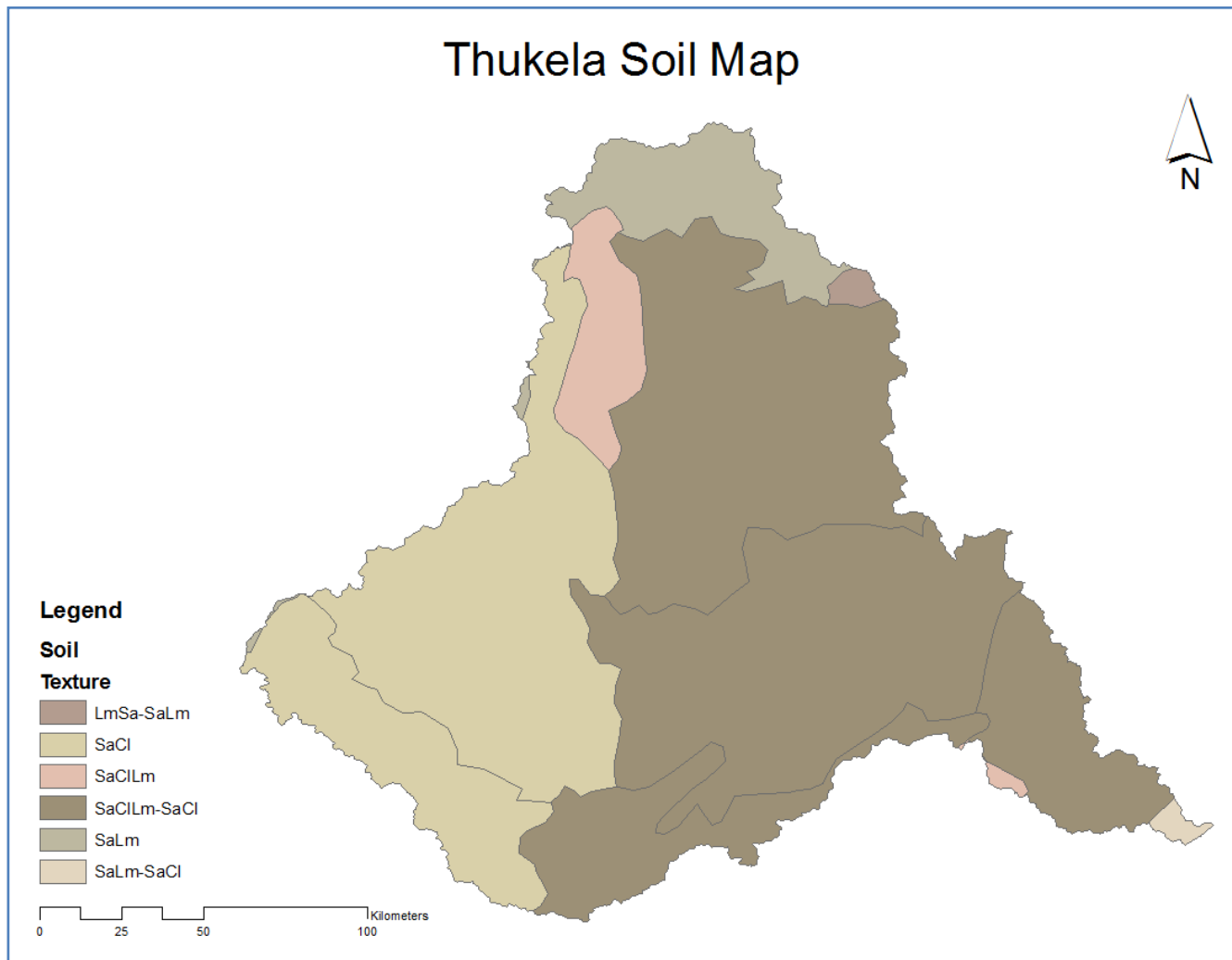


Figure 8: Soils within WMA

4.9 Geology

The Thukela WMA is predominantly underlain by strata from the Karoo Supergroup (Figure 9). The strata are mostly of sedimentary origin, and were deposited by various sedimentary agents, ranging from rivers to ice sheets and inland seas, between 200 and 400 million years ago. Capping these sedimentary layers are igneous rocks, which, because of their greater resistance to weathering, form the high mountains of Lesotho. In geological terms, the deposits are fairly young. The rock types in the area are mostly sandstone, siltstone and mudstone, while basalt makes up the highest reaches of the Thukela drainage area.

The outcrop of Dwyka Group Tillite is limited to the area around Kranskop. Sediments of the Ecca Group are found in the eastern part of the catchment and underlie much of the Sundays River and Buffalo River catchments, with rocks of the Vryheid Formation underlying much of the area. These rocks mainly comprise sandstones and are relatively resistant to erosion, resulting in relatively narrow and deeply incised river channels. The lower Beaufort Group (Adelaide subgroup) predominates in the western part of the catchment. These rocks are finer-grained and mostly comprise shales and mudstones, with subordinate sandstone horizons. A number of coal deposits are present within the Ecca Group of the Karoo Supergroup in the vicinity of Newcastle and Dundee.

All the above sedimentary strata have been extensively intruded by dykes and sills of dolerite



Photo 14: Dolerite outcrop in Ladysmith

(Photo 14). These features play an important role in the geohydrology of the area, and significantly enhance the water-bearing properties of aquifers in the WMA.

Small outcrops of granites from the Barberton Sequence occur west of Tugela Ferry. These are some of the oldest rocks known, and date in excess of 3000 Ma. Similarly, the Natal Metamorphic Province includes rocks of some 1000 Ma, but their extent is limited to the south-eastern part of the catchment between Kranskop and Mandini. The extent of the Natal Group is also limited to the area south-east of Kranskop. Younger unconsolidated sands are limited to the coastal area and are only of significance in the immediate vicinity of the estuary. King (1997) indicates the presence of localised, but significant alluvial sand deposits throughout the Thukela River Catchment. Some deposits reach a thickness of almost 40 m.

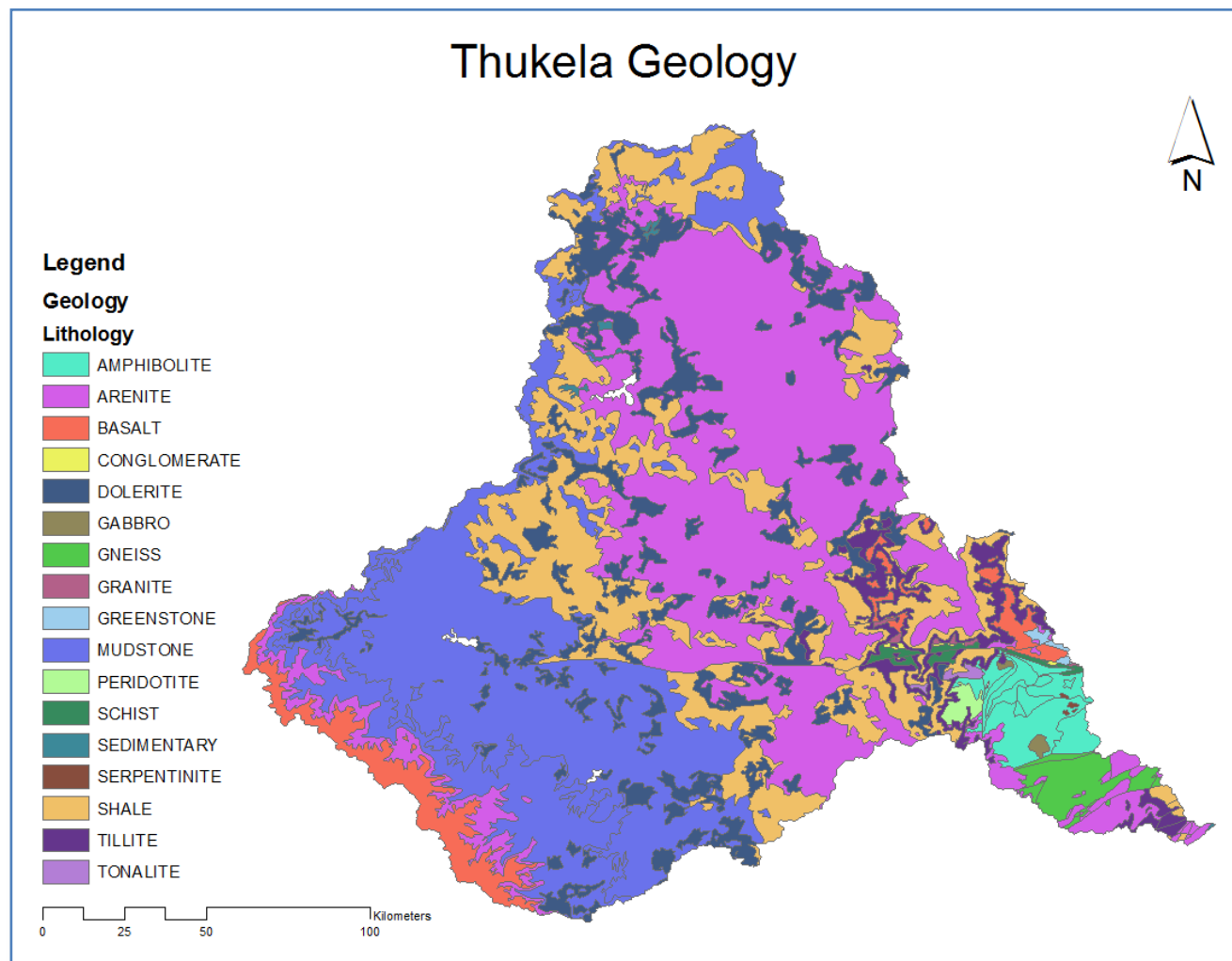


Figure 9: Geology of study area

4.10 Geohydrology

The study area is mostly underlain by the Karoo Supergroup and is either sub-horizontal or has a very gentle inland dip to the west, and a minor eastern coastal and coastal hinterland portion, wherein the structure comprises numerous south-easterly or seaward tilted fault blocks. These fault blocks play an important role in groundwater flow. In the low-standing east central portion of the basin, extending east to within about 20 km of the coast - 'Basement' rocks are exposed, comprising granite-gneiss, schists and amphibolites. Younger unconsolidated sands are limited to the coastal area and river beds.



Photo 15: School children abstracting groundwater

(Source: www.ewisa.co.za)

Aquifers within the study area include:

- Weathered and fractured hard rock aquifer systems.
- Primary aquifers that are confined to a narrow strip along the coast and the middle reaches of the Thukela, Sundays and Buffalo Rivers. The primary aquifer in the immediate vicinity of the estuary provides a source of moderate quality water to the estuary during periods of low flow.

Parsons and Conrad (1998) classify the aquifers in the study area as minor aquifers with moderate to low vulnerability to anthropogenic impacts. Except in the coastal area around the estuary, aquifers in the Thukela River Catchment are classified as minor aquifers. A good, spatially distributed data set of groundwater level measurements is available for the study area (Figure 10). Median depth to the water table in the WMA is 0 – 35 m.

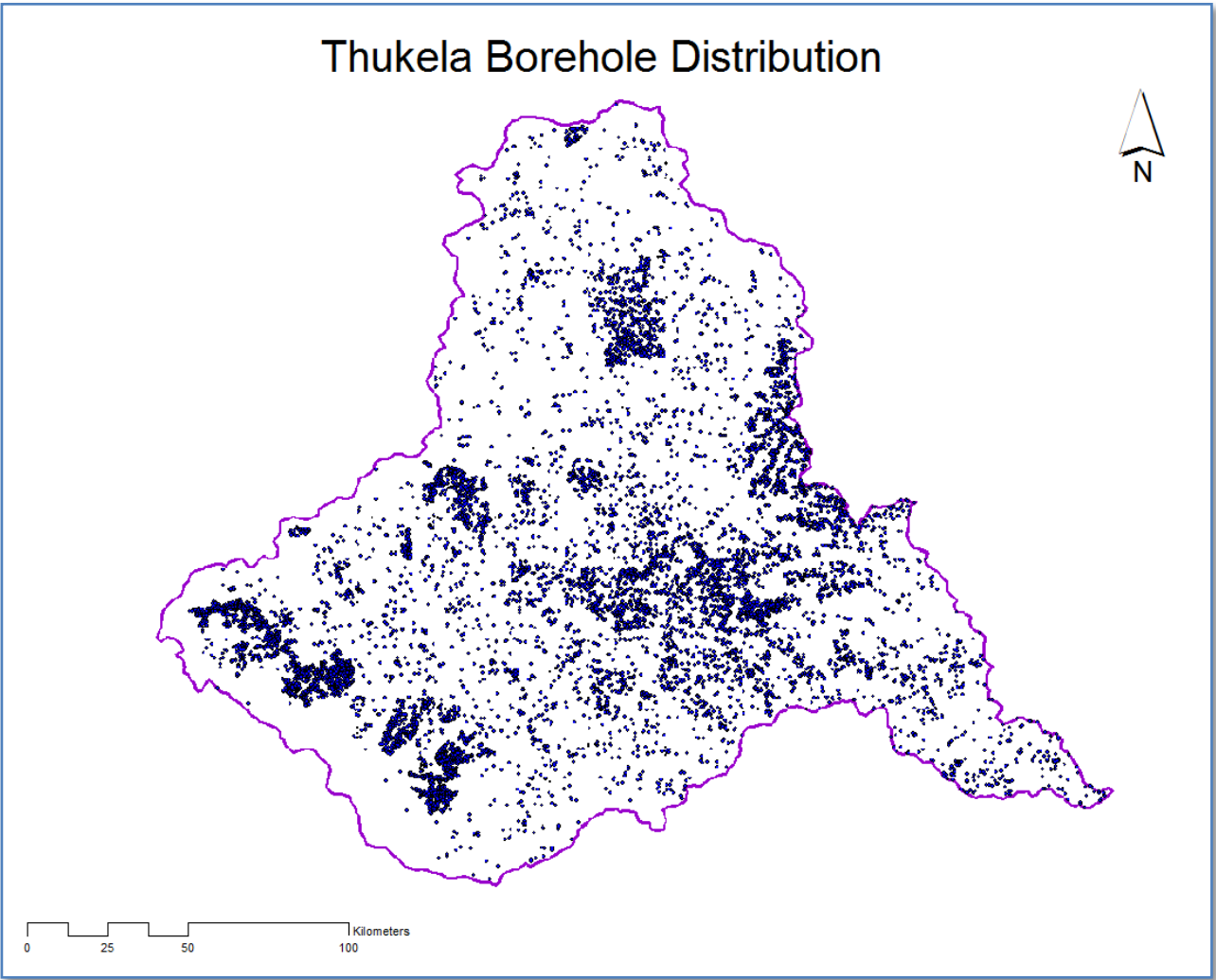


Figure 10: Spatial distribution of boreholes

Groundwater yields from 'hard-rock' boreholes in the WMA are generally low and in the range 0.1 to 0.6 l/s, although significantly higher yields (3 l/s) can be obtained in hydrogeologically favourable situations, such as fracturing and intrusive Karoo dolerite contact zones. Contacts between different lithologies were also seen to be important drilling targets. There is little difference in yield among the various geological formations.

Higher borehole yields can be obtained in some localities. Juxtaposition of sandstone horizons to dolerite, major structural features such as faults and fractures and more competent Natal Group quartzites and sandstones have produced borehole yields in excess of 2 l/s. The likelihood of obtaining yields in excess of 2 l/s, however, is less than 30%, while few boreholes yield more than 3 l/s.

Groundwater recharge over the WMA varies from 1 to 5 % of the mean annual precipitation (MAP), with an average of about 3 percent of the MAP. Overall, the average annual recharge over the WMA is some 25000 m³/km², varying from about 40 000 m³/km² in the higher rainfall portions of the area to about 15 000 m³/km² in the portions with lower rainfall.

Baron *et al.* (1998) report that effective storage rather than recharge dictates the potential of aquifer systems in the study area. They estimate the Harvest Potential for the Thukela River Catchment at 520 Mm³/a. Using the same data set, Haupt (2001) defines the Exploitation Potential of the catchment as 230 Mm³/a. The Harvest Potential is adjusted on the basis of low borehole yields that prevent the full Harvest Potential. Haupt bases his reduction on an average borehole yield of 0.85 l/s.

Groundwater with a CaMg-HCO₃ character is found in the western part of the catchment along the escarpment. These chemical characteristics are typical of younger groundwater in close proximity to the recharge area. Towards the east, groundwater quality deteriorates in the direction of flow and assumes a more dominant N-Cl character.

Groundwater quality in the WMA is generally good, with the best quality groundwater found in the higher rainfall portions, and the poorest quality in the lower rainfall areas. The total dissolved solid (TDS) content of the groundwater is generally in the range 50 to 200 mg/l, but this can rise to considerably more than 420 mg/l in the lower rainfall portions of the WMA.

Good quality groundwater is found in the mountain headwaters, with quality deteriorating in the direction of flow. Poorer quality groundwater is found in the lower reaches of the Upper Thukela, Bushmans and Mooi Catchments, probably reflecting the influence of the argillaceous sediments in this part of the study area. Instances of elevated fluoride were reported for the western part of the catchment.

Groundwater pollution in the WMA is generally not significant in proportion and, when present, it is significantly localised. Significant pollution of the groundwater can occur (although also localised) in the north-west portion of the WMA (Ladysmith-Dundee-Newcastle), where coal mining and dumping mine discard material has taken place over the last 100 years or longer. In addition to potential groundwater contamination in urban areas (waste and sewage disposal, underground storage tanks, chemical spills etc.), a number of potential sources of groundwater contamination exist in the study area. These include:



Photo 16: Acid mine drainage near Newcastle

- Mines (acid mine drainage (Photo 16) and closed mine decants in the Sundays and Buffalo Catchments)
- Agriculture (irrigation return flow, fertilizers and pesticides, feedlots)
- Rural communities (sanitation and informal waste sites)
- Sporadic non-compliance of effluent discharge occur in Estcourt, Newcastle and Mandini
- Domestic discharge into Wakkerstroom Vlei
- The discharge of effluent from paper mills
- Industrial spills in the Newcastle area

Groundwater pollution is generally difficult to assess on a regional scale, with impacts only apparent on a local scale. Seepage of acid rock drainage from coal dumps and slurry dams could have a significant impact on river quality, particularly during drier months. As coal mining is limited to areas underlain by the Vryheid Formation of the Ecca group, this potential problem is only relevant in the northern Buffalo River and Sundays River Catchments.

As the application of fertilizers and pesticides result in non-point source pollution, these impacts are difficult to detect. Cognisance of potential groundwater contamination impacts by farming must be taken when assessing the Reserve. Pit latrines and unserviced areas are a widespread, but probably low-risk, source of groundwater contamination.

5. Delineation of Resource Units

5.1 Introduction

Due to the large size of the study area, it is not feasible to determine a Groundwater Reserve for the entire area. Therefore the study area is divided into smaller sub-regions, called Resource Units (RU). Resource units are areas of similar physical or ecological properties that are grouped or typed to simplify the Reserve determination process. A 'groundwater resource unit' (or 'groundwater unit') is defined as a groundwater system that has been delineated or grouped into a single significant water resource based on the basis of one or more characteristics that are similar across that unit. Other components of the water cycle, such as wetlands and rivers, must also be considered at this stage, to assess possible interdependency and promote the integrated water resource management vision of the NWA.

5.2 Delineation Process

As already mentioned, there are 88 quaternary catchments within the Thukela WMA, making delineation a complex process. In addition, as the surface water Reserve has already been completed for the WMA, the groundwater Reserve must take these results into account, and the surface water RUs must therefore also be taken into account together with groundwater. The first step in the delineation process was to divide the study area into four sub-catchments, namely the Upper Thukela, Buffalo, Mooi/Sundays and Lower Thukela catchments (Figure 11). Each area is then divided into smaller and in most cases quaternary catchments. Other aspects taken into consideration are:

- Geology
- Climate
- Topography and geomorphology
- Recharge
- Groundwater levels and flow directions
- Groundwater quality
- Groundwater use (and stress)
- Groundwater-dependent ecosystems.

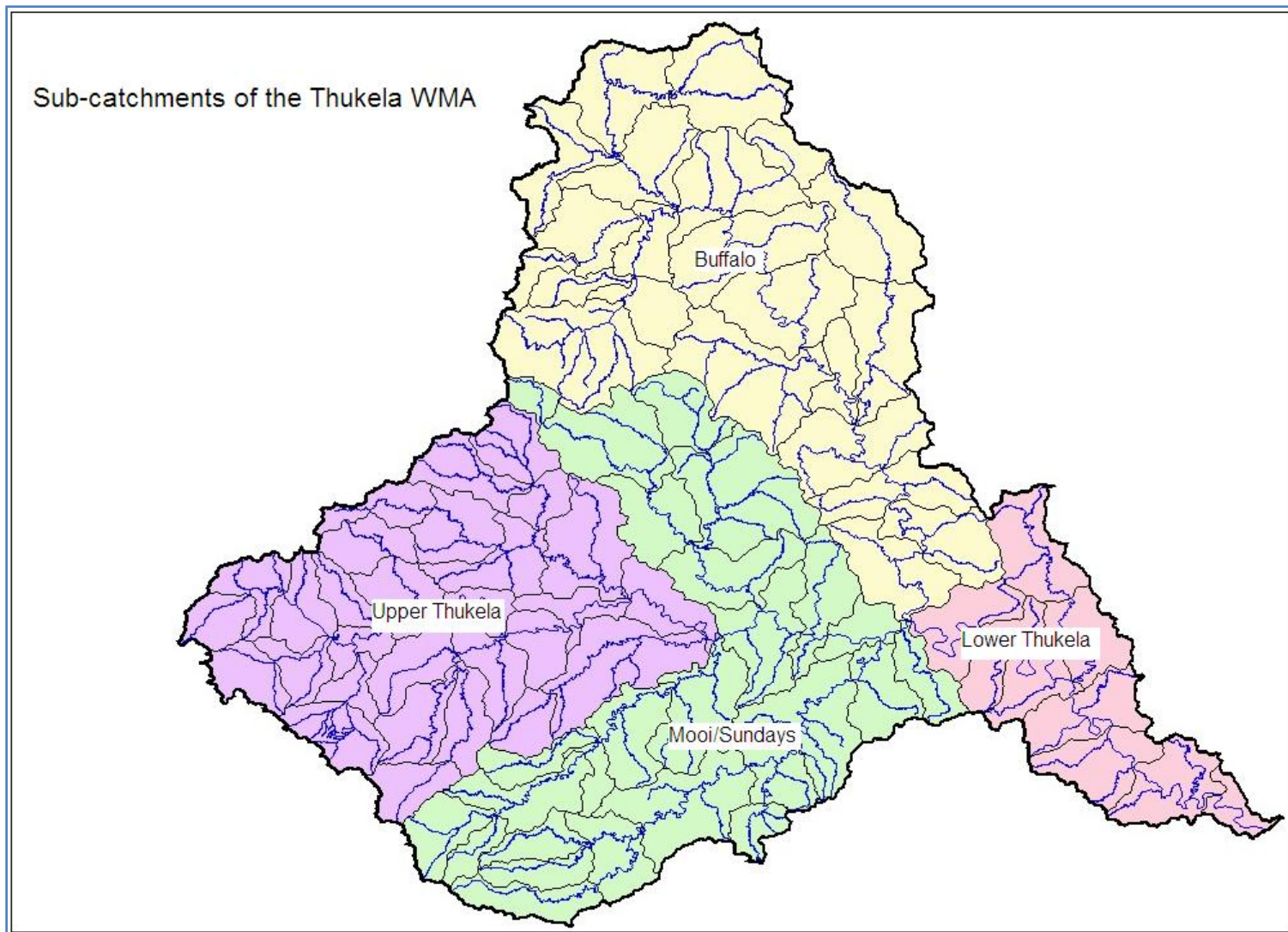


Figure 11: Four sub-catchments of the Thukela WMA

5.3 Upper Thukela

The Upper Thukela consists of the following quaternary catchments:

- V11A, V11B, V11C, V11D, V11E, V11F, V11G, V11H, V11J, V11K, V11M, V11L
- V12A, V12B, V12C, V12D, V12E, V12F, V12G
- V13A, V13B, V13C, V13D, V13E
- V14A, V14B, V14C, V14D, V14E

Geology and recharge together with surface water conditions are used to delineate the RUs. The delineation process is discussed in Table 12.

Table 12: Resource units in the Upper Thukela

Resource units	Characteristics
RU A: V11A, V11B, V11G, V11E and V11H (excluding protected areas: Giants Castle, Cathedral Peak, Natal Drakensberg Park and Ukhahlamba Drakensberg Park)	Mountainous area Headwaters of the Thukela River Recharge between 46 – 51 mm/a Geology: - Drakensberg Basalt - Karoo arenite and mudstone
RU B: V13A, V13B, V13C, V13D	Mountainous/hilly area Headwaters of the Little Thukela River Recharge between 43 – 46 mm/a Geology: - Drakensberg Basalt - Beaufort (arenite and mudstone)
RU C: V11C and V11D	Mountainous/hilly area Headwaters of the Thukela River Recharge averaging 14 mm/a Geology: - Molteno (arenite, shale and mudstone) - Beaufort (arenite and mudstone) - Dolerite intrusions
RU D: V11F and V11J	Tributaries of the Thukela River Recharge averaging 14 mm/a Geology: - Karoo o Beaufort (arenite and mudstone)
RU E: V11K and V11L (minus protected area)	Tributaries of the Thukela River Recharge averaging 14 – 43 mm/a Geology: - Beaufort (arenite and mudstone)
RU F: V11M, V13E and V14A	Little Thukela River and Thukela River join Recharge averaging 42 – 43 mm/a Geology: - Beaufort (arenite and mudstone) - Volksrust (shale) - Dolerite intrusions
RU G: V12A, V12B and V12C	Head waters of the Klip River Recharge averaging 42 – 43 mm/a Geology: - Beaufort (arenite and mudstone) - Volksrust (shale) - Dolerite intrusions
RU H: V12D, V12E and V12F	Tributaries to Sand River Recharge averaging 14 – 43 mm/a Geology: - Beaufort (arenite and mudstone) - Volksrust (shale) - Dolerite intrusions
RU I: V12G, V14B and V14E	Tributaries to Klip River. Klip River then joins Thukela River. Recharge averaging 42 – 43 mm/a Geology: - Vryheid (arenite, coal and shale)

	<ul style="list-style-type: none"> - Volksrust (shale) - Dolerite intrusions
RU J: V14C and V14D (excluding protected area)	Tributaries to Bloukrans River. Bloukrans River then joins Thukela River. Recharge averaging 42 – 43 mm/a Geology: <ul style="list-style-type: none"> - Vryheid (arenite, coal and shale) - Volksrust (shale) - Dolerite intrusions

Recharge values taken from Vegter (1995)

Please note that in some RUs, “hot spot” will be delineated if necessary, based on water quantity and/or quality stresses.

5.4 Mooi/Sundays

The Mooi/Sundays consists of the following quaternary catchments:

- V20A, V20B, V20C, V20D, V20E, V20F, V20G, V20H, V20J
- V60A, V60B, V60C, V60D, V60E, V60F, V60G, V60H, V60J, V60K
- V70A, V70B, V70C, V70D, V70E, V70F, V70G

Geology and recharge, together with surface water conditions, are used to delineate the RUs. The delineation process is discussed in Table 13.

Table 13: Resource units in the Mooi/Sundays

Resource units	Characteristics
RU K: V60A, V60B and V60C	Head waters of the Sundays River Recharge averaging 14 – 43 mm/a Geology: <ul style="list-style-type: none"> - Beaufort (arenite and mudstone) - Vryheid (arenite, coal and shale) - Volksrust (shale) - Dolerite intrusions
RU L: V60D and V60E	Head waters of the Wasbank River Recharge averaging 14 – 43 mm/a Geology: <ul style="list-style-type: none"> - Beaufort (arenite and mudstone) - Vryheid (arenite, coal and shale) - Volksrust (shale) - Dolerite intrusions
RU M: V60F, V60G, V60H, V60J, V60K, V20J and V20H	Sundays, Mooi, Bushmans and other tributaries join Thuleka River Recharge averaging 42 – 43 mm/a Geology: <ul style="list-style-type: none"> - Pietermaritzburg (shale) - Vryheid (arenite, coal and shale) - Volksrust (shale) - Dwyka (arenite, tillite, mudstone and shale) - Dolerite intrusions
RU N: V70A, V70B, V70C, V70D and V70E	Head waters of the Bushmans River Recharge averaging 14 – 46 mm/a Geology: <ul style="list-style-type: none"> - Drakensberg Basalt - Tarkastad (arenite and mudstone) - Beaufort (arenite and mudstone) - Dolerite intrusions
RU O: V20A, V20B, V20C and V20D	Head waters of the Mooi River Recharge averaging 14 – 46 mm/a Geology: <ul style="list-style-type: none"> - Drakensberg Basalt - Tarkastad (arenite and mudstone) - Beaufort (arenite and mudstone) - Dolerite intrusions
RU P: V70F and V70G	Bushmans River Recharge averaging 42 – 43 mm/a Geology: <ul style="list-style-type: none"> o Beaufort (arenite and mudstone) o Volksrust (shale) o Dolerite intrusions
RU Q: V20E, V20F and V20G	Mooi River Recharge averaging 42 – 43 mm/a Geology: <ul style="list-style-type: none"> - Beaufort (arenite and mudstone) - Volksrust (shale) - Vryheid (arenite, coal and shale) - Dolerite intrusions

Recharge values taken from Vegter (1995)

Please note that in some RUs, “hot spot” will be delineated if necessary, based on water quantity and/ or quality stresses.

5.5 Buffalo

The Buffalo consists of the following quaternary catchments:

- V31A, V31B, V31C, V31D, V31E, V31F, V31G, V31H, V31J, V31K
- V32A, V32B, V32C, V32D, V32E, V32F, V32G, V32H
- V33A, V33B, V33C, V33D

Geology and recharge, together with surface water conditions, are used to delineate the RUs. The delineation process is discussed in Table 14.

Table 14: Resource units in the Buffalo

Resource units	Characteristics
RU R: V31A, V31B, V31C, V31D, V31E, V31F, V31G, V31H, V31I, V31J and V31K and V32A (excluding protected area namely Normandien and Chelmsford Dam)	Head waters of the Buffalo River Recharge averaging 13 – 14 mm/a Geology: - Beaufort (arenite and mudstone) - Vryheid (arenite, coal and shale) - Volksrust (shale) - Dolerite intrusions
RU S: V32B, V32C, V32D, V32E and V32F	Tributaries of the Buffalo River Recharge averaging 43 mm/a Geology: - Vryheid (arenite, coal and shale) - Dolerite intrusions
RU T: V32G and V32H	Bloed River Recharge averaging 42 – 43 mm/a Geology: - Pietermaritzburg (shale) - Vryheid (arenite, coal and shale) - Dolerite intrusions
RU U: V33A, V33B, V33C and V33D (excluding protected area namely Islandlwana)	Buffalo River Recharge averaging 42 – 43 mm/a Geology: - Pietermaritzburg (shale) - Vryheid (arenite, coal and shale) - Volksrust (shale) - Dwyka (arenite, tillite, mudstone and shale) - Dolerite intrusions

Recharge values taken from Vegter (1995)

Please note that in some RUs, “hot spot” will be delineated if necessary, based on water quantity and/ or quality stresses.

5.6 Lower Thukela

The Lower Thukela consists of the following quaternary catchments:

- V40A, V40B, V40C, V40D, V40E
- V50A, V50B, V50C, V50D

Geology and recharge, together with surface water conditions, are used to delineate the RUs. The delineation process is discussed in Table 15.

Table 15: Resource units in the Lower Thukela

Resource units	Characteristics
RU V: V40A, V40B and V40E (excluding protected area namely Nkandla)	Nsuzi River Recharge averaging 14 – 43 mm/a Geology: <ul style="list-style-type: none"> - Pietermaritzburg (shale) - Vryheid (arenite, coal and shale) - Dwyka (arenite, tillite, mudstone and shale) - Natal (arenite and shale) - Tugela (Gneiss and schist)
RU W: V40C and V40D	Thukela River Recharge averaging 42 – 43 mm/a Geology: <ul style="list-style-type: none"> - Pietermaritzburg (shale) - Vryheid (arenite, coal and shale) - Dwyka (arenite, tillite, mudstone and shale) - Natal (arenite and shale) - Tugela (Gneiss and schist)
RU X: V50A, V50B and V50C	Nsuzi River joins Thukela River Recharge averaging 14 – 43 mm/a Geology: <ul style="list-style-type: none"> - Pietermaritzburg (shale) - Vryheid (arenite, coal and shale) - Dwyka (arenite, tillite, mudstone and shale) - Natal (arenite and shale) - Tugela (Gneiss and schist) - Mambulu (Gabbro and norite) - Mapumulo (Gneiss)
RU Y: V50D	Thukela River Mouth Recharge averaging 14 mm/a Geology: <ul style="list-style-type: none"> - Pietermaritzburg (shale) - Vryheid (arenite, coal and shale) - Dwyka (arenite, tillite, mudstone and shale) - Natal (arenite and shale) - Berea (Cenozoic and arenite) - Quaternary (sedimentary, sand and calcrete)

Recharge values taken from Vegter (1995)

Please note that in some RUs, “hot spot” will be delineated if necessary, based on water quantity and/ or quality stresses.

6. Classification and the Reserve for Resource Unit A

6.1 Location

Along the border between western KwaZulu-Natal and the Kingdom of Lesotho, the Drakensberg Mountains form part of the eastern escarpment of southern Africa. This area is regarded as the most important mountain catchment in South Africa, because of the high yield and quality of water it produces. The three largest rivers in KwaZulu-Natal, the Tugela, Mkhomazi and uMzimkhulu, originate in the Drakensberg and support rural, agricultural, urban and industrial consumers in both KwaZulu-Natal and Gauteng.

This RU (Figure 12) includes quaternary catchments V11A, V11B, V11G, V11E and V11H. It is located on the eastern border of Lesotho. There are no towns in this area, however, there are many resorts, including Cathedrals Peak.

The Natal Drakensberg Park was designated to RAMSAR in 1996 and is characterised by an abundance of high altitude mountain wetlands. These include high altitude tarns, springs, bogs, marshes and streams, which may be broadly classified as permanent rivers and streams, including waterfalls, permanent and seasonal marshes and ponds, with emergent vegetation waterlogged for at least most of the growing season, peatlands, freshwater springs, seasonally flooded meadows and sedge marshes.

The primary reason for the establishment of the uKhahlamba/Natal Drakensberg Park was to ensure the maintenance and production of quality water for the country's needs. As a result of the conservation efforts, crystal clear water flows from the Park in substantial volumes. The protected areas are documented in Table 16.

Table 16: Protected areas

PROTECTED AREA	AREA (ha)
Cathedral Peak State Forest	32246
Monk's Cowl State Forest	20379
Mkhomazi State Forest	49156
Cobham State Forest	30498
Garden Castle State Forest	30766
Royal Natal National Park	8094
Loteni Nature Reserve	3984
Vergelegen Nature Reserve	1159
Rugged Glen Nature Reserve	762

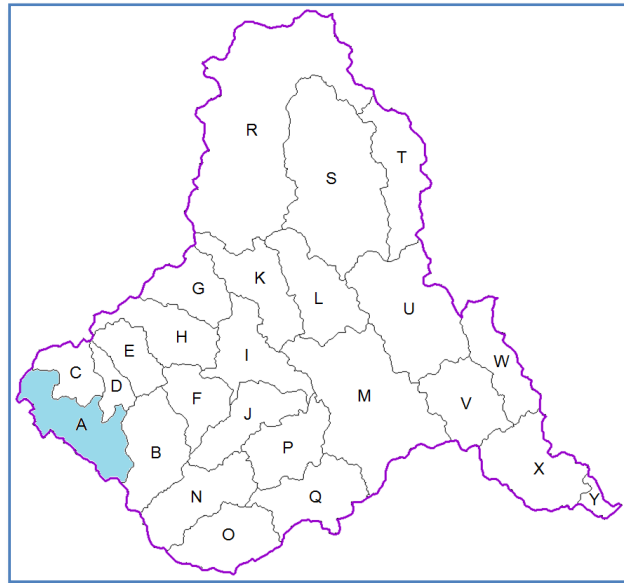


Figure 12: Location of RUA

6.2 Climate

The climate of the region is dominated by the influence of subtropical anticyclones and the Drakensberg is one of the best watered, least drought-prone areas of southern Africa. In winter, the subsidence of cold air causes atmospheric stability and a distinct dry season. In summer, the subsidence inversion may rise above the escarpment, resulting in an influx of humid air from the Indian Ocean in south-easterly winds. Precipitation is often in the form of thunderstorms. The annual precipitation is between 1000 and 2000 mm on the escarpment, precipitation between November to March accounts for 70% of the annual total, and the winter months account for less than 10%. Mist may account for as much as a quarter of the total precipitation. About 80 % of the annual rainfall occurs from October to March, leading to a summer moisture surplus and a winter moisture deficit. Snow usually falls in winter and night temperatures commonly drop to below 10 °C.

The mean annual temperature of the Drakensberg is about 16°C, but both seasonal and diurnal variations are considerable. The highest temperatures (up to 35°C) occur during summer on north-facing slopes at lower latitudes, while the lowest temperatures (down to about -20°C) occur during winter nights on the summit plateau.

Frost is common in winter with about 180 days between mid-April and October at higher elevations, but the local topography controls its distribution and intensity. It also occurs lower down when cold air from the high plateaus drains into lower-lying valleys.

6.3 Topography

Topography is varied, from extremely exposed basalt escarpments to more sheltered sandstone formations, and from undulating hill slopes to river valleys. For much of their length, the mountains are capped by a 4500 foot thick layer of basaltic lava, which has been heavily eroded over the centuries, leaving a bewildering assortment of rugged blocks and pinnacles (Photo 17). Erosion has caused the isolation of many free-standing rock peaks. The highest peaks are found in a compact area along the boundary between Lesotho and the Natal province. Here crags and



Photo 17: Topography
(Source: www.panoramio.com)

pinnacles tower above sandstone foothills and rolling grasslands. It is a wilderness of tumbled mountains, deep river valleys, and towering waterfalls. Some of the peaks are Mont-aux-Sources (3282 m), Monk's Cowl (3234 m), and Cathedral Peak (3004 m). The lower layers of the range are cave sandstone, and the many caves once provided dwellings for South Africa's earliest human inhabitants.

6.4 Flora and Fauna

The vegetation reflects the effects of climate and fire and the variety of the topography, elevation, geology, soils, slopes and drainage. It is largely grassland and occurs in three main belts: the river valleys, the spurs and the summit plateau which is an island of Afro-alpine flora. These form the low altitude valley belt (1280 - 1830 m) with *Podocarpus latifolius* forest in sheltered areas, the mid altitude belt (1830 - 2865 m) with *Passerina-Phillipia-Widdringtonia* fynbos with *Protea* parkland on spurs, and the high altitude belt of Afro-alpine tundra (2865 - 3480 m) with *Erica-Helichrysum* climax heath. The grassland is a dense sour Alti-grassland.

The fauna includes a total of 48 mammals, 299 birds, 48 reptiles, 26 amphibians and 8 species of fish.

The invertebrate fauna of the area is less well known but includes many species endemic to the region. These include for example 21 species of millipedes, and 32 species of craneflies. Of the 156 South African species of dragonflies, 44 have been found in the area, one being endemic, and 74 butterfly species, which is 11.7% of the butterflies found in the country.

6.5 Cultural Importance

The Drakensberg region ranks as one of the most important archaeological areas in South Africa. Archaeological sites from the Early, Middle and Late Stone Ages and the Late Iron Age are present, indicating that this region may have been occupied by man over the last million years. The first evidence of human occupation of the area dates from the Middle Stone Age, 20000 years ago, but it was the Late Stone Age San people who inhabited the area from about 8000 years ago. These Bushmen were hunter-gatherers and often lived in caves and rock shelters, now adorned with thousands of rock paintings dating from 2 - 3000 years ago, up to the 19th century, when they were added to by Bantu settlers.

6.6 Demography and Landcover

The Drakensberg is renowned for the quantity, quality and variety of rock art painted by now extinct Bushmen. Various activities currently take place in the area surrounding the protected areas. These include commercial and subsistence farming, as well as various recreation activities. Many private accommodation facilities like chalets, lodges, hotels and camp sites have been developed to cater for the tourist market. The number of people (2001 census data) within the study area is approximately 50000. Most of the population are rural or work within the protected areas. The landcover is shown in Figure 13.

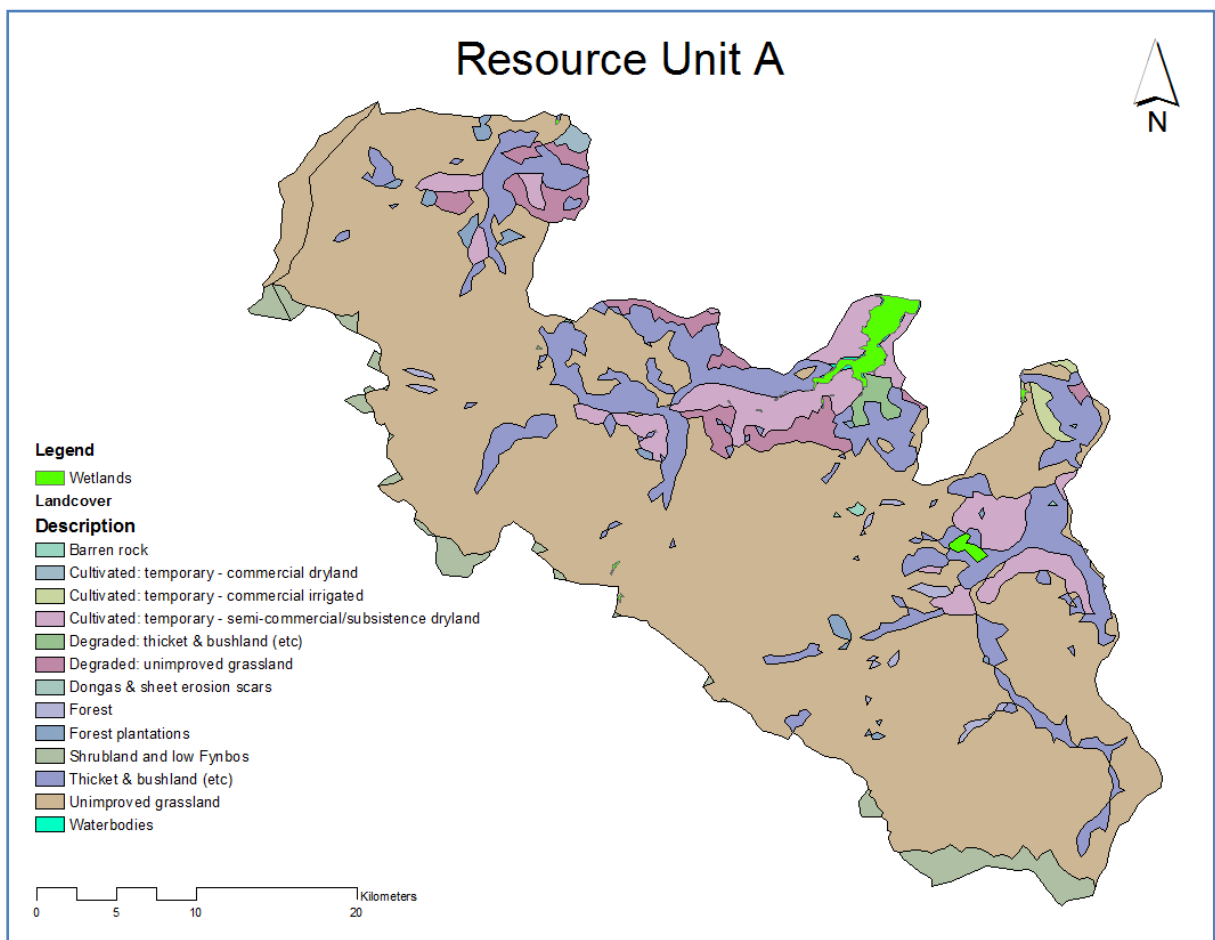


Figure 13: Landcover in RUA

6.7 Surface Water

The perennial rivers in the study area include the Thukela, Sithene, Mnweni, Nxwaye, Ndedema, Mhlwazini, Endumeni and Masongwan. These rivers are closest to natural conditions, with very little disturbance.

The Woodstock Dam (Photo 18) intercepts the study area, which forms part of the Tugela-Vaal water transfer system.



Photo 18: Woodstock Dam

(Source: www.dwaf.gov.za)

Runoff is a term used to describe the water from rain and snowmelt that flows over the land surface into streams, other surface waters, or land depressions. Interflow is a component of the runoff generation process where water flows at or near the surface without becoming part of regional

groundwater system. Photo 19 shows interflow occurring in the study area.



Photo 19: Interflow

Letlatsa (2004) states that the runoff in the mountain catchment areas is 22 - 24% of the mean annual precipitation (MAP). According to De Swart (2007), the runoff on site is approximately 30% of the MAP. WR90 (Midgley *et al.*, 1994) states that the runoff is 36% of MAP.

6.8 Wetlands and Springs

The area consist of an interconnected system of wetlands, ranging from open water bodies such as mountain tarns, a variety of marshes, to an intricate network of stream and river courses. These wetlands are present throughout the altitudinal gradient of the mountains, from the Afro-alpine to the Afromontane Belts. The networks of interconnected wetland systems are distributed in a complex mosaic, occupying a variety of positions in the landscape, ranging from small hanging wetlands, high on valley sides, down to the extensive watercourses (Photo 20). Most springs in the area are either perched or gravitational (or interflow) springs, as seen in Photo 19.



Photo 20: One of the largest wetlands in the uKhahlamba Drakensberg Park

(Source www.environment.gov.za)

6.9 Soils

The channel substrate at high altitudes (generally > 1850 m) consists of basalt bedrock and boulders, while at lower altitudes, sandstone bedrock and boulders dominate. In the lowest parts of the study area, sand and silt substrates become evident. Although mineral soils are more common, some of the wetland areas, particularly those on south-facing slopes and at higher altitudes, have organic soils (which tend to have a minerotrophic water supply). The soils are threatened by erosion.

6.10 Geology (summarised from Woodford and Chevallier, 2002)

The Drakensberg consists of a number of horizontally bedded geological strata forming steps. The thick sedimentary succession is capped by an accumulation of basaltic lava, comprising the upper part of the Karoo Supergroup, which has a composite thickness of up to 7000 m in this area. The Beaufort Group dominates in this RU and is stratigraphically divided into two major units, the upper Tarkastad Subgroup and the lower Adelaide Subgroup. The Tarkastad Subgroup is subdivided into the upper Burgersdorp Formation with its brightly coloured red, blue and green mudstones and the lower Katberg Formation which can be up to 900 m thick. The Katberg Formation also contains brightly coloured shales and mudstones, but mainly consists of thick layers of coarse-grained sandstone. The Adelaide Subgroup mainly consists of green, bluish, grey and red mudstones and fine-grained sandstones that form thick lens-shaped units. The central basin mainly consists of mudstones, shales and fine-grained sandstones. These fine-grained sediments were mainly deposited where the braided rivers began to meander. The sedimentary units in the Group therefore usually have very low primary hydraulic conductivities. Since the Beaufort Group was also deposited in a fluvial environment, one can expect that aquifers in these formations will, like those in the Ecca Group, be anisotropic. The geometry of these aquifers, however, is further complicated by the migration of the braided and meandering streams. Aquifers in the Beaufort Group will therefore not only be multi-layered, but also multi-porous with variable thicknesses. The contact plane between two different sedimentary layers will cause a discontinuity in the hydraulic properties of an aquifer.

The lifespan of a high-yielding borehole in the Beaufort Group may therefore be limited if the aquifer is not recharged frequently.

6.11 Geohydrology

1.1.1 Groundwater levels

It is clear the groundwater levels follow the topography as seen from Figure A1 in Appendix A, and therefore groundwater contour maps were generated using Bayesian interpolation. The groundwater levels for the study area are shown in Figure 14. The most probable depth to groundwater level in the RU is 3.7 mbgl, according to the histogram of water levels in the RU shown in Appendix A. Groundwater levels are expected to be lower than normal due to prevailing drought conditions. Unfortunately very little time series water level data are available to quantify the overall impact.

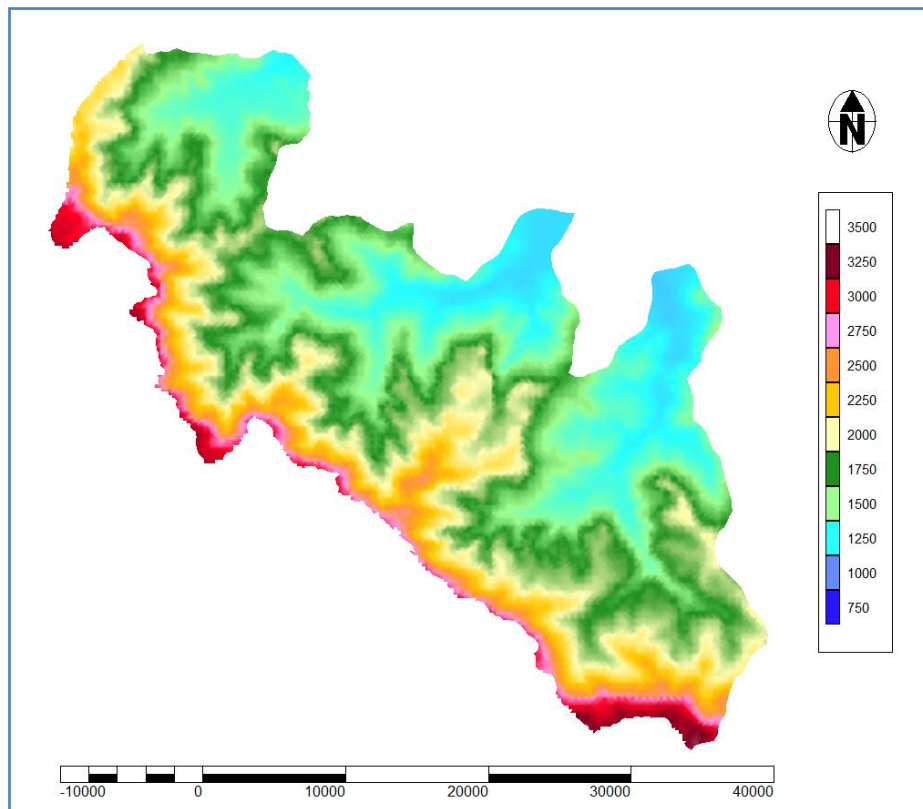


Figure 14: Groundwater levels in RUA

1.1.2 Groundwater recharge

The groundwater recharge calculated from the different methods is listed in Table 17. The different recharge methods applied are discussed in Section 2.3. The final recharge values for the RU are highlighted in red.

Table 17: Recharge values

Recharge							
MAP Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Volume Mm ³ /a	Calculated %	CMB %	Land Cover %	Geology %
1338.236	88.386	158.280	109.275	8.2%	8.2%	1.7%	3.0%

1.1.3 Basic human needs

The method for determining BHNs is discussed in Section 2.3. The final value for the study area is highlighted in red in Table 18.

Table 18: Basic human needs

Basic Human Need		
Census(2001) Adjusted	Dependence 18%	Estimate Mm ³ /a
66424	11956	0.108

1.1.4 Groundwater contribution to baseflow

The baseflow separation curves for the RU are shown in Figures 15 – 19.

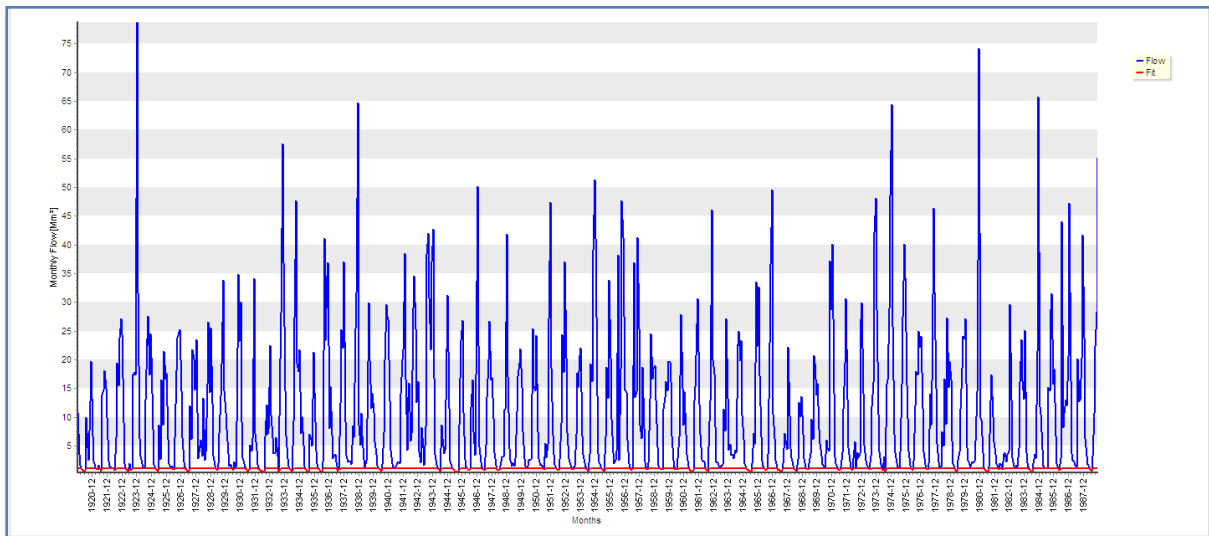


Figure 15: Baseflow separation for quaternary catchment V11A

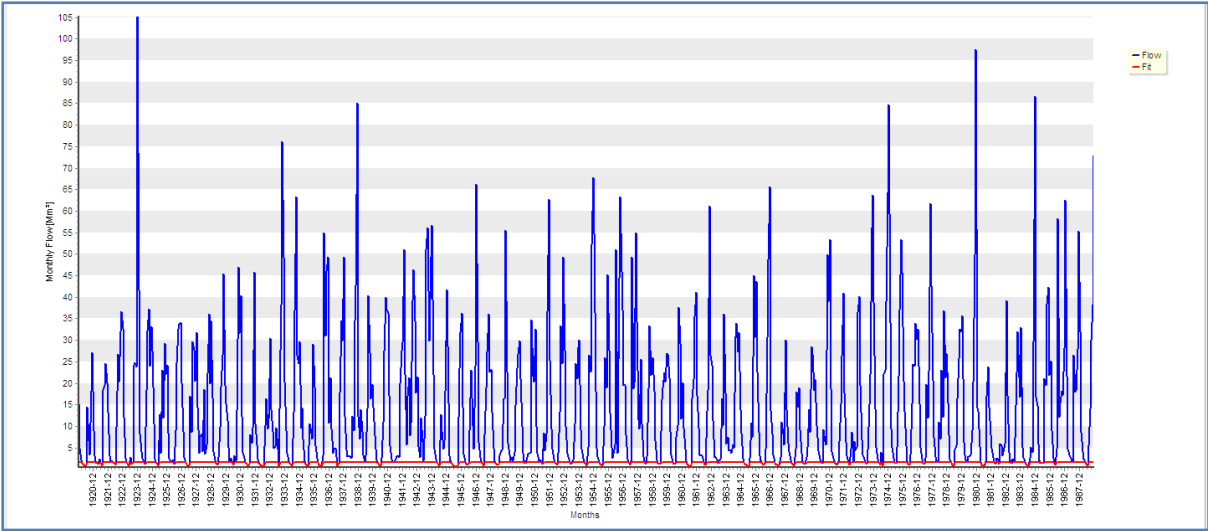


Figure 16: Baseflow separation for quaternary catchment V11B

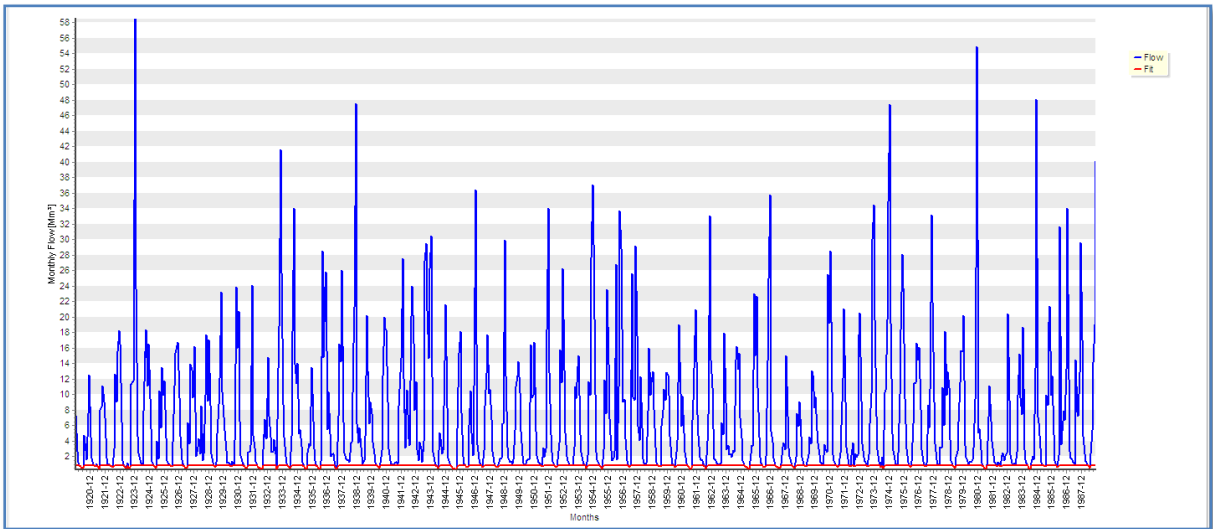


Figure 17: Baseflow separation for quaternary catchment V11E

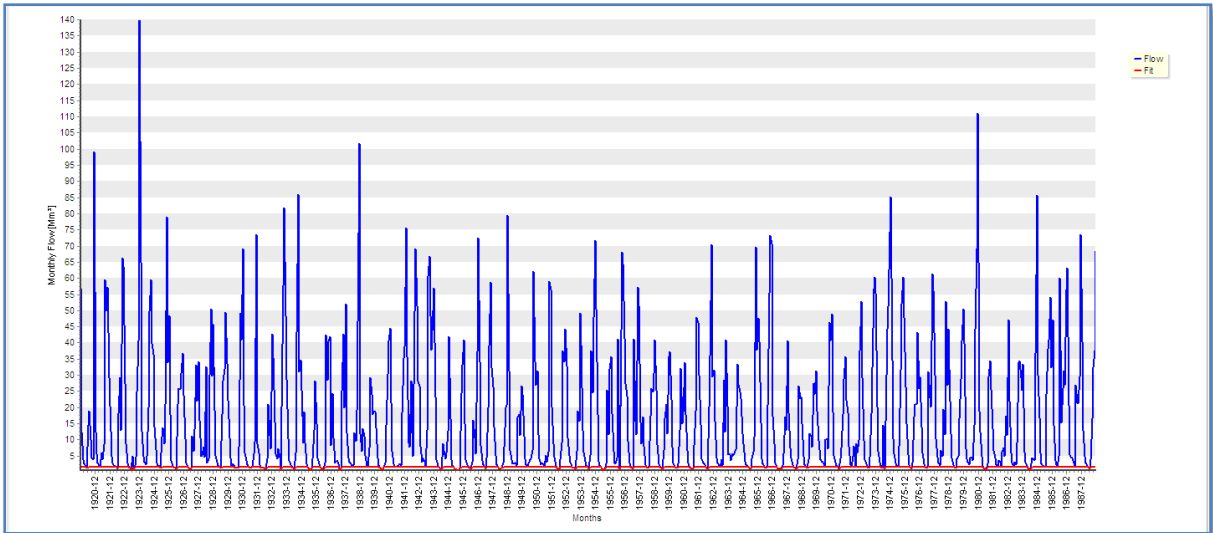


Figure 18: Baseflow separation for quaternary catchment V11G

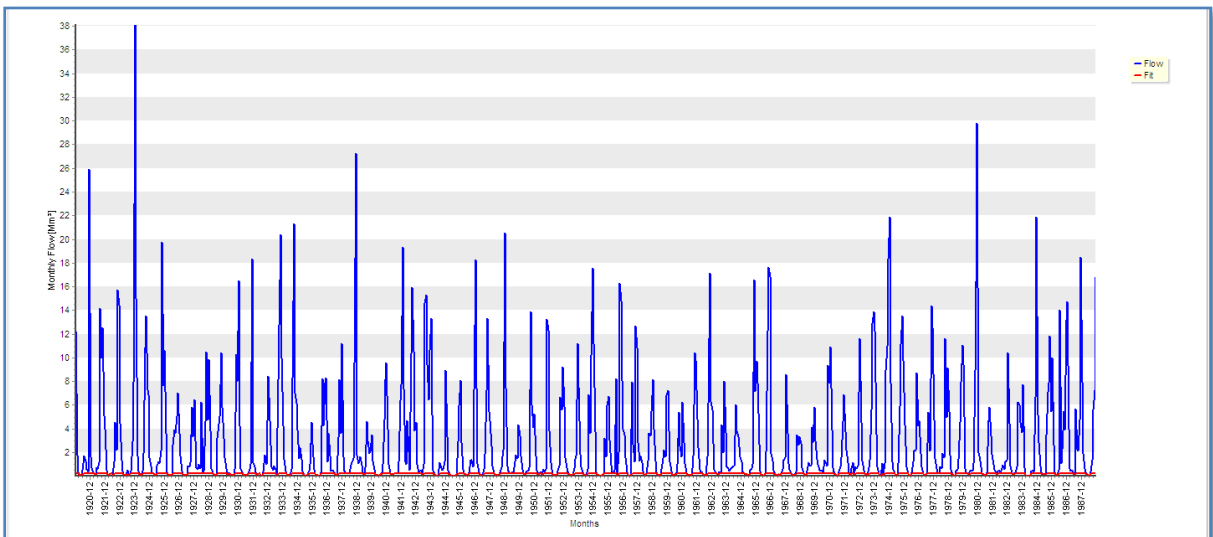


Figure 19: Baseflow separation for quaternary catchment V11H

The final groundwater contribution to baseflow values for the RU in Table 19 is highlighted in red.

Table 19: Groundwater contribution to baseflow

Groundwater Contribution to Baseflow							
GRDM Mm ³ /a	Hughes Mm ³ /a	Shultz Mm ³ /a	Pitman Mm ³ /a	vTonder Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Herold Mm ³ /a
38.266	230.847	113.629	47.116	99.909	38.266	230.847	58.880

1.1.5 Groundwater use

The groundwater use for the RU is listed in

Table 20.

Table 20: Groundwater use

Groundwater Use							
GRDM Mm ³ /a	WARMS Mm ³ /a	Hydrocensus Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Forrest Mm ³ /a	Crops Mm ³ /a	TOTAL Mm ³ /a
0.160	0.028	0.051	0.028	0.204	6.365	0.268	6.525

1.1.6 Groundwater quality

The TDS values for the RU are shown in Figure 20. They are classified according to SABS standards. Not all boreholes have quality data available, but those that do can be used to identify possible hot spots with regard to quality in the resource unit. The overall quality of the resource unit is well within the drinking water guidelines with the exception of four boreholes. These areas should be treated as hotspots rather than applying a poor classification to the whole resource unit. Treatment of the hot spot areas will be addressed under Resource Quality Objectives in Section 31.

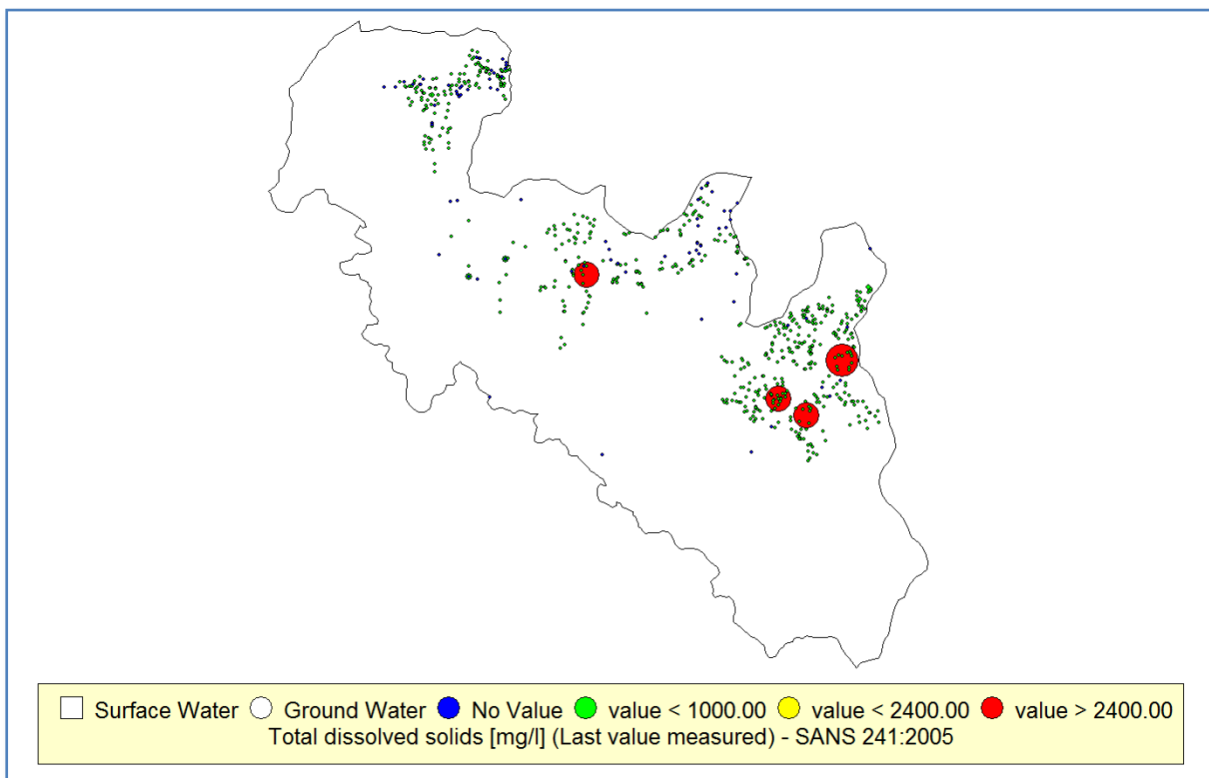


Figure 20: TDS values

1.1.7 Aquifer vulnerability

The aquifer vulnerability calculations are summarised in Table 21. The slope histogram is documented in Appendix B.

Table 21: Aquifer vulnerability

Aquifer Vulnerability						
Level mbgl	Recharge %	Slope %	Soil Texture	Aquifer Type	Vadose Zone	Vulnerability %
3.7	8.2%	3.7	SaCl	Weathered/Fractured	Karoo(southern)	62%

6.12 Classification

1.1.8 Groundwater usage

The stress index, defined as the ratio between total groundwater use and recharge, for the study area is calculated at 60%. Due to the uncertainty associated with the groundwater use component, the stress index was stochastically modelled through assigning a normal distribution curve with a standard deviation of 0.653 Mm³/a to the groundwater use estimate to account for the associated uncertainty. The stochastic results are shown in Figure 21. It is clear from the results that the stress index will vary between 58% and 61%, with a certainty of 99.4%. Due to the small variability in the obtained range and high certainty, the uncertainty in the groundwater use component will not affect the calculated stress index significantly.

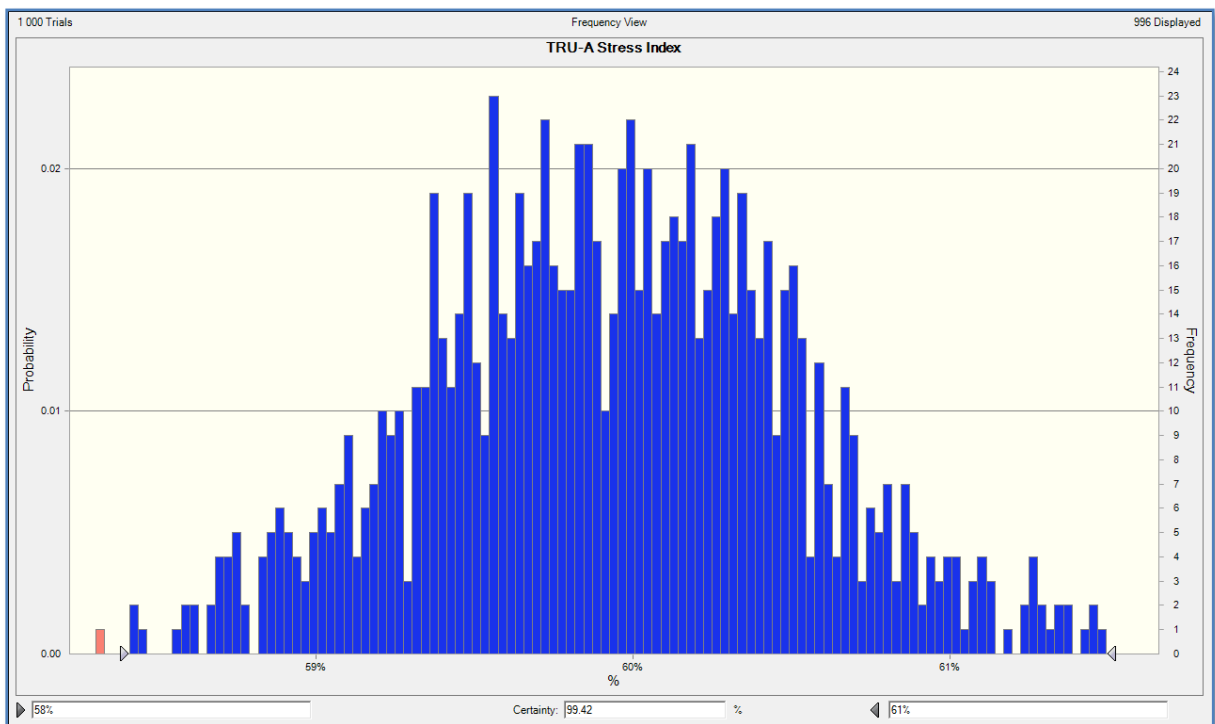


Figure 21: Stochastic results

1.1.9 Quality

The expanded Durov diagram with the groundwater quality is shown in Figure 22. An explanation of the classification process by means of the expanded Durov diagram is given in Section 2.3. It is apparent that the contamination category, according to the explanation, is A/B.

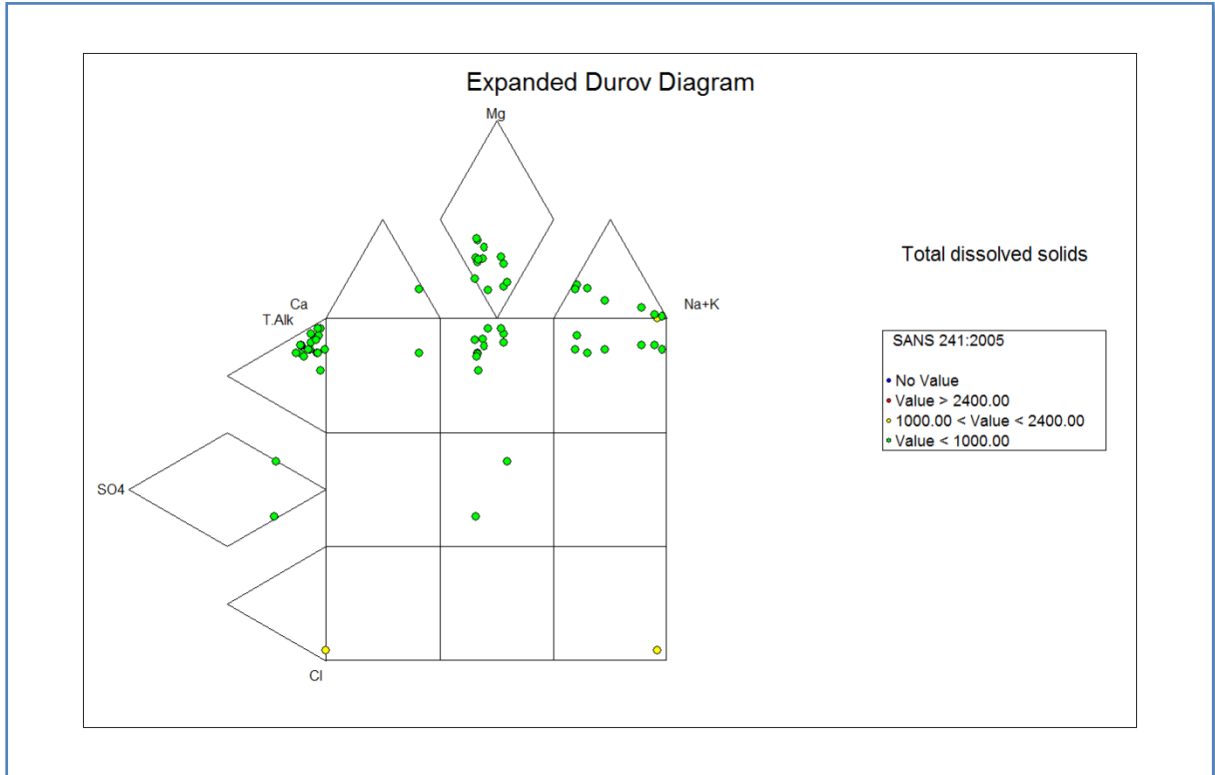


Figure 22: Expanded Durov diagram for RU

As documented the vulnerability is 62%. The impact of potential contamination according to Section 2.3, is low.

1.1.10 Final category

The final category for the RU is summarised in Table 22.

Table 22: Category for RU

Impact	Present status category	Water resource category
Groundwater usage	D	Fair
Groundwater contamination	A/B	Good
Potential groundwater contamination (vulnerability and impact)	B	Good
FINAL	B/C	Good/Fair

6.13 Quantification of the Reserve

The groundwater Reserve for the RU is summarised in Table 23.

Table 23: Reserve

Reserve			Allocation	
Baseflow Mm ³ /a	BHN Mm ³ /a	Reserve % Recharge	Allocation Mm ³ /a	Current Use Mm ³ /a
58.880	0.108	54%	43.762	6.525

7. Classification and the Reserve for Resource Unit B

7.1 Location

RU B: V13A, V13B, V13C, V13D. The protected area is Giant’s Castle Game Reserve, comprising an area of 34638 ha. The towns included in the area are Winterton, a small town situated on the banks of the Small Thukela River in the foothills of the Drakensberg Mountains. Winterton supports a large agricultural neighbourhood and acts as the gateway into this part of the “Berg”. Other towns are Zunckels, Champagne Castle, Loskop and Malta. The location of RUB is shown in Figure 23.

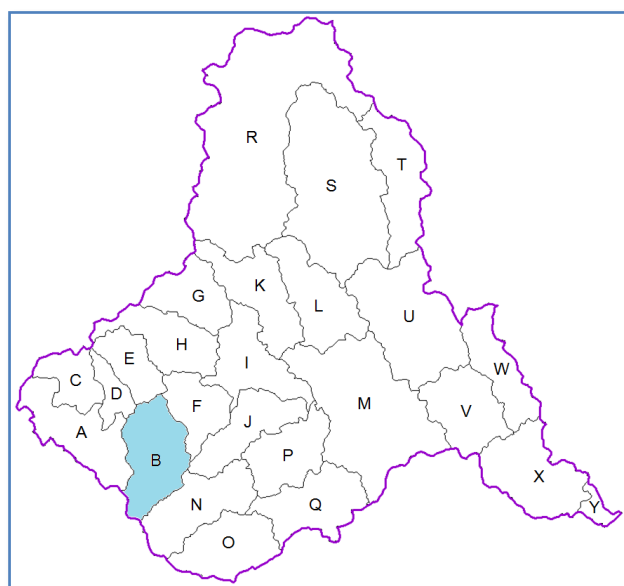


Figure 23: Location of RUB

7.2 Climate

Precipitation is often in the form of thunderstorms. The annual precipitation is between 800 and 1300 mm on the escarpment, precipitation between November to March accounts for 70% of the annual total, while the winter months accounts for less than 10%. The mean annual temperature of the area is about 16°C, but both seasonal and diurnal variations are considerable. The highest temperatures (up to 35°C) occur during summer on north-facing slopes at lower latitudes, while the lowest temperatures (down to about -20°C) occur during winter nights on the summit plateau.

Frost is common in winter, with about 180 days between mid-April and October at higher elevations, but the local topography controls its distribution and intensity. It also occurs lower down when cold air from the high plateaus drains into lower-lying valleys.

7.3 Topography

The Thukela River and some of its main tributaries rise in the west of the catchment in the high-lying Drakensberg Mountain Range. The headwaters of the Little Thukela River originates at an elevation of some 3000 mamsl close to Njesuthi (Photo 21), which is the highest mountain in South Africa. The river meanders down through the mountains through relatively undulating terrain, before joining the Thukela River.

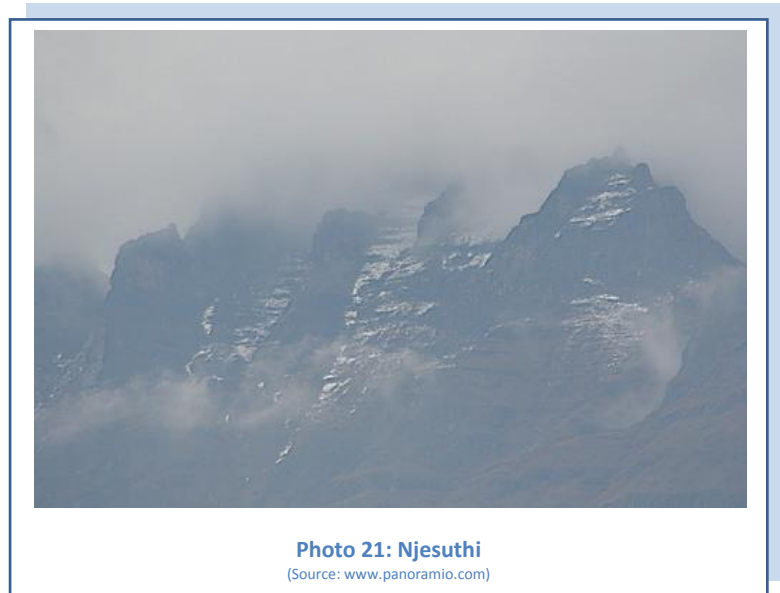


Photo 21: Njesuthi
(Source: www.panoramio.com)

7.4 Flora and Fauna

The vegetation reflects the effects of climate and fire and the variety of the topography, elevation, geology, soils, slopes and drainage. It is largely grassland and occurs in three main belts: the river valleys, the spurs and the summit plateau, which is an island of Afro-alpine flora. There are also some shrubs, fynbos and thicket. The fauna includes a total of 48 mammals, 299 birds, 48 reptiles, 26 amphibians and 8 species of fish. Large populations of several antelopes are present and include the endemic grey rhebok, reedbuck *and* eland.

The invertebrate fauna of the area is less well known, but includes many species endemic to the region. These include for example 21 species of millipedes, and 32 species of craneflies. Of the 156 South African species of dragonflies, 44 have been found in the area, one being endemic, and 74 butterfly species, which is 11.7% of the butterflies found in the country.

7.5 Cultural Importance

The Drakensberg region ranks as one of the most important archaeological areas in South Africa. Archaeological sites from the Early, Middle and Late Stone Ages and the Late Iron Age are present, indicating that this region may have been occupied by man over the last million years. The first evidence of human occupation of the area dates from the Middle Stone Age, 20000 years ago, but it was the Late Stone Age San people who inhabited the area from about 8000 years ago. These Bushmen were hunter-gatherers and often lived in caves and rock shelters, now adorned with thousands of rock paintings dating from 2 - 3000 years ago, up to the 19th century, when they were added to by Bantu settlers.

7.6 Demography and Landcover



Photo 22: Irrigation of crops

The number of people living in the catchment is estimated at 65000 (2001 census data). The upper areas are located in a nature reserve, with the implication that development in this area is unlikely. Areas adjacent to the nature reserve have however rapidly developed into popular tourist resorts in recent years, with the pressures of human habitation.

Due to limited water resources in the catchment and the large irrigation requirements (Photo 22), this area is considered to be stressed. Other land use contaminating water resources are informal waste sites, with one as close as 500 m from the Little Thukela River in Winterton (Photo 23), and some mining activities. The landcover is shown in Figure 24.



Photo 23: Informal waste site in Winterton

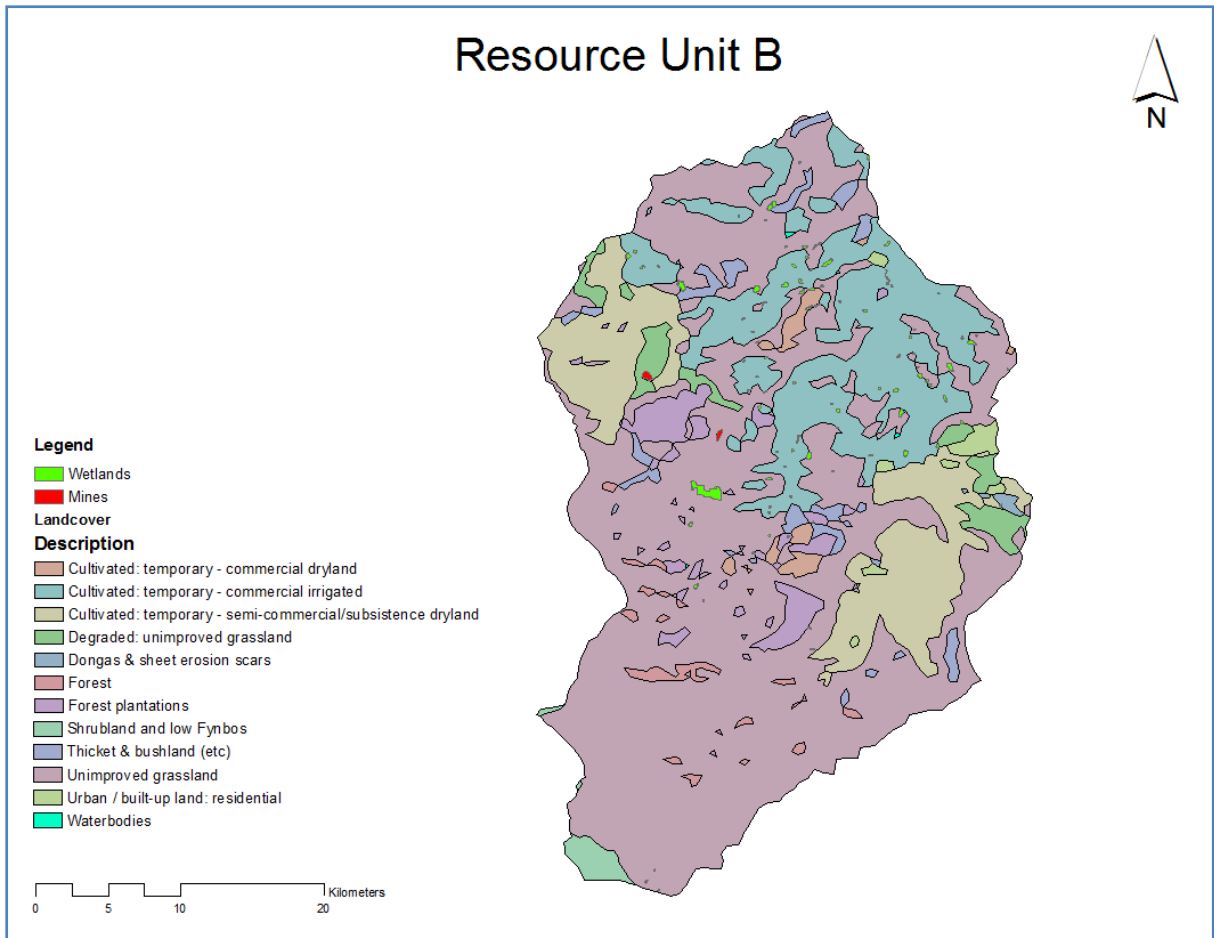


Figure 24: Landcover within RUB

7.7 Surface Water

The Little Thukela (Photo 24) is the main river within the RU. Other tributaries to the Little Thukela River include the Sterkspruit and Lindequespruit. The catchment is characterised by large irrigation requirements (36 Mm³/a). Other water use is insignificant. The only significant dam is the small Bell Park Dam. The dam is situated in the upper reaches of Little Thukela River. The dam is used mostly for irrigation purposes, and its potential is not fully utilised.

The naturally good water quality in the Little Thukela Key Area is threatened by large concentrations of tourism activities (e.g. Champagne Valley), agro-chemicals and fertilisers as a diffuse source of pollution.



Photo 24: Little Thukela River

7.8 Wetlands

The wetlands scattered throughout the resource unit is shown in Figure 24.

7.9 Soils

The channel substrate at high altitudes (generally > 1850 m) consists of basalt bedrock and boulders, while at lower altitudes, sandstone bedrock and boulders dominate. In the lowest parts of the study, sand and silt substrates become evident. Although mineral soils are more common, some of the wetland areas, particularly those on south-facing slopes and at higher altitudes, have organic soils (which tend to have a minerotrophic water supply). The soils are threatened by erosion.

7.10 Geology (summarised from Woodford and Chevallier, 2002)

The Drakensberg consists of a number of horizontally bedded geological strata, forming steps. The thick sedimentary succession is capped by an accumulation of basaltic lava, comprising the upper part of the Karoo Supergroup, which has a composite thickness of up to 7000 m in this area. The Beaufort Group dominates in this RU and is stratigraphically divided into two major units, the upper Tarkastad Subgroup and the lower Adelaide Subgroup. The Tarkastad Subgroup is subdivided into the upper Burgersdorp Formation with its brightly coloured red, blue and green mudstones and the lower Katberg Formation, which can be up to 900 m thick. The Katberg Formation also contains brightly coloured shales and mudstones, but mainly consists of thick layers of coarse-grained sandstone. The Adelaide Subgroup mainly consists of green, bluish, grey and red mudstones and fine-grained sandstones that form thick lens-shaped units. The central basin mainly consist of mudstones, shales and fine-grained sandstones. These fine-grained sediments were mainly deposited where the braided rivers began to meander. The sedimentary units in the Group therefore usually have very low primary hydraulic conductivities. Since the Beaufort Group was also deposited in a fluvial environment, one can expect that aquifers in these formations will, like those in the Ecca Group, be anisotropic. The geometry of these aquifers, however, is further complicated by the migration of the braided and meandering streams. Aquifers in the Beaufort Group will therefore not

only be multi-layered, but also multi-porous, with variable thicknesses. The contact plane between two different sedimentary layers will cause a discontinuity in the hydraulic properties of an aquifer. The lifespan of a high-yielding borehole in the Beaufort Group may therefore be limited if the aquifer is not recharged frequently.

The Molteno Formation (of the Stormberg Group) resembles the Katberg sandstone unit of the Beaufort Group, and forms a single sandstone unit with prominent topographical high areas. Pebbles often found at the contact of the Molteno Formation and Beaufort Group indicate that the base of the Molteno Formation is an erosional surface. The coal seams indicate that a rich and varied plant growth existed in swamps on the flood-plains during the Molteno era. The characteristics and depositional history of the Molteno Formation indicate that the Formation could form an ideal aquifer. This applies not only to the pebble conglomerates and coarse-grained sandstones at the base of the Formation, but also to the other sedimentary bodies. These sedimentary bodies are more persistent than those of the Beaufort Group, and are also sheetlike—the ideal geometry for an aquifer. Unfortunately, the Formation does not occur over a large area and tends to form topographical highs. It is thus difficult to site high-yielding boreholes in the Molteno Formation and to determine its hydrological behaviour.

Sills in the Karoo formations are sheetlike forms of dolerite intrusions that tend to follow the bedding planes of the formations concordantly. These structures, whose thicknesses vary from less than a metre to hundreds of metres, represent the dominant form in which dolerite is emplaced in the Karoo Supergroup. Dolerite sills in the Karoo Supergroup often have very complex forms. The linear dykes are also usually thinner than ring dykes and are confined to the Ecca and Beaufort Groups. This is a clear indication that the magmatic activity at the time the linear dykes intruded was less than when the ring dykes and sills intruded.

7.11 *Geohydrology*

1.1.11 *Groundwater levels*

It is clear the groundwater levels follow the topography, as seen from Figure A1 in Appendix A, and therefore groundwater contour maps were generated using Bayesian interpolation. The groundwater levels for the study area are shown in Figure 25. The most probable depth to groundwater level in the RU is 4.2 mbgl according to the histogram of water levels in the RU in Appendix A. Groundwater levels are expected to be lower than normal due to the prevailing drought conditions. Unfortunately, very little time series water level data are available to quantify the overall impact.

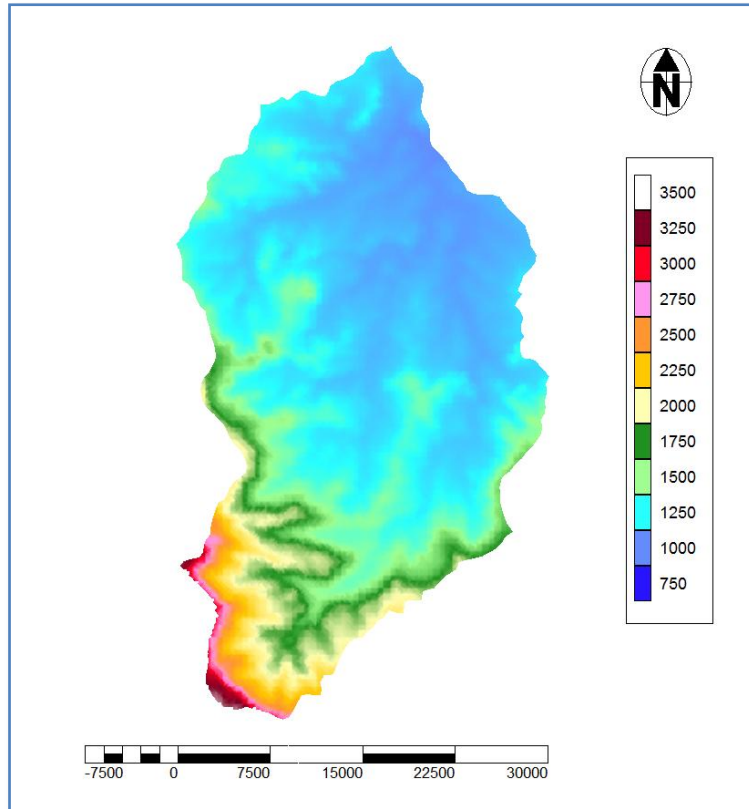


Figure 25: Groundwater levels in RUB

7.11.1 Groundwater recharge

The groundwater recharge calculated from the different methods is listed in Table 24. The different recharge methods applied are discussed in Section 2.3. The final recharge values for the RU are highlighted in red.

Table 24: Recharge values

Recharge							
MAP Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Volume Mm ³ /a	Calculated %	CMB %	Land Cover %	Geology %
1024.140	49.214	110.396	69.597	6.8%	6.8%	0.8%	2.0%

1.1.12 Basic human needs

The method for determining BHNs is discussed in Section 2.3. The final value for the study area is highlighted in red in Table 25.

Table 25: Basic human needs

Basic Human Need		
Census(2001) Adjusted	Dependence 18%	Estimate Mm ³ /a
75501	13590	0.122

1.1.13 Groundwater contribution to baseflow

The baseflow separation curves for the RU are shown in Figures 26 – 29.

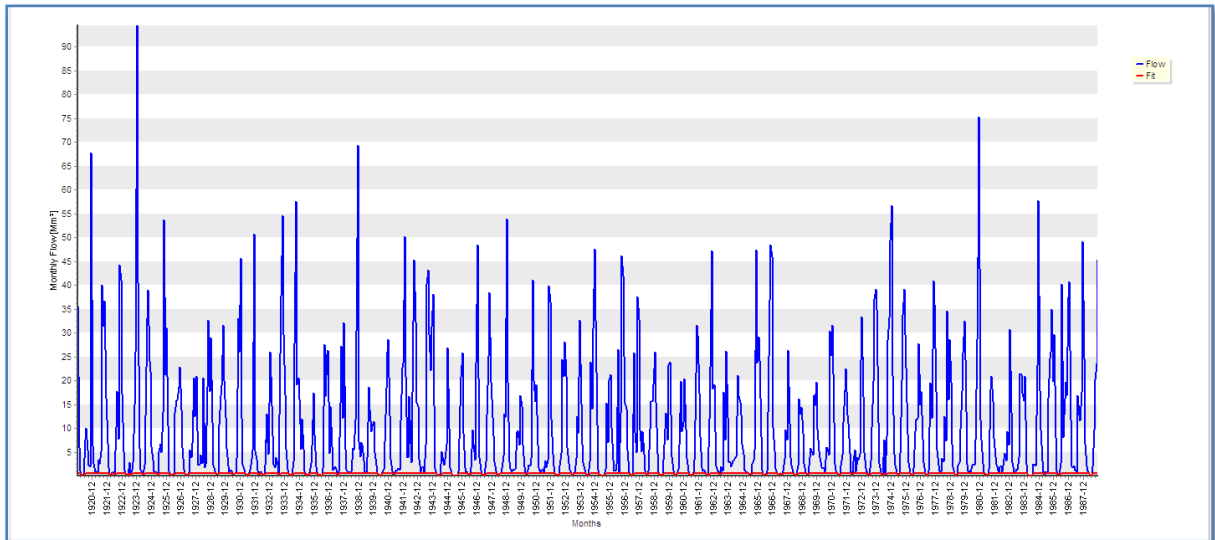


Figure 26: Baseflow separation for quaternary catchment V13A

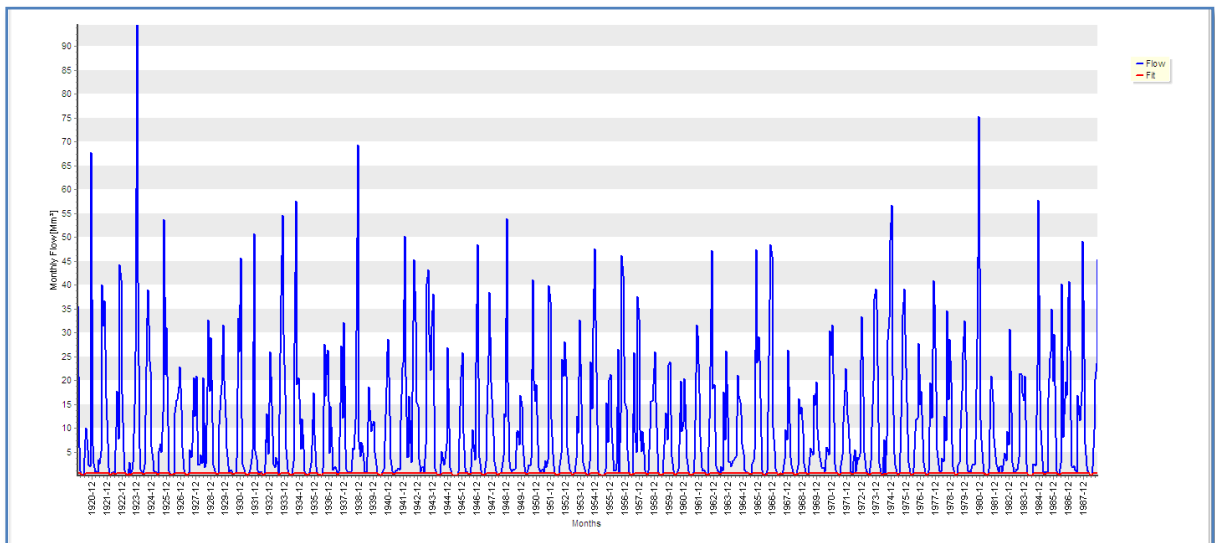


Figure 27: Baseflow separation for quaternary catchment V13B

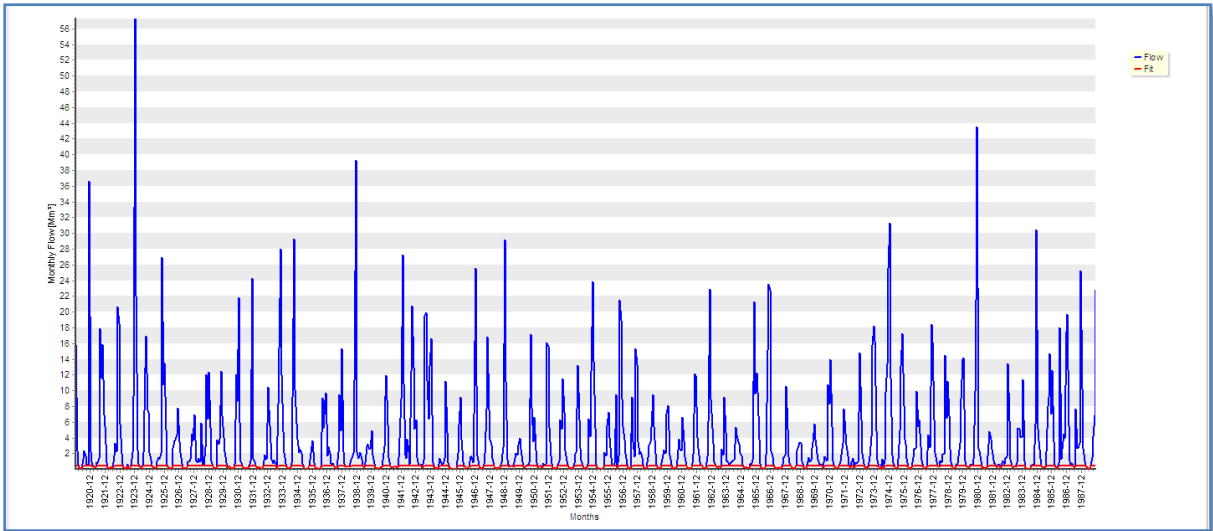


Figure 28: Baseflow separation for quaternary catchment V13C

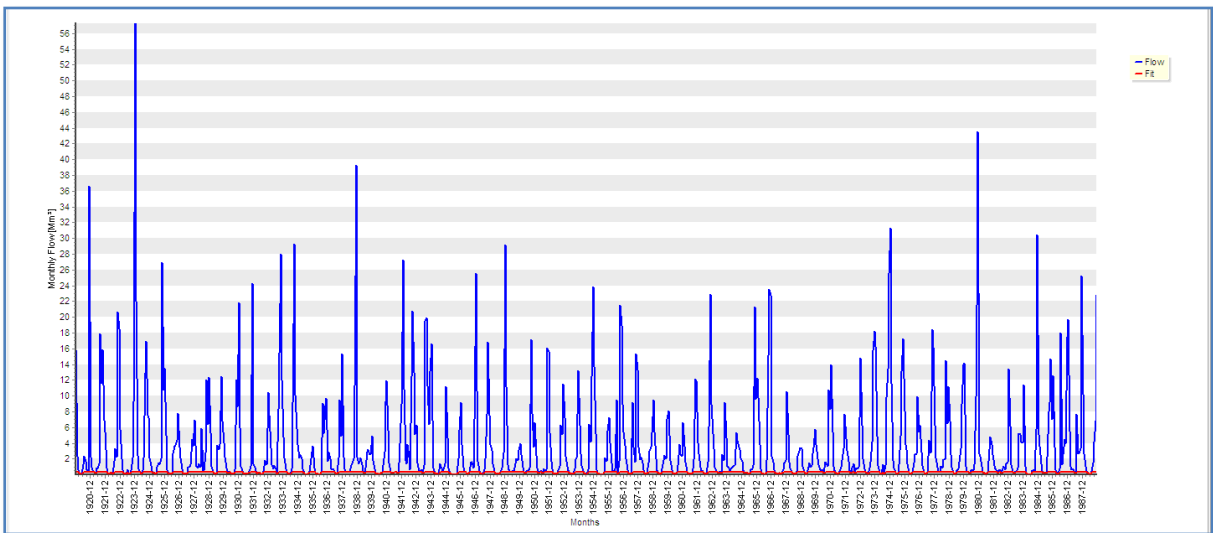


Figure 29: Baseflow separation for quaternary catchment V13D

The final groundwater contribution to baseflow values for the RU in Table 26 is highlighted in red.

Table 26: Groundwater contribution to baseflow

Groundwater Contribution to Baseflow							
GRDM Mm ³ /a	Hughes Mm ³ /a	Shultz Mm ³ /a	Pitman Mm ³ /a	vTonder Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Herold Mm ³ /a
23.642	96.553	41.054	11.815	35.685	11.815	96.553	19.210

1.1.14 Groundwater use

The groundwater use for the RU is listed in Table 27.

Table 27: Groundwater use

Groundwater Use							
GRDM Mm ³ /a	WARMS Mm ³ /a	Hydrocensus Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Forrest Mm ³ /a	Crops Mm ³ /a	TOTAL Mm ³ /a
0.190	0.095	0.812	0.095	3.247	28.793	0.938	29.609

1.1.15 Groundwater quality

The TDS values for the RU are shown in Figure 30. They are classified according to SABS standards. Not all boreholes have quality data available but those that do can be used to identify possible hot spots with regard to quality in the resource unit. The overall quality of the resource unit is well within the drinking water guidelines.

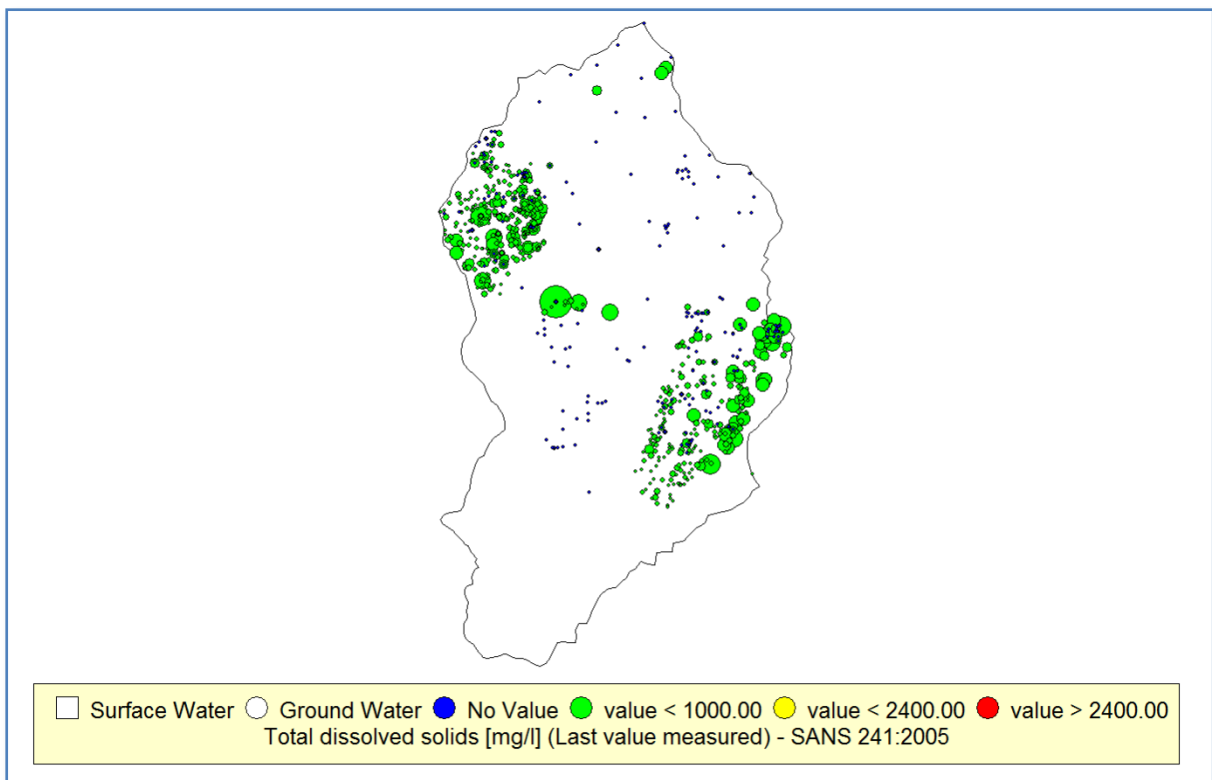


Figure 30: TDS values

1.1.16 Aquifer vulnerability

The aquifer vulnerability calculations are summarised in Table 28. The slope histogram is documented in Appendix B.

Table 28: Aquifer vulnerability

Aquifer Vulnerability						
Level mbgl	Recharge %	Slope %	Soil Texture	Aquifer Type	Vadose Zone	Vulnerability %
4.2	6.8%	4.2	SaClLm-SaCl	Weathered/Fractured	Karoo(southern)	59%

7.12 Classification

1.1.17 Groundwater usage

The stress index, defined as the ratio between total groundwater use and recharge, for the study area is calculated at 70%. Due to the uncertainty associated with the groundwater use component, the stress index was stochastically modelled through assigning a normal distribution curve with a standard deviation of 2.961 Mm³/a to the groundwater use estimate to account for the associated uncertainty. The stochastic results are shown in Figure 31. It is clear from the results that the stress index will vary between 60% and 80%, with a certainty of 97.49%. Due to the large variability in the range obtained, it is recommended that the uncertainty in the groundwater use be reduced by detailed studies focusing on groundwater use within the RU. Due to the relatively high stress index, this RU should be flagged as an area for further investigation.

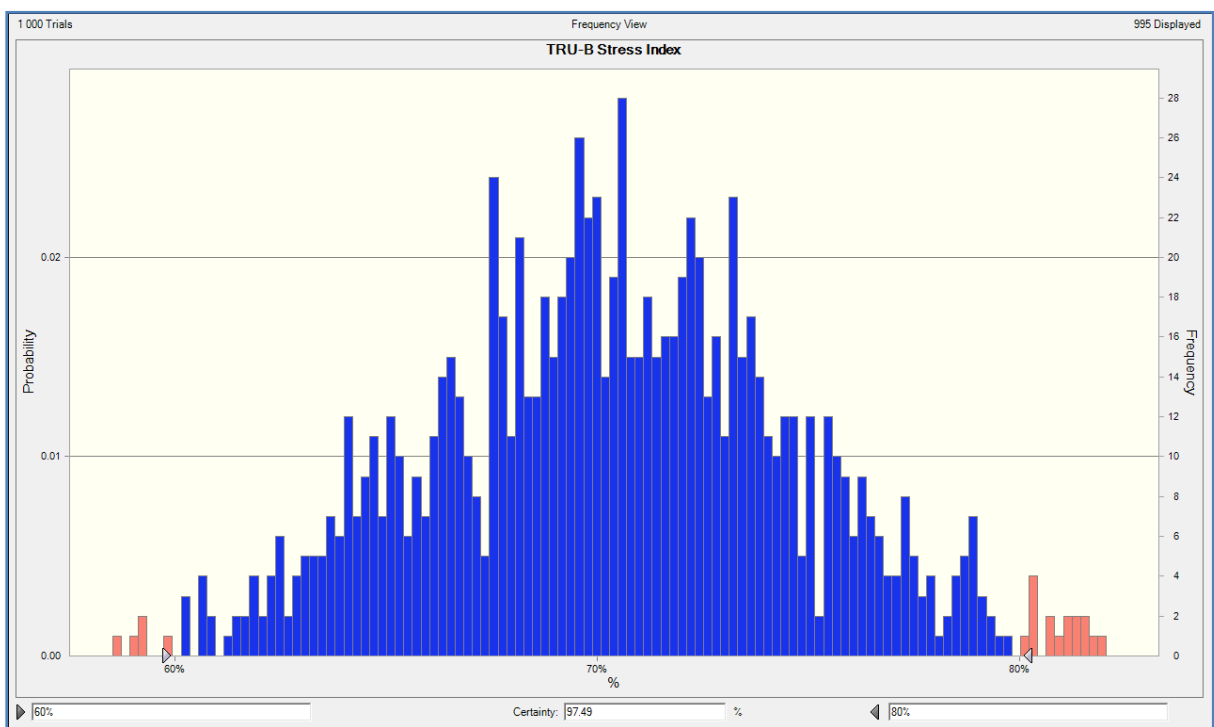


Figure 31: Stochastic results

1.1.18 Quality

The expanded Durov diagram with the groundwater quality is shown in Figure 32. An explanation of the classification process by means of the expanded Durov diagram is given in Section 2.3. Groundwater values fall into the A and C categories on diagram; however, because none of the water qualities exceeds the drinking water guidelines, the final category was set at A/B.

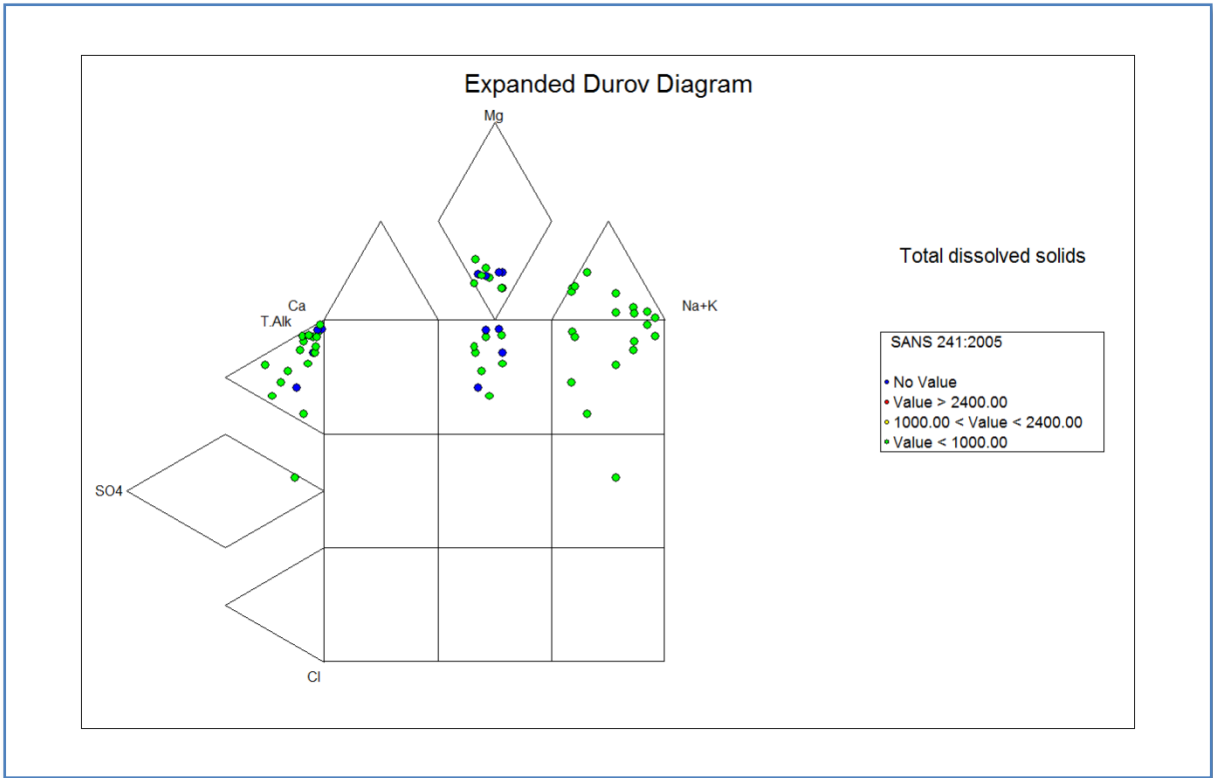


Figure 32: Expanded Durov diagram for RU

As documented in Section 7.11.6, the vulnerability is 59%. The impact of potential contamination according to Section 2.3 is moderate, due to the large amount of irrigation within the RU.

1.1.19 Final category

The final category for the RU is summarised in Table 29.

Table 29: Category for RU

Impact	Present status category	Water resource category
Groundwater usage	E	Poor
Groundwater contamination	A/B	Good
Potential groundwater contamination (vulnerability and impact)	B/C	Good/Fair
FINAL	C	Fair

7.13 Quantification of the Reserve

The groundwater Reserve for the RU is summarised in Table 30.

Table 30: Reserve

Reserve			Allocation	
Baseflow Mm ³ /a	BHN Mm ³ /a	Reserve % Recharge	Allocation Mm ³ /a	Current Use Mm ³ /a
19.210	0.122	28%	20.656	29.609

8. Classification and the Reserve for Resource Unit C

8.1 Location

There are no towns in this RU. However, there are many rural villages, especially around the Woodstock Dam. The quaternary catchments forming this RU are V11C and V11D. The location of the RU is shown in Figure 33.

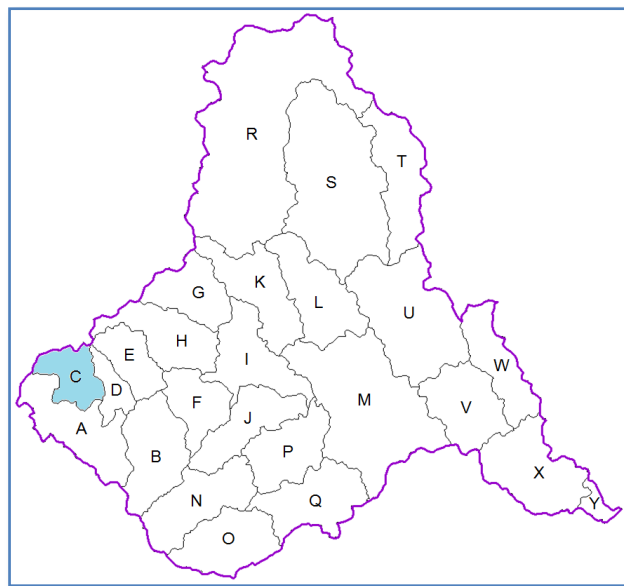


Figure 33: Location of RUC

8.2 Climate

Precipitation is often in the form of thunderstorms. The annual precipitation is between 900 and 1000 mm on the escarpment, with precipitation between November and March. The mean annual temperature of the area is about 16°C, but both seasonal and diurnal variations are considerable. The highest temperatures (up to 35°C) occur during summer on the north-facing slopes at lower latitudes, while the lowest temperatures (down to about -20°C) occur during winter nights on the summit plateau.

Frost is common in winter, with about 180 days between mid-April and October at higher elevations, but the local topography controls its distribution and intensity. It also occurs lower down when cold air from the high plateaus drains into lower-lying valleys.

8.3 Flora and Fauna

The vegetation reflects the effects of climate, fire, and the variety of the topography, elevation, geology, soils, slopes and drainage. It is largely grassland and occurs in three main belts: the river

valleys, the spurs and the summit plateau, which is an island of Afro-alpine flora. There is also thicket and bushland. The fauna includes a total of 48 mammals, 299 birds, 48 reptiles, 26 amphibians and 8 species of fish. Large populations of several antelopes are present and include the endemic grey rhebok, reedbuck and eland.

Seven species of fish have been recorded, including two introduced alien species of salmonidae and the rare endemic Drakensberg minnow *Oreodaimon zuathlambae*. The area contains 26 species and subspecies of frogs. There are 23 lizard and 25 species of snakes.

The invertebrate fauna of the area is less well known, but includes many species endemic to the region. These include for example 21 species of millipedes, and 32 species of craneflies. Of the 156 South African species of dragonflies, 44 have been found in the area, one being endemic, and 74 butterfly species, which is 11.7% of the butterflies found in the country.

8.4 Cultural Importance

The Drakensberg region ranks as one of the most important archaeological areas in South Africa. Archaeological sites from the Early, Middle and Late Stone Ages and the Late Iron Age are present, indicating that this region may have been occupied by man over the last million years. The first evidence of human occupation of the area dates from the Middle Stone Age, 20000 years ago, but it was the Late Stone Age San people who inhabited the area from about 8000 years ago. These Bushmen were hunter-gatherers, and often lived in caves and rock shelters, now adorned with thousands of rock paintings dating from 2 - 3000 years ago up to the 19th century, when they were added to by Bantu settlers.

8.5 Demography and Landcover

The number of people living in the catchment is estimated at 65600 (2001 census data). The upper areas are located in a nature reserve with the implication that development in this area is unlikely. The area has dryland, irrigation and live stock farming. The landcover for the RU is shown in Figure 34.

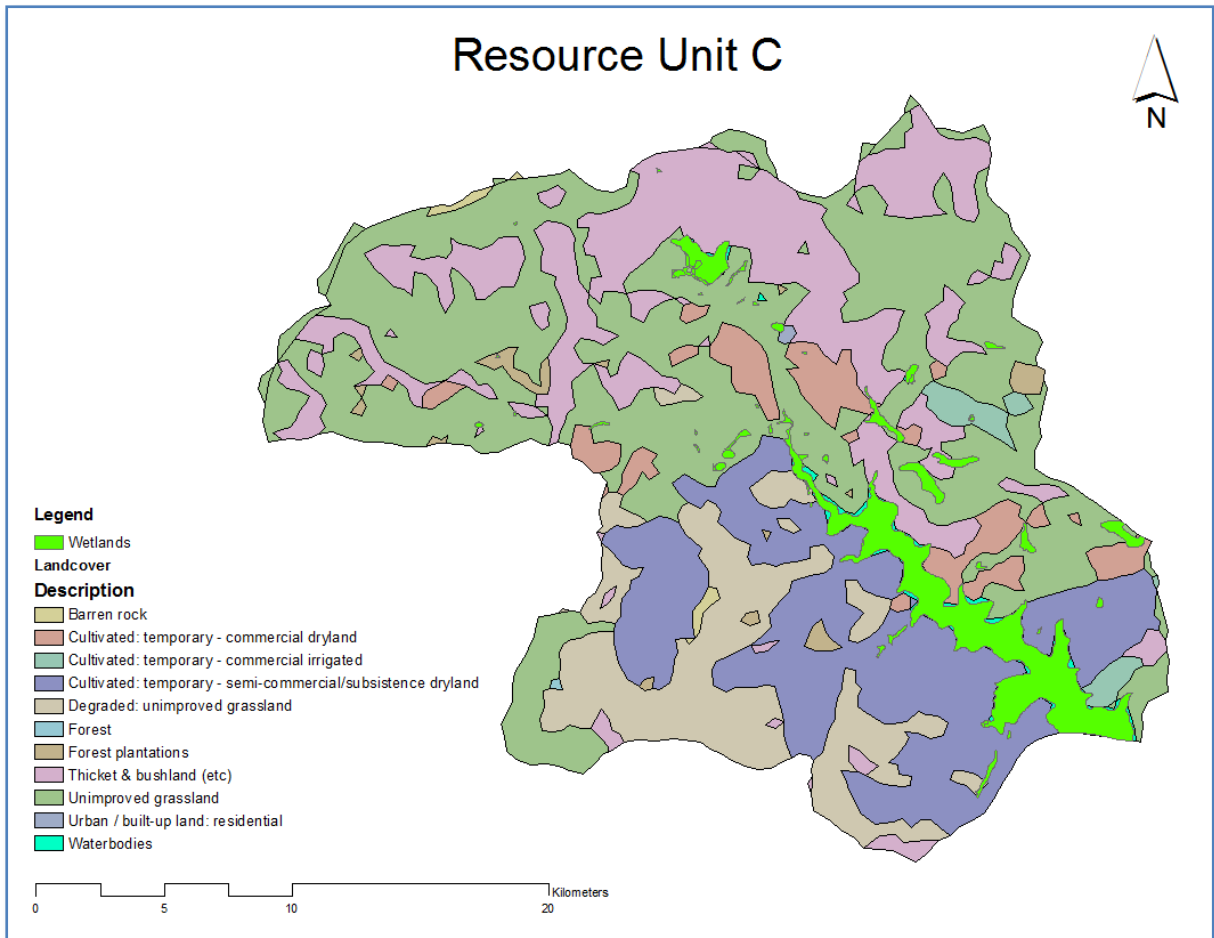


Figure 34: Landcover with RUC

8.6 Surface Water

The Putterill and Mpandweni Rivers are tributaries to the Thukela River. There are two dams in the area namely, the Kilburn Dam and the Woodstock Dam. Both these dams play a role in the Tugela-Vaal water transfer scheme. The naturally good water quality in area is threatened by large-scale farming activities, with agro-chemicals and fertilisers as diffuse sources of pollution.

8.7 Wetlands

There are large wetlands within the RU, as shown in Figure 34.

8.8 Soils

The channel substrate at high altitudes (generally > 1850 m) consists of basalt bedrock and boulders, while at lower altitudes, sandstone bedrock and boulders dominate. In the lowest parts of the study, sand and silt substrates become evident. Although mineral soils are more common, some of the wetland areas, particularly those on south-facing slopes and at higher altitudes, have organic soils (which tend to have a minerotrophic water supply). The soils are threatened by erosion.

8.9 Geology (summarised from Woodford and Chevallier, 2002)

Geologically, the Drakensberg is a remnant of the original African plateau. The mountains are capped by a layer of basalt up to 1500 m thick, with sandstone lower down, resulting in a combination of steep-sided blocks and pinnacles.

The Beaufort Group dominates in this RU, and is stratigraphically divided into two major units, the upper Tarkastad Subgroup and the lower Adelaide Subgroup. The Tarkastad Subgroup is subdivided into the upper Burgersdorp Formation, with brightly coloured red, blue and green mudstones and the lower Katberg Formation that can be up to 900 m thick. The Katberg Formation also contains brightly coloured shales and mudstones, but mainly consists of thick layers of coarse-grained sandstone. The Adelaide Subgroup mainly consists of green, bluish, grey and red mudstones and fine-grained sandstones that form thick lens-shaped units. The central basin mainly consists of mudstones, shales and fine-grained sandstones. These fine-grained sediments were mainly deposited where the braided rivers began to meander. The sedimentary units in the Group therefore usually have very low primary hydraulic conductivities. Since the Beaufort Group was also deposited in a fluvial environment, one can expect that aquifers in these formations will, like those in the Ecca Group, be anisotropic. The geometry of these aquifers, however, is further complicated by the migration of the braided and meandering streams. Aquifers in the Beaufort Group will therefore not only be multi-layered, but also multi-porous, with variable thicknesses. The contact plane between two different sedimentary layers will cause a discontinuity in the hydraulic properties of an aquifer. The lifespan of a high-yielding borehole in the Beaufort Group may therefore be limited if the aquifer is not recharged frequently. Caves are frequent in the sandstone, and many contain rock paintings by the Bushmen.

8.10 Geohydrology

1.1.20 Groundwater levels

It is clear the groundwater levels follow the topography as seen from Figure A1 in Appendix A, and therefore groundwater contour maps were generated using Bayesian interpolation. The groundwater levels for the study area are shown in Figure 35. The most probable depth to groundwater level in the RU is 2.2 mbgl, according to the histogram of water levels in the RU shown in Appendix A. Groundwater levels are expected to be lower than normal due to the prevailing drought conditions. Unfortunately very little time series water level data are available to quantify the overall impact.

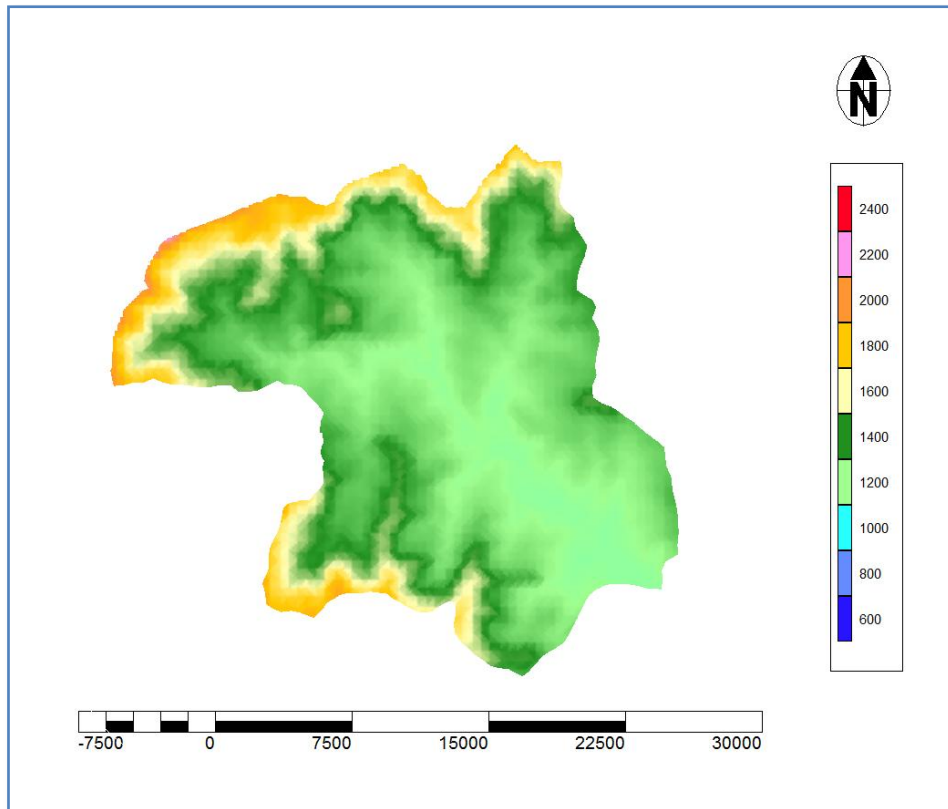


Figure 35: Groundwater levels in RUC

8.10.1 Groundwater recharge

The groundwater recharge calculated from the different methods is listed in Table 31. The different recharge methods applied are discussed in Section 2.3. The final recharge values for the RU are highlighted in red.

Table 31: Recharge values

Recharge							
MAP Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Volume Mm ³ /a	Calculated %	CMB %	Land Cover %	Geology %
499.706	33.658	59.335	44.273	8.9%	8.9%	0.7%	2.5%

1.1.21 Basic human needs

The method for determining BHNs is discussed in Section 2.3. The final value for the study area is highlighted in red in Table 32.

Table 32: Basic human needs

Basic Human Need		
Census(2001) Adjusted	Dependence 18%	Estimate Mm ³ /a
80443	14480	0.130

1.1.22 Groundwater contribution to baseflow

The baseflow separation curves for the RU are shown in Figures 36 & 37.

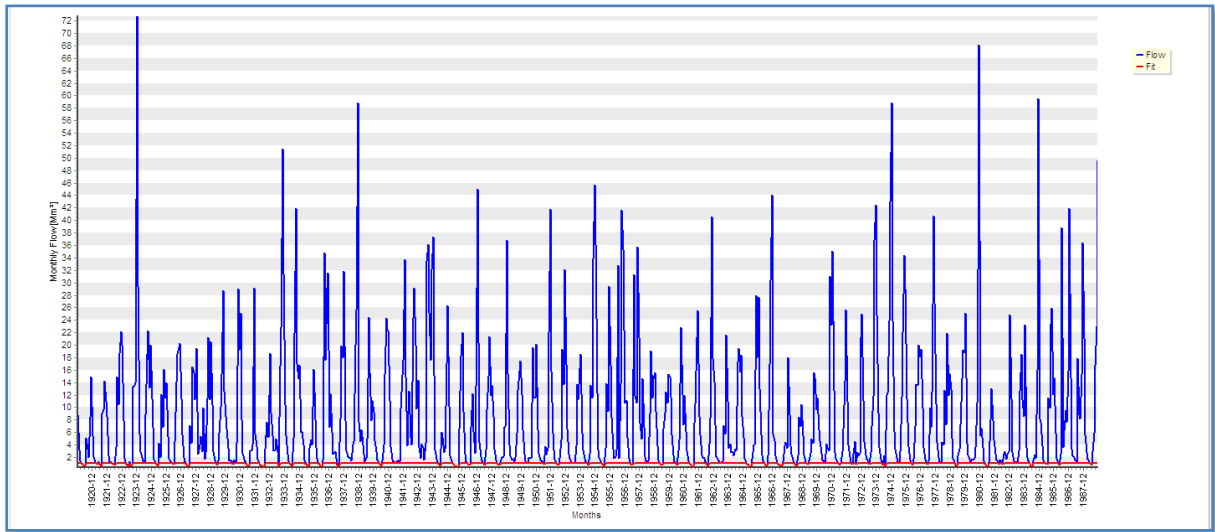


Figure 36: Baseflow separation for quaternary catchment V11C

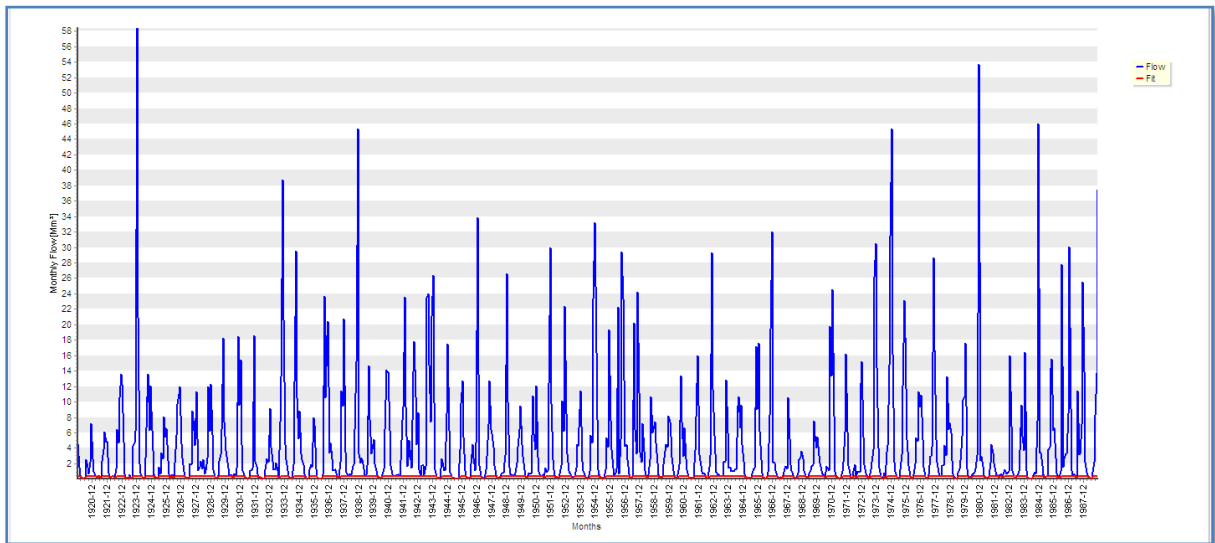


Figure 37: Baseflow separation for quaternary catchment V11D

The final groundwater contribution to baseflow values for the RU in Table 33 is highlighted in red.

Table 33: Groundwater contribution to baseflow

Groundwater Contribution to Baseflow							
GRDM Mm ³ /a	Hughes Mm ³ /a	Shultz Mm ³ /a	Pitman Mm ³ /a	vTonder Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Herold Mm ³ /a
10.234	58.169	32.031	11.218	25.981	10.234	58.169	15.890

1.1.23 Groundwater use

The groundwater use for the RU is listed in Table 34.

Table 34: Groundwater use

Groundwater Use							
GRDM Mm ³ /a	WARMS Mm ³ /a	Hydrocensus Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Forrest Mm ³ /a	Crops Mm ³ /a	TOTAL Mm ³ /a
0.220	0.000	0.085	0.000	0.339	13.238	0.000	13.107

1.1.24 Groundwater quality

The TDS values for the RU are shown in Figure 38. They are classified according to SABS standards. Not all boreholes have quality data available but those that do can be used to identify possible hot spots with regard to quality in the resource unit. The overall quality of the resource unit is well within the drinking water guidelines with the exception of two boreholes. These areas should be treated as hot spots rather than applying a poor classification to the whole resource unit. Treatment of the hotspot areas will be addressed under Resource Quality Objectives in Section 31.

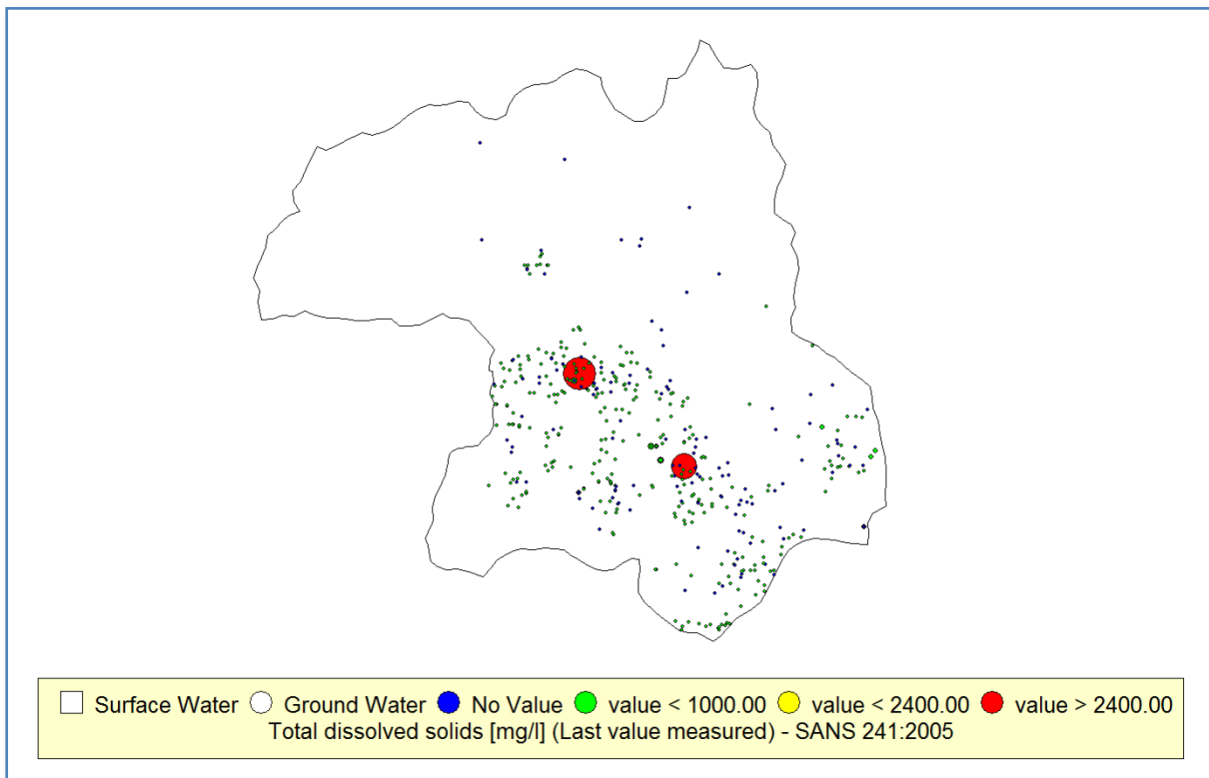


Figure 38: TDS values

1.1.25 Aquifer vulnerability

The aquifer vulnerability calculations are summarised in Table 35. The slope histogram is documented in Appendix B.

Table 35: Aquifer vulnerability

Aquifer Vulnerability						
Level mbgl	Recharge %	Slope %	Soil Texture	Aquifer Type	Vadose Zone	Vulnerability %
2.2	8.9%	1.8	SaCl	Weathered/Fractured	Karoo(southern)	66%

8.11 Classification

1.1.26 Groundwater usage

The stress index, defined as the ratio between total groundwater use and recharge, for the study area is calculated at 66%. Due to the uncertainty associated with the groundwater use component, the stress index was stochastically modelled through assigning a normal distribution curve with a standard deviation of 1.311 Mm³/a to the groundwater use estimate to account for the associated uncertainty. The stochastic results are shown in Figure 39. It is clear from the results that the stress index will vary between 57% and 73% with a certainty of 99.03%. Due to the large variability in the range obtained, it is recommended that the uncertainty in the groundwater use be reduced by detailed studies focusing on groundwater use within the RU. Due to the relatively high stress index this RU should be flagged as an area further investigation.

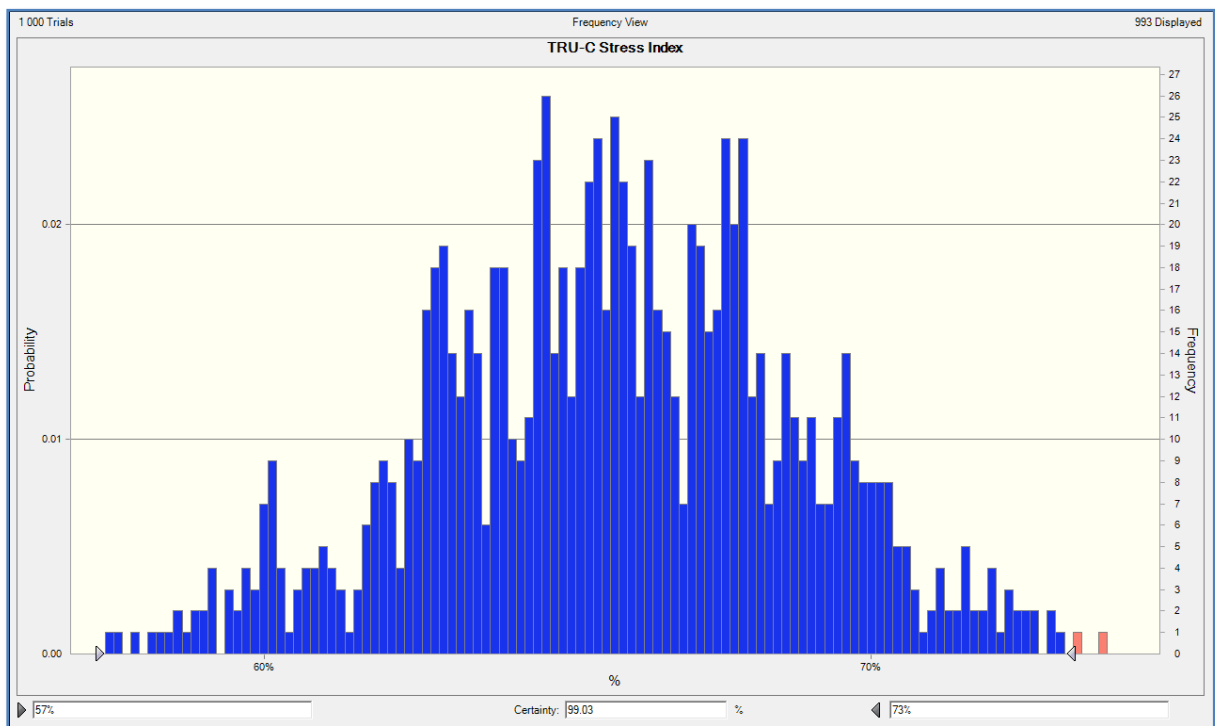


Figure 39: Stochastic results

1.1.27 Quality

The expanded Durov diagram with groundwater quality is shown in Figure 40. An explanation of the classification process by means of the expanded Durov diagram is given in Section 2.3. Groundwater

falls into the A and C categories, however, the majority falls under A. Therefore it was decided to set the category to A/B.

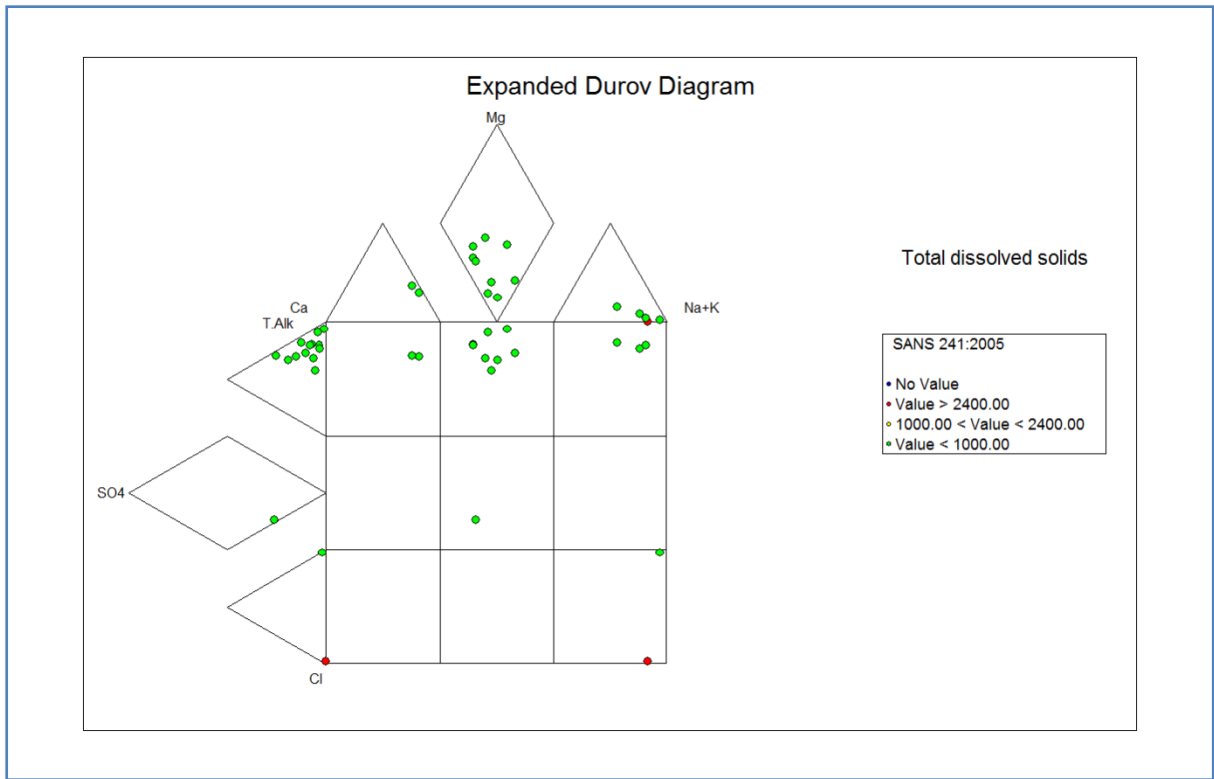


Figure 40: Expanded Durov diagram for RU

As documented the vulnerability is 66%. The impact of potential contamination, according to Section 2.3, is low.

1.1.28 Final category

The final category for the RU is summarised in Table 36.

Table 36: Category for RU

Impact	Present status category	Water resource category
Groundwater usage	E	Poor
Groundwater contamination	A/B	Natural/Good
Potential groundwater contamination (vulnerability and impact)	B	Good
FINAL	C	Fair

8.12 Quantification of the Reserve

The groundwater Reserve for the RU is summarised in Table 37.

Table 37: Reserve

Reserve			Allocation	
Baseflow Mm ³ /a	BHN Mm ³ /a	Reserve % Recharge	Allocation Mm ³ /a	Current Use Mm ³ /a
15.890	0.130	36%	15.145	13.107

9. Classification and the Reserve for Resource Unit D

9.1 Location

Bergville is the only town within this RU. Bergville is a small town situated in the foothills of the Drakensberg mountains, KwaZulu-Natal, South Africa. It was established as Bergville Mountain Village in 1897 and is now the commercial centre for a 2500 km² dairy and cattle farming area. The quaternary catchments falling into this RU are: V11F and V11J. The location of the RU is shown in Figure 41.

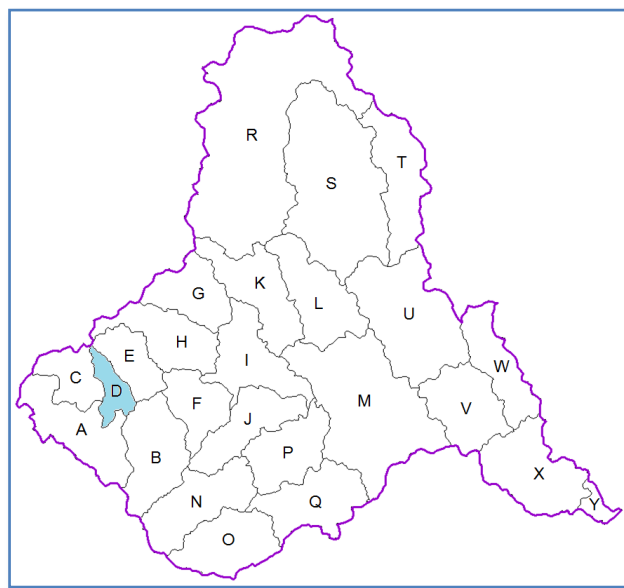


Figure 41: Location of RUD

9.2 Climate

The average mean annual precipitation for the RU is approximately 830 mm/a. Bergville normally receives about 643 mm of rain per year, with most rainfall occurring during mid-summer. It receives the lowest rainfall (2 mm) in July and the highest (129 mm) in January. The monthly distribution of average daily maximum temperatures shows that the average midday temperatures for Bergville range from 19.3°C in June to 27.9°C in January. The region is the coldest during July, when the mercury drops to 2.1°C on average during the night.

9.3 Vegetation (taken from www.deat.gov.za)

This is an open savanna, with scattered trees of Paperbark Thorn *Acacia sieberiana*, Sweet Thorn *A. karroo*, Scented Thorn *A. nilotica* and *A. caffra*. The herbaceous layer is quite variable, with secondary grassland, dominated by patches of tall Common Thatchgrass *Hyparrhenia hirta*, and sour

grassland, dominated by Hairy Tridentgrass *Tristachya leucothrix*. Thicket and bushland are also present.

Where this vegetation type occurs on highly erodible, shallow duplex soils, grazing and fire require careful management. This highly transformed vegetation type is very poorly conserved.

9.4 Demography and Landcover

The population is estimated at 16600 (2001 census data). Land use includes cultivated dryland, irrigation farming, and cattle (including dairy) farming. The landcover for the RU is shown in Figure 42.

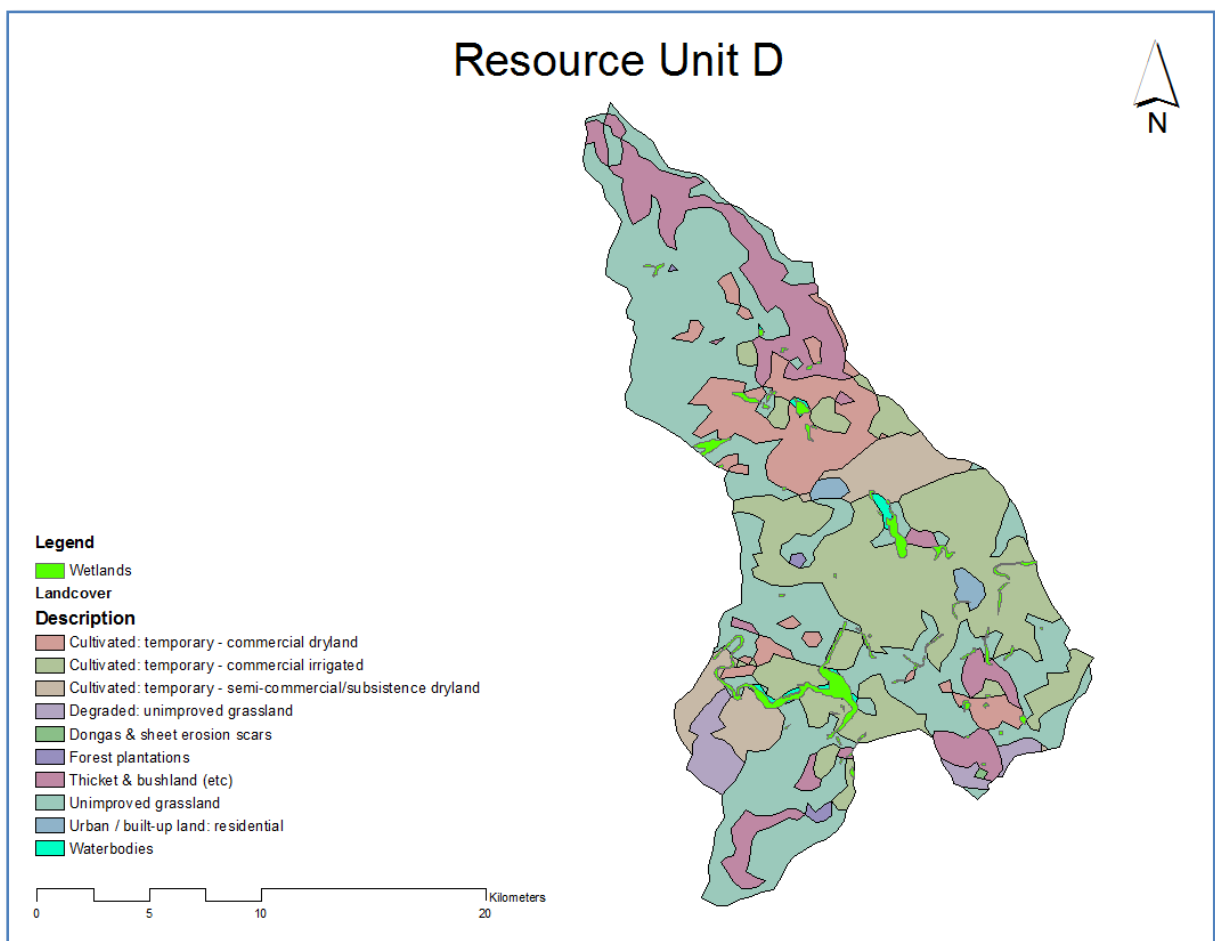


Figure 42: Landcover within the study area

9.5 Surface Water

The main tributary to the Thukela in this area includes the Sandspruit. The Samrock Dam is located in catchment V11F and the Driel Barrage is located in catchment V11J.

9.6 Wetlands

A number of the wetlands within the RU are associated with the rivers flowing through the area, as shown in Figure 42.

9.7 Soils (taken from www.deat.gov.za)

The soil is shallow, derived from shales and mudstones of the Ecca Group of the Karoo Sequence. The area is characterised by subsoils, which are either duplex, which renders them potentially highly erodible, or dominated by black clays.

9.8 Geology (summarised from Woodford and Chevallier, 2002)

The Lesotho (Drakensberg) Formation was formed when the deposition of the Karoo Basin sediments ended with the outpouring and covering of basaltic lava. The basalt formation is termed as Lesotho Formation on the 1981 maps issued by the Lesotho Department of Mining and Geology. This basalt is also called the Drakensberg Formation by the South African Committee on Stratigraphy (S.A.C.S), 1980.

The Beaufort Group dominates in this RU, and is stratigraphically divided into two major units, the upper Tarkastad Subgroup and the lower Adelaide Subgroup. The Tarkastad Subgroup is subdivided into the upper Burgersdorp Formation with its brightly coloured red, blue and green mudstones and the lower Katberg Formation, which can be up to 900 m thick. The Katberg Formation also contains brightly coloured shales and mudstones, but mainly consists of thick layers of coarse-grained sandstone. The Adelaide Subgroup mainly consists of green, bluish, grey and red mudstones and fine-grained sandstones that form thick lens-shaped units. The central basin mainly consists of mudstones, shales and fine-grained sandstones. These fine-grained sediments were mainly deposited where the braided rivers began to meander. The sedimentary units in the Group therefore usually have very low primary hydraulic conductivities. Since the Beaufort Group was also deposited in a fluvial environment, aquifers in these formations, like those in the Ecca Group, can be expected to be anisotropic. The geometry of these aquifers, however, is further complicated by the migration of the braided and meandering streams. Aquifers in the Beaufort Group will therefore not only be multi-layered, but also multi-porous with variable thicknesses. The contact plane between two different sedimentary layers will cause a discontinuity in the hydraulic properties of an aquifer. The lifespan of a high-yielding borehole in the Beaufort Group may therefore be limited if the aquifer is not recharged frequently.

Dolerite dykes are believed to be feeders of the basalt flows. The numerous dykes crisscross the Karoo Basin, cut through the sedimentary rocks and die out at various levels within the basalt flows. Basalt has been extruded flow upon flow to a thickness of at least 1450 m. The huge aerial extent of individual flows shows that the flood basalts were highly mobile.

9.9 Geohydrology

1.1.29 Groundwater levels

It is clear the groundwater levels follow the topography, as seen from Figure A1 in Appendix A and therefore groundwater contour maps were generated using Bayesian interpolation. The groundwater levels for the study area are shown in Figure 43. The most probable depth to groundwater level in the RU is 1.6 mbgl, according to the histogram of water levels in the RU in Appendix A. Groundwater levels are expected to be lower than normal due to the prevailing drought conditions. Unfortunately, very little time series water level data was available to quantify the overall impact.

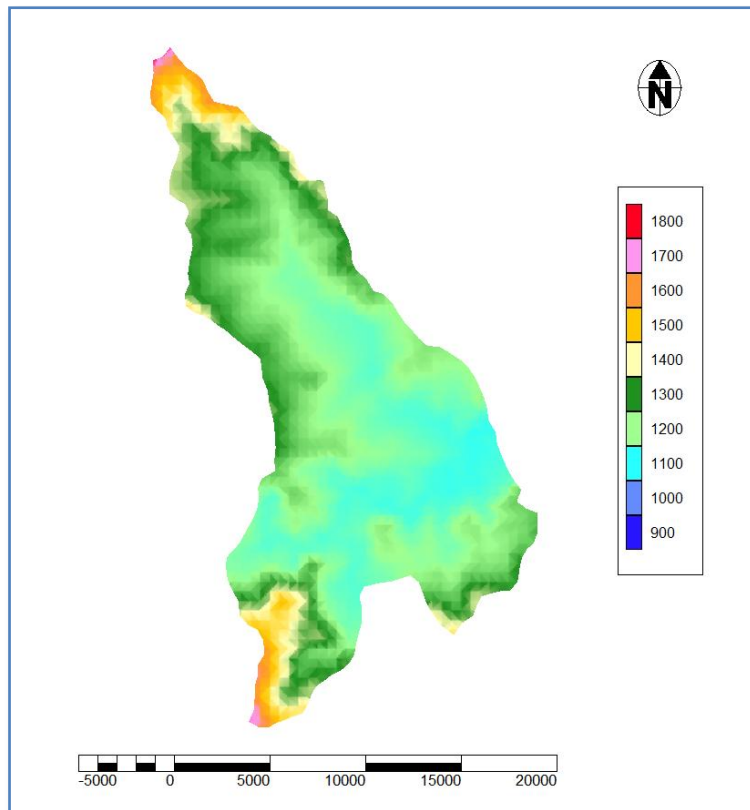


Figure 43: Groundwater levels in RUD

9.9.1 Groundwater recharge

The groundwater recharge calculated from the different methods is listed in Table 38. The different recharge methods applied are discussed in Section 2.3. The final recharge values for the RU are highlighted in red.

Table 38: Recharge values

Recharge							
MAP Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Volume Mm ³ /a	Calculated %	CMB %	Land Cover %	Geology %
251.937	14.080	24.126	15.498	6.2%	6.2%	0.5%	2.1%

1.1.30 Basic human needs

The method for determining BHNs is discussed in Section 2.3. The final value for the study area is highlighted in red in Table 39.

Table 39: Basic human needs

Basic Human Need		
Census(2001) Adjusted	Dependence 18%	Estimate Mm ³ /a
19136	3444	0.031

1.1.31 Groundwater contribution to baseflow

The baseflow separation curves for the RU are shown in Figures 44 & 45.

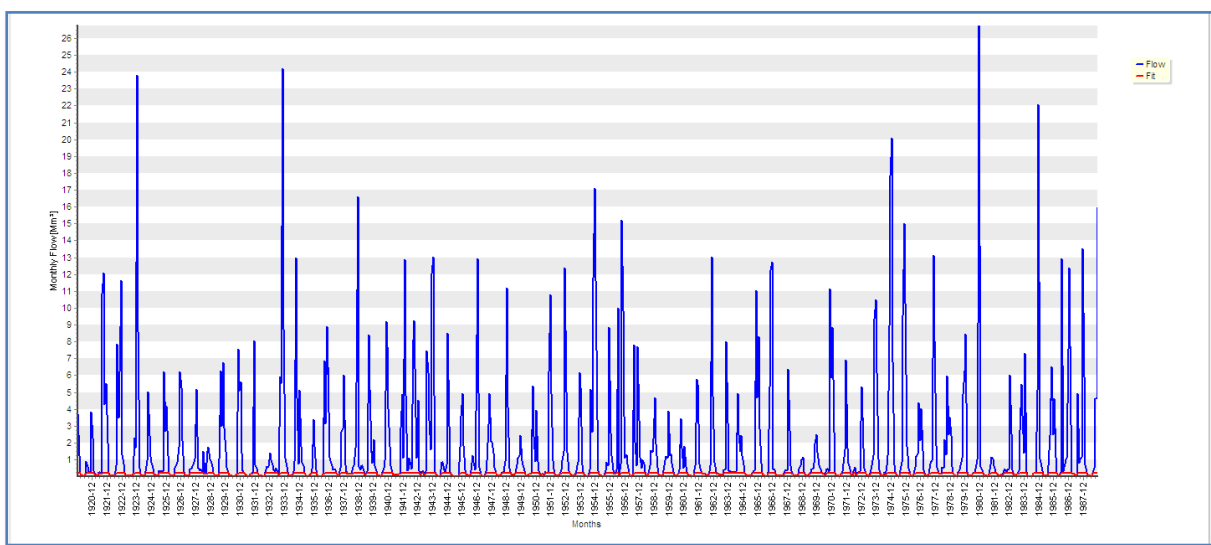


Figure 44: Baseflow separation for quaternary catchment V11F

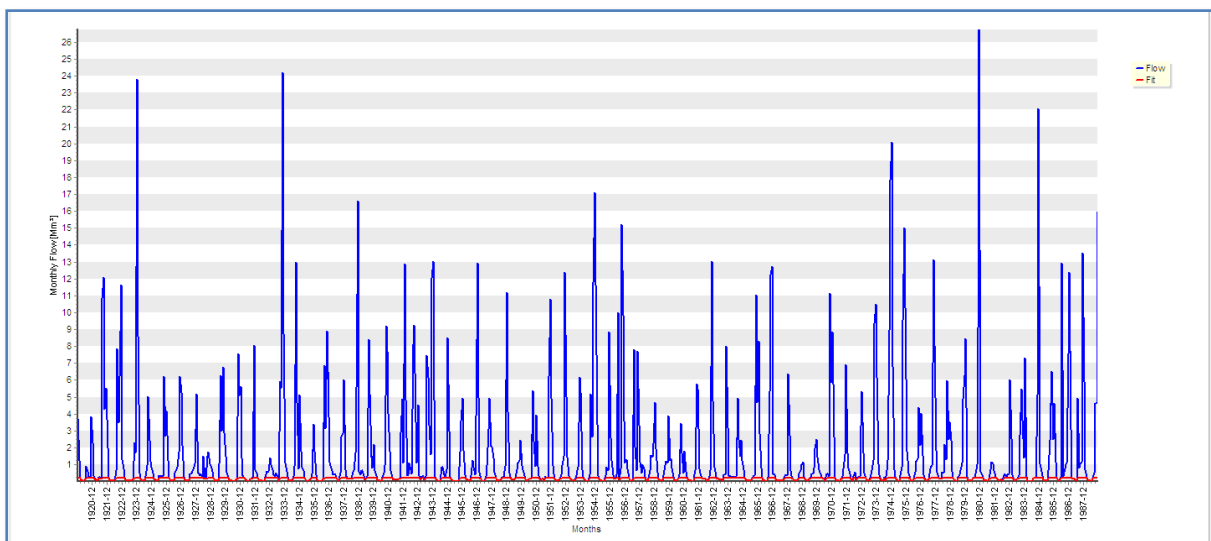


Figure 45: Baseflow separation for quaternary catchment V11J

The final groundwater contribution to baseflow values for the RU in Table 40 is highlighted in red.

Table 40: Groundwater contribution to baseflow

Groundwater Contribution to Baseflow							
GRDM Mm ³ /a	Hughes Mm ³ /a	Shultz Mm ³ /a	Pitman Mm ³ /a	vTonder Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Herold Mm ³ /a
2.595	15.393	7.243	1.952	5.956	1.952	15.393	4.070

1.1.32 Groundwater use

The groundwater use for the RU is listed in Table 41.

Table 41: Groundwater use

Groundwater Use							
GRDM Mm ³ /a	WARMS Mm ³ /a	Hydrocensus Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Forrest Mm ³ /a	Crops Mm ³ /a	TOTAL Mm ³ /a
0.130	0.003	0.048	0.003	0.191	9.529	0.026	9.524

1.1.33 Groundwater quality

The TDS values for the RU are shown in Figure 46. They are classified according to SABS standards. Not all boreholes have quality data available, but those that do can be used to identify possible hot spots with regard to quality in the resource unit. The overall quality of the resource unit is well within the drinking water guidelines.

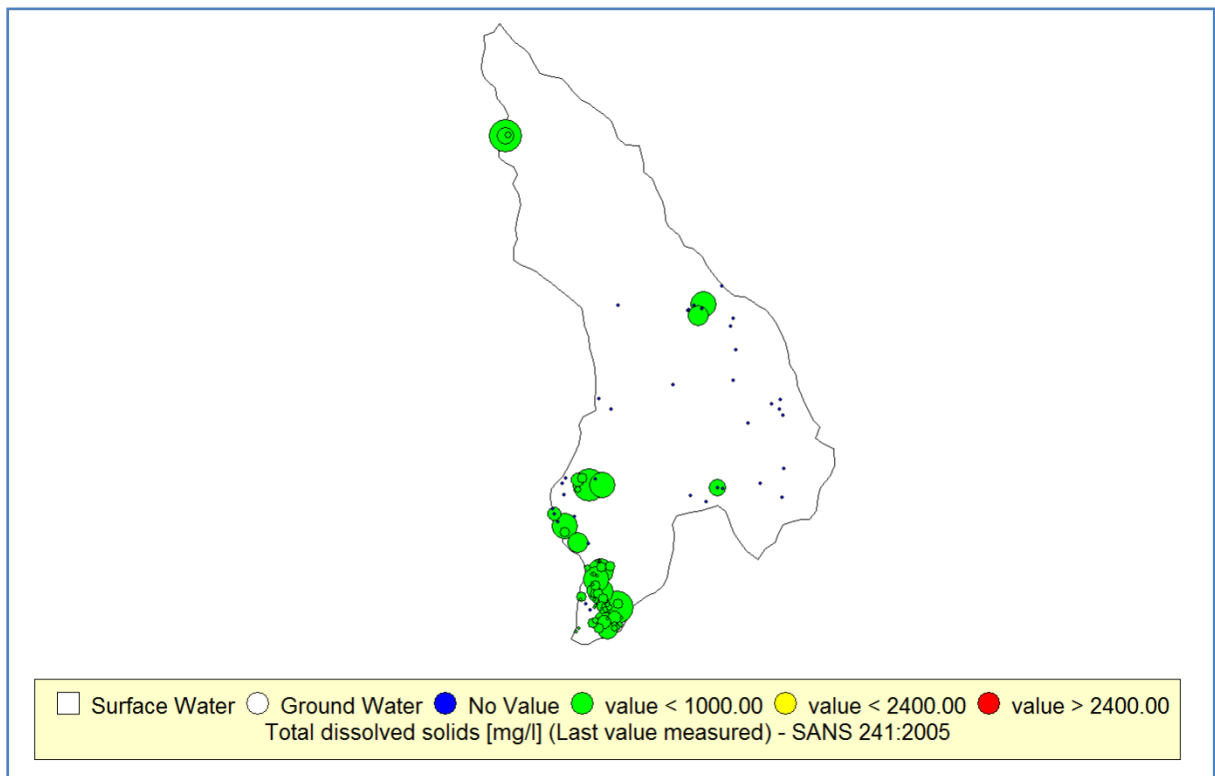


Figure 46: TDS values

1.1.34 Aquifer vulnerability

The aquifer vulnerability calculations are summarised in Table 42. The slope histogram is documented in Appendix B.

Table 42: Aquifer vulnerability

Aquifer Vulnerability						
Level mbgl	Recharge %	Slope %	Soil Texture	Aquifer Type	Vadose Zone	Vulnerability %
1.6	6.2%	3.8	SaClLm-SaCl	Weathered/Fractured	Karoo(southern)	63%

9.10 Classification

1.1.35 Groundwater usage

The stress index, defined as the ratio between total groundwater use and recharge, for the study area is calculated at 88%. Due to the uncertainty associated with the groundwater use component, the stress index was stochastically modelled through assigning a normal distribution curve with a standard deviation of 0.952Mm³/a to the groundwater use estimate to account for the associated uncertainty. The stochastic results are shown in Figure 47. Due to the large variability in the range obtained, it is recommended that the uncertainty in the groundwater use be reduced by detailed studies focusing on groundwater use within the RU. Due to the relatively high stress index, this RU should be flagged as an area for further investigation.

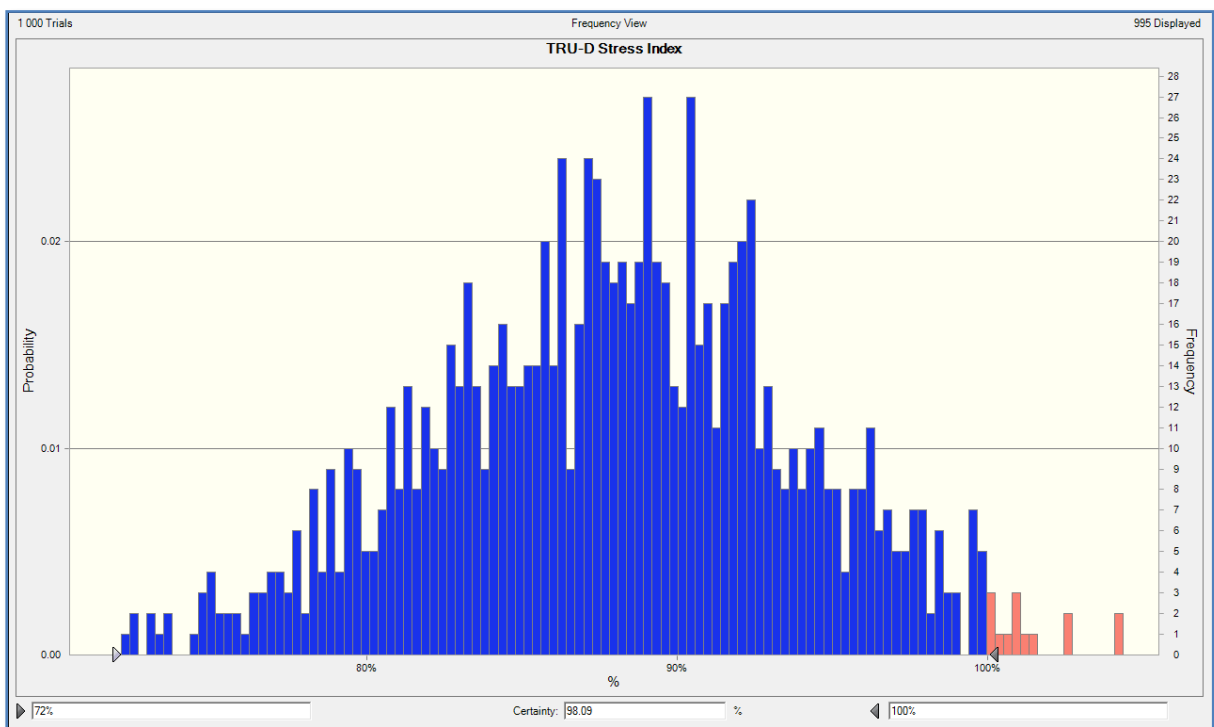


Figure 47: Stochastic results

1.1.36 Quality

The expanded Durov diagram with groundwater quality is shown in Figure 48. An explanation of the classification process by means of the expanded Durov diagram is given in Section 2.3. Very little chemistry data are available, however, with the available data it is classified as A.

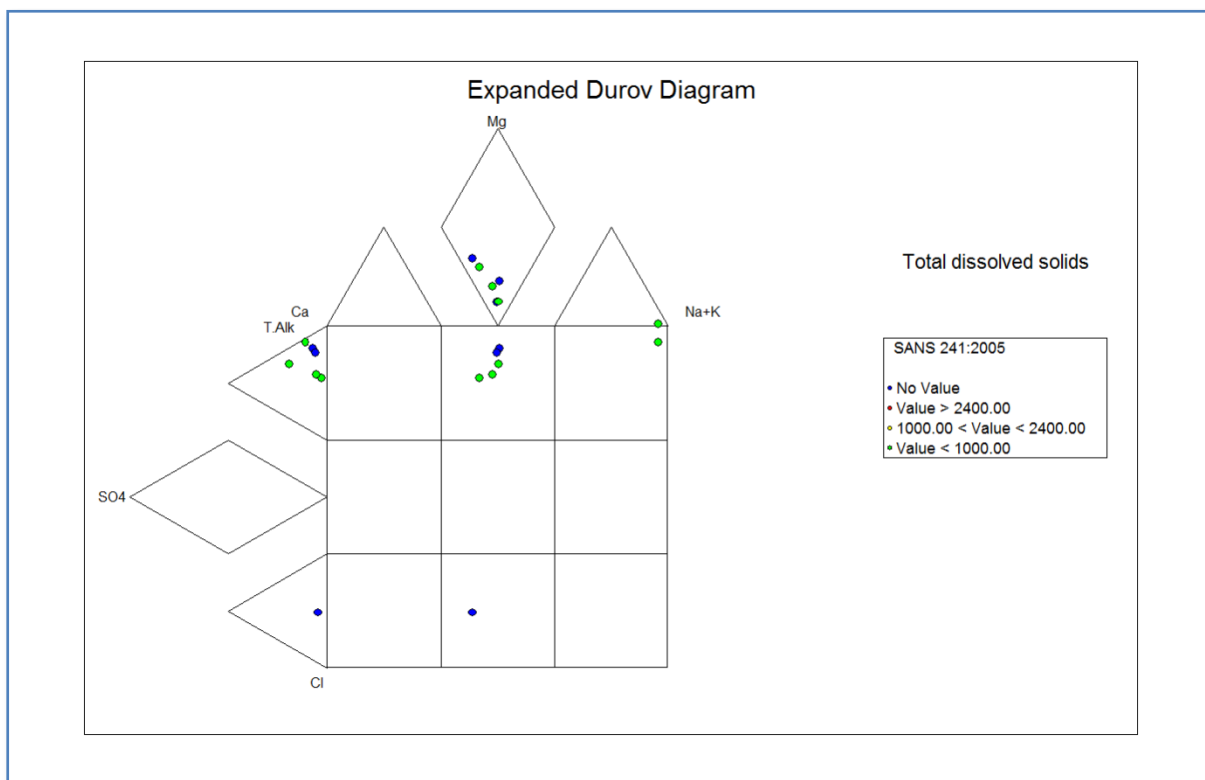


Figure 48: Expanded Durov diagram for RU

As documented the vulnerability is 63%. The impact of potential contamination according to Section 2.3 is low due to agricultural activities.

1.1.37 Final category

The final category for the RU is summarised in Table 43.

Table 43: Category for RU

Impact	Present status category	Water resource category
Groundwater usage	E	Poor
Groundwater contamination	A	Natural
Potential groundwater contamination (vulnerability and impact)	B	Good
FINAL	B/C	Good/Fair

9.11 *Quantification of the Reserve*

The groundwater Reserve for the RU is summarised in Table 44.

Table 44: Reserve

Reserve			Allocation	
Baseflow Mm ³ /a	BHN Mm ³ /a	Reserve % Recharge	Allocation Mm ³ /a	Current Use Mm ³ /a
4.070	0.031	26%	1.873	9.524

10. Classification and the Reserve for Resource Unit E

10.1 Location

The location of RUE is shown in Figure 49, and includes quaternary catchments V11K and V11L. The towns in the area include Geluksburg and Acton Homes. Geluksburg is a village in the KwaZulu Natal province in South Africa, close to the Free State border between the Oliviershoek and Van Reenen mountain passes. The protected area in this RU is the Spioenkop Dam and Nature Reserve.

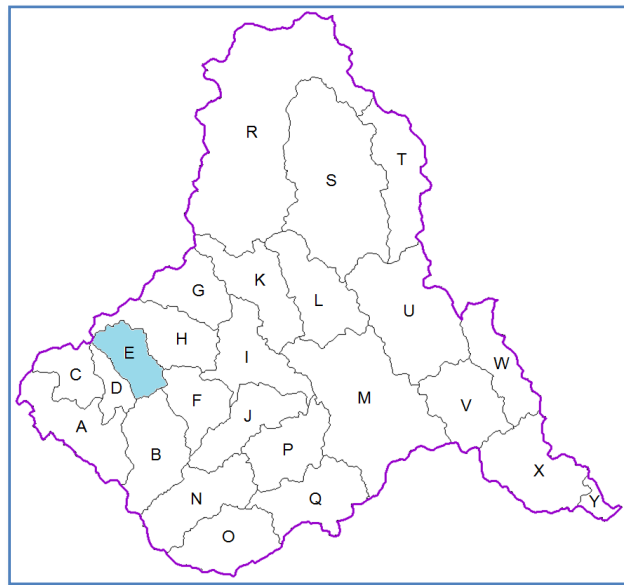


Figure 49: Location of RUE

10.2 Climate

The average mean annual precipitation for the RU varies between 800 - 1000 mm/a, with most rainfall occurring during mid-summer. The monthly distribution of average daily maximum temperatures shows that midday temperatures range from 19.3°C in June to 27.9°C in January. The region is the coldest during July, when the mercury drops to 2.1°C on average during the night.

10.3 Flora and Fauna (taken from www.deat.gov.za)

The higher-lying areas of the RU are grasslands, but a woody layer - with an average height of 3 to 5 m - may form dense thickets in places. The hot north-facing slopes are dry, poor in species, and dominated by the grasses Common Thatchgrass *Hyparrhenia hirta* and Copperwire Grass *Aristida diffusa*. On relatively moist, steep, cooler, south-facing slopes, species-rich, dense thickets with sparse undergrowth are dominated by a non-grassy herbaceous layer.

The lower-lying areas of the RU, are open savanna, with scattered trees of Paperbark Thorn *Acacia sieberiana*, Sweet Thorn *A. karroo*, Scented Thorn *A. nilotica* and *A. caffra*. The herbaceous layer is quite variable, with secondary grassland, dominated by patches of tall Common Thatchgrass *Hyparrhenia hirta*, and sour grassland, dominated by Hairy Tridentgrass *Tristachya leucothrix*.

Where this vegetation type occurs on highly erodible, shallow duplex soils, grazing and fire require careful management. This highly transformed vegetation type is very poorly conserved.

White Rhino, Giraffe, Buffalo and numerous species of antelope occur in the RU.

10.4 Demography and Landcover

The population is approximately 16000 (2001 census data). Seventy percent of the population use either pit latrines or VIPs. Eleven percent are dependent on boreholes, and 23% dependent on springs for their basic human needs. Landcover includes cultivated farming and stock farming. Forest plantations are also present. The landcover for the RU is shown in Figure 50.

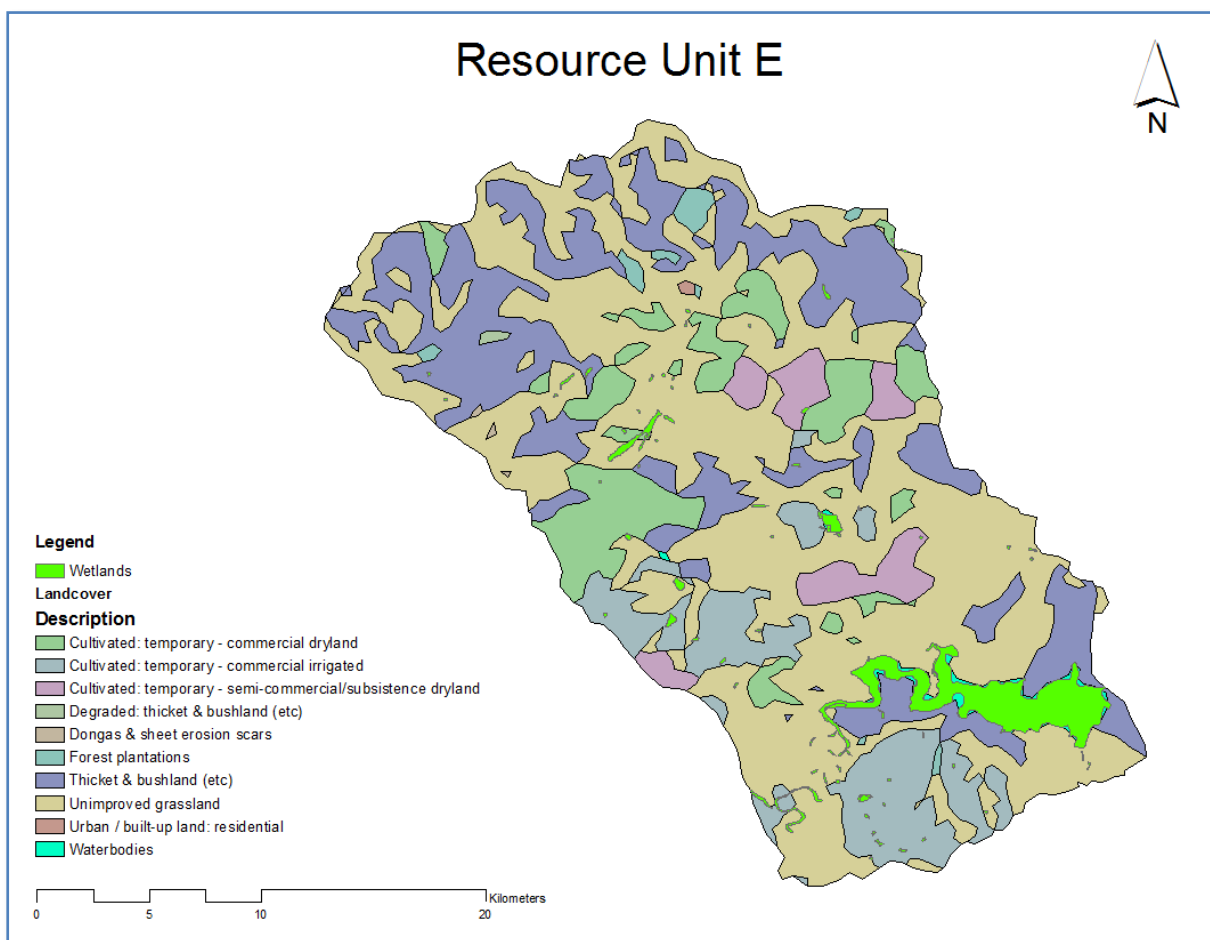
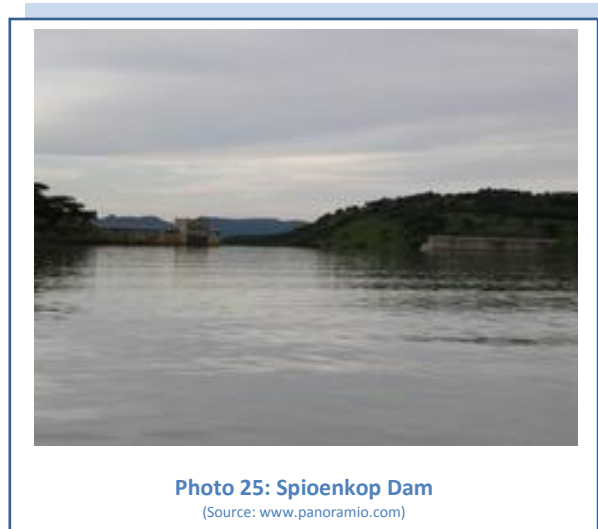


Figure 50: Landcover within the study area

10.5 Surface Water

The Njongola and Venterspruit form tributaries to the Thukela River. The Spioenkop Dam (Photo 25) falls within the RU. The Spioenkop Dam is under-utilised. There are no significant water quality problems. The rapid development of the Action Homes settlement above the Spioenkop Dam could cause eutrophication and excessive organic load problems in the dam in the future.



10.6 Wetlands

The wetlands in the study area are shown in Figure 50.

10.7 Soils (taken from www.deat.gov.za)

Soils in the higher-lying areas are typical of a mountain landscape, and include shallow lithosols, mainly representative of the Glenrosa and Mispah soil forms. Sandstones and mudstones of the Elliot and Molteno Formations (Karoo Sequence) and the Beaufort Group are predominant rock types.

In the lower lying areas the soil is shallow, derived from shales and mudstones the Karoo Sequence. The area is characterised by subsoils which are either duplex, which renders them potentially highly erodible, or dominated by black clays.

10.8 Geology (summarised from [Woodford and Chevallier, 2002](#))

The Beaufort Group dominates in this RU, and is stratigraphically divided into two major units, the upper Tarkastad Subgroup and the lower Adelaide Subgroup. The Tarkastad Subgroup is subdivided into the upper Burgersdorp Formation, with brightly coloured red, blue and green mudstones and the lower Katberg Formation, which can be up to 900 m thick. The Katberg Formation also contains brightly coloured shales and mudstones, but mainly consists of thick layers of coarse-grained sandstone. The Adelaide Subgroup mainly consists of green, bluish, grey and red mudstones and fine-grained sandstones that form thick lens-shaped units. The central basin mainly consists of

mudstones, shales and fine-grained sandstones. These fine-grained sediments were mainly deposited where the braided rivers began to meander. The sedimentary units in the Group therefore usually have very low primary hydraulic conductivities. Since the Beaufort Group was also deposited in a fluvial environment, one can expect that aquifers in these formations will, like those in the Ecca Group, be anisotropic. The geometry of these aquifers, however, is further complicated by the migration of the braided and meandering streams. Aquifers in the Beaufort Group will therefore not only be multi-layered, but also multi-porous with variable thicknesses. The contact plane between two different sedimentary layers will cause a discontinuity in the hydraulic properties of an aquifer. The lifespan of a high-yielding borehole in the Beaufort Group may therefore be limited if the aquifer is not recharged frequently.

10.9 Geohydrology

1.1.38 Groundwater levels

It is clear the groundwater levels follow the topography as seen from Figure A1 in Appendix A, and therefore groundwater contour maps were generated using Bayesian interpolation. The groundwater levels for the study area are shown in Figure 51. The most probable depth to groundwater level in the RU is 2 mbgl, according to the histogram of water levels in the RU in Appendix A. Groundwater levels are expected to be lower than normal due to the prevailing drought conditions. Unfortunately, very little time series water level data are available to quantify the overall impact.

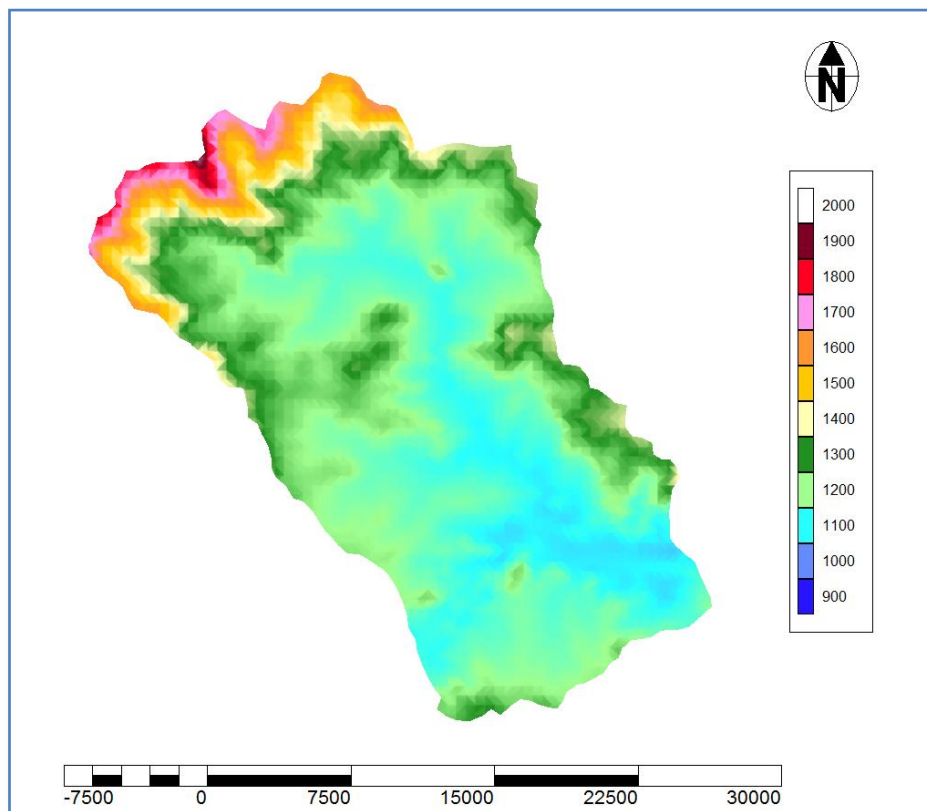


Figure 51: Groundwater levels in RUE

10.9.1 Groundwater recharge

The groundwater recharge calculated from the different methods is listed in Table 45. The different recharge methods applied are discussed in Section 2.3. The final recharge values for the RU are highlighted in red.

Table 45: Recharge values

Recharge							
MAP Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Volume Mm ³ /a	Calculated %	CMB %	Land Cover %	Geology %
455.116	27.885	36.303	25.694	5.6%	5.6%	0.7%	2.1%

1.1.39 Basic human needs

The method for determining BHNs is discussed in Section 2.3. The final value for the study area is highlighted in red in Table 46.

Table 46: Basic human needs

Basic Human Need		
Census(2001) Adjusted	Dependence 18%	Estimate Mm ³ /a
18469	3324	0.030

1.1.40 Groundwater contribution to baseflow

The baseflow separation curves for the RU are shown in Figures 52 & 53.

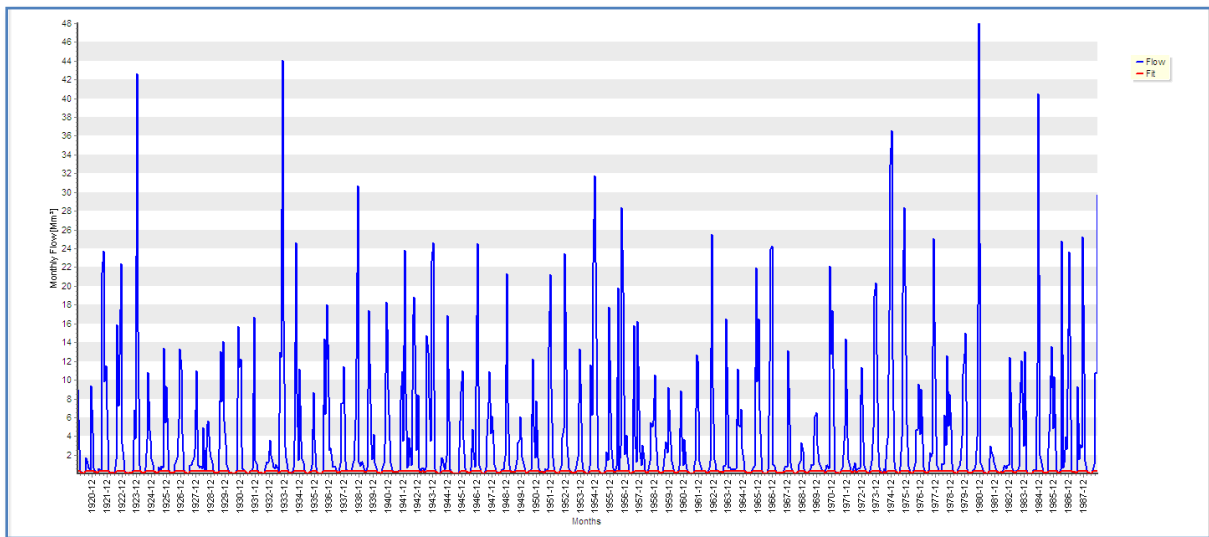


Figure 52: Baseflow separation for quaternary catchment V11K

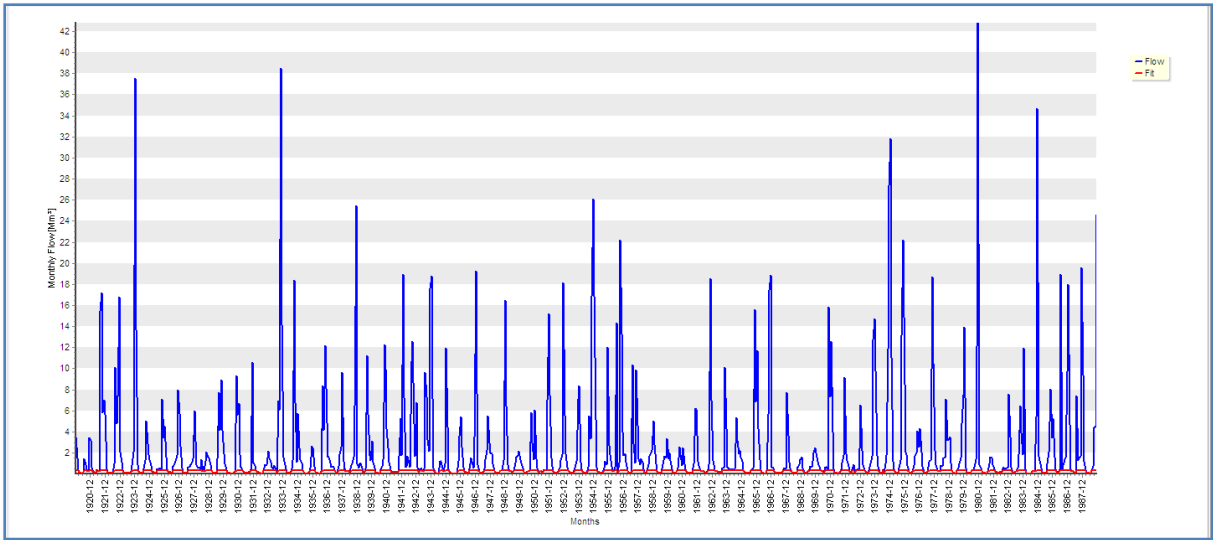


Figure 53: Baseflow separation for quaternary catchment V11L

The final groundwater contribution to baseflow values for the RU in Table 47 is highlighted in red.

Table 47: Groundwater contribution to baseflow

Groundwater Contribution to Baseflow							
GRDM Mm ³ /a	Hughes Mm ³ /a	Shultz Mm ³ /a	Pitman Mm ³ /a	vTonder Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Herold Mm ³ /a
7.788	23.776	10.677	2.441	8.742	2.441	23.776	5.960

1.1.41 Groundwater use

The groundwater use for the RU is listed in Table 48.

Table 48: Groundwater use

Groundwater Use							
GRDM Mm ³ /a	WARMS Mm ³ /a	Hydrocensus Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Forrest Mm ³ /a	Crops Mm ³ /a	TOTAL Mm ³ /a
0.190	0.035	0.314	0.035	1.256	14.310	0.992	15.272

1.1.42 Groundwater quality

The TDS values for the RU are shown in Figure 54. They are classified according to SABS standards. Not all boreholes have quality data available but those that do can be used to identify possible hot spots with regard to quality in the resource unit. The overall quality of the resource unit is well within the drinking water guidelines, with the exception of one borehole that is still allowable.

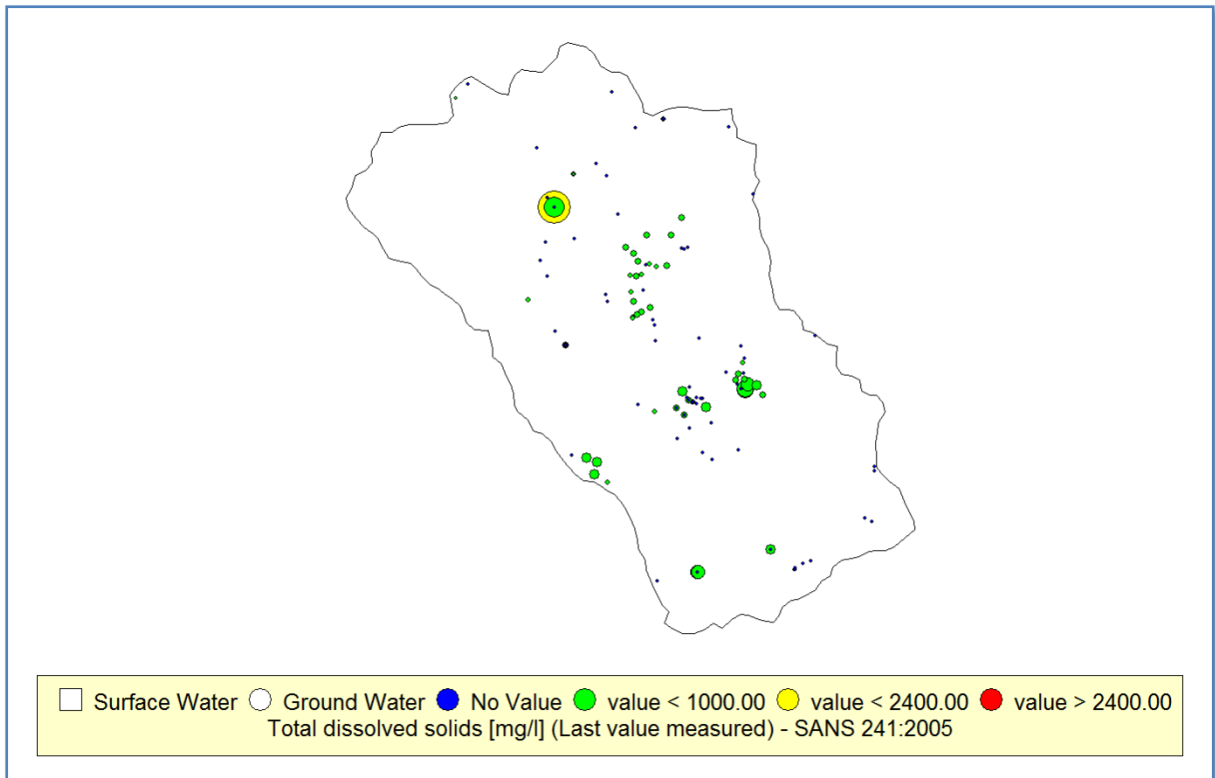


Figure 54: TDS values

1.1.43 Aquifer vulnerability

The aquifer vulnerability calculations are summarised in Table 49. The slope histogram is documented in Appendix B.

Table 49: Aquifer vulnerability

Aquifer Vulnerability						
Level mbgl	Recharge %	Slope %	Soil Texture	Aquifer Type	Vadose Zone	Vulnerability %
2.0	5.6%	0.2	SaClIm-SaCl, SaCl	Weathered/Fractured	Karoo(southern)	65%

10.10 Classification

1.1.44 Groundwater usage

The stress index, defined as the ratio between total groundwater use and recharge, for the study area is calculated at 83%. Due to the uncertainty associated with the groundwater use component, the stress index was stochastically modelled through assigning a normal distribution curve with a standard deviation of 1.527Mm³/a to the groundwater use estimate to account for the associated uncertainty. The stochastic results are shown in Figure 55. It is clear from the results that the stress index will vary between 67% and 97% with a certainty of 99.33%. Due to the large variability in the range obtained, it is recommended that the uncertainty in the groundwater use be reduced by detailed studies focusing on groundwater use within the RU. Due to the relatively high stress index this RU should be flagged as an area which requires further investigation.

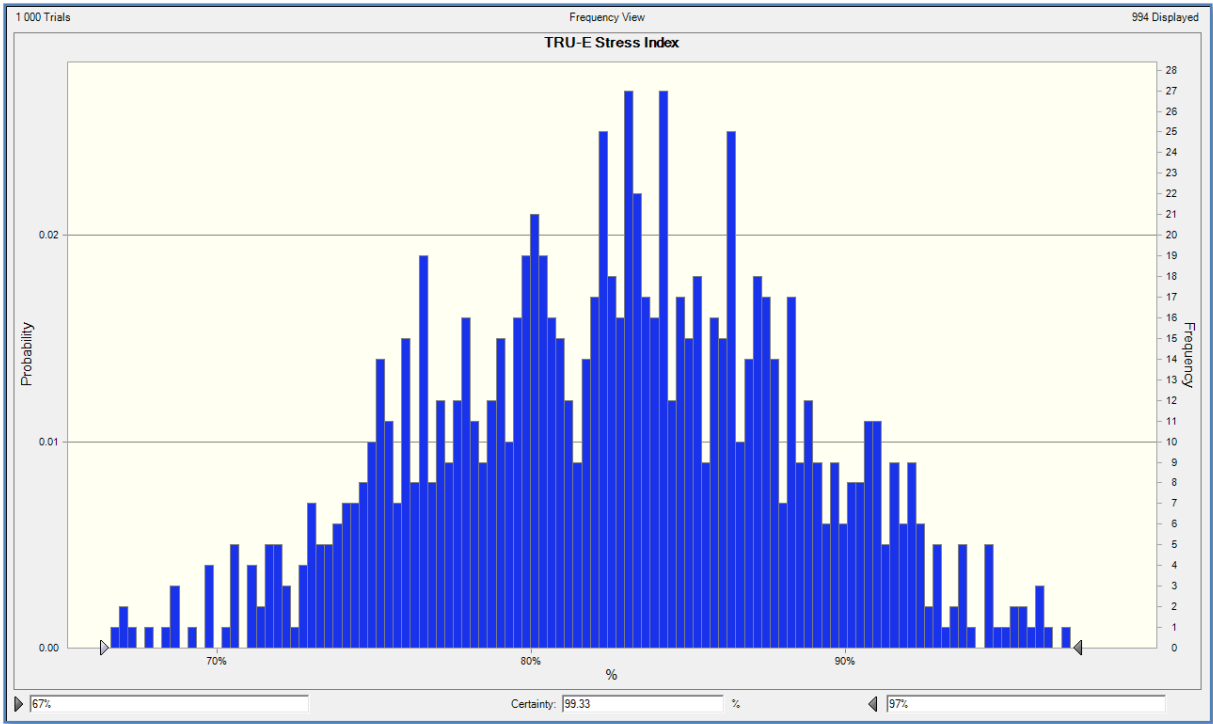


Figure 55: Stochastic results

1.1.45 Quality

The expanded Durov diagram with the groundwater quality is shown in Figure 56. An explanation of the classification process by means of the expanded Durov diagram is given in Section 2.3. It is apparent that the boreholes in the RU fall in contamination category A and C. However, because the water quality in all boreholes is relatively good, a final category of A/B was set.

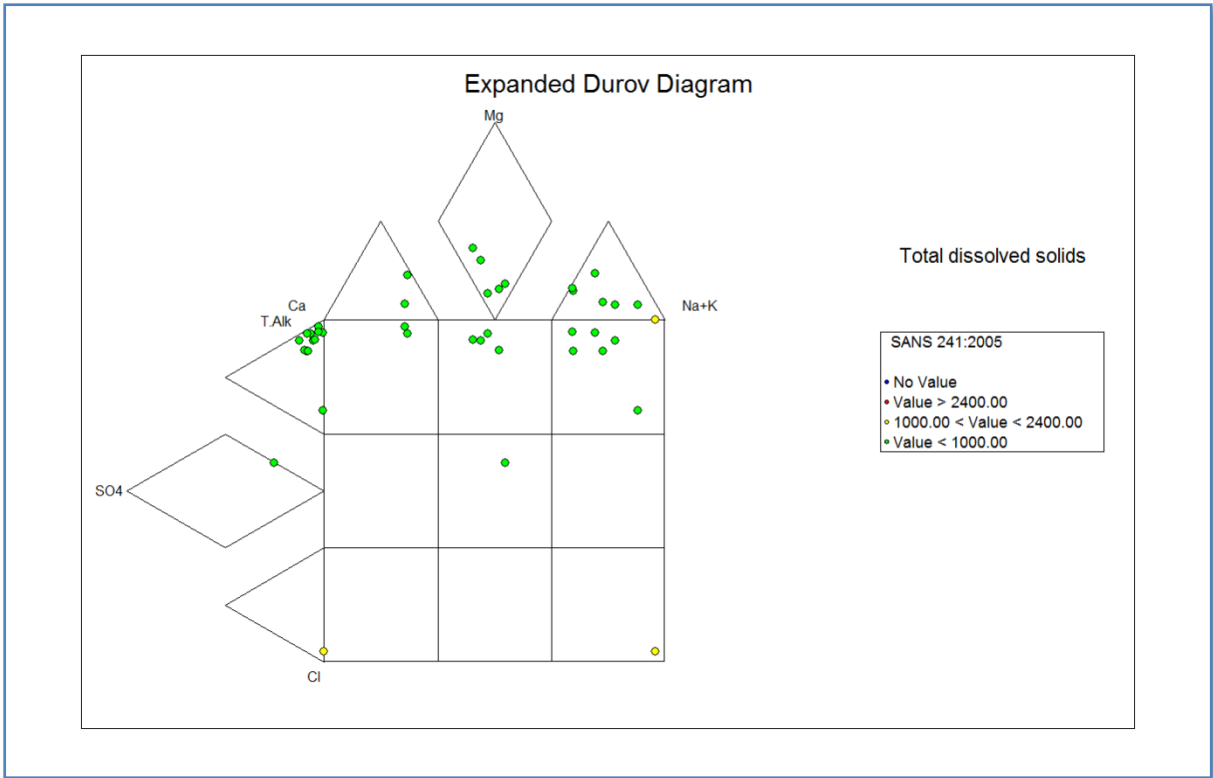


Figure 56: Expanded Durov diagram for RU

As documented the vulnerability is 65%. The impact of potential contamination, according to Section 2.3, is moderate due to agricultural activities within the RU.

1.1.46 Final category

The final category for the RU is summarised in Table 50.

Table 50: Category for RU

Impact	Present status category	Water resource category
Groundwater usage	E	Poor
Groundwater contamination	A/B	Natural/Good
Potential groundwater contamination (vulnerability and impact)	C	Good/Fair
FINAL	B/C	Good/Fair

10.11 Quantification of the Reserve

The groundwater Reserve for the RU is summarised in Table 51.

Table 51: Reserve

Reserve			Allocation	
Baseflow Mm ³ /a	BHN Mm ³ /a	Reserve % Recharge	Allocation Mm ³ /a	Current Use Mm ³ /a
5.960	0.030	23%	4.431	15.272

11. Classification and the Reserve for Resource Unit F

11.1 Location

RUF consists of the following quaternary catchments: V11M, V13E and V14A. There are no towns within the RU. The location of the RU is shown in Figure 57.

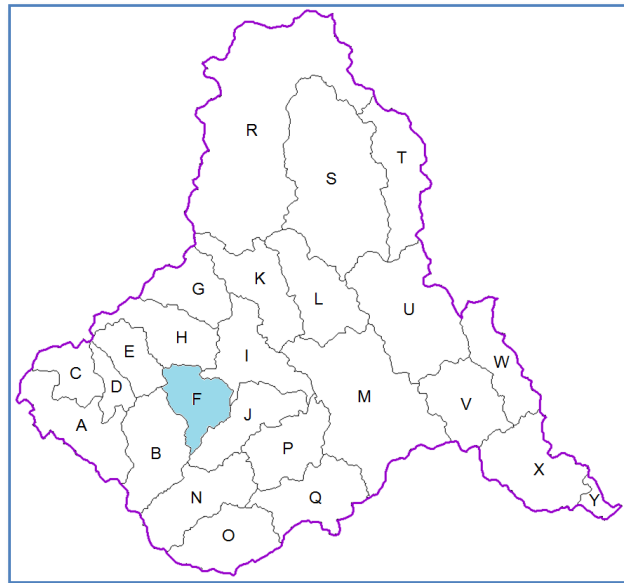


Figure 57: Location of RUF

11.2 Climate

Precipitation is often in the form of thunderstorms. The annual precipitation is between 700 and 750 mm between November and March, accounting for 70% of the annual total, with the winter months accounting for less than 10%. The mean annual temperature of the area is about 16°C, but both seasonal and diurnal variations are considerable. The highest temperatures (up to 35°C) occur during summer on north-facing slopes at lower latitudes, while the lowest temperatures (down to about -20°C) occur during winter nights on the summit plateau.

Frost is common in winter, with about 180 days between mid-April and October at higher elevations, but the local topography controls its distribution and intensity. It also occurs lower down when cold air from the high plateaus drains into lower-lying valleys

11.3 Vegetation (taken from www.deat.gov.za)

This RU is open savanna, with scattered trees of Paperbark Thorn *Acacia sieberiana*, Sweet Thorn *A. karroo*, Scented Thorn *A. nilotica* and *A. caffra*. The herbaceous layer is quite variable, with secondary grassland, dominated by patches of tall Common Thatchgrass *Hyparrhenia hirta*, and sour

grassland, dominated by Hairy Tridentgrass *Tristachya leucothrix*. Thicket and bushlands are prominent in the northern regions of the RU.

Where this vegetation type occurs on highly erodible, shallow duplex soils, grazing and fire require careful management. This highly transformed vegetation type is very poorly conserved.

11.4 Demography and Landcover

The population is approximately 5500 (2001 census data). Land use includes crop farming (Photo 26) and stock farming. There are informal settlements in upper sub-catchment and a formal irrigation scheme in the lower parts. Overstocking (i.e. double the livestock carrying capacity) is a problem in the RU. Erosion is also prominent in the east of the RU. The landcover for the RU is shown in Figure 58.



Photo 26: Dryland farming
(Source: www.panoramio.com)

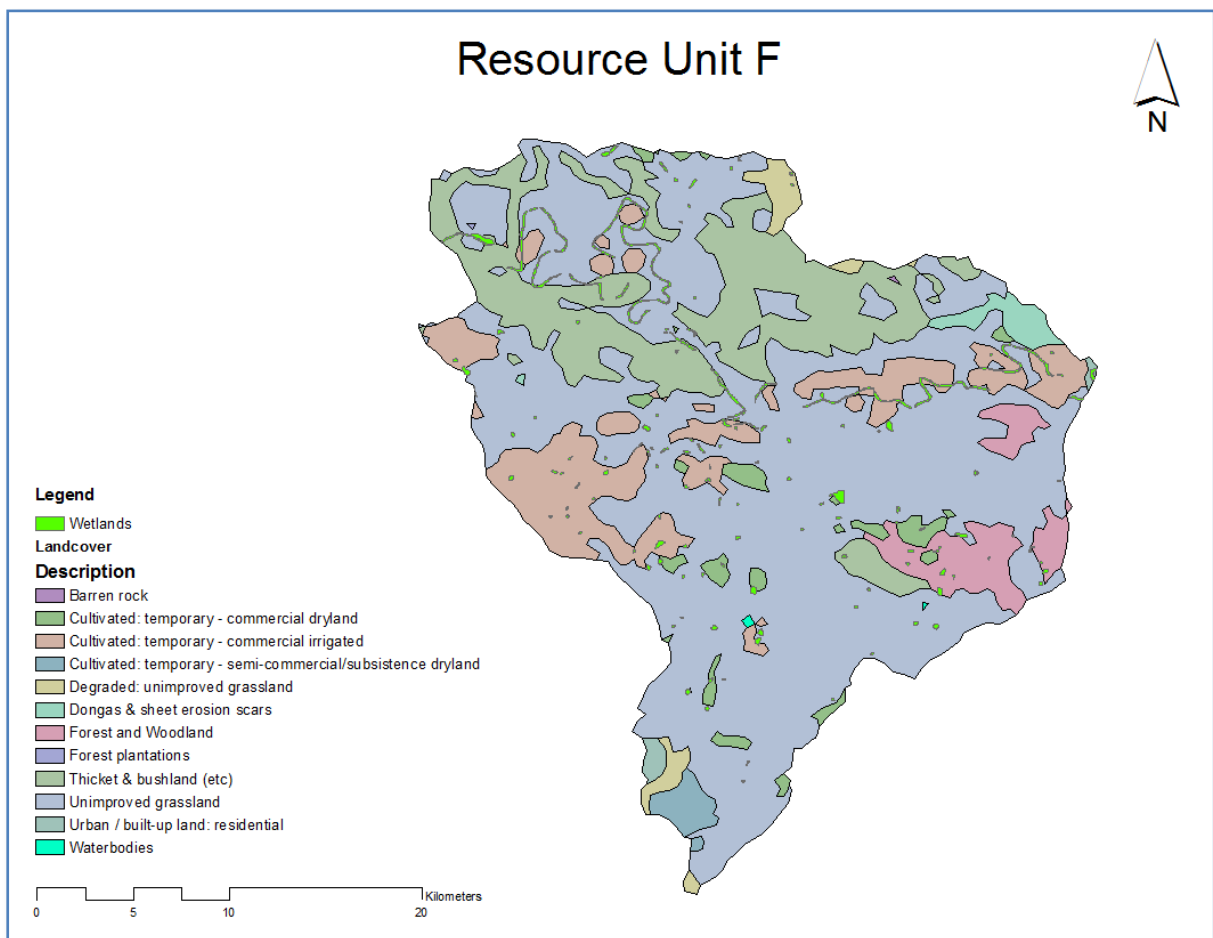


Figure 58: Landcover within the study area

11.5 Surface Water

In this resource unit, the Little Thukela River and Kaalspruit join the Thukela River. There are numerous farm dams in the area.

11.6 Wetlands

Numerous wetlands are scattered throughout the RU, as shown in Figure 58.

1.1 Soils (taken from www.deat.gov.za)

The soil is shallow, derived from shales and mudstones of the Karoo Sequence. The area is characterised by subsoils which are either duplex, which renders them potentially highly erodible, or dominated by black clays.

11.7 Geology (summarised from Woodford and Chevallier, 2002)

The Beaufort Group dominates in this RU and is stratigraphically divided into two major units, the upper Tarkastad Subgroup and the lower Adelaide Subgroup. The Tarkastad Subgroup is subdivided into the upper Burgersdorp Formation with its brightly coloured red, blue and green mudstones and the lower Katberg Formation, which can be up to 900 m thick. The Katberg Formation also contains brightly coloured shales and mudstones, but mainly consists of thick layers of coarse-grained sandstone. The Adelaide Subgroup mainly consists of green, bluish, grey and red mudstones and fine-grained sandstones that form thick lens-shaped units. The central basin mainly consists of mudstones, shales and fine-grained sandstones. These fine-grained sediments were mainly deposited where the braided rivers began to meander. The sedimentary units in the Group therefore usually have very low primary hydraulic conductivities. Since the Beaufort Group was also deposited in a fluvial environment, one can expect that aquifers in these formations will, like those in the Ecca Group, be anisotropic. The geometry of these aquifers, however, is further complicated by the migration of the braided and meandering streams. Aquifers in the Beaufort Group will therefore not only be multi-layered, but also multi-porous with variable thicknesses. The contact plane between two different sedimentary layers will cause a discontinuity in the hydraulic properties of an aquifer. The lifespan of a high-yielding borehole in the Beaufort Group may therefore be limited if the aquifer is not recharged frequently.

Sills in the Karoo formations are sheet-like forms of dolerite intrusions that tend to follow the bedding planes of the formations concordantly. These structures, whose thicknesses vary from less than a metre to hundreds of metres, represent the dominant form in which dolerite is emplaced in the Karoo Supergroup. Dolerite sills in the Karoo Supergroup often have very complex forms.

The linear dykes are also usually thinner than ring dykes and are confined to the Ecca and Beaufort Groups. This is a clear indication that the magmatic activity at the time the linear dykes intruded was less than when the ring dykes and sills intruded.

11.8 Geohydrology

1.1.47 Groundwater levels

It is clear the groundwater levels follow the topography, as seen from Figure A1 in Appendix A and therefore groundwater contour maps were generated using Bayesian interpolation. The groundwater levels for the study area are shown in Figure 59. The most probable depth to groundwater level in the RU is 5.9 mbgl according to the histogram of water levels in the RU in Appendix A. Groundwater levels are expected to be lower than normal due to the prevailing drought conditions. Unfortunately, very little time series water level data are available to quantify the overall impact.

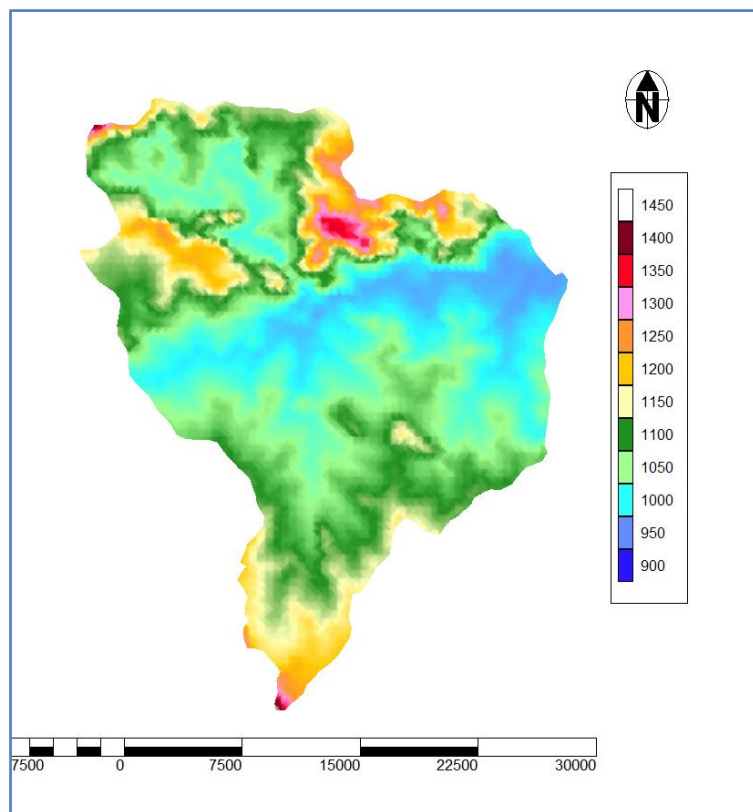


Figure 59: Groundwater levels in RUF

11.8.1 Groundwater recharge

The groundwater recharge calculated from the different methods is listed in Table 52. The different recharge methods applied are discussed in Section 2.3. The final recharge values for the RU are highlighted in red.

Table 52: Recharge values

Recharge							
MAP Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Volume Mm ³ /a	Calculated %	CMB %	Land Cover %	Geology %
477.263	21.091	29.210	24.195	5.1%	5.1%	0.8%	2.6%

1.1.48 Basic human needs

The method for determining BHNs is discussed in Section 2.3. The final value for the study area is highlighted in red in Table 53.

Table 53: Basic human needs

Basic Human Need		
Census(2001) Adjusted	Dependence 18%	Estimate Mm ³ /a
10757	1936	0.017

1.1.49 Groundwater contribution to baseflow

The baseflow separation curves for the RU are shown in Figures 60 – 62.

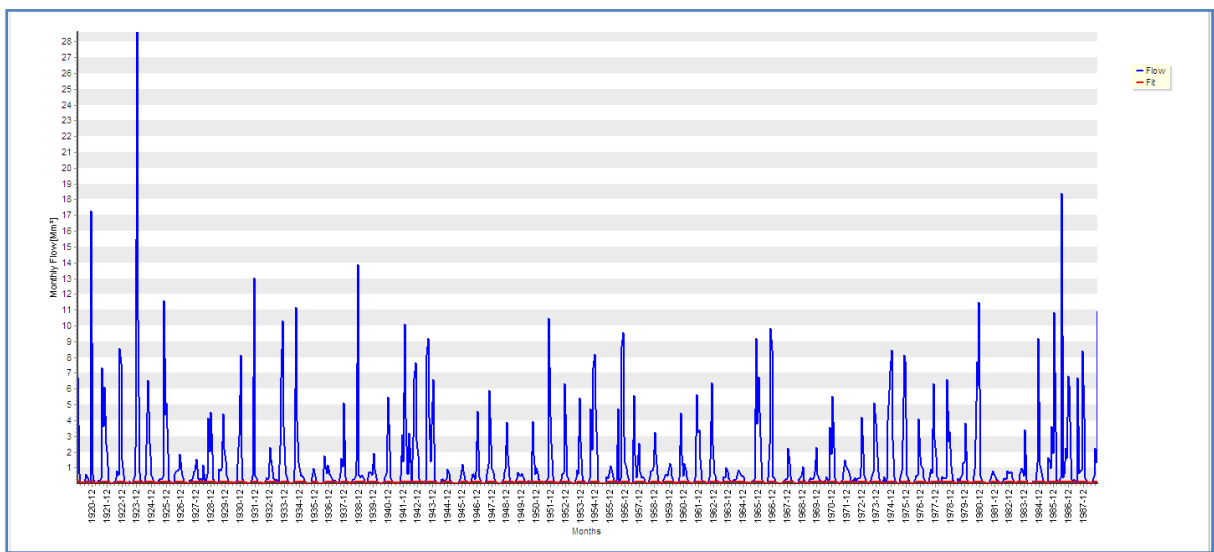


Figure 60: Baseflow separation for quaternary catchment V11M

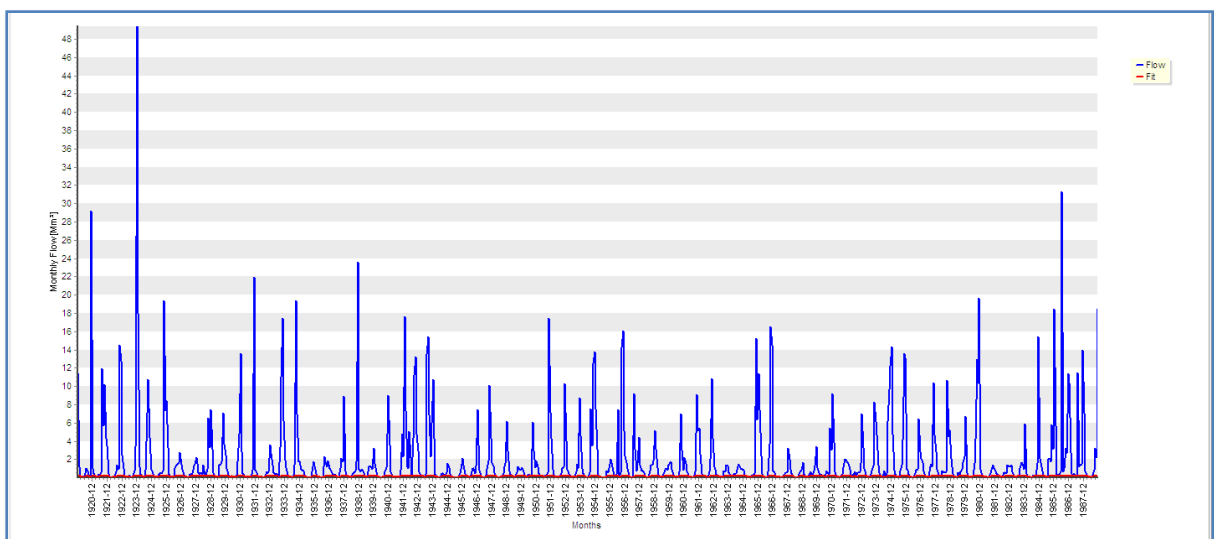


Figure 61: Baseflow separation for quaternary catchment V13E

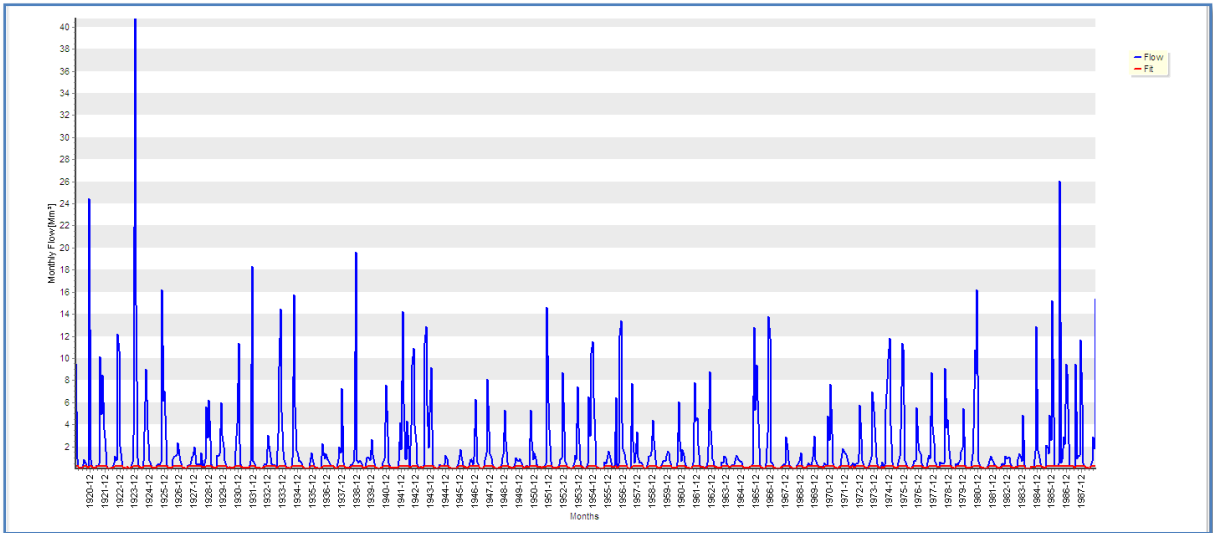


Figure 62: Baseflow separation for quaternary catchment V14A

The final groundwater contribution to baseflow values for the RU in Table 54 is highlighted in red.

Table 54: Groundwater contribution to baseflow

Groundwater Contribution to Baseflow							
GRDM Mm ³ /a	Hughes Mm ³ /a	Shultz Mm ³ /a	Pitman Mm ³ /a	vTonder Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Herold Mm ³ /a
6.741	19.067	10.502	2.290	7.823	2.290	19.067	5.030

1.1.50 Groundwater use

The groundwater use for the RU is listed in Table 55.

Table 55: Groundwater use

Groundwater Use							
GRDM Mm ³ /a	WARMS Mm ³ /a	Hydrocensus Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Forrest Mm ³ /a	Crops Mm ³ /a	TOTAL Mm ³ /a
0.240	0.033	0.871	0.033	3.483	16.528	0.378	16.889

1.1.51 Groundwater quality

The TDS values for the RU are shown in Figure 63. They are classified according to SABS standards. Not all boreholes have quality data available but those that do can be used to identify possible hot spots with regard to quality in the resource unit. The overall quality of the resource unit is well within the drinking water guidelines, with the exception of one borehole, which is allowable.

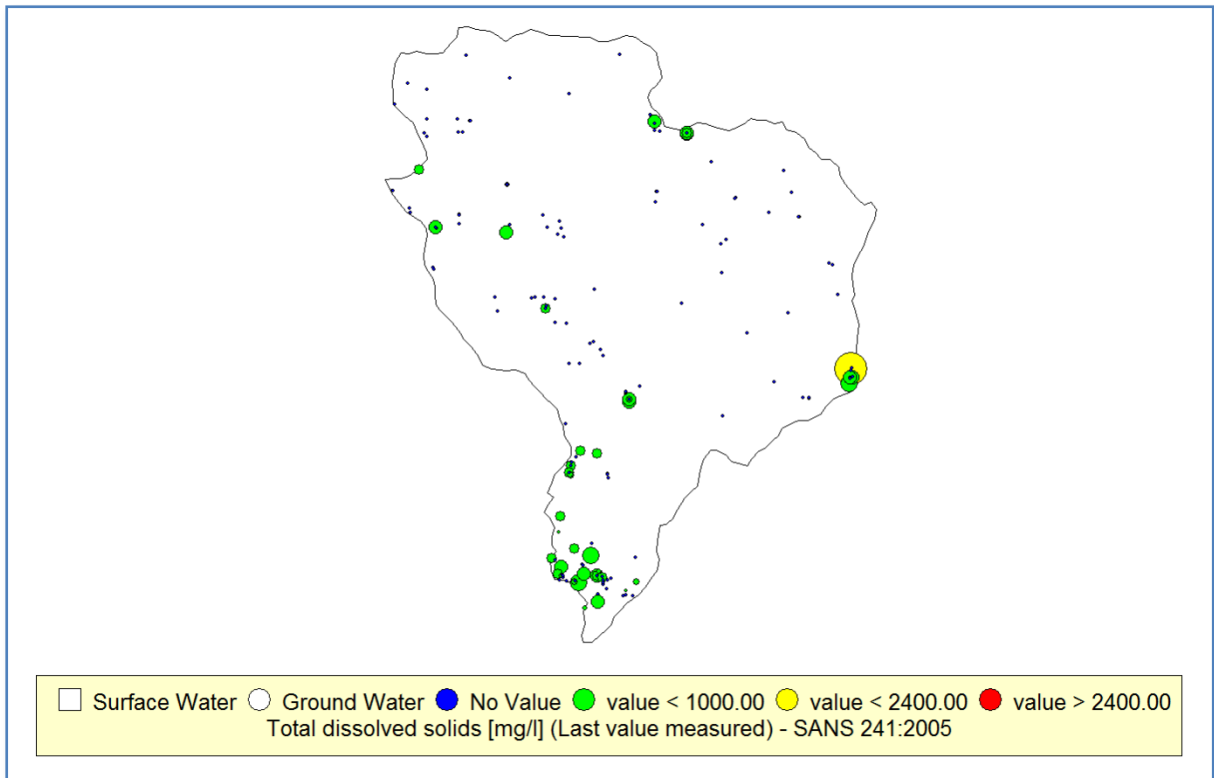


Figure 63: TDS values

1.1.52 Aquifer vulnerability

The aquifer vulnerability calculations are summarised in Table 56. The slope histogram is documented in Appendix B.

Table 56: Aquifer vulnerability

Aquifer Vulnerability						
Level mbgl	Recharge %	Slope %	Soil Texture	Aquifer Type	Vadose Zone	Vulnerability %
5.9	5.1%	1.0	SaCLm-SaCl	Weathered/Fractured	Karoo(southern)	57%

11.9 Classification

1.1.53 Groundwater usage

The stress index, defined as the ratio between total groundwater use and recharge, for the study area is calculated at 91%. Due to the uncertainty associated with the groundwater use component, the stress index was stochastically modelled through assigning a normal distribution curve with a standard deviation of 1.689 Mm³/a to the groundwater use estimate to account for the associated uncertainty. The stochastic results are shown in Figure 64. It is clear from the results that the stress index will vary between 72% and 100% with a certainty of 89.54%. Due to the large variability in the range obtained, it is recommended that the uncertainty in groundwater use be reduced by detailed studies focusing on groundwater use within the RU. Due to the relatively high stress index this RU should be flagged as an area for further investigation.

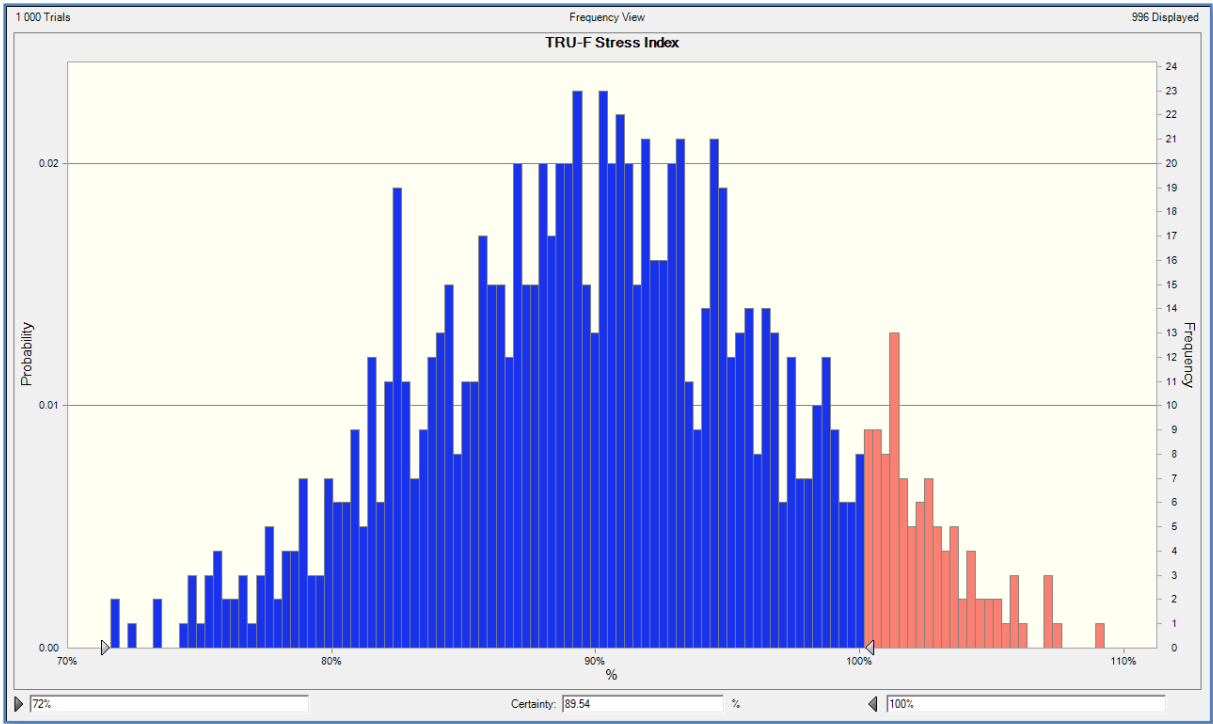


Figure 64: Stochastic results

1.1.54 Quality

The expanded Durov diagram with groundwater quality, is shown in Figure 65. An explanation of the classification process by means of the expanded Durov diagram is given in Section 2.3. It is apparent that the contamination category, according to the explanation is A/B.

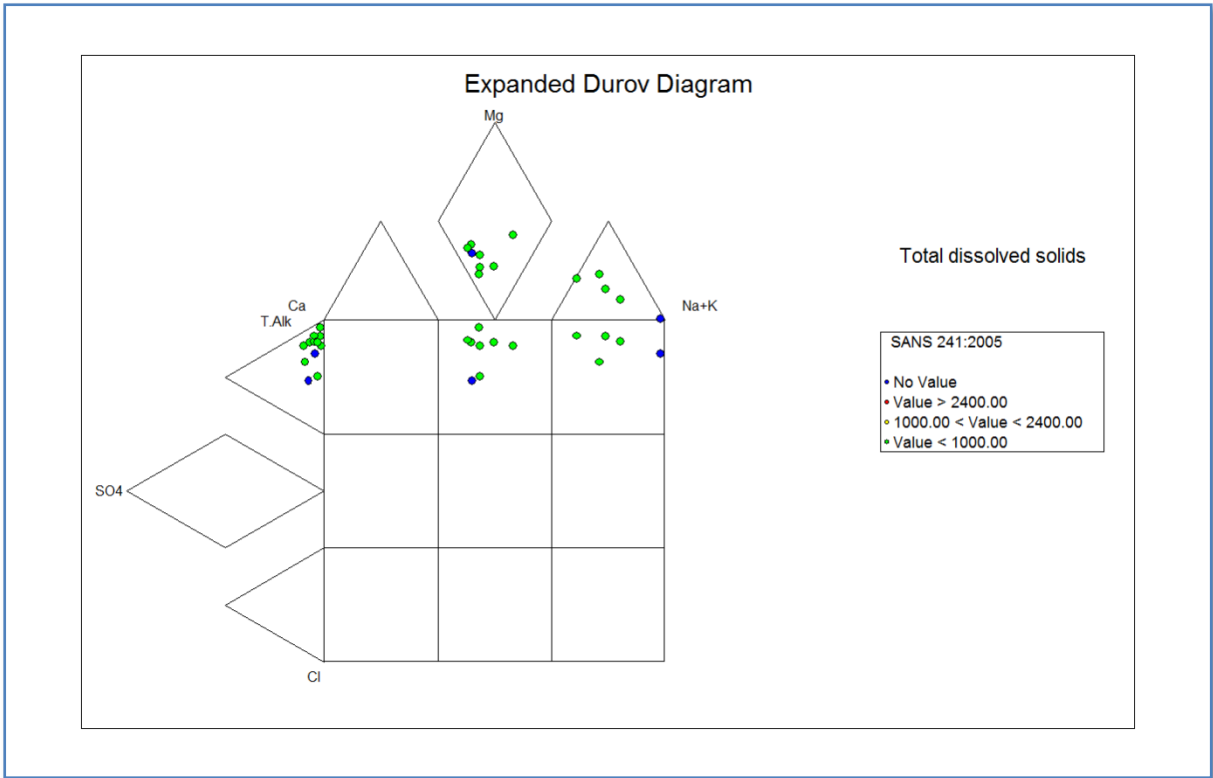


Figure 65: Expanded Durov diagram for RU

As documented the vulnerability is 57%. The impact of potential contamination according to Section 2.3, is moderate due to agricultural activities.

1.1.55 Final category

The final category for the RU is summarised in Table 57.

Table 57: Category for RU

Impact	Present status category	Water resource category
Groundwater usage	E	Poor
Groundwater contamination	A/B	Natural/Good
Potential groundwater contamination (vulnerability and impact)	B/C	Good/Fair
FINAL	B/C	Good/Fair

11.10 Quantification of the Reserve

The groundwater Reserve for the RU is summarised in Table 58.

Table 58: Reserve

Reserve			Allocation	
Baseflow Mm ³ /a	BHN Mm ³ /a	Reserve % Recharge	Allocation Mm ³ /a	Current Use Mm ³ /a
5.030	0.017	21%	2.259	16.889

12. Classification and the Reserve for Resource Unit G

12.1 Location

The only town in this RU is Driefontein, which is located to the north of the RU. The RU includes the following quaternary catchments, namely V12A, V12B and V12C. The location of the RU is shown in Figure 66.

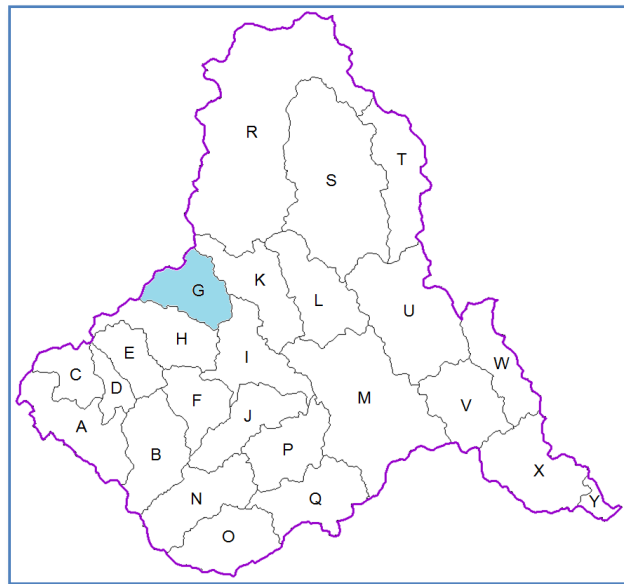


Figure 66: Location of RUG

12.2 Climate

Precipitation is often in the form of thunderstorms. The annual precipitation is between 700 and 750 mm between November and March, accounting for 70% of the annual total, with the winter months accounting for less than 10%. The mean annual temperature of the area is about 16°C, but both seasonal and diurnal variations are considerable. The highest temperatures (up to 35°C) occur during summer on north-facing slopes at lower latitudes, while the lowest temperatures (down to about -20°C) occur during the winter nights on the summit plateau.

Frost is common in winter with about 180 days between mid-April and October at higher elevations, but the local topography controls its distribution and intensity. It also occurs lower down when cold air from the high plateaus drains into lower-lying valleys

12.3 Vegetation (taken from www.deat.gov.za)

The Grassland Biome found in this RU is mainly found on the high central plateau and the inland areas of KwaZulu Natal. The topography is mainly flat and rolling, but includes the escarpment itself. Altitude varies from near sea level to 2850 m above sea level.

Grasslands are dominated by a single layer of grasses. The amount of cover depends on rainfall and the degree of grazing. Thickets and bushland are present in a few localised habitats. Geophytes are often abundant. Frosts, fire and grazing maintain the grass dominance and prevent the establishment of trees.

There are two categories of grass plants: sweet grasses and sour grasses. At higher rainfall and on more acidic soils, sour grasses prevail, with 625 mm per year taken as the level at which unpalatable grasses predominate.

12.4 Demography and Landcover

The total population for the RU is 67000 (2001 census data). The area is known for its dairy, beef and wool production in South Africa. The cornerstone product is maize, and many grassland types have been devoted to this crop. Sorghum, wheat (Photo 27) and sunflowers are also farmed on a smaller scale. A Corobrick factory is located in Driefontein. The landcover for the RU is shown in Figure 67.



Photo 27: Wheat fields in the RU

(Source: www.panoramio.com)

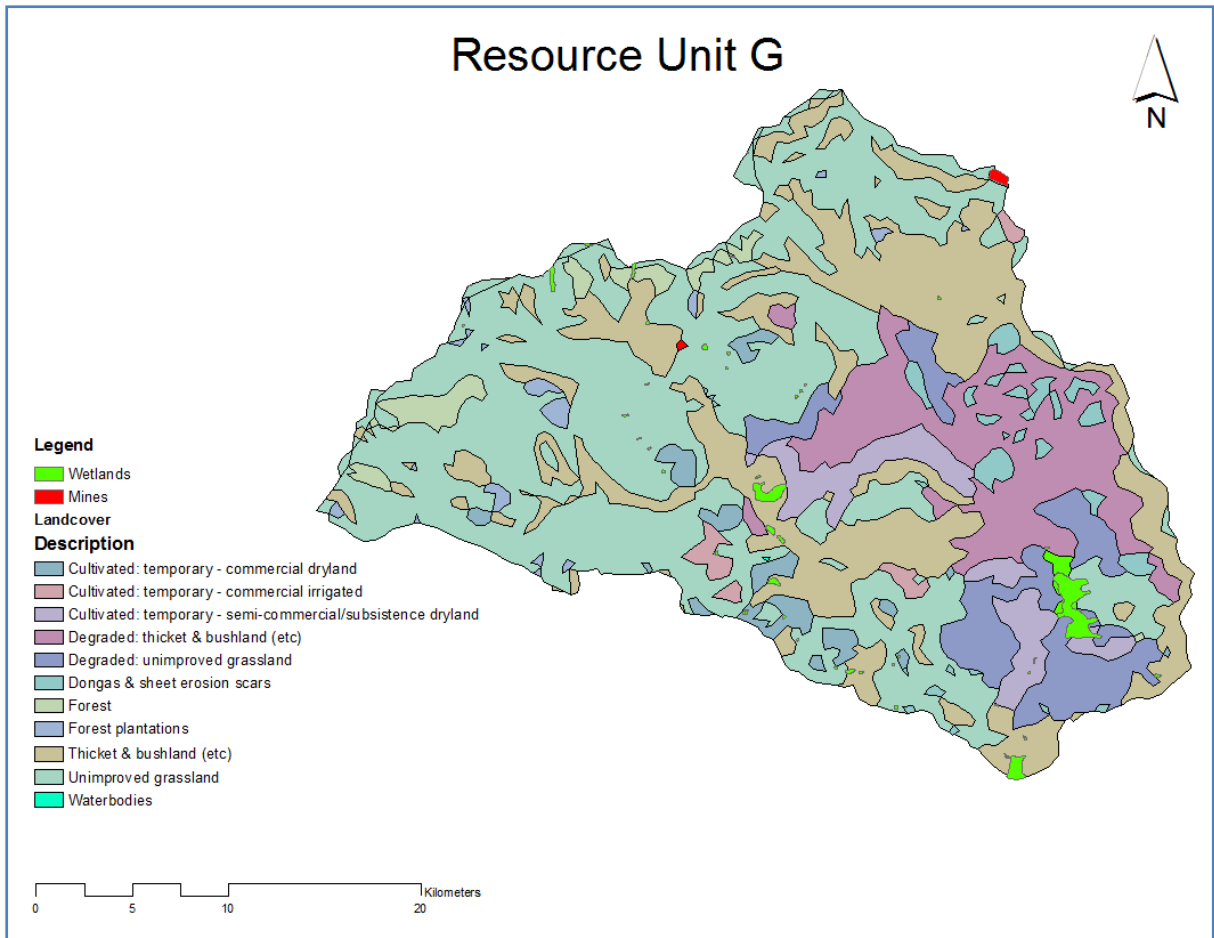


Figure 67: Landcover for RUG

12.5 Surface Water

The Ngogo, Tatana, Mhlwane and Braamhoeks Rivers join to form the Klip River.

12.6 Wetlands

The wetlands located in the RU are shown in Figure 67.

12.7 Soils (taken from www.deat.gov.za)

The soil is shallow, derived from shales and mudstones of the Karoo Sequence. The area is characterised by subsoils which are either duplex, which renders them potentially highly erodible, or dominated by black clays.

12.8 Geology (summarised from Woodford and Chevallier, 2002)

The Beaufort Group dominates in this RU and is stratigraphically divided into two major units, the upper Tarkastad Subgroup and the lower Adelaide Subgroup. The Tarkastad Subgroup is subdivided into the upper Burgersdorp Formation with brightly coloured red, blue and green mudstones and

the lower Katberg Formation, which can be up to 900 m thick. The Katberg Formation also contains brightly coloured shales and mudstones, but mainly consists of thick layers of coarse-grained sandstone. The Adelaide Subgroup mainly consists of green, bluish, grey and red mudstones and fine-grained sandstones that form thick lens-shaped units. The central basin mainly consists of mudstones, shales and fine-grained sandstones. These fine-grained sediments were mainly deposited where the braided rivers began to meander. The sedimentary units in the Group therefore usually have very low primary hydraulic conductivities. Since the Beaufort Group was also deposited in a fluvial environment, one can expect that aquifers in these formations will, like those in the Ecca Group, be anisotropic. The geometry of these aquifers, however, is further complicated by the migration of the braided and meandering streams. Aquifers in the Beaufort Group will therefore not only be multi-layered, but also multi-porous with variable thicknesses. The contact plane between two different sedimentary layers will cause a discontinuity in the hydraulic properties of an aquifer. The lifespan of a high-yielding borehole in the Beaufort Group may therefore be limited if the aquifer is not recharged frequently.

The Volksrust Formation (of the Ecca Group) is a predominantly argillaceous unit, which interfingers with the overlying Beaufort Group and underlying Vryheid Formation. The Formation consists of grey to black, silty shale with thin, usually bioturbated, siltstone or sandstone lenses and beds, particularly towards its upper and lower boundaries. Thin phosphate and carbonate beds and concretions are relatively common.

Sills in the Karoo formations are sheetlike forms of dolerite intrusions that tend to follow the bedding planes of the formations concordantly. These structures, whose thicknesses vary from less than a metre to hundreds of metres, represent the dominant form in which dolerite is emplaced in the Karoo Supergroup. Dolerite sills in the Karoo Supergroup often have very complex forms. The linear dykes are also usually thinner than ring dykes and are confined to the Ecca and Beaufort Groups. This is a clear indication that the magmatic activity at the time the linear dykes intruded was less than when the ring dykes and sills intruded.

12.9 *Geohydrology*

1.1.56 *Groundwater levels*

It is clear the groundwater levels follow the topography, as seen from Figure A1 in Appendix A and therefore groundwater contour maps were generated using Bayesian interpolation. The groundwater levels for the study area are shown in Figure 68. The most probable depth to groundwater level in the RU is 6.1 mbgl, according to the histogram of water levels in the RU shown in Appendix A. Groundwater levels are expected to be lower than normal due to the prevailing drought conditions. Unfortunately, very little time series water level data are available to quantify the overall impact.

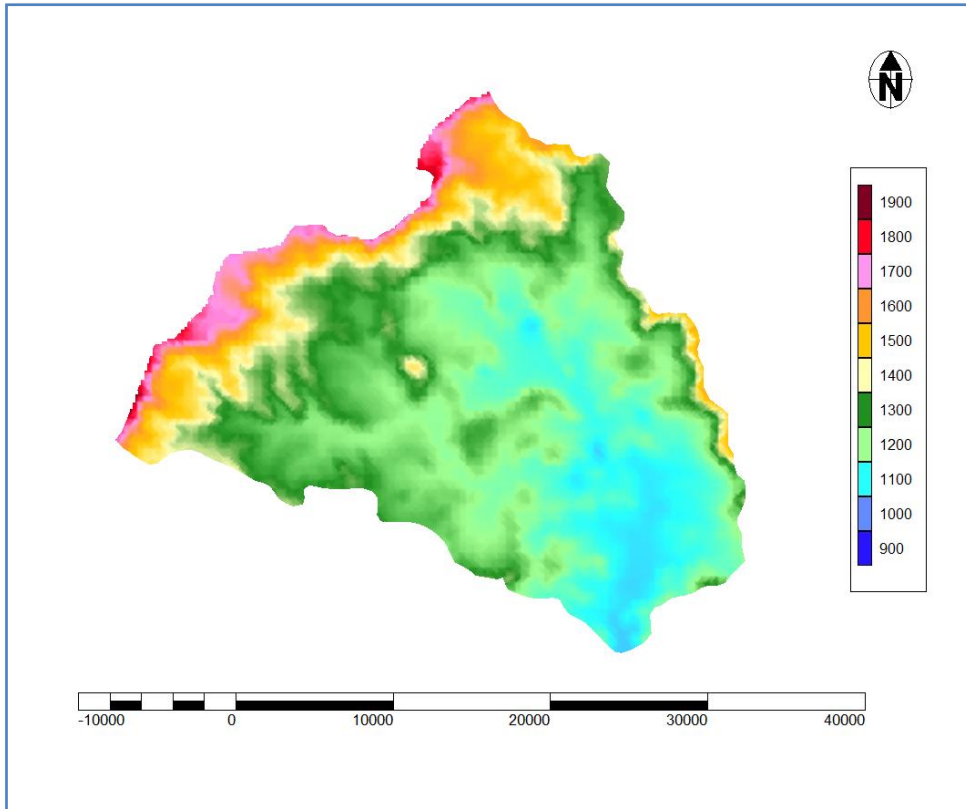


Figure 68: Groundwater levels in RUG

12.9.1 Groundwater recharge

The groundwater recharge calculated from the different methods is listed in Table 59. The different recharge methods applied are discussed in Section 2.3. The final recharge values for the RU are highlighted in red.

Table 59: Recharge values

Recharge							
MAP Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Volume Mm ³ /a	Calculated %	CMB %	Land Cover %	Geology %
665.943	42.365	49.088	41.220	6.2%	6.2%	1.7%	1.9%

1.1.57 Basic human needs

The method for determining BHNs is discussed in Section 2.3. The final value for the study area is highlighted in red in Table 60.

Table 60: Basic human needs

Basic Human Need		
Census(2001) Adjusted	Dependence 18%	Estimate Mm ³ /a
77002	13860	0.125

1.1.58 Groundwater contribution to baseflow

The baseflow separation curves for the RU are shown in Figures 69 – 71.

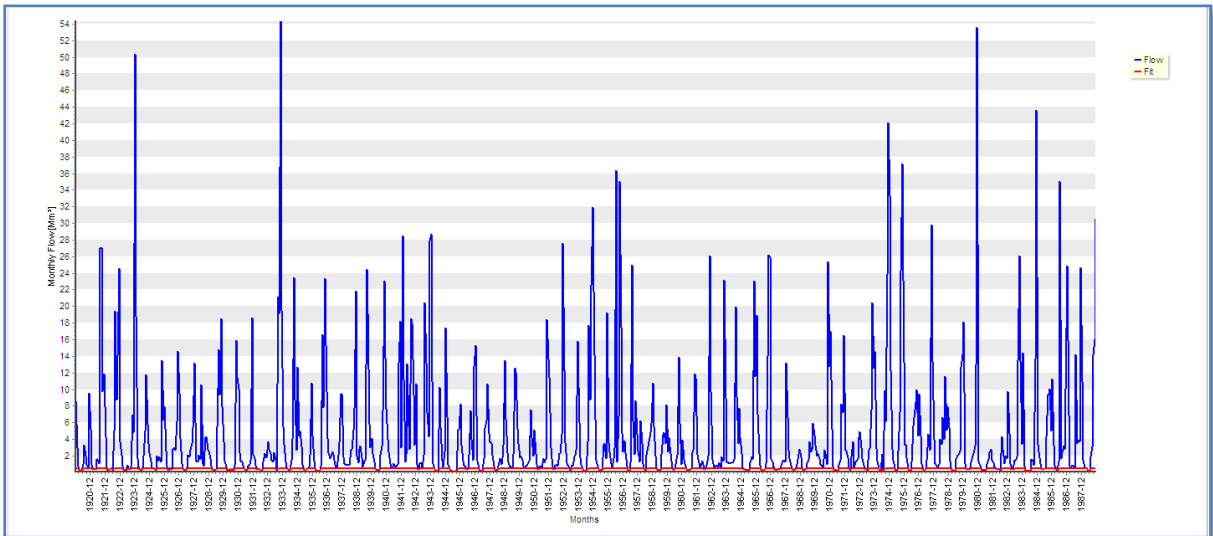


Figure 69: Baseflow separation for quaternary catchment V12A

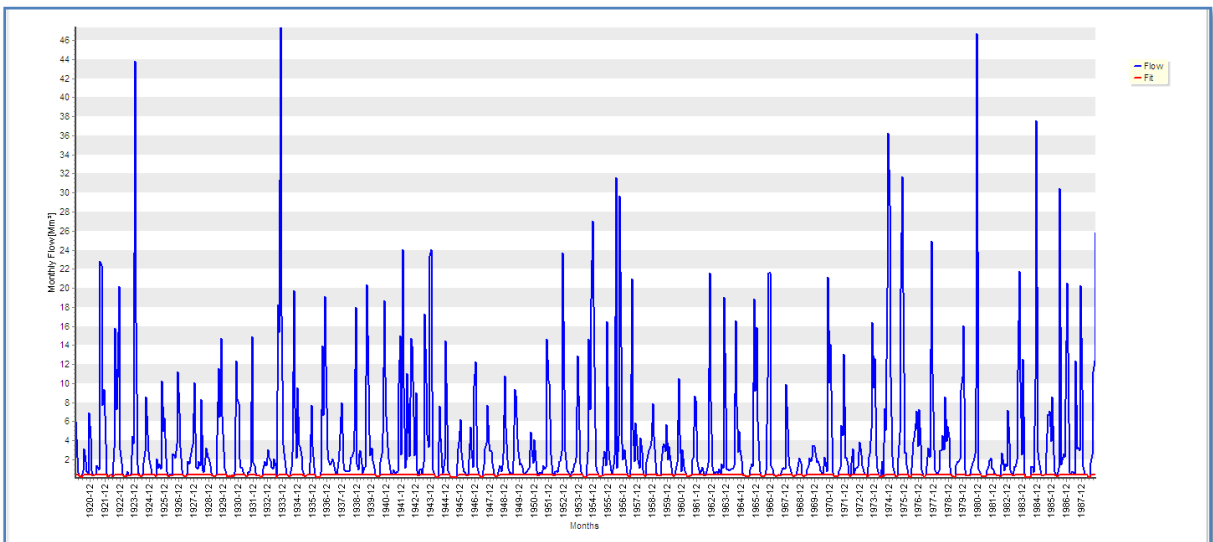


Figure 70: Baseflow separation for quaternary catchment V12B

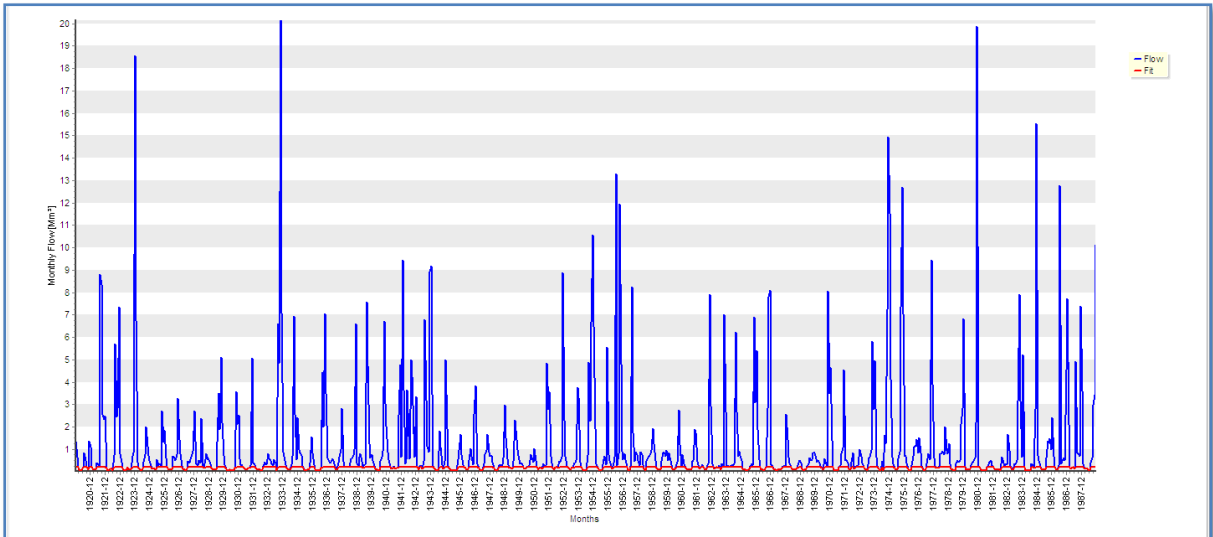


Figure 71: Baseflow separation for quaternary catchment V12C

The final groundwater contribution to baseflow values for the RU in Table 61 is highlighted in red.

Table 61: Groundwater contribution to baseflow

Groundwater Contribution to Baseflow							
GRDM Mm ³ /a	Hughes Mm ³ /a	Shultz Mm ³ /a	Pitman Mm ³ /a	vTonder Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Herold Mm ³ /a
11.951	42.061	20.497	9.633	18.659	9.633	42.061	12.140

1.1.59 Groundwater use

The groundwater use for the RU is listed in Table 62.

Table 62: Groundwater use

Groundwater Use							
GRDM Mm ³ /a	WARMS Mm ³ /a	Hydrocensus Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Forrest Mm ³ /a	Crops Mm ³ /a	TOTAL Mm ³ /a
0.360	0.002	0.215	0.002	0.861	9.079	0.051	9.005

1.1.60 Groundwater quality

The TDS values for the RU are shown in Figure 72. They are classified according to SABS standards. Not all boreholes have quality data available but those that do can be used to identify possible hot spots with regard to quality in the resource unit. The overall quality of the resource unit is well within the drinking water guidelines with the exception of three boreholes. These areas should be treated as hotspots rather than penalising the whole resource unit with a poor classification. Treatment of the hotspot areas will be addressed under Resource Quality Objectives in Section 31.

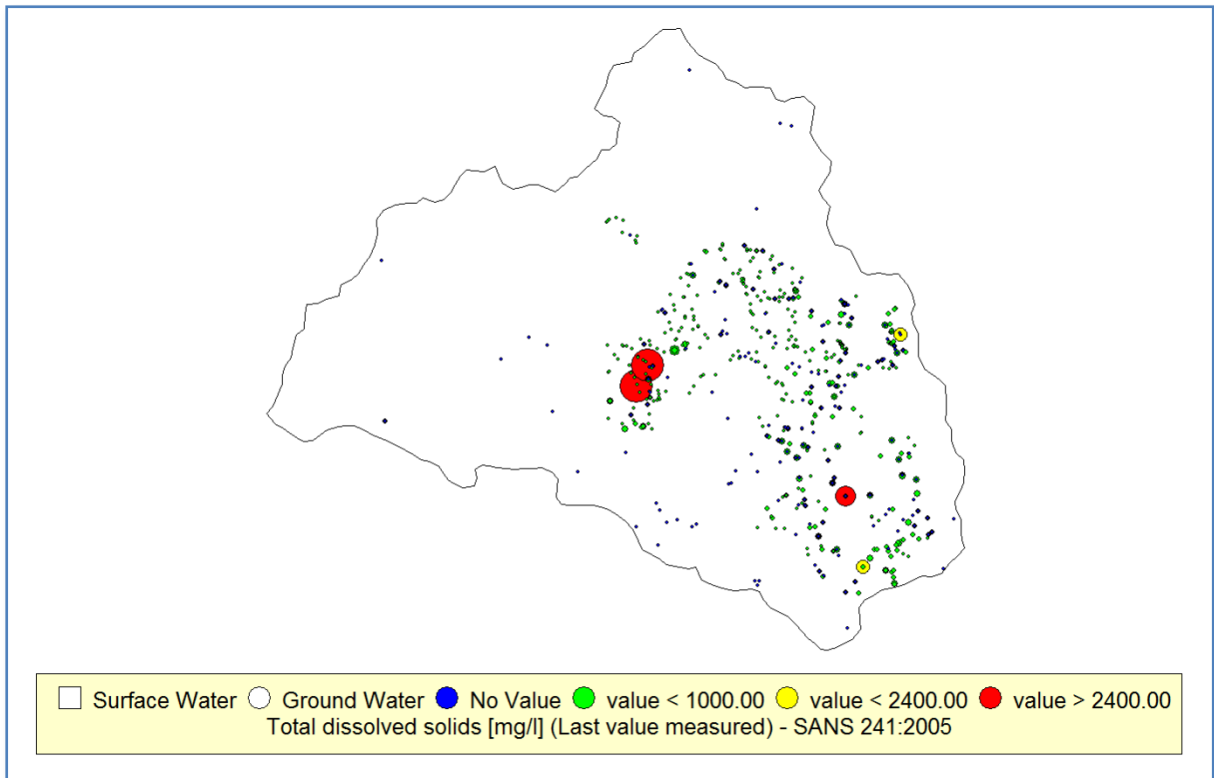


Figure 72: TDS values

1.1.61 Aquifer vulnerability

The aquifer vulnerability calculations are summarised in Table 63. The slope histogram is documented in Appendix B.

Table 63: Aquifer vulnerability

Aquifer Vulnerability						
Level mbgl	Recharge %	Slope %	Soil Texture	Aquifer Type	Vadose Zone	Vulnerability %
6.1	6.2%	1.4	SaCLlM-SaCl	Weathered/Fractured	Karoo(southern)	60%

12.10 Classification

1.1.62 Groundwater usage

The stress index, defined as the ratio between total groundwater use and recharge, for the study area is calculated at 52%. Due to the uncertainty associated with the groundwater use component, the stress index was stochastically modelled through assigning a normal distribution curve with a standard deviation of 0.901 Mm³/a to the groundwater use estimate to account for the associated uncertainty. The stochastic results are shown in Figure 73. It is clear from the results that the stress index will vary between 46% and 56% with a certainty of 99.24%. Due to the small variability in the obtained range and high certainty, the uncertainty in the groundwater use component will not affect the calculated stress index significantly.

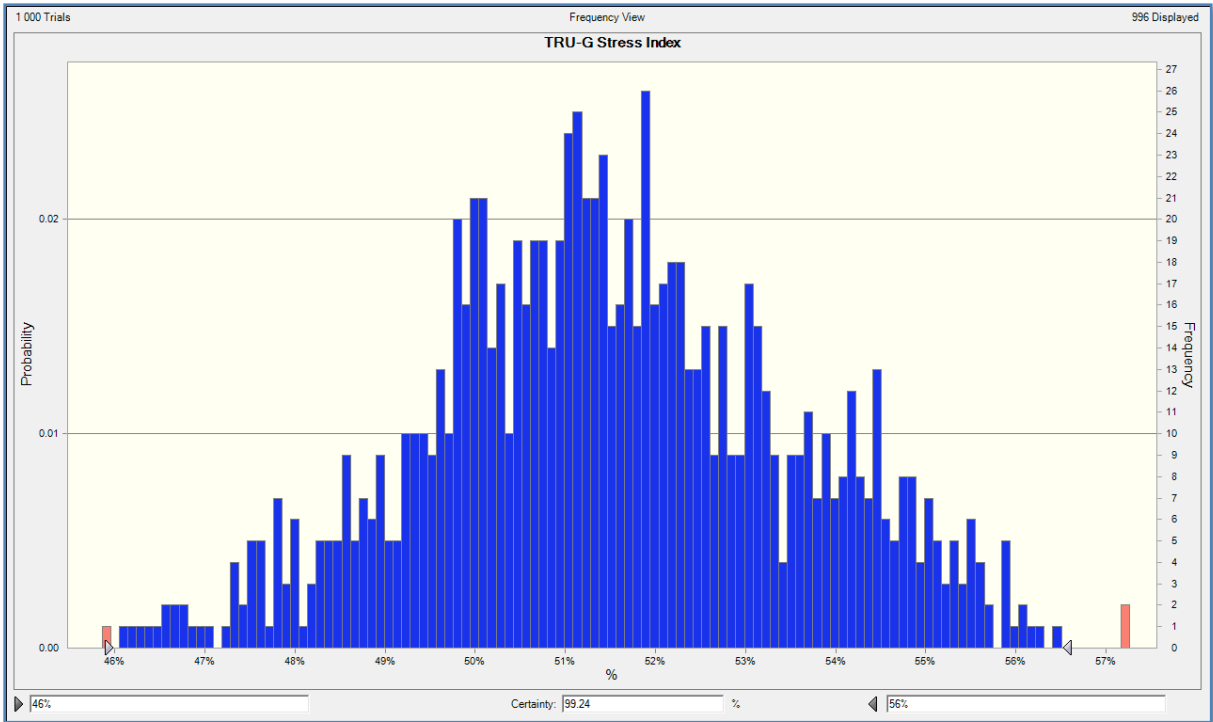


Figure 73: Stochastic results

1.1.63 Quality

The expanded Durov diagram with the groundwater quality is shown in Figure 74. An explanation of the classification process by means of the expanded Durov diagram is given in Section 2.3. It is apparent that the contamination category according to the explanation is a B/C.

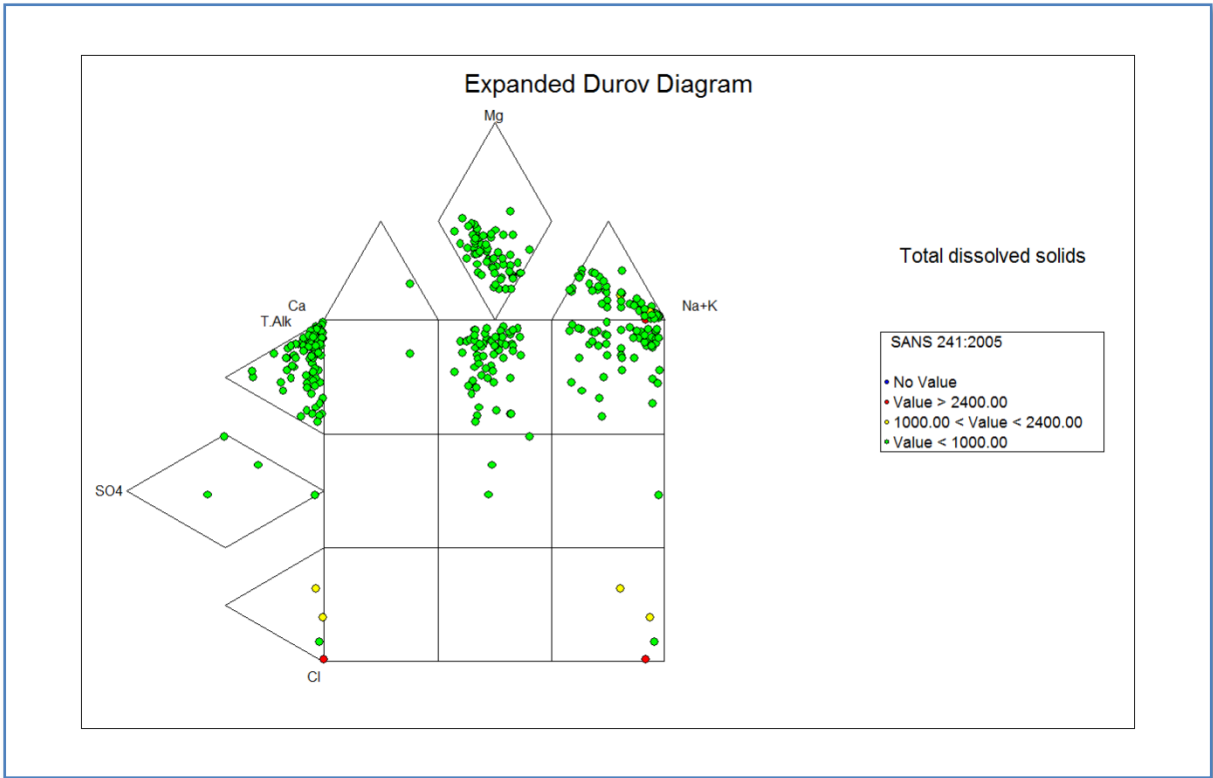


Figure 74: Expanded Durov diagram for RU

As documented, the vulnerability is 57%. The impact of potential contamination according to Section 2.3 is moderate due to mining and agricultural activities within the RU.

1.1.64 Final category

The final category for the RU is summarised in Table 64.

Table 64: Category for RU

Impact	Present status category	Water resource category
Groundwater usage	D	Fair
Groundwater contamination	B/C	Good/Fair
Potential groundwater contamination (vulnerability and impact)	C	Good/Fair
FINAL	C	Fair

12.11 Quantification of the Reserve

The groundwater Reserve for the RU is summarised in Table 65.

Table 65: Reserve

Reserve			Allocation	
Baseflow Mm ³ /a	BHN Mm ³ /a	Reserve % Recharge	Allocation Mm ³ /a	Current Use Mm ³ /a
12.140	0.125	30%	19.950	9.005

13. Classification and the Reserve for Resource Unit H

13.1 Location

The quaternary catchments located in this study area are: V12D, V12E and V12F. The main towns include Van Reenen and Roosboom. The location of the study area is shown in Figure 75.

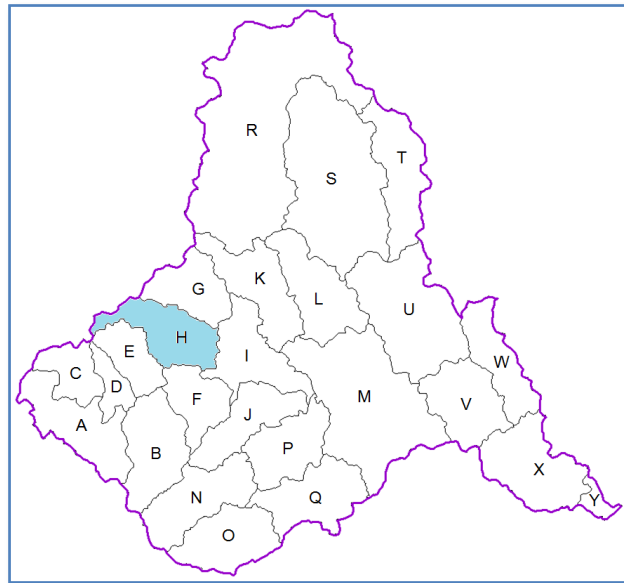


Figure 75: Location of RUH

13.2 Climate

Van Reenen normally receives about 751 mm of rain per year, with most rainfall occurring mainly during mid-summer. It receives the lowest rainfall (3 mm) in June and the highest (141 mm) in January. The monthly distribution of average daily maximum temperatures shows that the average midday temperatures for Van Reenen range from 15.8°C in June to 25°C in January. The region is the coldest during July, when the mercury drops to 1°C on average during the night.

Roosboom normally receives about 639 mm of rain per year, with most rainfall occurring mainly during mid-summer. It receives the lowest rainfall (1 mm) in June and the highest (122 mm) in January. The monthly distribution of average daily maximum temperatures shows that the average midday temperatures for Roosboom range from 20°C in June to 28.1°C in January. The region is the coldest during July, when the mercury drops to 3.1°C on average during the night.

The average rainfall for the catchment varies between 630 – 1000 mm/a.

13.3 Vegetation (taken from www.deat.gov.za)

The highlands are grasslands, but a woody layer - with an average height of 3 to 5 m - may form dense thickets in places. The hot north-facing slopes are dry, poor in species, and dominated by the grasses Common Thatchgrass *Hyparrhenia hirta* and Copperwire Grass *Aristida diffusa* with Tassel Bristlegrass *A. congesta* dominating overgrazed sites. On relatively moist, steep, cooler, south-facing slopes, species-rich, dense thickets with a sparse undergrowth are dominated by a non-grassy herbaceous layer.

The low land is an open savanna (Photo 28), with scattered trees of Paperbark Thorn *Acacia sieberiana*, Sweet Thorn *A. karroo*, Scented Thorn *A. nilotica* and *A. caffra*. The herbaceous layer is quite variable, with secondary grassland.

13.4 Demography and Landcover

The total population for the study area is 3200 (2001 census data). Land use includes cultivated dryland irrigation farming and stock farming. Forest plantations occur to the north of the study area. Erosion occurs in the central parts of the RU. The landcover is shown in Figure 76.



Photo 28: Savanna areas
(Source: www.panoramio.com)

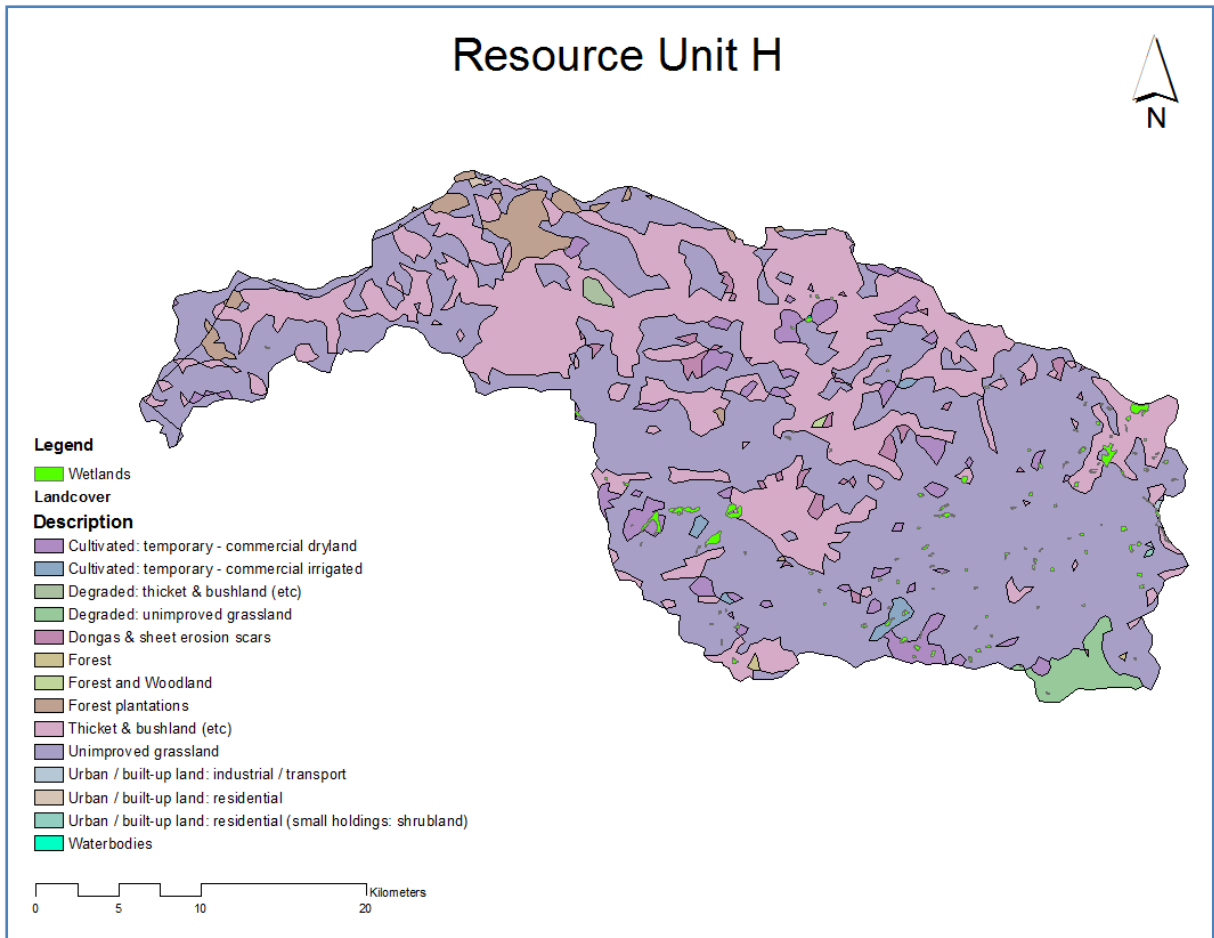


Figure 76: Landcover within RU

13.5 Surface Water

The Sand, Dew and Middle Streams join to form the Sand River.

13.6 Wetlands

The wetlands in the RU are shown in Figure 76.

13.7 Soils (taken from www.deat.gov.za)

In the high lands the soils are typical of a mountain landscape, are shallow lithosols, mainly representative of the Glenrosa and Mispah soil forms. The low land soil is shallow, derived from shales and mudstones of the Ecca Group of the Karoo Sequence. With a smaller rainfall, it is characterised by subsoils, which are either duplex, which renders them potentially highly erodible, or dominated by black clays.

13.8 Geology (summarised from Woodford and Chevallier, 2002)

The Beaufort Group dominates in this RU and is stratigraphically divided into two major units, the upper Tarkastad Subgroup and the lower Adelaide Subgroup. The Tarkastad Subgroup is subdivided into the upper Burgersdorp Formation with its brightly coloured red, blue and green mudstones and the lower Katberg Formation that can be up to 900 m thick. The Katberg Formation also contains brightly coloured shales and mudstones, but mainly consists of thick layers of coarse-grained sandstone. The Adelaide Subgroup mainly consists of green, bluish, grey and red mudstones and fine-grained sandstones that form thick lens-shaped units. The central basin mainly consists of mudstones, shales and fine-grained sandstones. These fine-grained sediments were mainly deposited where the braided rivers began to meander. The sedimentary units in the Group therefore usually have very low primary hydraulic conductivities. Since the Beaufort Group was also deposited in a fluvial environment, one can expect that aquifers in these formations will, like those in the Ecca Group, be anisotropic. The geometry of these aquifers, however, is further complicated by the migration of the braided and meandering streams. Aquifers in the Beaufort Group will therefore not only be multi-layered, but also multi-porous with variable thicknesses. The contact plane between two different sedimentary layers will cause a discontinuity in the hydraulic properties of an aquifer. The lifespan of a high-yielding borehole in the Beaufort Group may therefore be limited if the aquifer is not recharged frequently.

The Volksrust Formation (of the Ecca Group) is a predominantly argillaceous unit, which interfingers with the overlying Beaufort Group and underlying Vryheid Formation. The Formation consists of grey to black, silty shale with thin, usually bioturbated, siltstone or sandstone lenses and beds, particularly towards its upper and lower boundaries. Thin phosphate and carbonate beds and concretions are relatively common.

Sills in the Karoo formations are sheetlike forms of dolerite intrusions that tend to follow the bedding planes of the formations concordantly. These structures, whose thicknesses vary from less than a metre to hundreds of metres, represent the dominant form in which dolerite is emplaced in the Karoo Supergroup. Dolerite sills in the Karoo Supergroup often have very complex forms. The linear dykes are also usually thinner than ring dykes and are confined to the Ecca and Beaufort Groups. This is a clear indication that the magmatic activity at the time the linear dykes intruded was less than when the ring dykes and sills intruded.

13.9 Geohydrology

1.1.65 Groundwater levels

It is clear that the groundwater levels follow the topography as seen from Figure A1 in Appendix A and therefore groundwater contour maps were generated using Bayesian interpolation. The groundwater levels for the study area are shown in Figure 77. The most probable depth to groundwater level in the RU is 2.9 mbgl according to the histogram of water levels in the RU shown in Appendix A. Groundwater levels are expected to be lower than normal due to the prevailing drought conditions. Unfortunately, very little time series water level data are available to quantify the overall impact.

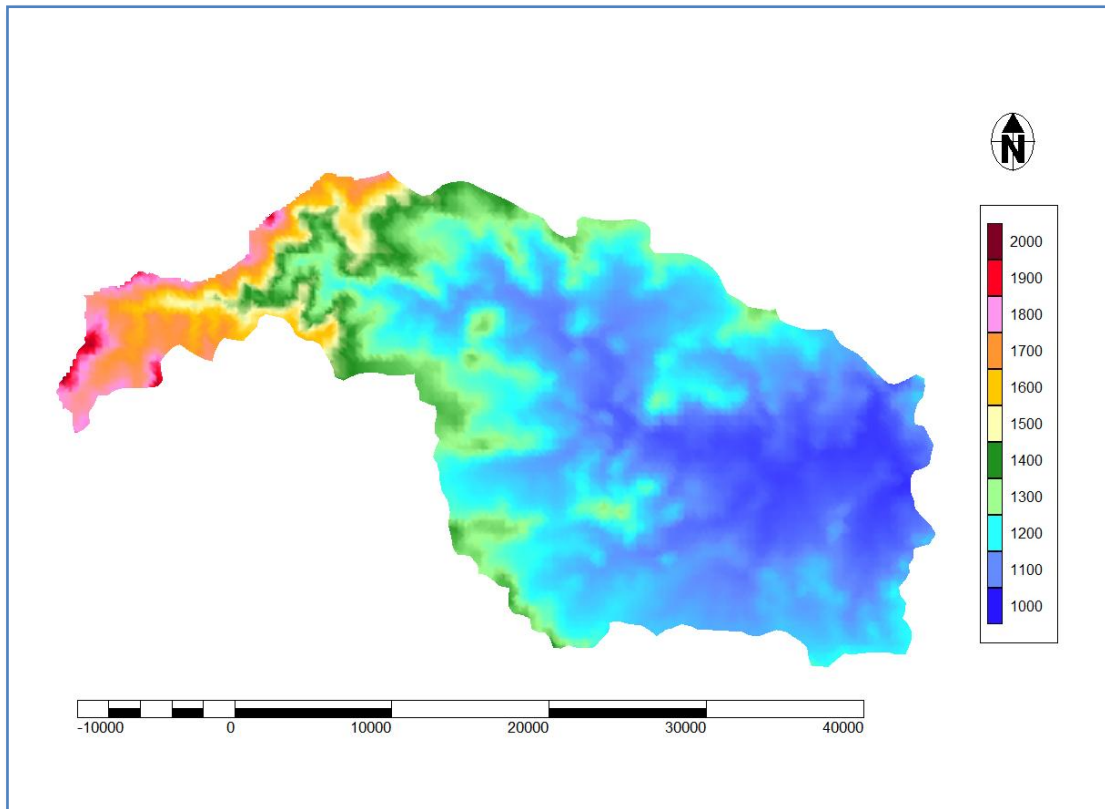


Figure 77: Groundwater levels in RUH

13.9.1 Groundwater recharge

The groundwater recharge calculated from the different methods is listed in Table 66. The different recharge methods applied are discussed in Section 2.3. The final recharge values for the RU are highlighted in red.

Table 66: Recharge values

Recharge							
MAP Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Volume Mm ³ /a	Calculated %	CMB %	Land Cover %	Geology %
738.264	40.575	59.233	39.041	5.3%	5.3%	0.9%	2.0%

1.1.66 Basic human needs

The method for determining BHNs is discussed in Section 2.3. The final value for the study area is highlighted in red in Table 67.

Table 67: Basic human needs

Basic Human Need		
Census(2001) Adjusted	Dependence 18%	Estimate Mm ³ /a
4214	759	0.007

1.1.67 Groundwater contribution to baseflow

The baseflow separation curves for the RU are shown in Figures 78 – 80.

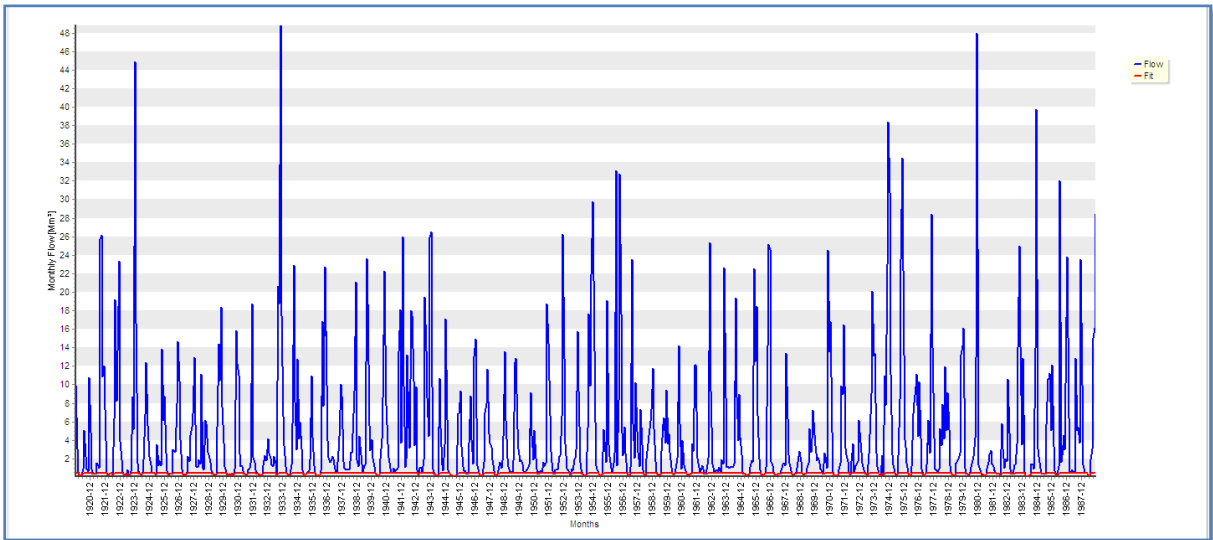


Figure 78: Baseflow separation for quaternary catchment V12D

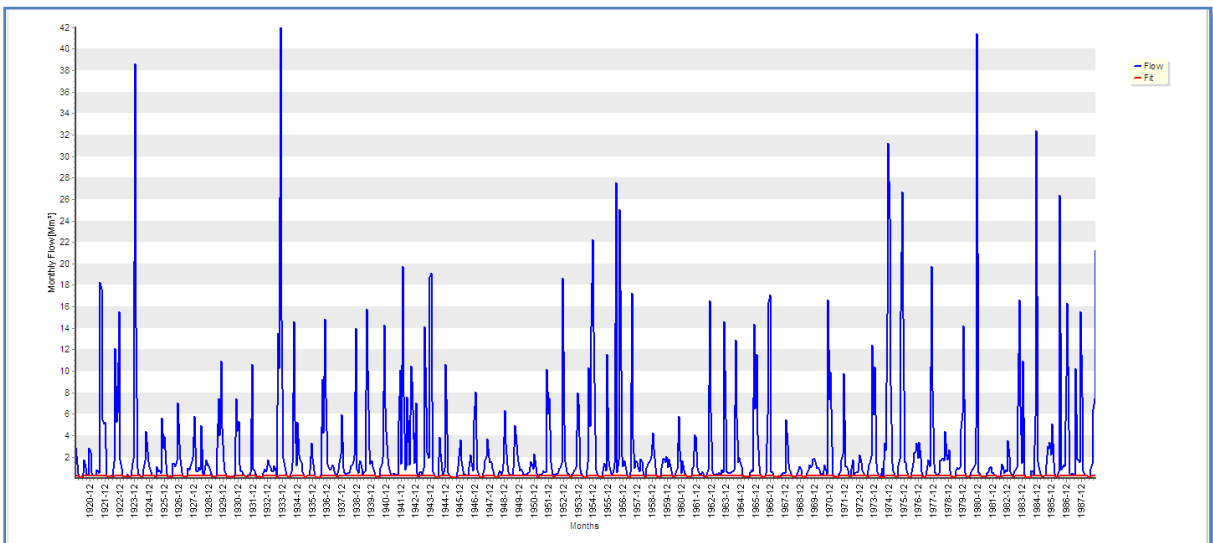


Figure 79: Baseflow separation for quaternary catchment V12E

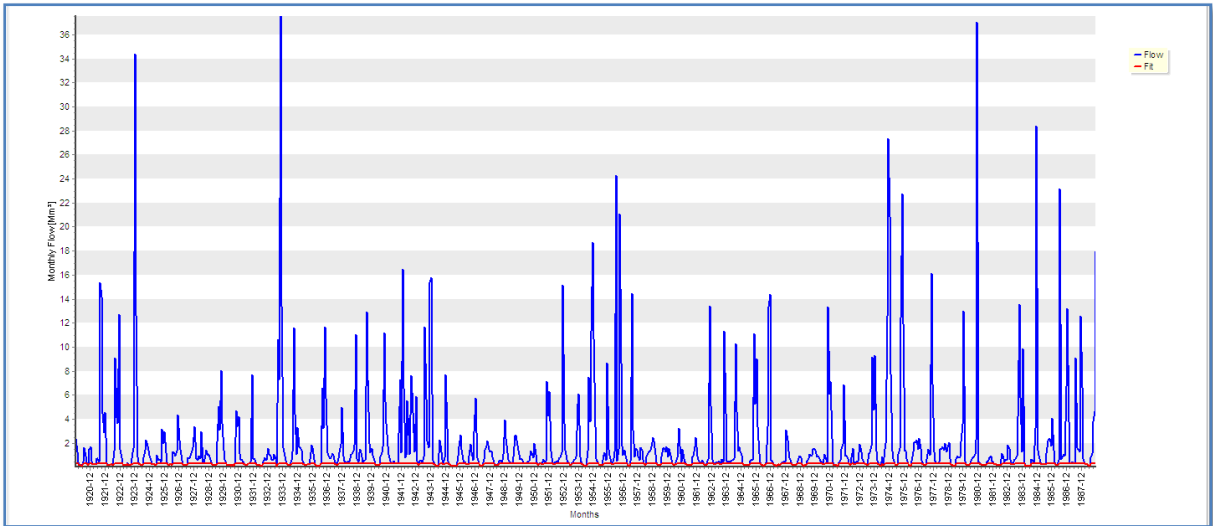


Figure 80: Baseflow separation for quaternary catchment V12F

The final groundwater contribution to baseflow values for the RU is highlighted in red in Table 68.

Table 68: Groundwater contribution to baseflow

Groundwater Contribution to Baseflow							
GRDM Mm ³ /a	Hughes Mm ³ /a	Shultz Mm ³ /a	Pitman Mm ³ /a	vTonder Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Herold Mm ³ /a
13.946	39.452	21.041	8.547	17.862	8.547	39.452	11.040

1.1.68 Groundwater use

The groundwater use for the RU is listed in Table 69.

Table 69: Groundwater use

Groundwater Use							
GRDM Mm ³ /a	WARMS Mm ³ /a	Hydrocensus Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Forrest Mm ³ /a	Crops Mm ³ /a	TOTAL Mm ³ /a
0.240	0.136	0.608	0.136	2.434	20.873	0.264	21.130

1.1.69 Groundwater quality

The TDS values for the RU are shown in Figure 81. They are classified according to SABS standards. Not all boreholes have quality data available but those that do can be used to identify possible hot spots with regard to quality in the resource unit. The overall quality of the resource unit is well within the drinking water guidelines with the exception of one borehole. These areas should be treated as hotspots rather than penalising the whole resource unit with a poor classification. Treatment of the hotspot areas will be addressed under Resource Quality Objectives in Section 31.

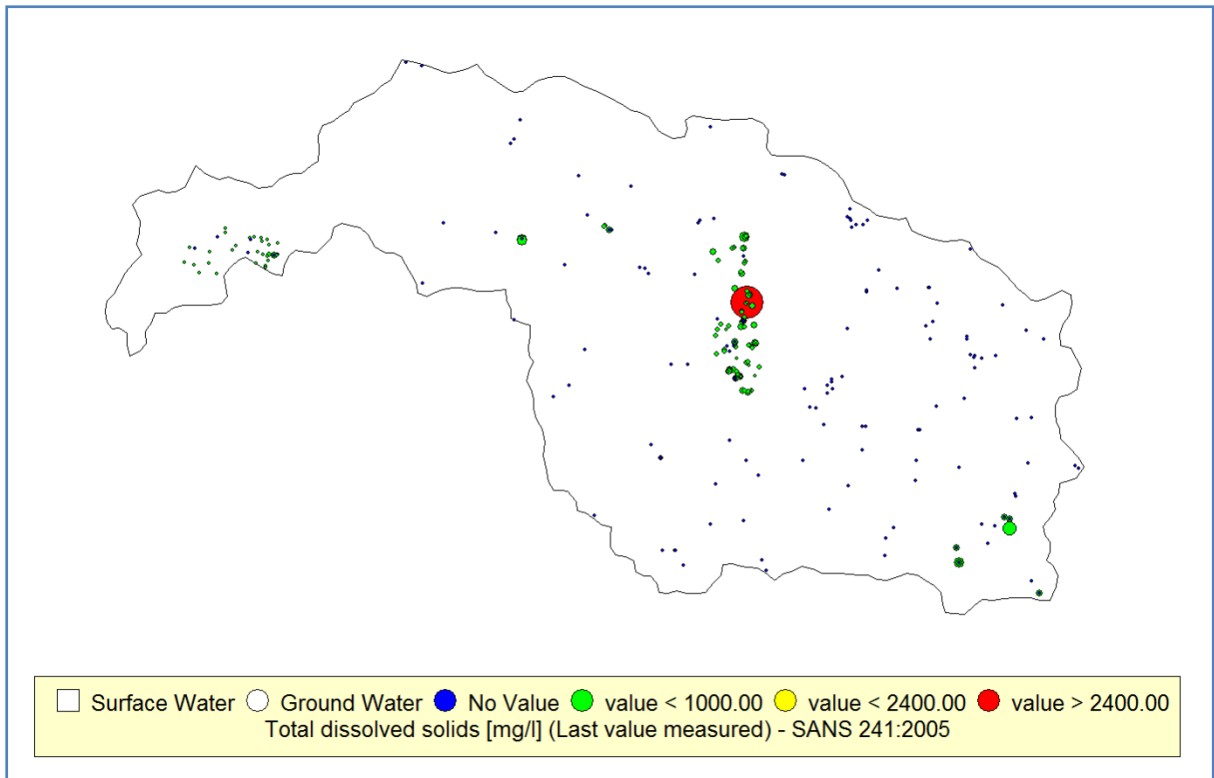


Figure 81: TDS values

1.1.70 Aquifer vulnerability

The aquifer vulnerability calculations are summarised in Table 70. The slope histogram is documented in Appendix B.

Table 70: Aquifer vulnerability

Aquifer Vulnerability						
Level mbgl	Recharge %	Slope %	Soil Texture	Aquifer Type	Vadose Zone	Vulnerability %
2.9	5.3%	1.4	SaClLm-SaCl	Weathered/Fractured	Karoo(southern)	60%

13.10 Classification

1.1.71 Groundwater usage

The stress index, defined as the ratio between total groundwater use and recharge, for the study area is calculated at 82%. Due to the uncertainty associated with the groundwater use component, the stress index was stochastically modelled through assigning a normal distribution curve with a standard deviation of 2.113 Mm³/a to the groundwater use estimate to account for the associated uncertainty. The stochastic results are shown in Figure 82. It is clear from the results that the stress index will vary between 68% and 96% with a certainty of 98.92%. Due to the large variability in the range obtained, it is recommended that the uncertainty in the groundwater use be reduced by detailed studies focusing on groundwater use within the RU. Due to the relatively high stress index this RU should be flagged as an area which requires further investigation.

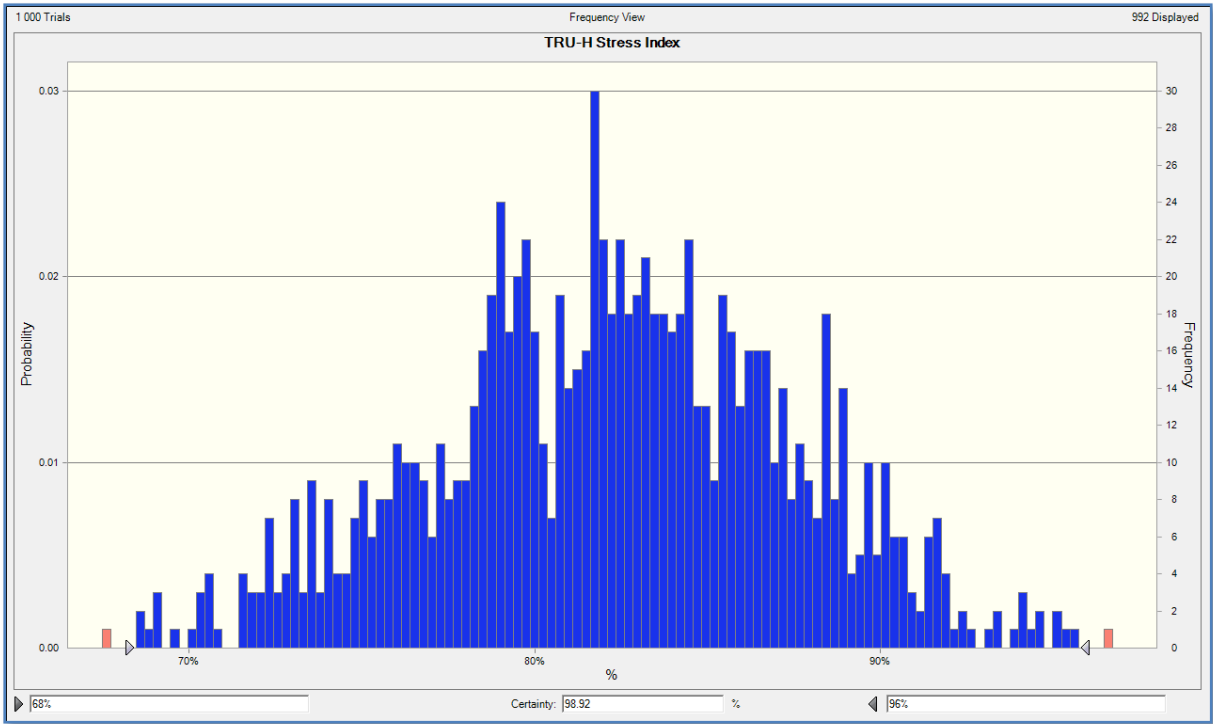


Figure 82: Stochastic results

1.1.72 Quality

The expanded Durov diagram with the groundwater quality is shown in Figure 83. An explanation of the classification process by means of the expanded Durov diagram is given in Section 2.3. Most of the boreholes fall into category A; however, there are numerous that fall into category C, therefore the final category was set as B.

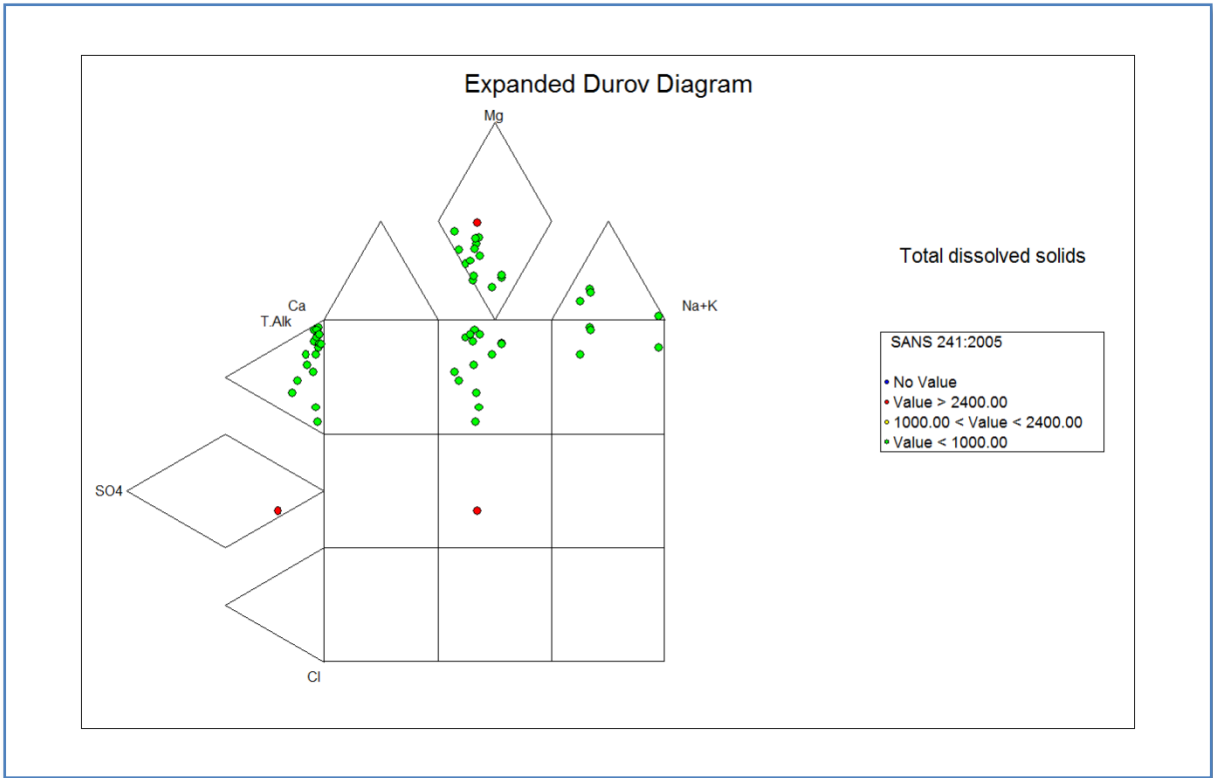


Figure 83: Expanded Durov diagram for RU

As documented, the vulnerability is 60%. The impact of potential contamination according to Section 2.3 is low.

1.1.73 Final category

The final category for the RU is summarised in Table 71.

Table 71: Category for RU

Impact	Present status category	Water resource category
Groundwater usage	E	Poor
Groundwater contamination	B	Good
Potential groundwater contamination (vulnerability and impact)	B	Good
FINAL	B/C	Good/Fair

13.11 Quantification of the Reserve

The groundwater Reserve for the RU is summarised in Table 72.

Table 72: Reserve

Reserve			Allocation	
Baseflow Mm ³ /a	BHN Mm ³ /a	Reserve % Recharge	Allocation Mm ³ /a	Current Use Mm ³ /a
11.040	0.007	28%	6.864	21.130

14. Classification and the Reserve for Resource Unit I

14.1 Location

The quaternary catchments included in this RU are: V12G, V14B and V14E. The main town in the study area is Ladysmith, a town on the banks of the Klip River. It is 230 km north-west of Durban and 365 km south of Johannesburg. Pepworth is located to the north of the RU. The location of the study area is shown in Figure 84.

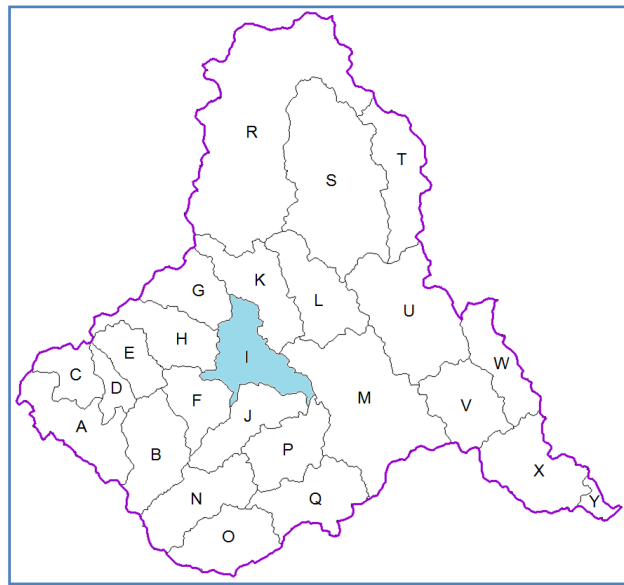


Figure 84: Location of RU I

14.2 Climate

Ladysmith normally receives about 639 mm of rain per year, with most rainfall occurring during mid-summer. It receives the lowest rainfall (1 mm) in June and the highest (122 mm) in January. The monthly distribution of average daily maximum temperatures shows that the average midday temperatures for Ladysmith range from 20°C in June to 28.1°C in January. The region is the coldest during July, when the mercury drops to 3.1°C on average during the night.

14.3 Vegetation (taken from www.deat.gov.za)

The flora has transitional Tongoland-Pondoland and Afrontane affinities. The closed canopy is up to 6 m in height and woody evergreen species are dominant, rather than succulent trees or shrubs. There is a great diversity of species in this thicket type. Common species are Kooboo-berry *Cassine aethiopica*, Thornfern *Asparagus spp.*, *Plumbago auriculata*, *Dovyalis spp.*, *Diospyros dichrophylla*, *Euphorbia triangularis* and *E. tetragona*. Grasslands also occur within the study area.

14.4 Demography and Landcover

The total population for the RU is approximately 150000 (2001 census data). Important industries in the area include food processing, textile and tyre production. Tyres are produced by Dunlop near to Steadville. Dunlop employs many skilled and unskilled labourers, contributing to Ladysmith's economy. One large local manufacturer of refrigerators, freezers, stoves, washing machines and tumble driers has its refrigerator and freezer manufacturing operations in Ezakheni (near Ladysmith). One of the large



Photo 29: Textile factory

abattoirs situated in Ladysmith produces approximately 65000 tons of red meat, which is distributed predominantly in Northern KwaZulu-Natal. The cattle and sheep are transported by road from areas in the Free State such as Harrismith, Bethlehem and Vrede to the abattoir. There are textile companies that process fibre or raw cotton into yarn or cotton (Photo 29). Farming also occurs within the study area. The landcover for the RU is shown in Figure 85.

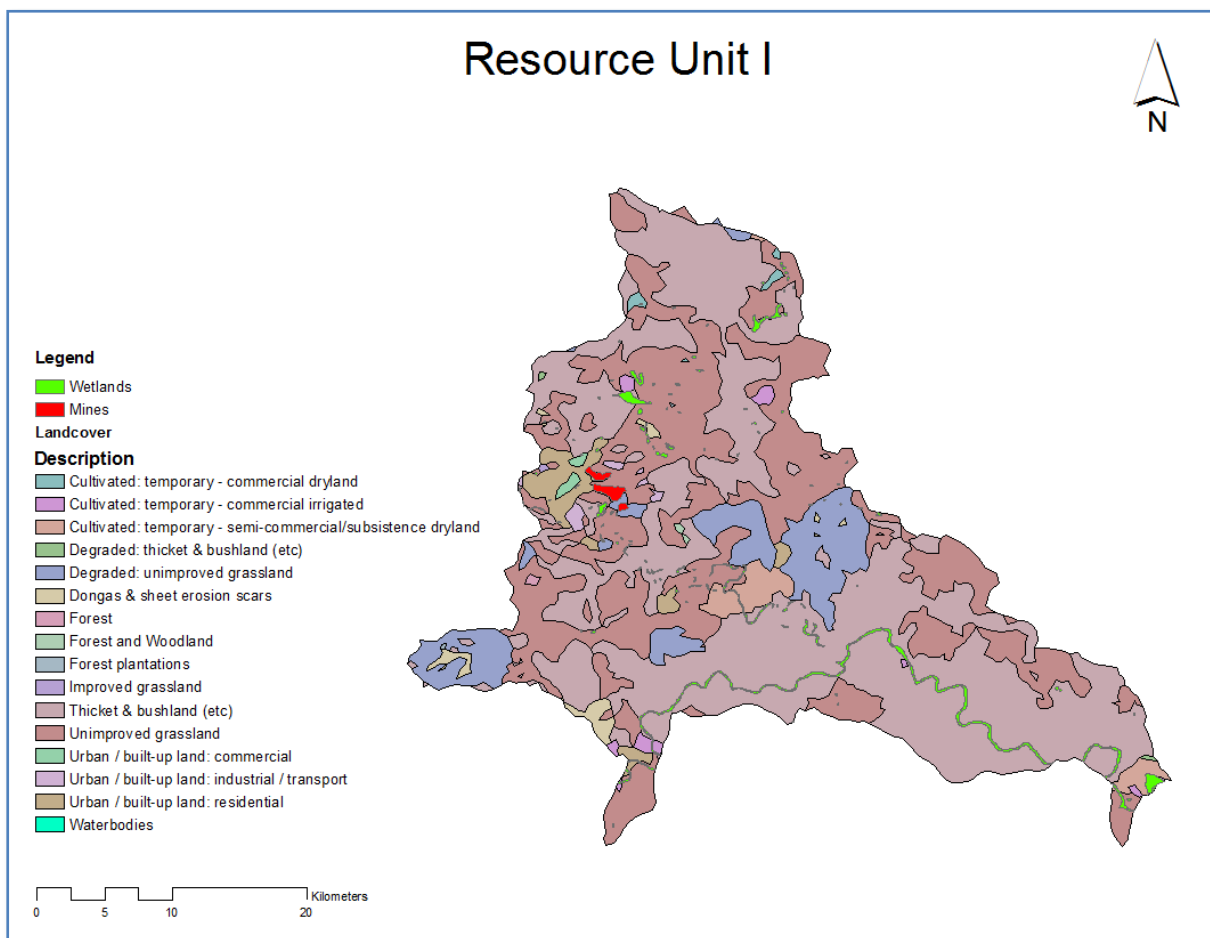


Figure 85: Landcover within RUI

14.5 Surface Water

The Modderspruit joins the Klip River. Thousands of people in Ladysmith face a serious hazard of water-borne diseases with a sewer pipe feeding faeces into the river.

14.6 Wetlands

The wetlands within the study area are shown in Figure 85.

14.7 Soils (taken from www.deat.gov.za)

The flora has transitional Tongoland-Pondoland and Afromontane affinities. The closed canopy is up to 6 m in height and woody evergreen species are dominant, rather than succulent trees or shrubs. There is a great diversity of species in this thicket type. Locally there may be many endemic species, such as in the Albany "hot spot". Common species are Kooboo-berry *Cassine aethiopica*, *Thornfern* *Asparagus* spp., *Plumbago auriculata*, *Dovyalis* spp., *Diospyros dichrophylla*, *Euphorbia triangularis* and *E. tetragona*. However, there are so many variations of this thicket, that it is difficult to characterise them in this short account. In the past their distribution was controlled by large browsers such as rhino and kudu.

14.8 Geology (summarised from Woodford and Chevallier, 2002)

The Beaufort Group dominates in this RU and is stratigraphically divided into two major units, the upper Tarkastad Subgroup and the lower Adelaide Subgroup. The Tarkastad Subgroup is subdivided into the upper Burgersdorp Formation with its brightly coloured red, blue and green mudstones and the lower Katberg Formation that can be up to 900 m thick. The Katberg Formation also contains brightly coloured shales and mudstones, but mainly consists of thick layers of coarse-grained sandstone. The Adelaide Subgroup mainly consists of green, bluish, grey and red mudstones and fine-grained sandstones that form thick lens-shaped units. The central basin mainly consists of mudstones, shales and fine-grained sandstones. These fine-grained sediments were mainly deposited where the braided rivers began to meander. The sedimentary units in the Group therefore usually have very low primary hydraulic conductivities. Since the Beaufort Group was also deposited in a fluvial environment, one can expect that aquifers in these formations will, like those in the Ecca Group, be anisotropic. The geometry of these aquifers, however, is further complicated by the migration of the braided and meandering streams. Aquifers in the Beaufort Group will therefore not only be multi-layered, but also multi-porous with variable thicknesses. The contact plane between two different sedimentary layers will cause a discontinuity in the hydraulic properties of an aquifer. The lifespan of a high-yielding borehole in the Beaufort Group may therefore be limited if the aquifer is not recharged frequently.

The Volksrust Formation (of the Ecca Group) is a predominantly argillaceous unit, which interfingers with the overlying Beaufort Group and underlying Vryheid Formation. The Formation consists of grey to black, silty shale with thin, usually bioturbated, siltstone or sandstone lenses and beds, particularly towards its upper and lower boundaries. Thin phosphate and carbonate beds and concretions are relatively common.

Sills in the Karoo formations are sheetlike forms of dolerite intrusions that tend to follow the bedding planes of the formations concordantly. These structures, whose thicknesses vary from less than a metre to hundreds of metres, represent the dominant form in which dolerite is emplaced in the Karoo Supergroup. Dolerite sills in the Karoo Supergroup often have very complex forms. The linear dykes are also usually thinner than ring dykes and are confined to the Ecca and Beaufort Groups. This is a clear indication that the magmatic activity at the time the linear dykes intruded was less than when the ring dykes and sills intruded.

14.9 Geohydrology

1.1.74 Groundwater levels

It is clear the groundwater levels follow the topography, as seen from Figure A1 in Appendix A and therefore groundwater contour maps were generated using Bayesian interpolation. The groundwater levels for the study area are shown in Figure 86. The most probable depth to groundwater level in the RU is 5.9 mbgl, according to the histogram of water levels in the RU shown in Appendix A. Groundwater levels are expected to be lower than normal due to the prevailing drought conditions. Unfortunately very little time series water level data are available to quantify the overall impact.

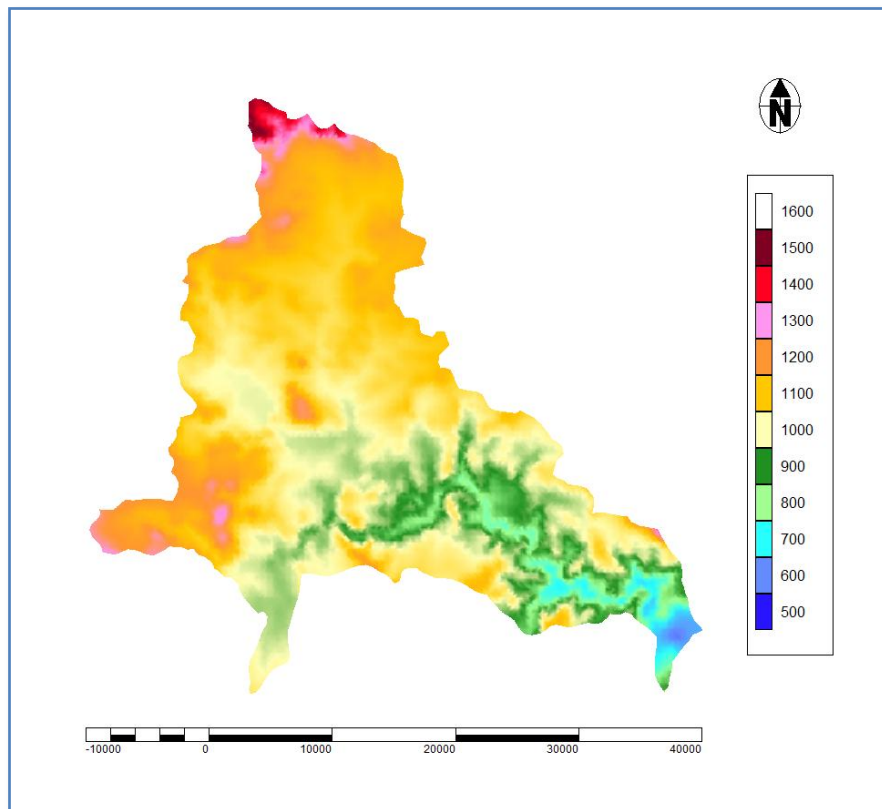


Figure 86: Groundwater levels in RUI

14.9.1 Groundwater recharge

The groundwater recharge calculated from the different methods is listed in Table 73. The different recharge methods applied are discussed in Section 2.3. The final recharge values for the RU are highlighted in red.

Table 73: Recharge values

Recharge							
MAP Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Volume Mm ³ /a	Calculated %	CMB %	Land Cover %	Geology %
713.920	30.803	52.863	47.506	6.7%	6.7%	2.4%	2.9%

1.1.75 Basic human needs

The method for determining BHNs is discussed in Section 2.3. The final value for the study area is highlighted in red in Table 74.

Table 74: Basic human needs

Basic Human Need		
Census(2001) Adjusted	Dependence 18%	Estimate Mm ³ /a
171954	30952	0.279

1.1.76 Groundwater contribution to baseflow

The baseflow separation curves for the RU are shown in Figures 87 – 89.

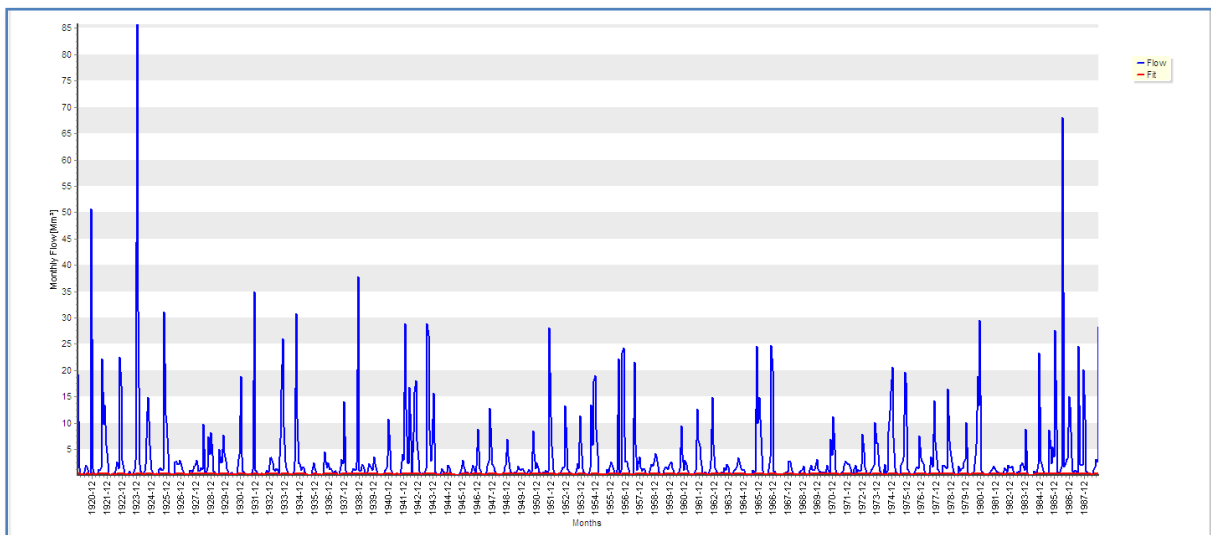


Figure 87: Baseflow separation for quaternary catchment V12G

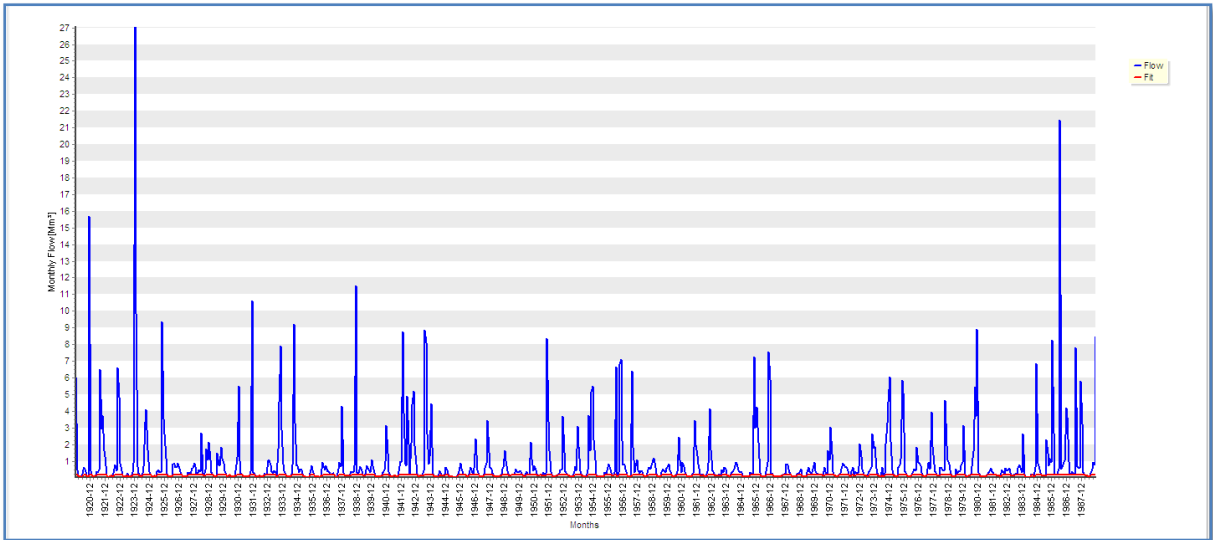


Figure 88: Baseflow separation for quaternary catchment V14B

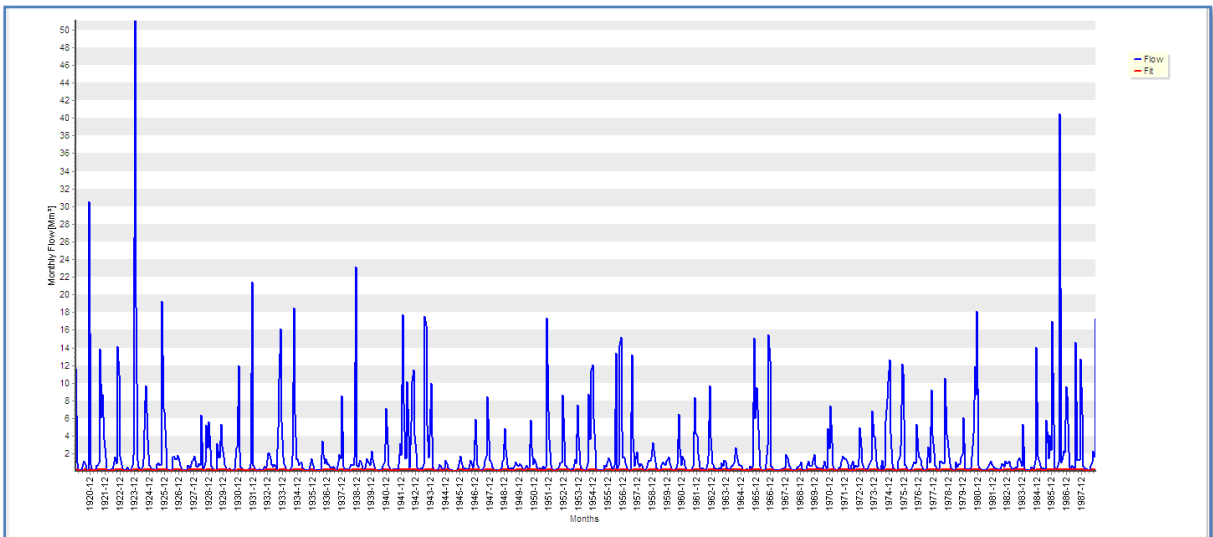


Figure 89: Baseflow separation for quaternary catchment V14E

The final groundwater contribution to baseflow values for the RU is highlighted in red in Table 75.

Table 75: Groundwater contribution to baseflow

Groundwater Contribution to Baseflow							
GRDM Mm ³ /a	Hughes Mm ³ /a	Shultz Mm ³ /a	Pitman Mm ³ /a	vTonder Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Herold Mm ³ /a
16.621	26.182	15.703	6.333	12.765	6.333	26.182	8.420

1.1.77 Groundwater use

The groundwater use for the RU is listed in Table 76.

Table 76: Groundwater use

Groundwater Use							
GRDM Mm ³ /a	WARMS Mm ³ /a	Hydrocensus Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Forrest Mm ³ /a	Crops Mm ³ /a	TOTAL Mm ³ /a
0.170	0.006	0.563	0.006	2.252	13.666	0.285	13.672

1.1.78 Groundwater quality

The TDS values for the RU are shown in Figure 90. They are classified according to SABS standards. Not all boreholes have quality data available but those that do can be used to identify possible hot spots with regard to quality in the resource unit. The overall quality of the resource unit is well within the drinking water guidelines with the exception of three boreholes. These areas should be treated as hotspots rather than penalising the whole resource unit with a poor classification. Treatment of the hotspot areas will be addressed under Resource Quality Objectives in Section 31.

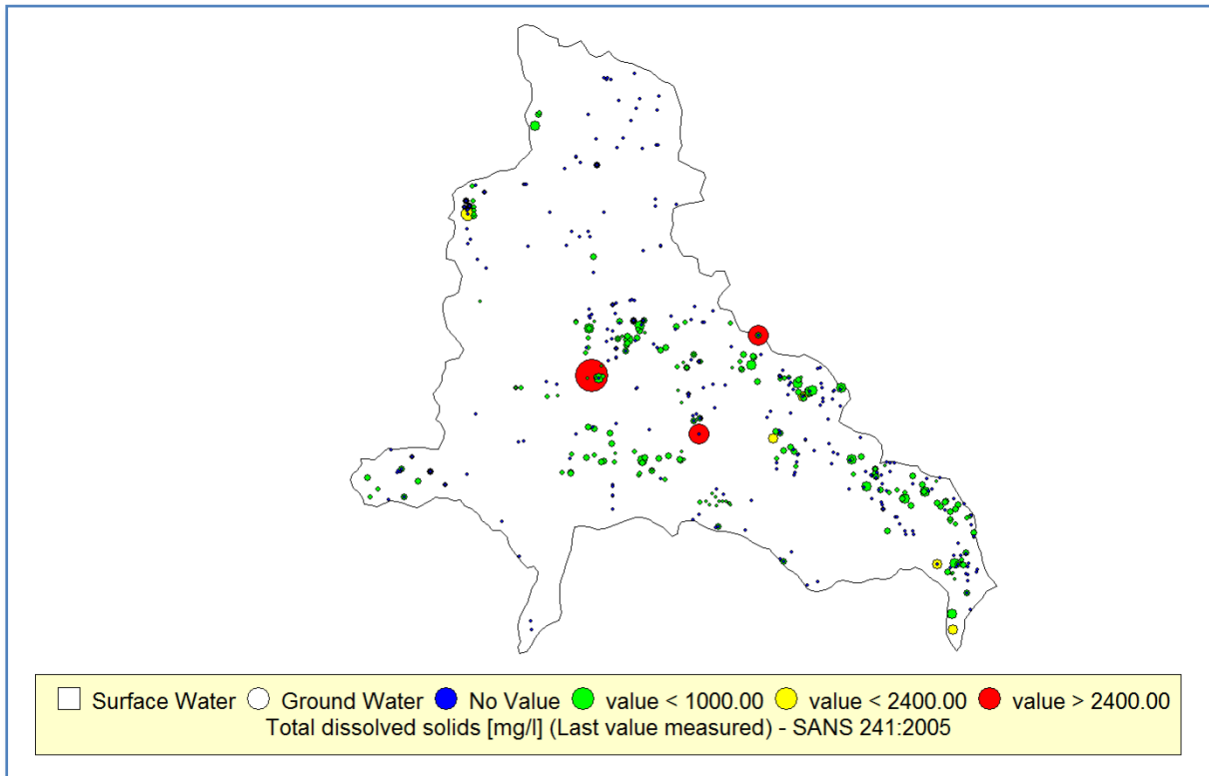


Figure 90: TDS values

1.1.79 Aquifer vulnerability

The aquifer vulnerability calculations are summarised in Table 77. The slope histogram is documented in Appendix B.

Table 77: Aquifer vulnerability

Aquifer Vulnerability						
Level mbgl	Recharge %	Slope %	Soil Texture	Aquifer Type	Vadose Zone	Vulnerability %
5.9	6.7%	1.1	SaCLm-SaCl	Weathered/Fractured	Karoo(southern)	61%

14.10 Classification

1.1.80 Groundwater usage

The stress index, defined as the ratio between total groundwater use and recharge, for the study area is calculated at 47%. Due to the uncertainty associated with the groundwater use component, the stress index was stochastically modelled through assigning a normal distribution curve with a standard deviation of 1.367 Mm³/a to the groundwater use estimate to account for the associated uncertainty. The stochastic results are shown in Figure 91. It is clear from the results that the stress index will vary between 40% and 50% with a certainty of 98.73%. Due to the small variability in the obtained range and high certainty, the uncertainty in the groundwater use component will not affect the calculated stress index significantly.

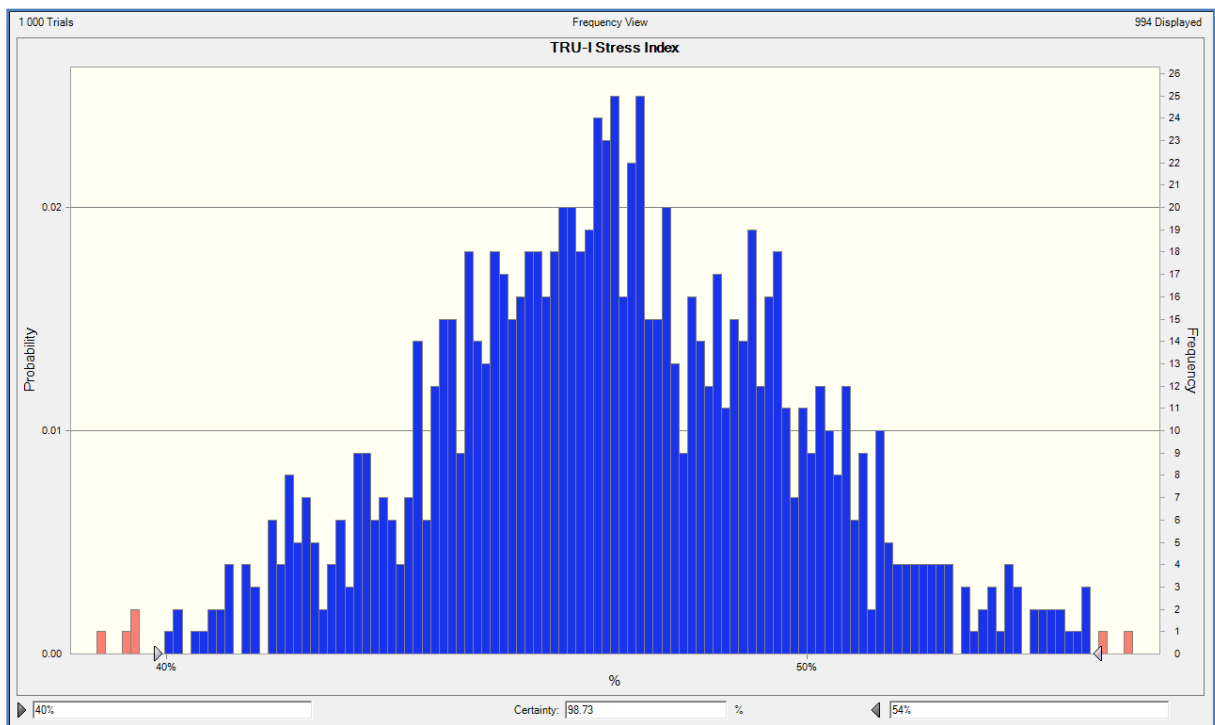


Figure 91: Stochastic results

1.1.81 Quality

The expanded Durov diagram with the groundwater quality is shown in Figure 92. An explanation of the classification process by means of the expanded Durov diagram is given in Section 2.3. Due to the number of boreholes in the b and C categories it was decided to set the quality category as B/C.

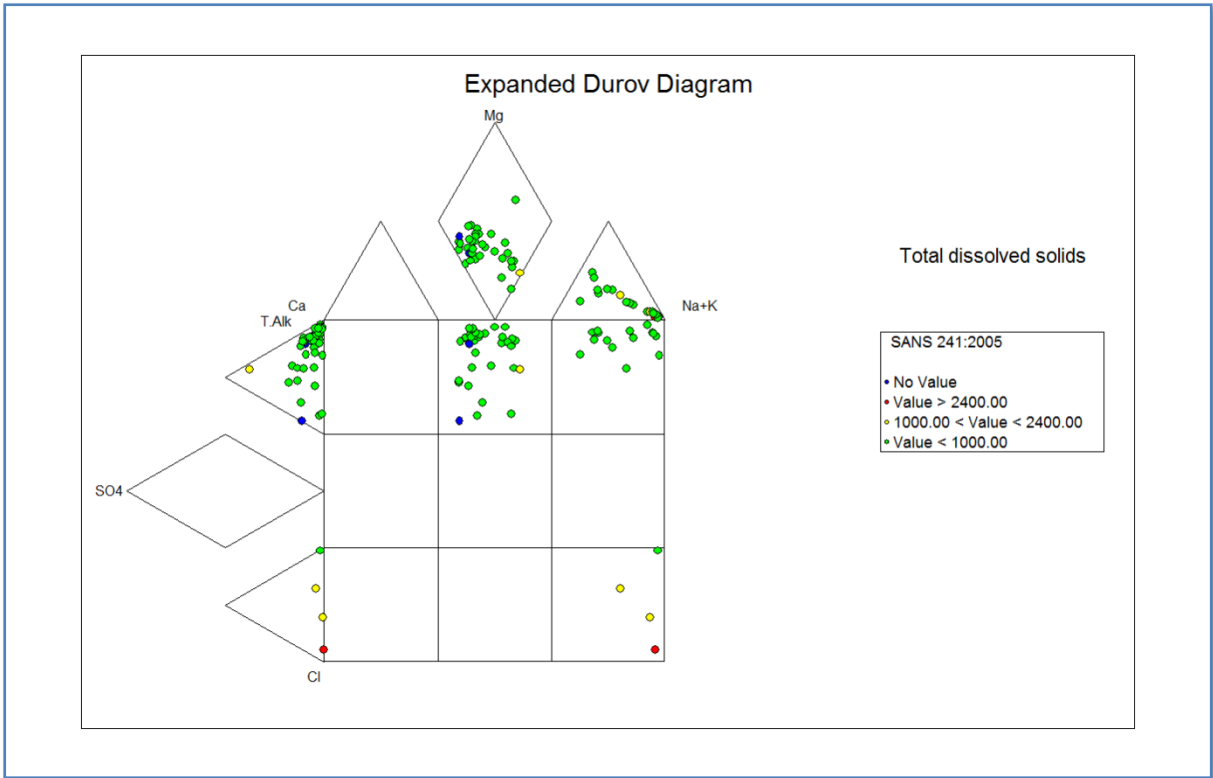


Figure 92: Expanded Durov diagram for RU

As documented the vulnerability is 61%. The impact of potential contamination according to Section 2.3 is moderate because of the mines and agricultural activities in the RU.

1.1.82 Final category

The final category for the RU is summarised in Table 78.

Table 78: Category for RU

Impact	Present status category	Water resource category
Groundwater usage	D	Fair
Groundwater contamination	B/C	Good/Fair
Potential groundwater contamination (vulnerability and impact)	C	Good/Fair
FINAL	C	Fair

14.11 Quantification of the Reserve

The groundwater Reserve for the RU is summarised in Table 79.

Table 79: Reserve

Reserve			Allocation	
Baseflow Mm ³ /a	BHN Mm ³ /a	Reserve % Recharge	Allocation Mm ³ /a	Current Use Mm ³ /a
8.420	0.279	18%	25.136	13.672

15. Classification and the Reserve for Resource Unit J

15.1 Location

The quaternary catchments located in this RU are V14C and V14D. There are no major towns in the study area, although there is the Weenen Game Reserve. The location of the RU is shown in Figure 93.

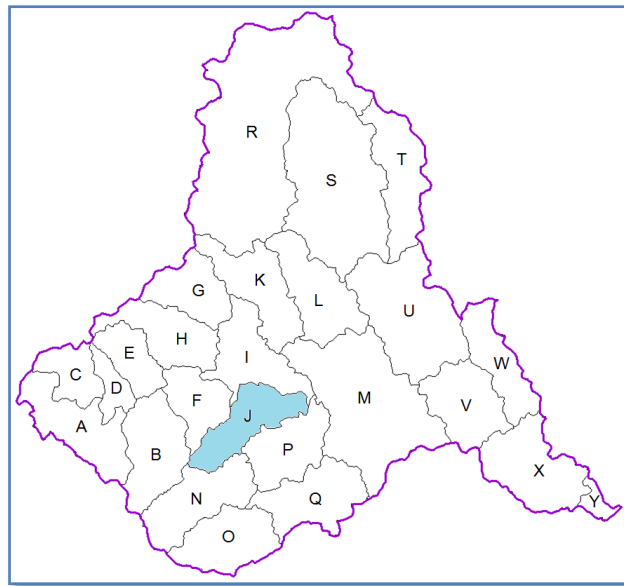


Figure 93: Location of RUJ

15.2 Climate

The RU normally receives about 720 – 790 mm of rain per year, with most rainfall occurring during mid-summer. The RU receives the lowest rainfall in June, and the highest in January. The monthly distribution of average daily maximum temperatures shows that the average midday temperatures range from 18.7°C in June to 26.4°C in January. The region is the coldest during June, when the mercury drops to 1.7°C on average during the night.

15.3 Flora and Fauna (taken from www.deat.gov.za)

The area is typical inland KwaZulu-Natal acacia grassland, with occasional thickets. More than 230 species of birds have been recorded, and the Weenen Reserve is an excellent example of how a severely degraded habitat can be successfully rehabilitated. Wildlife in the reserve includes rhino, giraffe (Photo 30), hyaena, jackal, bushbuck, reedbuck, steenbok and porcupine.



15.4 Demography and Landcover

The total population is approximately 12000 (2001 census data). Land use includes cultivated dryland and irrigation farming, and stock farming. Overgrazing is a problem within the RU. The Game Reserve covers a large area of the RU. The landcover within the RU is shown in Figure 94.

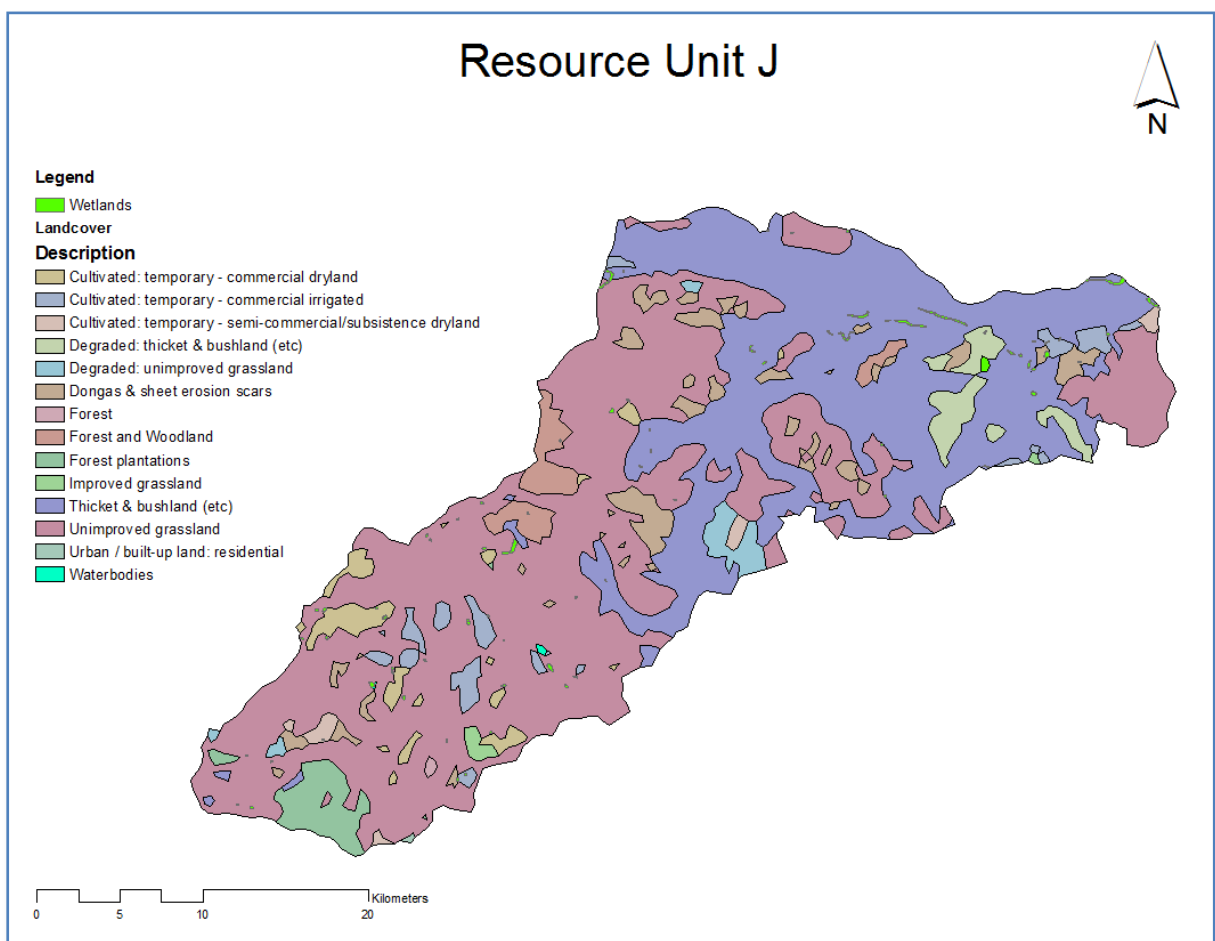


Figure 94: Landcover within RUJ

15.5 Surface Water

The Drakespruit, Nyandu and Mtontwanes join the Bloukrans River in this RU. TDS, Sulphate and Phosphate on Bloukrans somewhat elevated (possibly due to Cornfields Tembahlile settlements).

15.6 Wetlands

The wetlands in the study area are shown in Figure 94.

15.7 Soils (taken from www.deat.gov.za)

Where this vegetation type occurs on highly erodible, shallow duplex soils, grazing and fire require careful management.

15.8 Geology (summarised from Woodford and Chevallier, 2002)

The Beaufort Group dominates in this RU, and is stratigraphically divided into two major units, the upper Tarkastad Subgroup and the lower Adelaide Subgroup. The Tarkastad Subgroup is subdivided into the upper Burgersdorp Formation with its brightly coloured red, blue and green mudstones and the lower Katberg Formation, that can be up to 900 m thick. The Katberg Formation also contains brightly coloured shales and mudstones, but mainly consists of thick layers of coarse-grained sandstone. The Adelaide Subgroup mainly consists of green, bluish, grey and red mudstones and fine-grained sandstones that form thick lens-shaped units. The central basin mainly consists of mudstones, shales and fine-grained sandstones. These fine-grained sediments were mainly deposited where the braided rivers began to meander. The sedimentary units in the Group therefore usually have very low primary hydraulic conductivities. Since the Beaufort Group was also deposited in a fluvial environment, one can expect that aquifers in these formations will, like those in the Ecca Group, be anisotropic. The geometry of these aquifers, however, is further complicated by the migration of the braided and meandering streams. Aquifers in the Beaufort Group will therefore not only be multi-layered, but also multi-porous with variable thicknesses. The contact plane between two different sedimentary layers will cause a discontinuity in the hydraulic properties of an aquifer. The lifespan of a high-yielding borehole in the Beaufort Group may therefore be limited if the aquifer is not recharged frequently.

The Volksrust Formation (of the Ecca Group) is a predominantly argillaceous unit, which interfingers with the overlying Beaufort Group and underlying Vryheid Formation. The Formation consists of grey to black, silty shale with thin, usually bioturbated, siltstone or sandstone lenses and beds, particularly towards its upper and lower boundaries. Thin phosphate and carbonate beds and concretions are relatively common.

Sills in the Karoo formations are sheetlike forms of dolerite intrusions that tend to follow the bedding planes of the formations concordantly. These structures, whose thicknesses vary from less than a metre to hundreds of metres, represent the dominant form in which dolerite is emplaced in the Karoo Supergroup. Dolerite sills in the Karoo Supergroup often have very complex forms.

The linear dykes are also usually thinner than ring dykes and are confined to the Ecca and Beaufort Groups. This is a clear indication that the magmatic activity at the time the linear dykes intruded was less than when the ring dykes and sills intruded.

15.9 *Geohydrology*

1.1.83 Groundwater levels

It is clear the groundwater levels follow the topography as seen from Figure A1 in Appendix A and therefore groundwater contour maps were generated using Bayesian interpolation. The groundwater levels for the study area are shown in Figure 95. The most probable depth to groundwater level in the RU is 6.2 mbgl according to the histogram of water levels in the RU shown in Appendix A. Groundwater levels are expected to be lower than normal due to the prevailing drought conditions. Unfortunately very little time series water level data are available to quantify the overall impact.

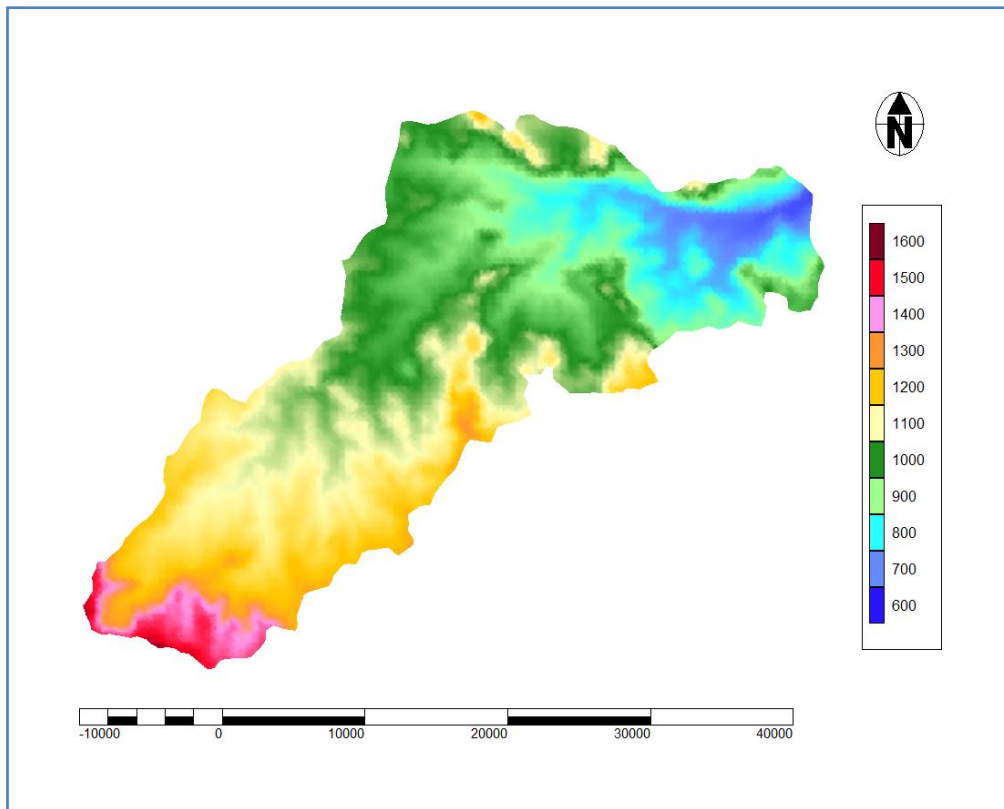


Figure 95: Groundwater levels in RU

15.9.1 Groundwater recharge

The groundwater recharge calculated from the different methods is listed in Table 80. The different recharge methods applied are discussed in Section 2.3. The final recharge values for the RU are highlighted in red.

Table 80: Recharge values

Recharge							
MAP Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Volume Mm ³ /a	Calculated %	CMB %	Land Cover %	Geology %
605.313	26.464	53.755	50.633	8.4%	8.4%	1.5%	2.5%

1.1.84 Basic human needs

The method for determining BHNs is discussed in Section 2.3. The final value for the study area is highlighted in red in Table 81.

Table 81: Basic human needs

Basic Human Need		
Census(2001) Adjusted	Dependence 18%	Estimate Mm ³ /a
20965	3774	0.034

1.1.85 Groundwater contribution to baseflow

The baseflow separation curves for the RU are shown in Figures 96 & 97.

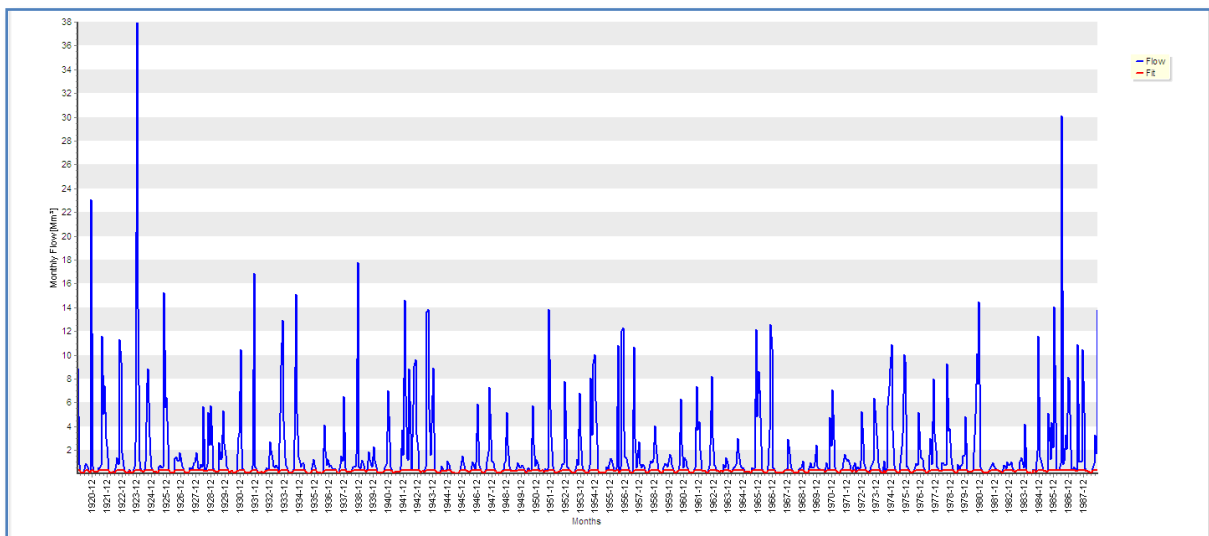


Figure 96: Baseflow separation for quaternary catchment V14C

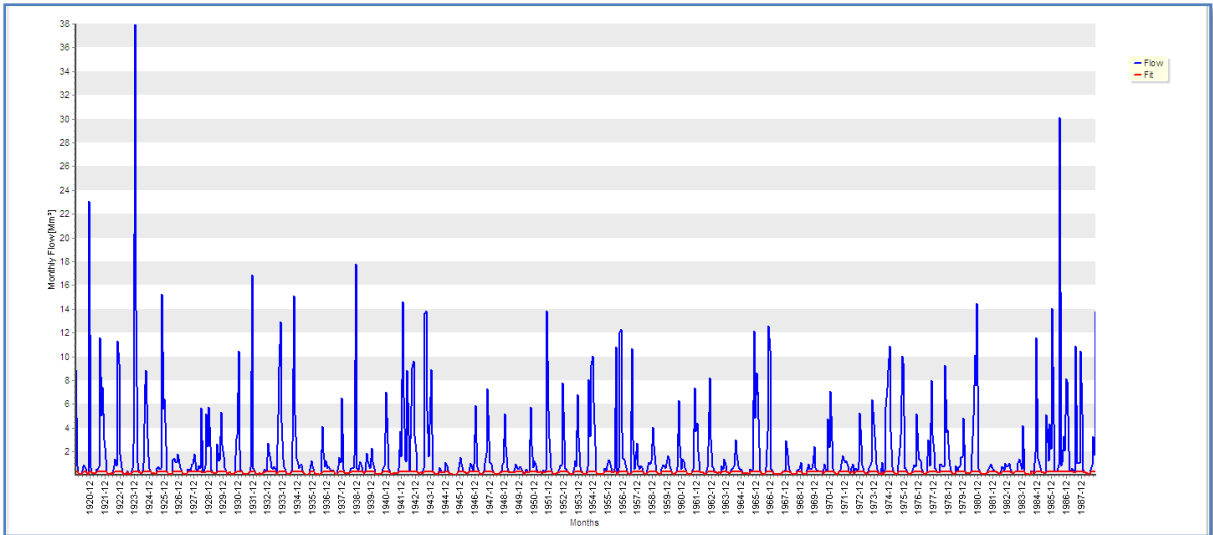


Figure 97: Baseflow separation for quaternary catchment V14D

The final groundwater contribution to baseflow values for the RU is highlighted in red in Table 82.

Table 82: Groundwater contribution to baseflow

Groundwater Contribution to Baseflow							
GRDM Mm ³ /a	Hughes Mm ³ /a	Shultz Mm ³ /a	Pitman Mm ³ /a	vTonder Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Herold Mm ³ /a
15.411	24.089	13.472	5.628	11.319	5.628	24.089	12.274

1.1.86 Groundwater use

The groundwater use for the RU is listed in Table 83.

Table 83: Groundwater use

Groundwater Use							
GRDM Mm ³ /a	WARMs Mm ³ /a	Hydrocensus Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Forrest Mm ³ /a	Crops Mm ³ /a	TOTAL Mm ³ /a
0.070	0.016	0.796	0.016	3.185	13.032	0.691	13.689

1.1.87 Groundwater quality

The TDS values for the RU are shown in Figure 98. They are classified according to SABS standards. Not all boreholes have quality data available but those that do can be used to identify possible hot spots with regard to quality in the resource unit. The overall quality of the resource unit is well within the drinking water guidelines with the exception of one borehole which is allowable.

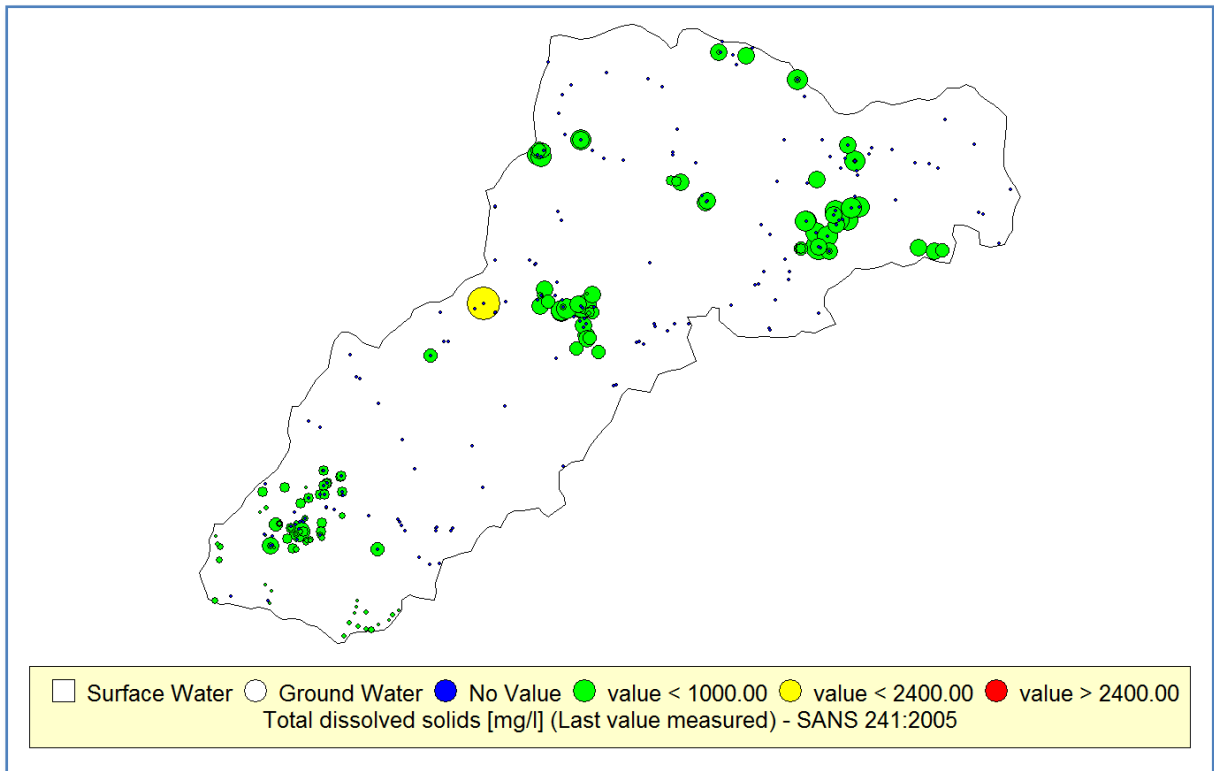


Figure 98: TDS values

1.1.88 Aquifer vulnerability

The aquifer vulnerability calculations are summarised in Table 84. The slope histogram is documented in Appendix B.

Table 84: Aquifer vulnerability

Aquifer Vulnerability						
Level mbgl	Recharge %	Slope %	Soil Texture	Aquifer Type	Vadose Zone	Vulnerability %
6.2	8.4%	1.1	SaClIm-SaCl	Weathered/Fractured	Karoo(southern)	63%

15.10 Classification

1.1.89 Groundwater usage

The stress index, defined as the ratio between total groundwater use and recharge, for the study area is calculated at 51%. Due to the uncertainty associated with the groundwater use component, the stress index was stochastically modelled through assigning a normal distribution curve with a standard deviation of 1.367 Mm³/a to the groundwater use estimate to account for the associated uncertainty. The stochastic results are shown in Figure 99. It is clear from the results that the stress index will vary between 44% and 58% with a certainty of 99.21%. Due to the small variability in the obtained range and high certainty, the uncertainty in the groundwater use component will not affect the calculated stress index significantly.

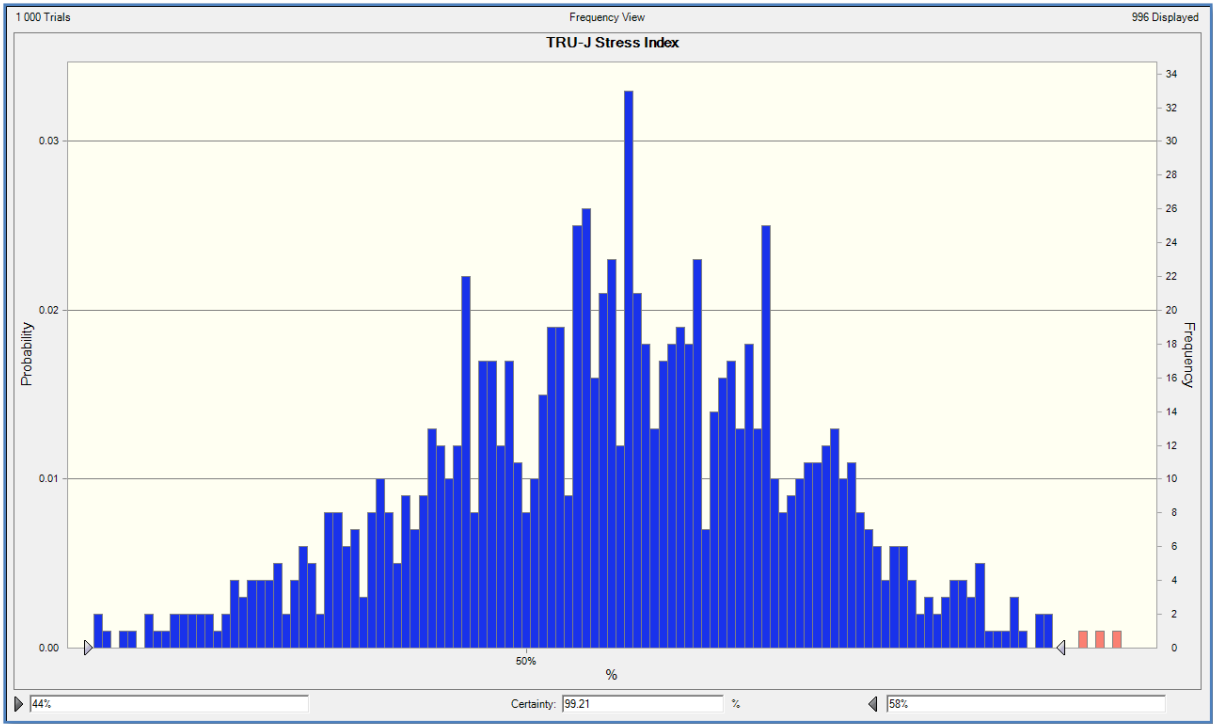


Figure 99: Stochastic results

1.1.90 Quality

The expanded Durov diagram with the groundwater quality is shown in Figure 100. An explanation of the classification process by means of the expanded Durov diagram is given in Section 2.3. There are numerous boreholes in categories A and C, however the overall water quality is relatively good therefore the final category was set as a B.

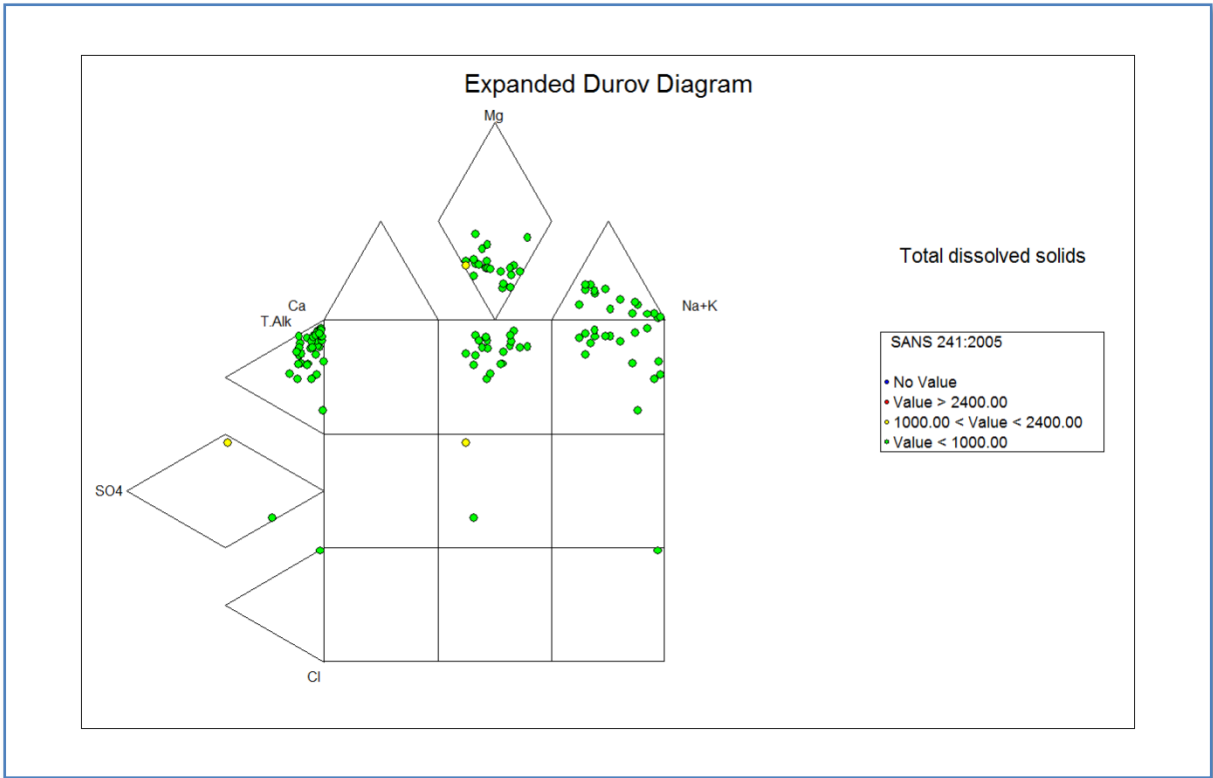


Figure 100: Expanded Durov diagram for RU

As documented the vulnerability is 63%. The impact of potential contamination according to Section 2.3 is low.

1.1.91 Final category

The final category for the RU is summarised in Table 85.

Table 85: Category for RU

Impact	Present status category	Water resource category
Groundwater usage	E	Fair
Groundwater contamination	B	Good
Potential groundwater contamination (vulnerability and impact)	B	Good
FINAL	B/C	Good/Fair

15.11 Quantification of the Reserve

The groundwater Reserve for the RU is summarised in Table 86.

Table 86: Reserve

Reserve			Allocation	
Baseflow Mm ³ /a	BHN Mm ³ /a	Reserve % Recharge	Allocation Mm ³ /a	Current Use Mm ³ /a
12.274	0.034	24%	24.635	13.689

16. Classification and the Reserve for Resource Unit K

16.1 Location

The quaternary catchments included in the RU are V60A, V60B and V60C. Towns in the area include Elandslaagte, Craigsforth, Biggarsberg and Cundyleugh. The location of the RU is shown in Figure 101.

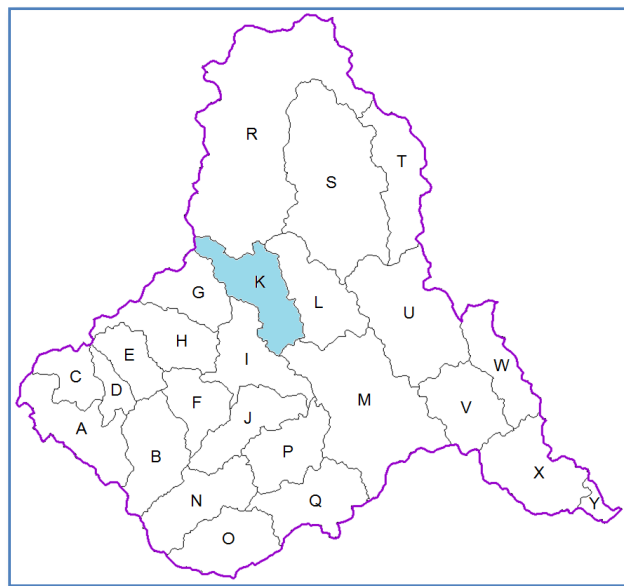


Figure 101: Location of RUK

16.2 Climate

The rainfall is 800 to 900 mm per year in summer. Mean temperatures for January are around 22°C with a mean maximum of 29°C. In winter, mean annual temperatures in July are about 10°C, with a mean minimum of about 3°C.

16.3 Vegetation (taken from www.deat.gov.za)

The Grassland Biome is found mainly on the high central plateau of South Africa, and the inland areas of KwaZulu-Natal. The topography is mainly flat and rolling, but includes the escarpment itself. Altitude varies from near sea level to 2 000 m above sea level.

Grasslands are dominated by a single layer of grasses. The amount of cover depends on rainfall and the degree of grazing. Thicket and bushland are present at localised habitats. Geophytes are often abundant. Frosts, fire and grazing maintain the grass dominance and prevent the establishment of trees.

16.4 Demography and Landcover

The population is approximately 29000 (2001 census data). Main activities in the area include cattle and game farming, forestry and agriculture. There are also coal mines located in the RU. The landcover is shown in Figure 102.

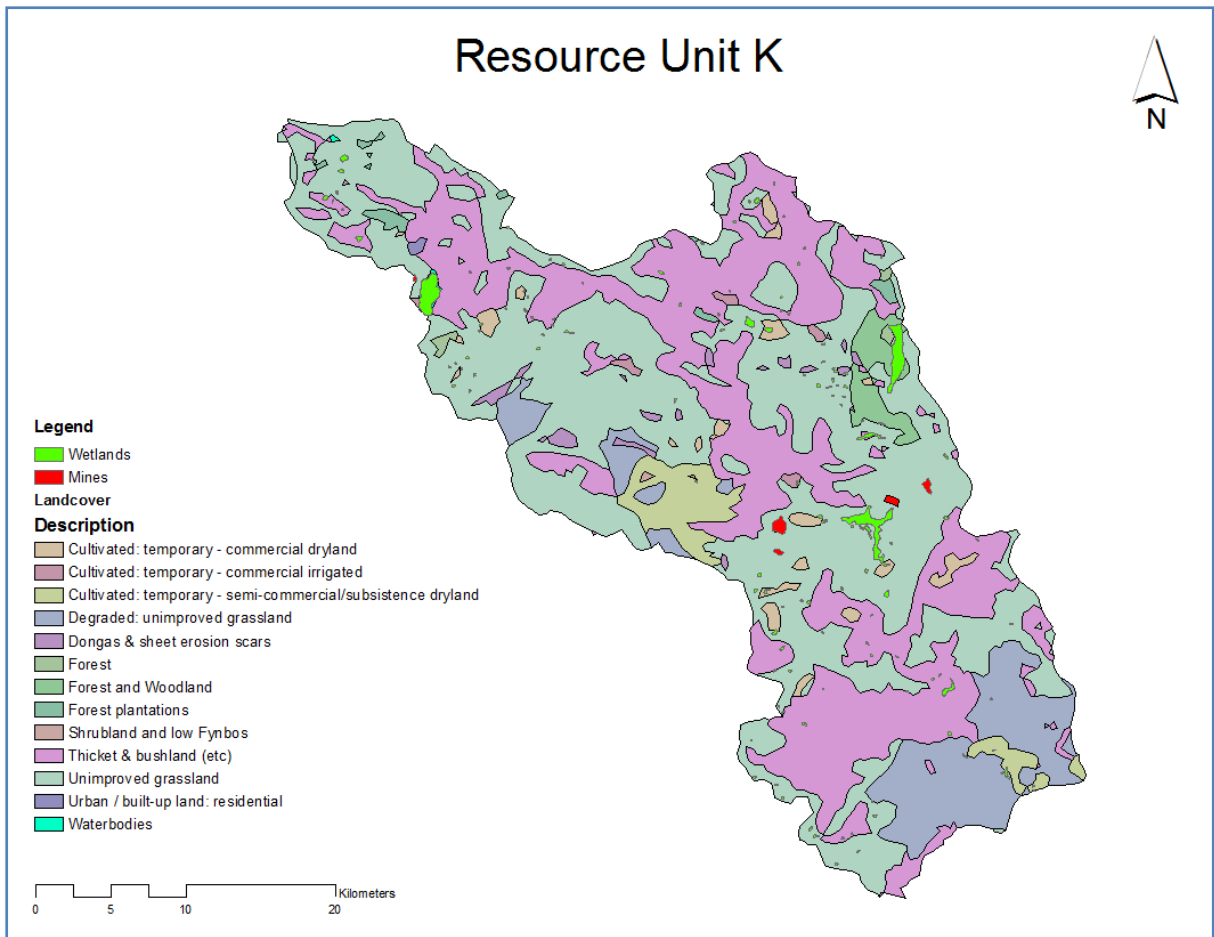


Figure 102: Landcover in RUK

16.5 Surface Water

The Dwars, Wasbank, Manzimnyama, Uithoekspruit and Biggersgatspruit join the Sundays River. The Slangdraai Dam is included in the RU.

16.6 Wetlands

The wetlands in the study area are shown in Figure 102.

16.7 Soils (taken from www.deat.gov.za)

The soil is shallow, derived from shales and mudstones of the Karoo Sequence. With a rainfall of less than 450 mm it is characterised by subsoils which are either duplex, which renders them potentially highly erodible, or dominated by black clays.

16.8 *Geology (summarised from Woodford and Chevallier, 2002)*

The Beaufort Group dominates in this RU and is stratigraphically divided into two major units, the upper Tarkastad Subgroup and the lower Adelaide Subgroup. The Tarkastad Subgroup is subdivided into the upper Burgersdorp Formation with its brightly coloured red, blue and green mudstones and the lower Katberg Formation, that can be up to 900 m thick. The Katberg Formation also contains brightly coloured shales and mudstones, but mainly consists of thick layers of coarse-grained sandstone. The Adelaide Subgroup mainly consists of green, bluish, grey and red mudstones and fine-grained sandstones that form thick lens-shaped units. The central basin consist mainly of mudstones, shales and fine-grained sandstones. These fine-grained sediments were mainly deposited where the braided rivers began to meander. The sedimentary units in the Group therefore usually have very low primary hydraulic conductivities. Since the Beaufort Group was also deposited in a fluvial environment, one can expect that aquifers in these formations will, like those in the Ecca Group, be anisotropic. The geometry of these aquifers, however, is further complicated by the migration of the braided and meandering streams. Aquifers in the Beaufort Group will therefore not only be multi-layered, but also multi-porous with variable thicknesses. The contact plane between two different sedimentary layers will cause a discontinuity in the hydraulic properties of an aquifer. The lifespan of a high-yielding borehole in the Beaufort Group may therefore be limited if the aquifer is not recharged frequently.

The Volksrust Formation (of the Ecca Group) is a predominantly argillaceous unit, which interfingers with the overlying Beaufort Group and underlying Vryheid Formation. The Formation consists of grey to black, silty shale with thin, usually bioturbated, siltstone or sandstone lenses and beds, particularly towards its upper and lower boundaries. Thin phosphate and carbonate beds and concretions are relatively common.

The Vryheid Formation (of the Ecca Group) comprises mudrock, rhythmite, siltstone and fine- to coarse-grained sandstone (pebbly in places). The Formation contains up to five (mineable) coal seams. The different lithofacies are mainly arranged in upward coarsening deltaic cycles (up to 80m thick in the southeast). Linear coastline cycles are, however, fairly common particularly in the thin northwestern part where they constitute the entire Vryheid in places. A relatively thin fluvial interval (60 m thick) which grades distally into deltaic deposits towards the south-west and south occurs approximately in the middle of the formation in the east and north-east. Fining upward fluvial cycles, of which up to six are present in the east, are typically sheet like in geometry, although some form valley-fill deposits. They comprise coarse grained to pebbly, immature sandstones - with an abrupt upward transition into fine grained sediments and coal seams.

Since these shales are very dense, they were often neglected as sources of groundwater in the past. The prodelta sandstones represent another formation of the Ecca Group in which one would expect to find high-yielding aquifers. Unfortunately, the permeabilities of these sandstones are also usually very low.

Sills in the Karoo formations are sheetlike forms of dolerite intrusions that tend to follow the bedding planes of the formations concordantly. These structures, whose thicknesses vary from less than a metre to hundreds of metres, represent the dominant form in which dolerite is emplaced in

the Karoo Supergroup. Dolerite sills in the Karoo Supergroup often have very complex forms. The linear dykes are also usually thinner than ring dykes and are confined to the Ecca and Beaufort Groups. This is a clear indication that the magmatic activity at the time the linear dykes intruded was less than when the ring dykes and sills intruded.

16.9 Geohydrology

1.1.92 Groundwater levels

It is clear the groundwater levels follow the topography as seen from Figure A1 in Appendix A and therefore groundwater contour maps were generated using Bayesian interpolation. The groundwater levels for the study area are shown in Figure 103. The most probable depth to groundwater level in the RU is 44.4 mbgl according to the histogram of water levels in the RU shown in Appendix A. Groundwater levels are expected to be lower than normal due to the prevailing drought conditions. Unfortunately very little time series water level data are available to quantify the overall impact.

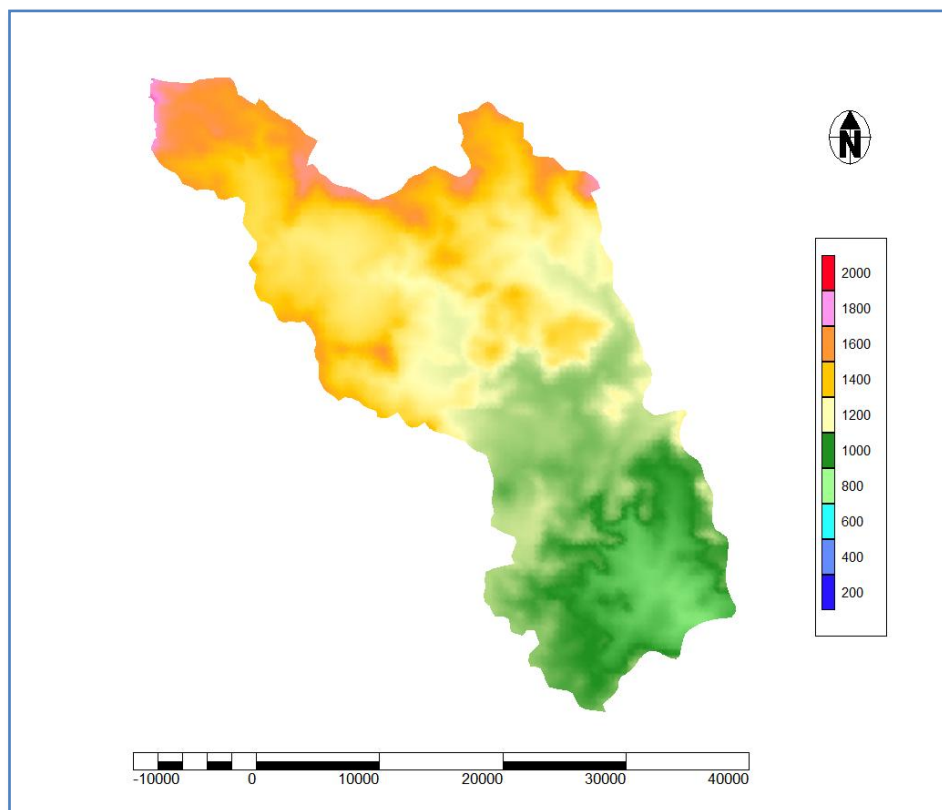


Figure 103: Groundwater levels in RUK

16.9.1 Groundwater recharge

The groundwater recharge calculated from the different methods is listed in Table 87. The different recharge methods applied are discussed in Section 2.3. The final recharge values for the RU are highlighted in red.

Table 87: Recharge values

Recharge							
MAP Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Volume Mm ³ /a	Calculated %	CMB %	Land Cover %	Geology %
826.451	42.631	59.030	41.252	5.0%	5.0%	2.0%	3.6%

1.1.93 Basic human needs

The method for determining BHNs is discussed in Section 2.3. The final value for the study area is highlighted in red in Table 88.

Table 88: Basic human needs

Basic Human Need		
Census(2001) Adjusted	Dependence 18%	Estimate Mm ³ /a
44275	7970	0.072

1.1.94 Groundwater contribution to baseflow

The baseflow separation curves for the RU are shown in Figures 104 – 106.

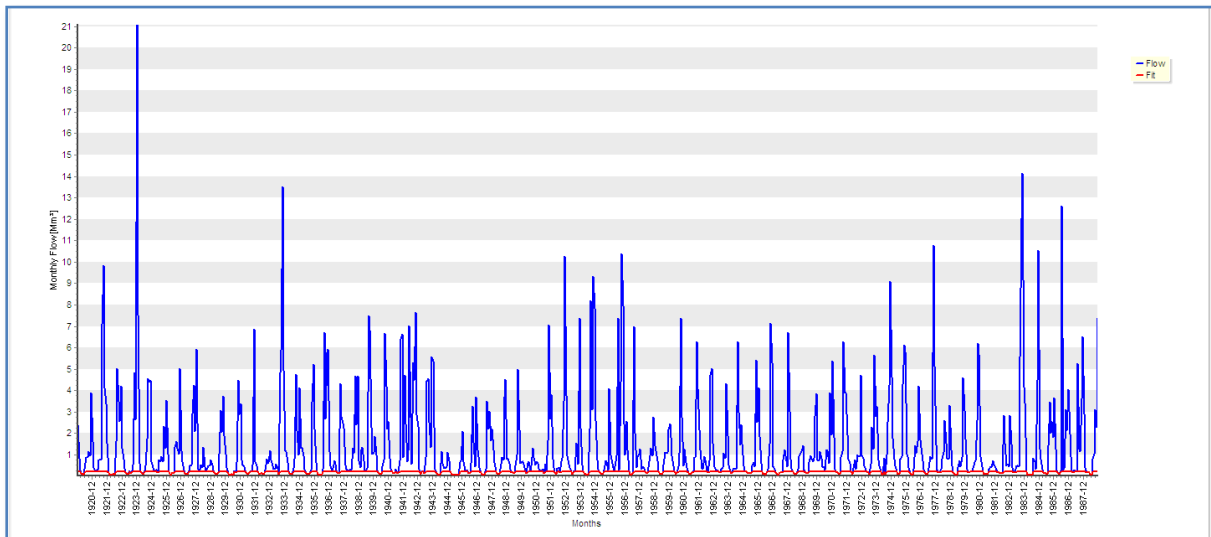


Figure 104: Baseflow separation for quaternary catchment V60A

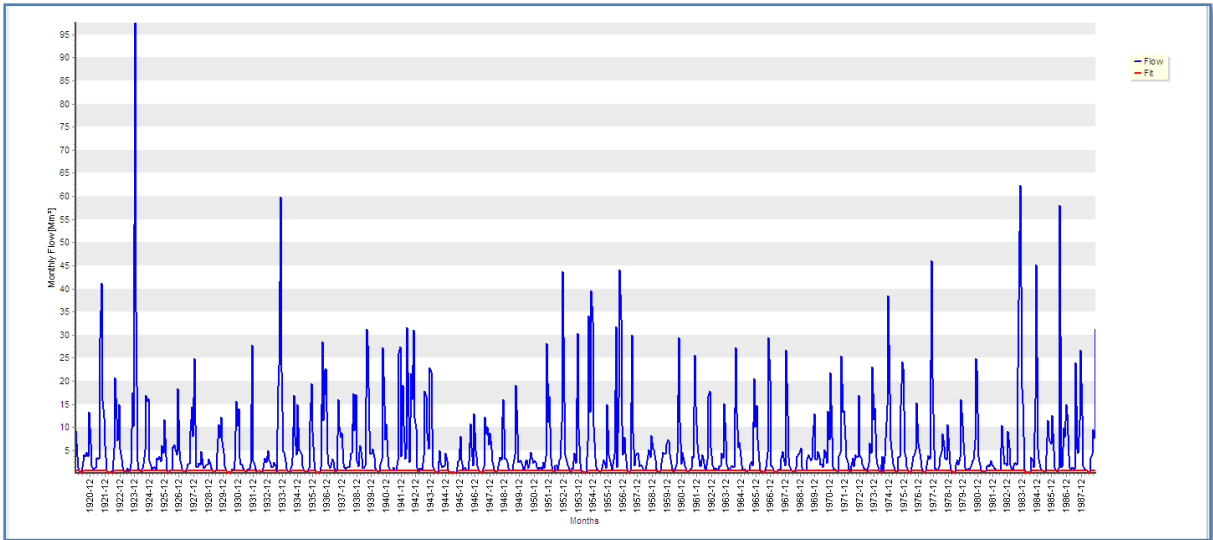


Figure 105: Baseflow separation for quaternary catchment V60B

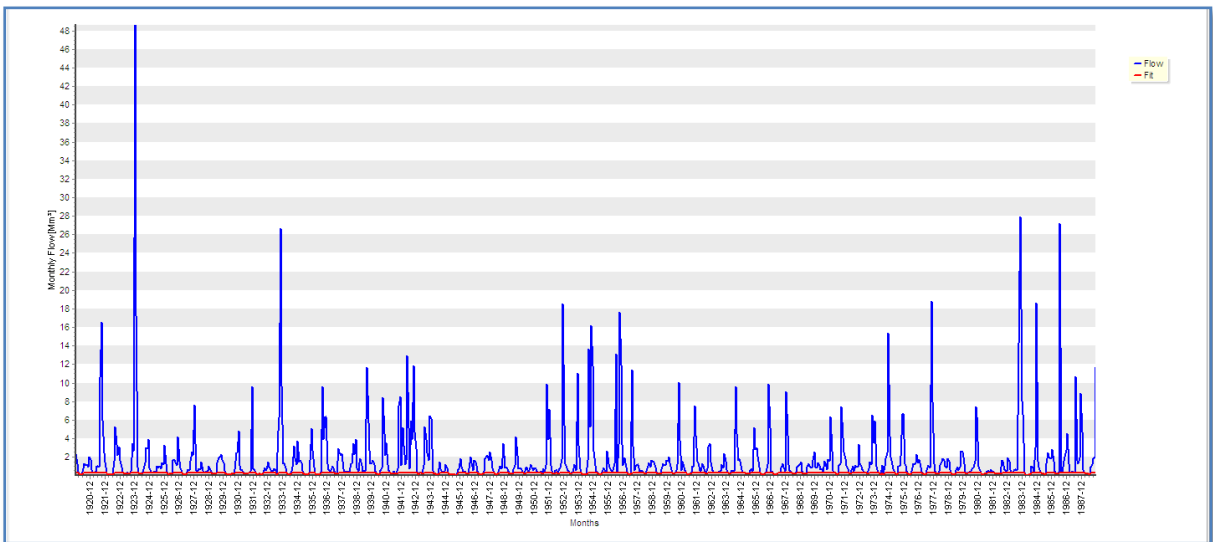


Figure 106: Baseflow separation for quaternary catchment V60C

The final groundwater contribution to baseflow values for the RU is highlighted in red in Table 89.

Table 89: Groundwater contribution to baseflow

Groundwater Contribution to Baseflow							
GRDM Mm ³ /a	Hughes Mm ³ /a	Shultz Mm ³ /a	Pitman Mm ³ /a	vTonder Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Herold Mm ³ /a
22.944	41.232	21.752	11.078	19.661	11.078	41.232	13.360

1.1.95 Groundwater use

The groundwater use for the RU is listed in Table 90.

Table 90: Groundwater use

Groundwater Use							
GRDM Mm ³ /a	WARMS Mm ³ /a	Hydrocensus Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Forrest Mm ³ /a	Crops Mm ³ /a	TOTAL Mm ³ /a
0.850	0.000	0.143	0.000	0.850	17.032	0.000	16.960

1.1.96 Groundwater quality

The TDS values for the RU are shown in Figure 107. They are classified according to SABS standards. Not all boreholes have quality data available but those that do can be used to identify possible hot spots with regard to quality in the resource unit. The overall quality of the resource unit is well within the drinking water guidelines with the exception of one borehole. These areas should be treated as hotspots rather than penalising the whole resource unit with a poor classification. Treatment of the hotspot areas will be addressed under Resource Quality Objectives in Section 31.

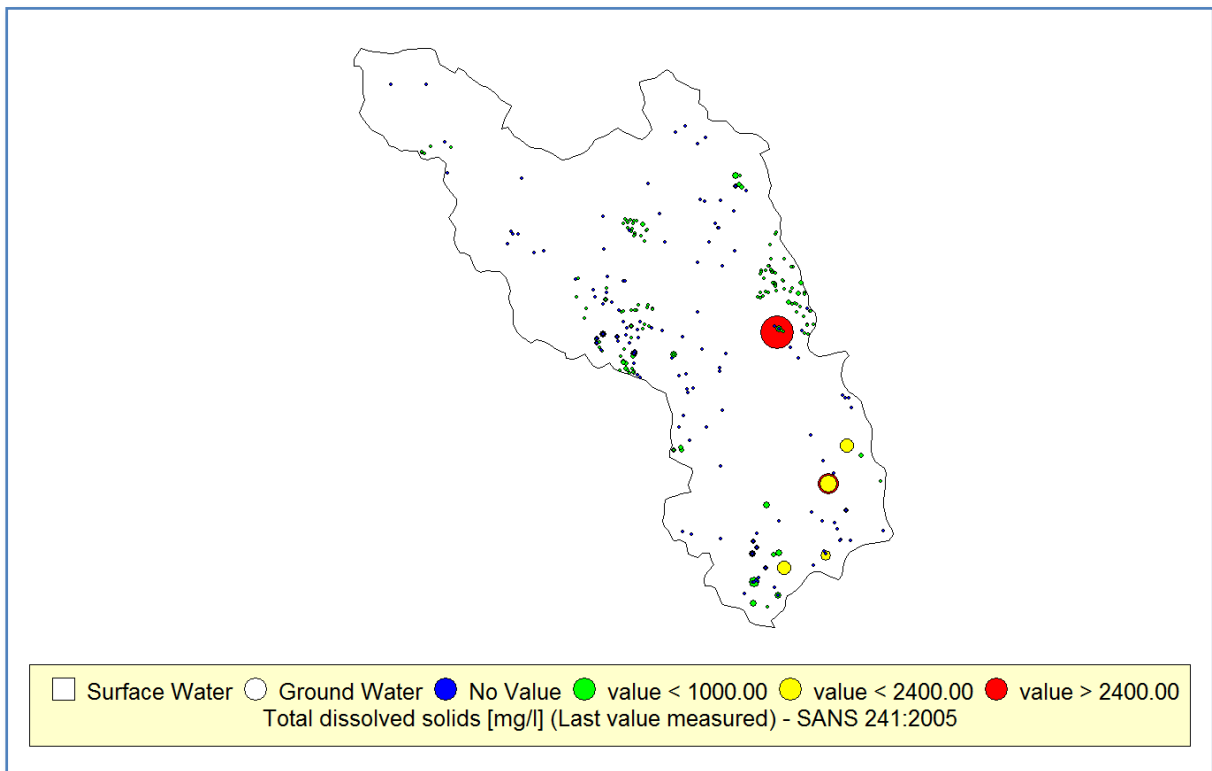


Figure 107: TDS values

1.1.97 Aquifer vulnerability

The aquifer vulnerability calculations are summarised in Table 91. The slope histogram is documented in Appendix B.

Table 91: Aquifer vulnerability

Aquifer Vulnerability						
Level mbgl	Recharge %	Slope %	Soil Texture	Aquifer Type	Vadose Zone	Vulnerability %
44.4	5.0%	2.3	SaCLm-SaCl	Weathered/Fractured	Karoo(southern)	38%

16.10 Classification

1.1.98 Groundwater usage

The stress index, defined as the ratio between total groundwater use and recharge, for the study area is calculated at 74%. Due to the uncertainty associated with the groundwater use component, the stress index was stochastically modelled through assigning a normal distribution curve with a standard deviation of 1.696Mm³/a to the groundwater use estimate to account for the associated uncertainty. The stochastic results are shown in Figure 108. It is clear from the results that the stress index will vary between 70% and 80% with a certainty of 99.32%. Due to the small variability in the obtained range and high certainty, the uncertainty in the groundwater use component will not affect the calculated stress index significantly.

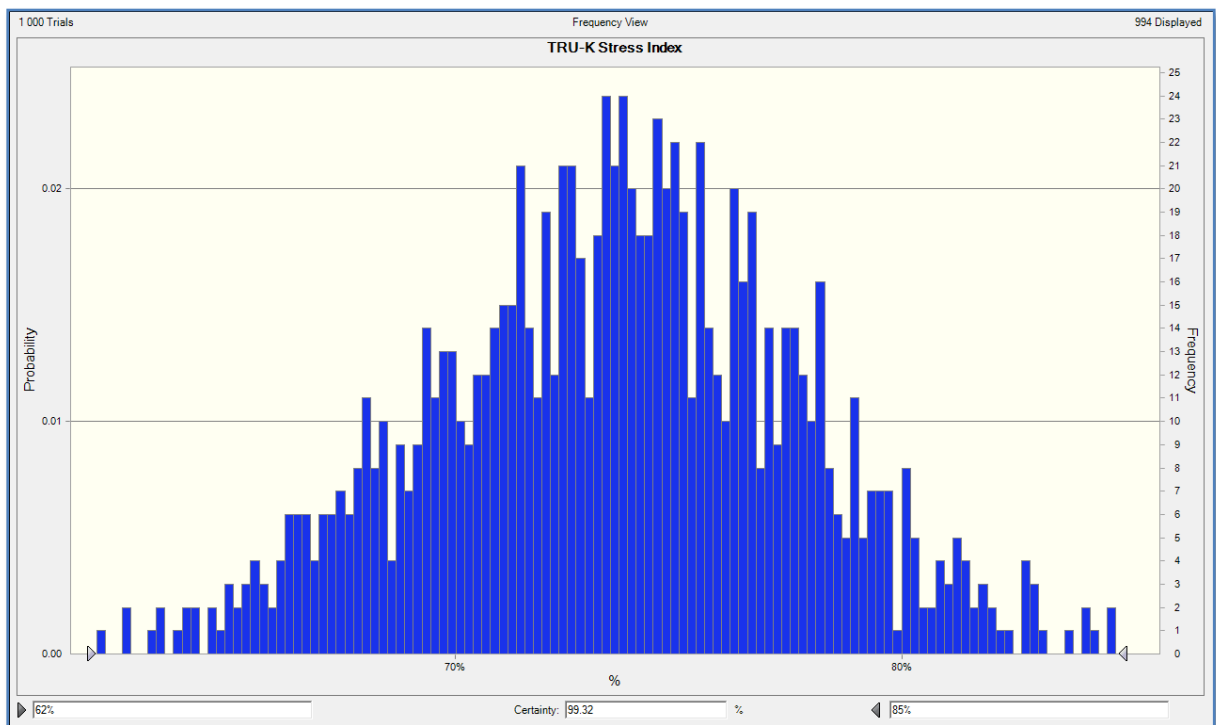


Figure 108: Stochastic results

1.1.99 Quality

The expanded Durov diagram with the groundwater quality is shown in Figure 109. An explanation of the classification process by means of the expanded Durov diagram is given in Section 2.3. There are numerous boreholes in categories A and C, however the overall water quality is relatively good. Therefore the final category was set as a B.

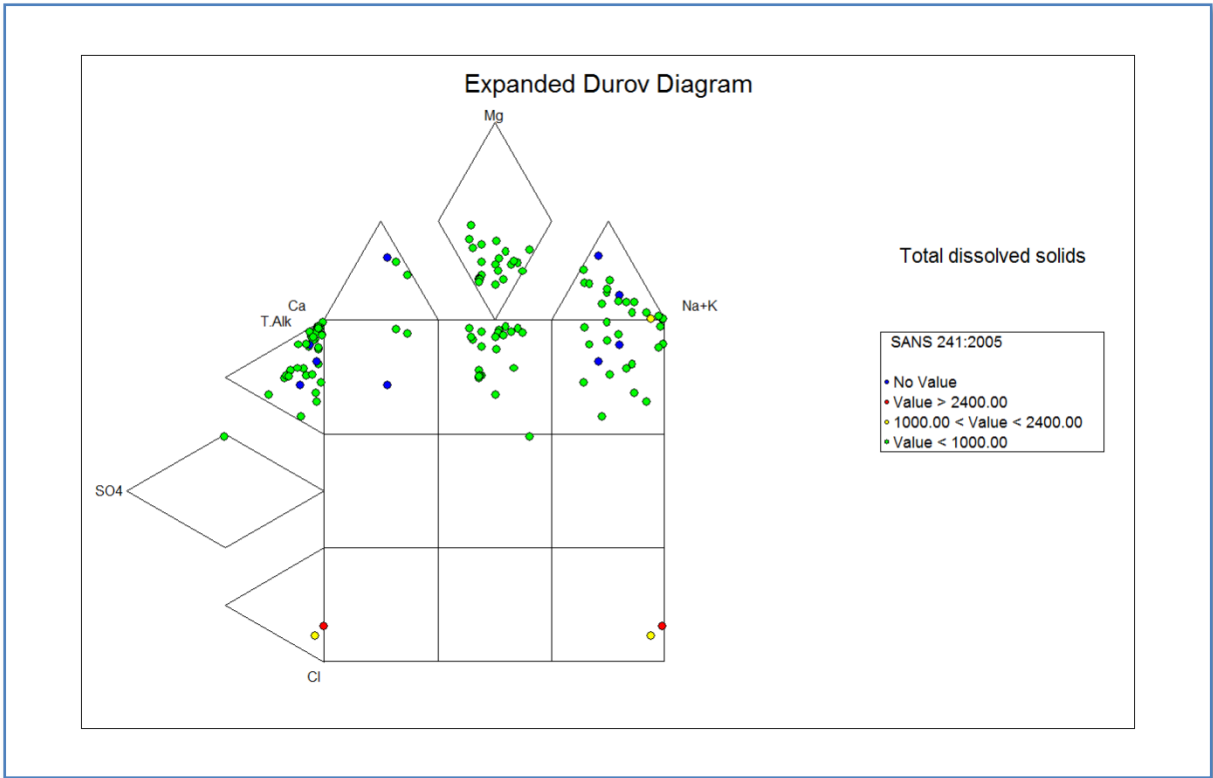


Figure 109: Expanded Durov diagram for RU

As documented in the vulnerability is 38%. The impact of potential contamination according to Section 2.3 is moderate due to mining and agricultural activities.

1.1.100 Final category

The final category for the RU is summarised in Table 92.

Table 92: Category for RU

Impact	Present status category	Water resource category
Groundwater usage	E	Poor
Groundwater contamination	B	Good
Potential groundwater contamination (vulnerability and impact)	B	Good
FINAL	B/C	Good/Fair

16.11 Quantification of the Reserve

The groundwater Reserve for the RU is summarised in Table 93.

Table 93: Reserve

Reserve			Allocation	
Baseflow Mm ³ /a	BHN Mm ³ /a	Reserve % Recharge	Allocation Mm ³ /a	Current Use Mm ³ /a
13.360	0.072	33%	10.860	16.960

17. Classification and the Reserve for Resource Unit L

17.1 Location

The quaternary catchments included in the RU area: V60D and V60E. The main towns are Glencoe and Wasbank. The location of the RU is shown in Figure 110.

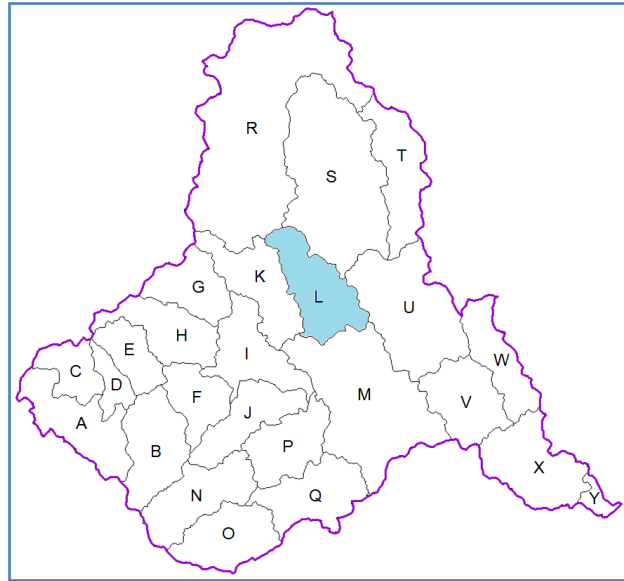


Figure 110: Location of RUL

17.2 Climate

The rainfall is 700 to 850 mm per year in summer. Mean temperatures for January are around 22°C with a mean maximum of 29°C. In winter, mean annual temperatures in July are about 10°C with a mean minimum of about 3°C.

17.3 Vegetation (taken from www.deat.gov.za)

This area is open savanna, with scattered trees of Paperbark Thorn *Acacia sieberiana*, Sweet Thorn *A. karroo*, Scented Thorn *A. nilotica* and *A. caffra*. The herbaceous layer is quite variable, with secondary grassland, dominated by patches of tall Common Thatchgrass *Hyparrhenia hirta*, and sour grassland, dominated by Hairy Tridentgrass *Tristachya leucothrix*.

17.4 Demography and Landcover

The total population is approximately 100 000 (2001 census data). Economic activity in the area revolves around coal mining (Photo 31) while sheep and cattle ranching are also practiced. The landcover is shown in Figure 111.



Photo 31: Coalfields
(Source: www.panoramio.com)

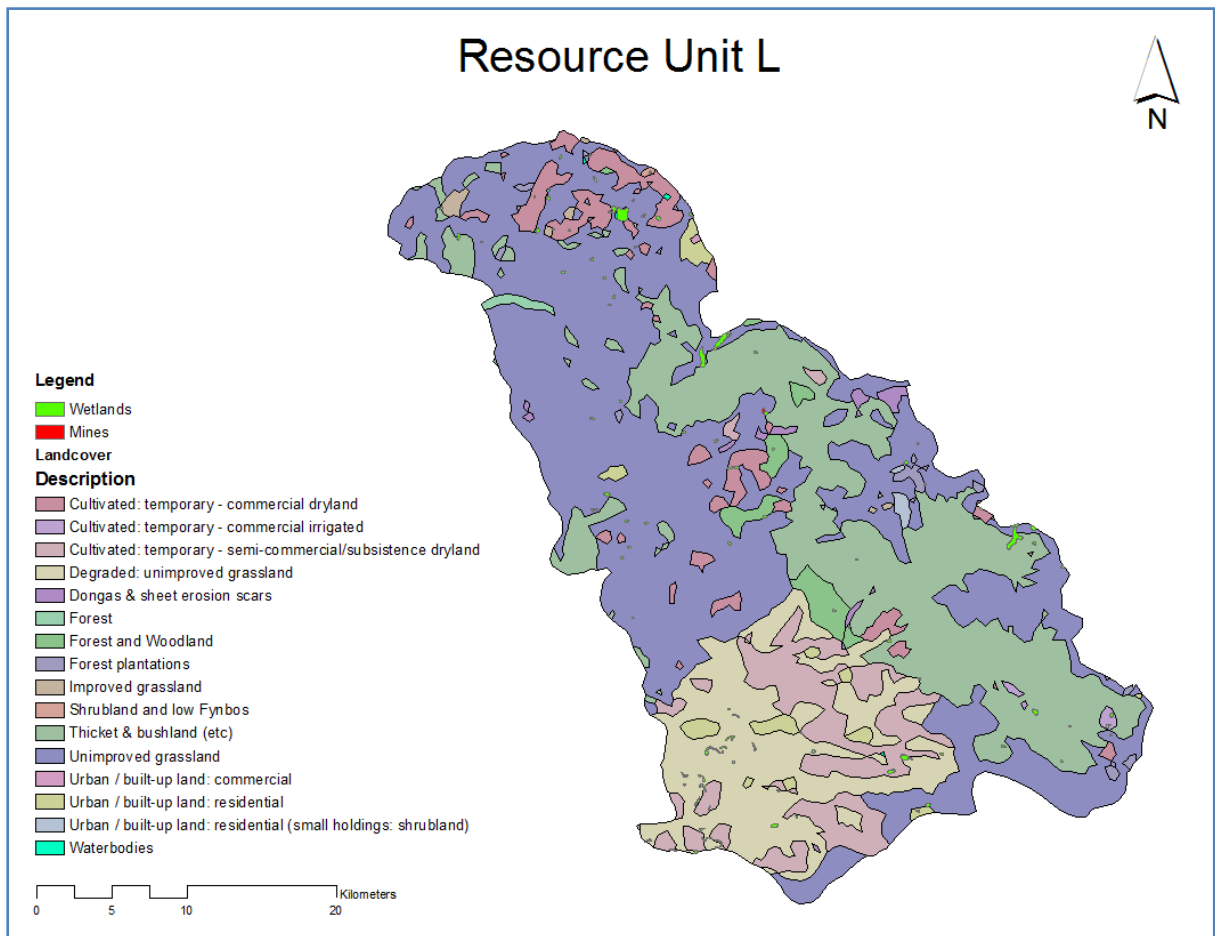


Figure 111: Landcover in RUL

17.5 Surface Water

The Blinkwater, Tholeni Manzimnyama, Uithoekspruit and Biggersgatspruit join the Wasbank River.

17.6 Wetlands

The wetlands in the RU are shown in Figure 111.

17.7 Soils (taken from www.deat.gov.za)

The soil is shallow, derived from shales and mudstones of the Ecca Group of the Karoo Sequence. With a rainfall of less than 450 mm it is characterised by subsoils which are either duplex, which renders them potentially highly erodible, or dominated by black clays.

17.8 Geology (summarised from Woodford and Chevallier, 2002)

The Beaufort Group dominates in this RU and is stratigraphically divided into two major units, the upper Tarkastad Subgroup and the lower Adelaide Subgroup. The Tarkastad Subgroup is subdivided into the upper Burgersdorp Formation with its brightly coloured red, blue and green mudstones and the lower Katberg Formation, that can be up to 900 m thick. The Katberg Formation also contains brightly coloured shales and mudstones, but mainly consists of thick layers of coarse-grained sandstone. The Adelaide Subgroup mainly consists of green, bluish, grey and red mudstones and fine-grained sandstones that form thick lens-shaped units. The central basin consist mainly of mudstones, shales and fine-grained sandstones. These fine-grained sediments were mainly deposited where the braided rivers began to meander. The sedimentary units in the Group therefore usually have very low primary hydraulic conductivities. Since the Beaufort Group was also deposited in a fluvial environment, one can expect that aquifers in these formations will, like those in the Ecca Group, be anisotropic. The geometry of these aquifers, however, is further complicated by the migration of the braided and meandering streams. Aquifers in the Beaufort Group will therefore not only be multi-layered, but also multi-porous with variable thicknesses. The contact plane between two different sedimentary layers will cause a discontinuity in the hydraulic properties of an aquifer. The lifespan of a high-yielding borehole in the Beaufort Group may therefore be limited if the aquifer is not recharged frequently.

The Volksrust Formation (of the Ecca Group) is a predominantly argillaceous unit, which interfingers with the overlying Beaufort Group and underlying Vryheid Formation. The Formation consists of grey to black, silty shale with thin, usually bioturbated, siltstone or sandstone lenses and beds, particularly towards its upper and lower boundaries. Thin phosphate and carbonate beds and concretions are relatively common.

The Vryheid Formation (of the Ecca Group) comprises mudrock, rhythmite, siltstone and fine- to coarse-grained sandstone (pebbly in places). The Formation contains up to five (mineable) coal seams. The different lithofacies are mainly arranged in upward-coarsening deltaic cycles (up to 80m thick in the southeast). Linear coastline cycles are, however, fairly common particularly in the thin northwestern part where they constitute the entire Vryheid in places.

A relatively thin fluvial interval (60 m thick) which grades distally into deltaic deposits towards the southwest and south occurs approximately in the middle of the formation in the east and northeast. Fining-upward fluvial cycles, of which up to six are present in the east, are typically sheet-like in geometry, although some form valley-fill deposits. They comprise coarse-grained to pebbly, immature sandstones - with an abrupt upward transition into fine-grained sediments and coal seams. Since these shales are very dense, they were often neglected as sources of groundwater in the past. The prodelta sandstones represent another formation of the Ecca Group in which one would expect to find high-yielding aquifers. Unfortunately, the permeabilities of these sandstones are also usually very low.

Sills in the Karoo formations are sheetlike forms of dolerite intrusions that tend to follow the bedding planes of the formations concordantly. These structures, whose thicknesses vary from less than a metre to hundreds of metres, represent the dominant form in which dolerite is emplaced in the Karoo Supergroup. Dolerite sills in the Karoo Supergroup often have very complex forms. The linear dykes are also usually thinner than ring dykes and are confined to the Ecca and Beaufort Groups. This is a clear indication that the magmatic activity at the time the linear dykes intruded was less than when the ring dykes and sills intruded.

17.9 *Geohydrology*

1.1.101 Groundwater levels

It is clear the groundwater levels follow the topography as seen from Figure A1 in Appendix A and therefore groundwater contour maps were generated using Bayesian interpolation. The groundwater levels for the study area are shown in Figure 112. The most probable depth to groundwater level in the RU is 7 mbgl according to the histogram of water levels in the RU shown in Appendix A. Groundwater levels are expected to be lower than normal due to the prevailing drought conditions. Unfortunately very little time series water level data are available to quantify the overall impact.

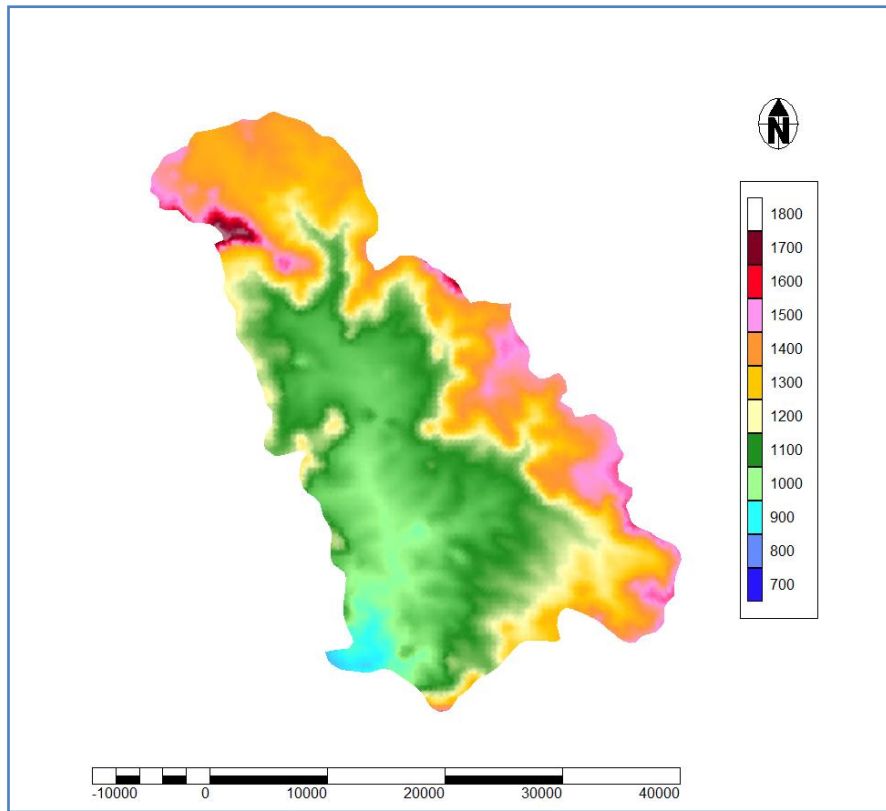


Figure 112: Groundwater levels in RUL

17.9.1 Groundwater recharge

The groundwater recharge calculated from the different methods is listed in Table 94. The different recharge methods applied are discussed in Section 2.3. The final recharge values for the RU are highlighted in red.

Table 94: Recharge values

Recharge							
MAP Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Volume Mm ³ /a	Calculated %	CMB %	Land Cover %	Geology %
797.457	37.766	53.638	36.900	4.6%	4.6%	2.8%	3.7%

1.1.102 Basic human needs

The method for determining BHNs is discussed in Section 2.3. The final value for the study area is highlighted in red in Table 95.

Table 95: Basic human needs

Basic Human Need		
Census(2001) Adjusted	Dependence 18%	Estimate Mm ³ /a
104823	18868	0.170

1.1.103 Groundwater contribution to baseflow

The baseflow separation curves for the RU are shown in Figures 113 & 114.

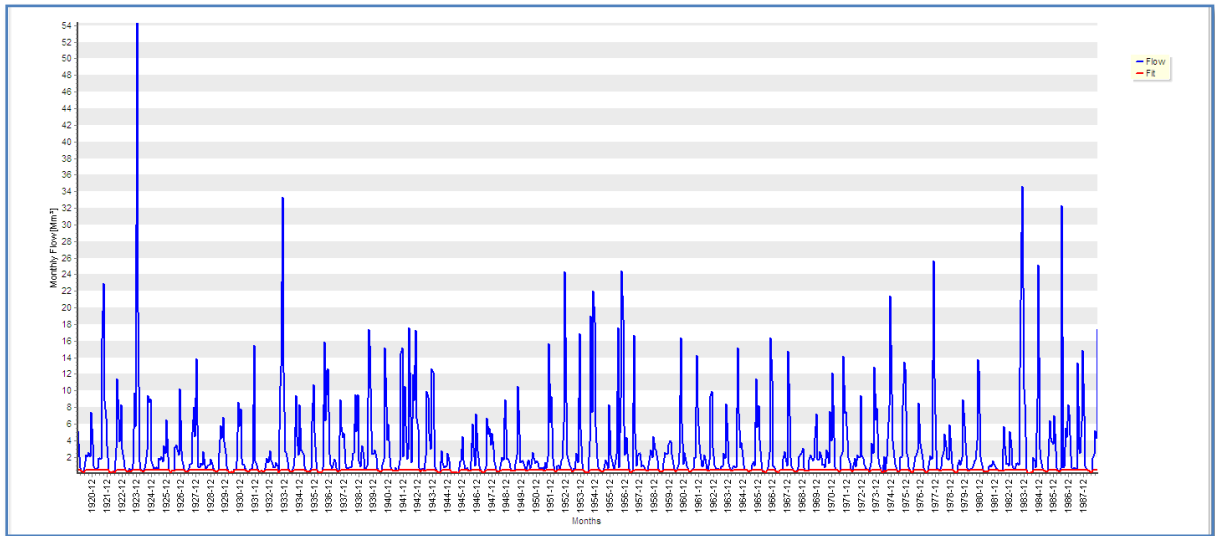


Figure 113: Baseflow separation for quaternary catchment V60D

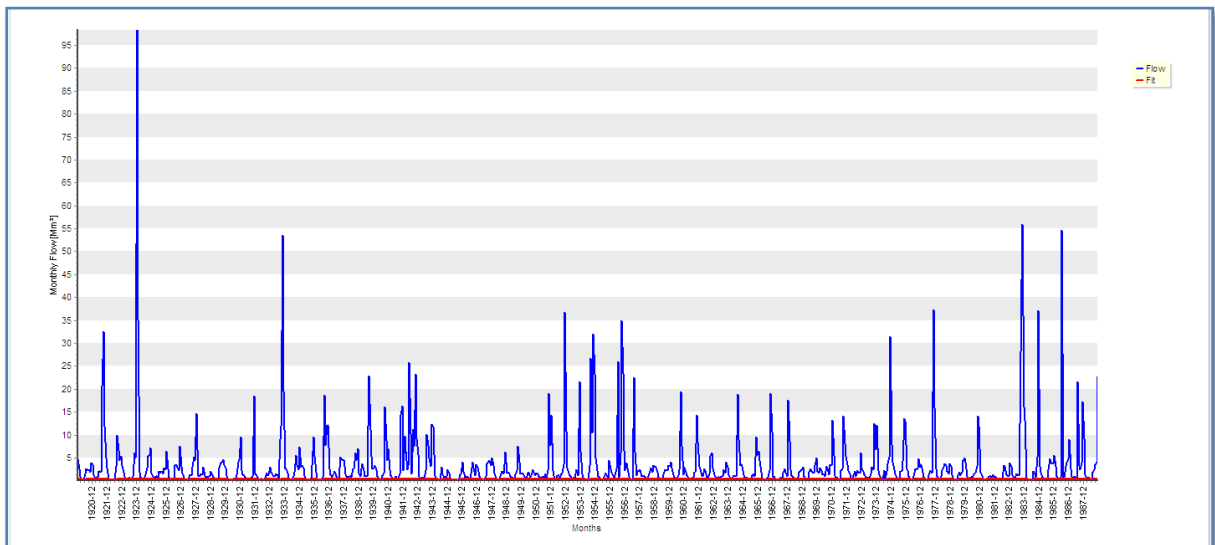


Figure 114: Baseflow separation for quaternary catchment V60E

The final groundwater contribution to baseflow values for the RU is highlighted in red in Table 96.

Table 96: Groundwater contribution to baseflow

Groundwater Contribution to Baseflow							
GRDM Mm ³ /a	Hughes Mm ³ /a	Shultz Mm ³ /a	Pitman Mm ³ /a	vTonder Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Herold Mm ³ /a
24.755	31.239	19.134	9.155	16.162	9.155	31.239	11.100

1.1.104 Groundwater use

The groundwater use for the RU is listed in Table 97.

Table 97: Groundwater use

Groundwater Use							
GRDM Mm ³ /a	WARMS Mm ³ /a	Hydrocensus Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Forrest Mm ³ /a	Crops Mm ³ /a	TOTAL Mm ³ /a
0.170	0.015	0.451	0.015	1.805	13.864	1.083	14.776

1.1.105 Groundwater quality

The TDS values for the RU are shown in Figure 115. They are classified according to SABS standards. Not all boreholes have quality data available but those that do can be used to identify possible hot spots with regard to quality in the resource unit. The overall quality of the resource unit is well within the drinking water guidelines with the exception of one borehole. These areas should be treated as hotspots rather than penalising the whole resource unit with a poor classification. Treatment of the hotspot areas will be addressed under Resource Quality Objectives in Section 31.

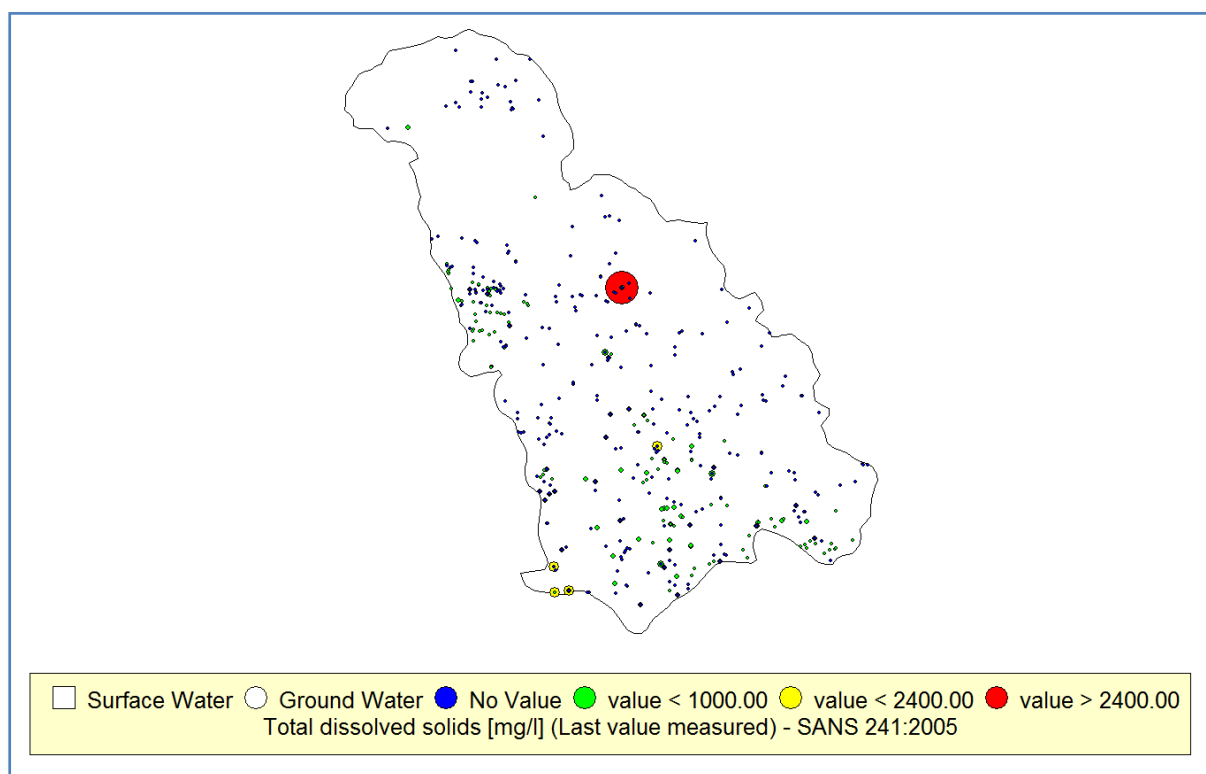


Figure 115: TDS values

1.1.106 Aquifer vulnerability

The aquifer vulnerability calculations are summarised in Table 98. The slope histogram is documented in Appendix B.

Table 98: Aquifer vulnerability

Aquifer Vulnerability						
Level mbgl	Recharge %	Slope %	Soil Texture	Aquifer Type	Vadose Zone	Vulnerability %
7.0	4.6%	1.2	SaCLm-SaCl	Weathered/Fractured	Karoo(southern)	57%

17.10 Classification

1.1.107 Groundwater usage

The stress index, defined as the ratio between total groundwater use and recharge, for the study area is calculated at 71%. Due to the uncertainty associated with the groundwater use component, the stress index was stochastically modelled through assigning a normal distribution curve with a standard deviation of 1.478 Mm³/a to the groundwater use estimate to account for the associated uncertainty. The stochastic results are shown in Figure 116. It is clear from the results that the stress index will vary between 60% and 80% with a certainty of 99.02%. Due to the large variability in the range obtained, it is recommended that the uncertainty in the groundwater use be reduced by detailed studies focusing on groundwater use within the RU. Due to the relatively high stress index this RU should be flagged as an area which requires further investigation.

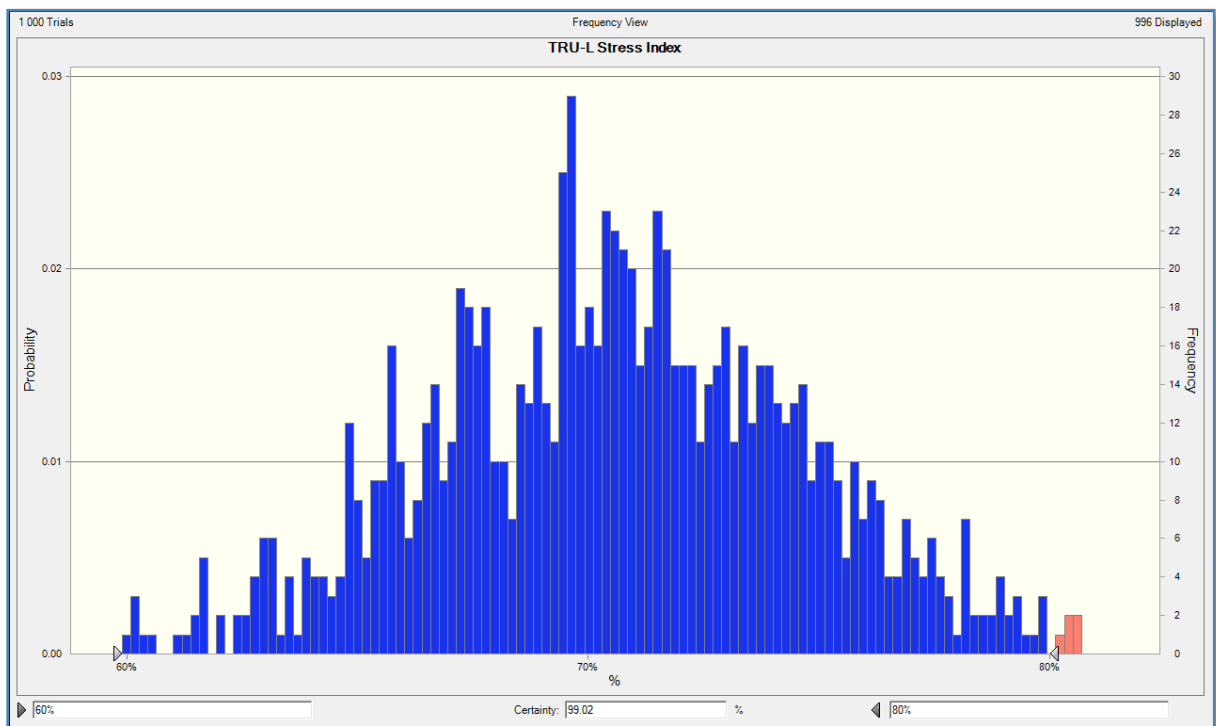


Figure 116: Stochastic results

1.1.108 Quality

The expanded Durov diagram with the groundwater quality is shown in Figure 117. An explanation of the classification process by means of the expanded Durov diagram is given in Section 2.3. There

are numerous boreholes in categories A and C, however the overall water quality is relatively good therefore the final category was set as a B.

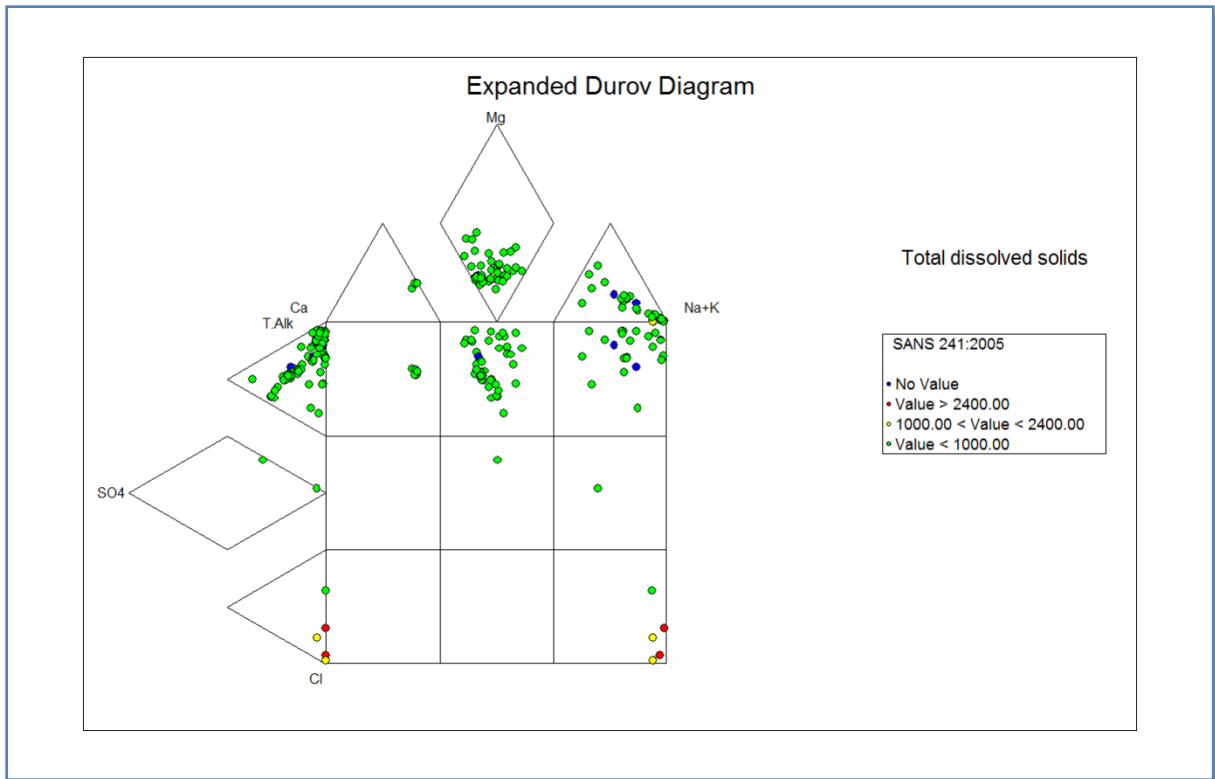


Figure 117: Expanded Durov diagram for RU

As documented in the vulnerability is 57%. The impact of potential contamination according to Section 2.3 is low due to minimal agricultural and mining activities.

1.1.109 Final category

The final category for the RU is summarised in Table 99.

Table 99: Category for RU

Impact	Present status category	Water resource category
Groundwater usage	E	Poor
Groundwater contamination	B	Good
Potential groundwater contamination (vulnerability and impact)	B	Good
FINAL	B/C	Good/Fair

17.11 Quantification of the Reserve

The groundwater Reserve for the RU is summarised in Table 100.

Table 100: Reserve

Reserve			Allocation	
Baseflow Mm ³ /a	BHN Mm ³ /a	Reserve % Recharge	Allocation Mm ³ /a	Current Use Mm ³ /a
11.100	0.170	31%	10.854	14.776

18. Classification and the Reserve for Resource Unit M

18.1 Location

The quaternary catchments included in the RU area: V60F, V60G, V60H, V60J, V60K, V20J and V20H. Towns included in the study area are Tugela Ferry (Photo 32) and Pomeroy. These two towns are dependent on groundwater. The location of the RU is shown in Figure 118.



Photo 32: Tugela Ferry
(Source: www.panoramio.com)

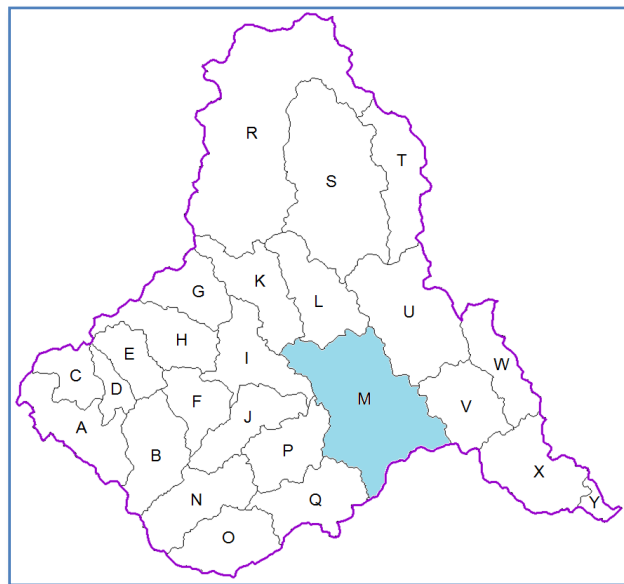


Figure 118: Location of RUM

18.2 Climate

The rainfall is 680 to 800 mm per year, in summer. Mean temperatures for January are around 22°C with a mean maximum of 29°C. In winter mean annual temperatures in July are about 10°C with a mean minimum of about 3°C.

18.3 Vegetation (taken from www.deat.gov.za)

The west of the RU is open savanna, with scattered trees of Paperbark Thorn *Acacia sieberiana*, Sweet Thorn *A. karroo*, Scented Thorn *A. nilotica* and *A. caffra*. The herbaceous layer is quite variable, with secondary grassland, dominated by patches of tall Common Thatchgrass *Hyparrhenia hirta*, and sour grassland, dominated by Hairy Tridentgrass *Tristachya leucothrix*.

In the east the flora has transitional Tongoland-Pondoland and Afromontane affinities. The closed canopy is up to 6 m in height and woody evergreen species are dominant, rather than succulent trees or shrubs. There is a great diversity of species in this thicket type.

18.4 Demography and Landcover

The population is on average 22000 (2001 census data). There are cultivated lands and subsistence farming. It is the best area for Angora and Boer goat farming. The landcover is shown in Figure 119.

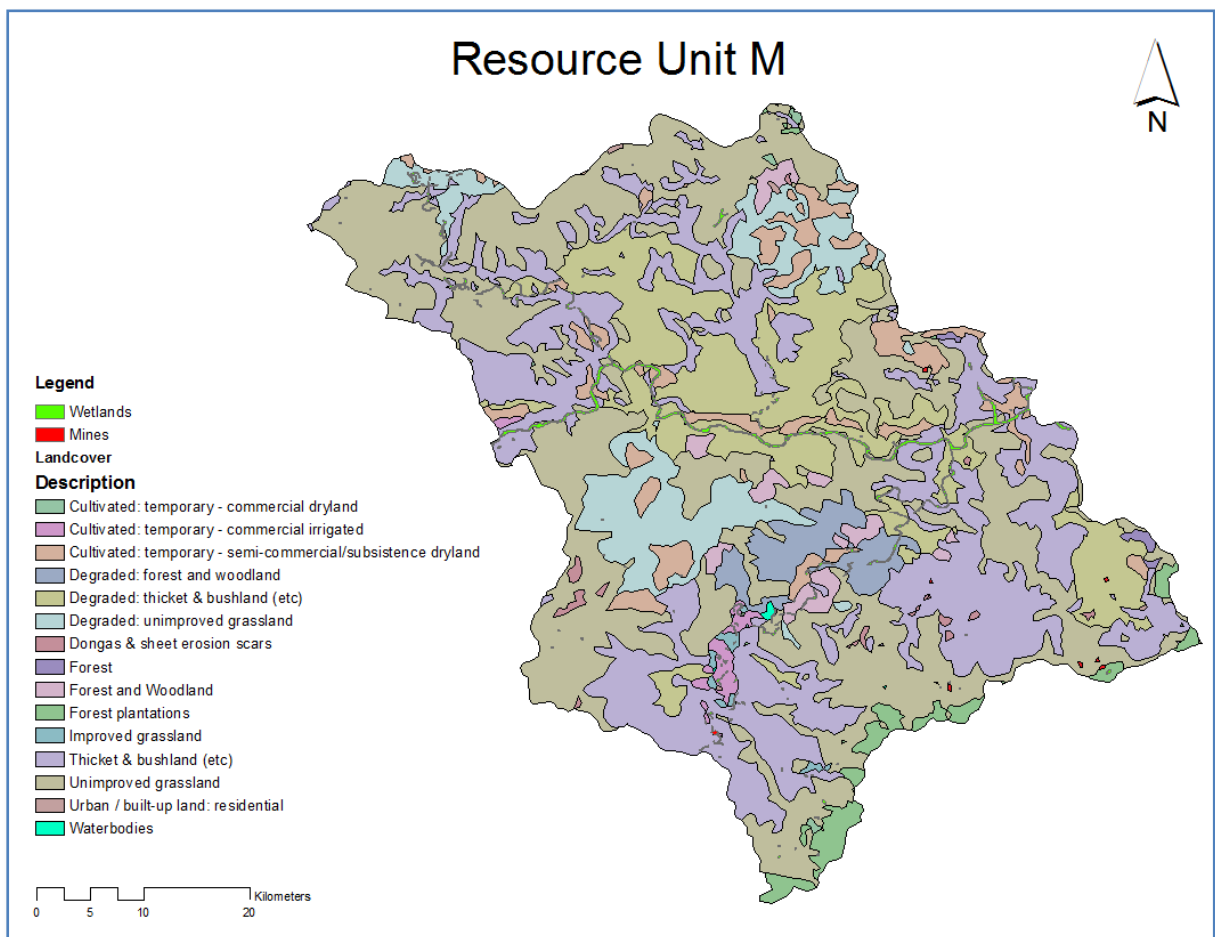


Figure 119: Landcover in RUM

18.5 Surface Water

The Sundays and Sampofu Rivers join the Thukela River from the north. The Nadi, Mooi and Loza join the Thukela River from the south.

18.6 Wetlands

The wetlands in the study area are shown in Figure 119.

18.7 Soils (taken from www.deat.gov.za)

To the west of the study area the soil is shallow, derived from shales and mudstones of the Ecca Group of the Karoo Sequence. With a rainfall of less than 450 mm it is characterised by subsoils which are either duplex, which renders them potentially highly erodible, or dominated by black clays.

To the east soils vary from sandy clays and lithosols of the Cape Supergroup and Dwyka and Ecca Formations, to deep solonchic soils derived from dolerites.

18.8 Geology (summarised from Woodford and Chevallier, 2002)

The Dwyka sediments, which are situated at the base of the Karoo Supergroup, have been deposited on older Precambrian granitic rocks in the north and sedimentary rocks, associated with the Cape Fold Belt in the south. The Dwyka Formation mainly consists of Dwyka diamictite—angular to rounded clasts of the basement rocks, embedded in a clay and silt matrix. However, varved shales, sandstone layers and conglomerates, typical of a fluvio-glacial environment, are also present. The Dwyka diamictite, shales and tillites have very low hydraulic conductivities [$\sim 10^{-11}$ to 10^{-12} m/s] and virtually no primary voids. They therefore tend to form more aquitards than aquifers. The few sandstone bodies deposited in the glacial valleys of the northern facies are very limited in extent, and sealed off by the diamictite. The aquifers in them are therefore limited and often only contain fossil water. Since the Dwyka sediments were deposited mainly under marine conditions, the water in these aquifers tends to be saline.

The Pietermaritzburg Formation (of the Ecca Group) comprises dark, upward coarsening, silty mudrock, which is heavily bioturbated. Pene-contemporaneously deformed sandy and silty beds appear near the top of the formation.

The Volksrust Formation (of the Ecca Group) is a predominantly argillaceous unit, which interfingers with the overlying Beaufort Group and underlying Vryheid Formation. The Formation consists of grey to black, silty shale with thin, usually bioturbated, siltstone or sandstone lenses and beds, particularly towards its upper and lower boundaries. Thin phosphate and carbonate beds and concretions are relatively common.

The Vryheid Formation (of the Ecca Group) comprises mudrock, rhythmite, siltstone and fine- to coarse-grained sandstone (pebbly in places). The Formation contains up to five (mineable) coal seams. The different lithofacies are mainly arranged in upward-coarsening deltaic cycles (up to 80m thick in the southeast). Linear coastline cycles are, however, fairly common particularly in the thin northwestern part where they constitute the entire Vryheid in places. A relatively thin fluvial interval (60 m thick) which grades distally into deltaic deposits towards the southwest and south occurs

approximately in the middle of the formation in the east and northeast. Fining-upward fluvial cycles, of which up to six are present in the east, are typically sheet-like in geometry, although some form valley-fill deposits. They comprise coarse-grained to pebbly, immature sandstones - with an abrupt upward transition into fine-grained sediments and coal seams.

Since these shales are very dense, they were often neglected as sources of groundwater in the past. The prodelta sandstones represent another formation of the Ecca Group in which one would expect to find high-yielding aquifers. Unfortunately, the permeabilities of these sandstones are also usually very low.

Sills in the Karoo formations are sheetlike forms of dolerite intrusions that tend to follow the bedding planes of the formations concordantly. These structures, whose thicknesses vary from less than a metre to hundreds of metres, represent the dominant form in which dolerite is emplaced in the Karoo Supergroup. Dolerite sills in the Karoo Supergroup often have very complex forms. The linear dykes are also usually thinner than ring dykes and are confined to the Ecca and Beaufort Groups. This is a clear indication that the magmatic activity at the time the linear dykes intruded was less than when the ring dykes and sills intruded.

18.9 *Geohydrology*

1.1.110 Groundwater levels

It is clear the groundwater levels follow the topography as seen from Figure A1 in Appendix A and therefore groundwater contour maps were generated using Bayesian interpolation. The groundwater levels for the study area are shown in Figure 120. The most probable depth to groundwater level in the RU is 9.2 mbgl according to the histogram of water levels in the RU shown in Appendix A. Groundwater levels are expected to be lower than normal due to the prevailing drought conditions. Unfortunately very little time series water level data are available to quantify the overall impact.

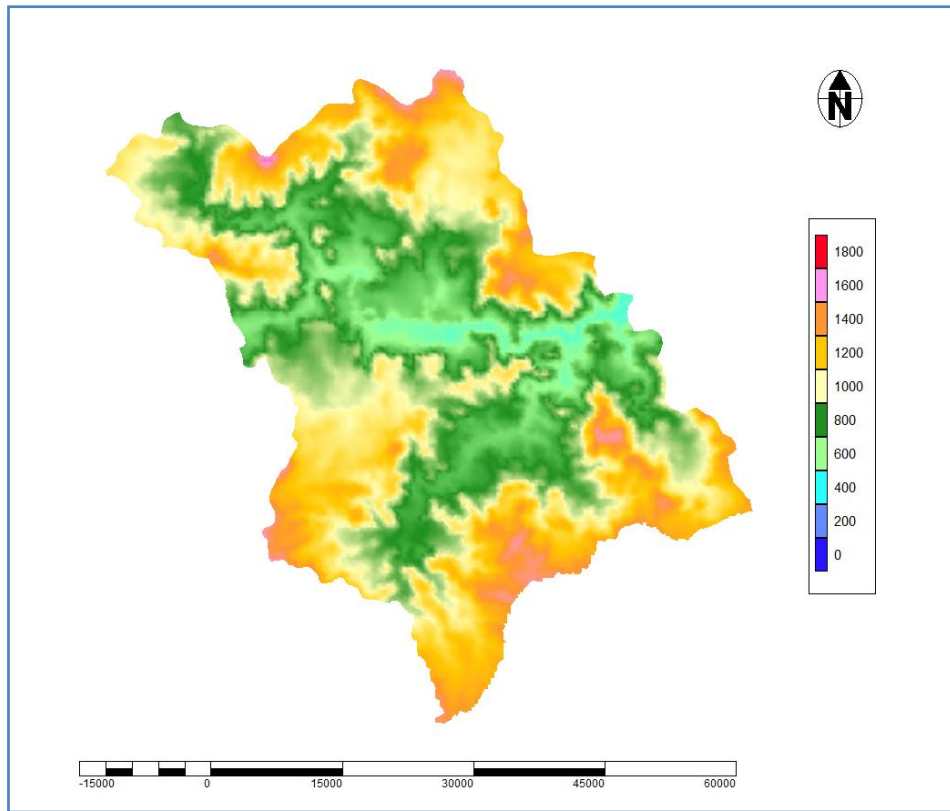


Figure 120: Groundwater levels in RUM

18.9.1 Groundwater recharge

The groundwater recharge calculated from the different methods is listed in Table 101. The different recharge methods applied are discussed in Section 2.3. The final recharge values for the RU are highlighted in red.

Table 101: Recharge values

Recharge							
MAP Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Volume Mm ³ /a	Calculated %	CMB %	Land Cover %	Geology %
1806.642	81.715	139.338	62.028	3.4%	3.4%	3.5%	3.4%

1.1.111 Basic human needs

The method for determining BHNs is discussed in Section 2.3. The final value for the study area is highlighted in red in Table 102.

Table 102: Basic human needs

Basic Human Need		
Census(2001) Adjusted	Dependence 18%	Estimate Mm ³ /a
139909	25184	0.227

1.1.112 Groundwater contribution to baseflow

The baseflow separation curves for the RU are shown in Figures 121 – 127.

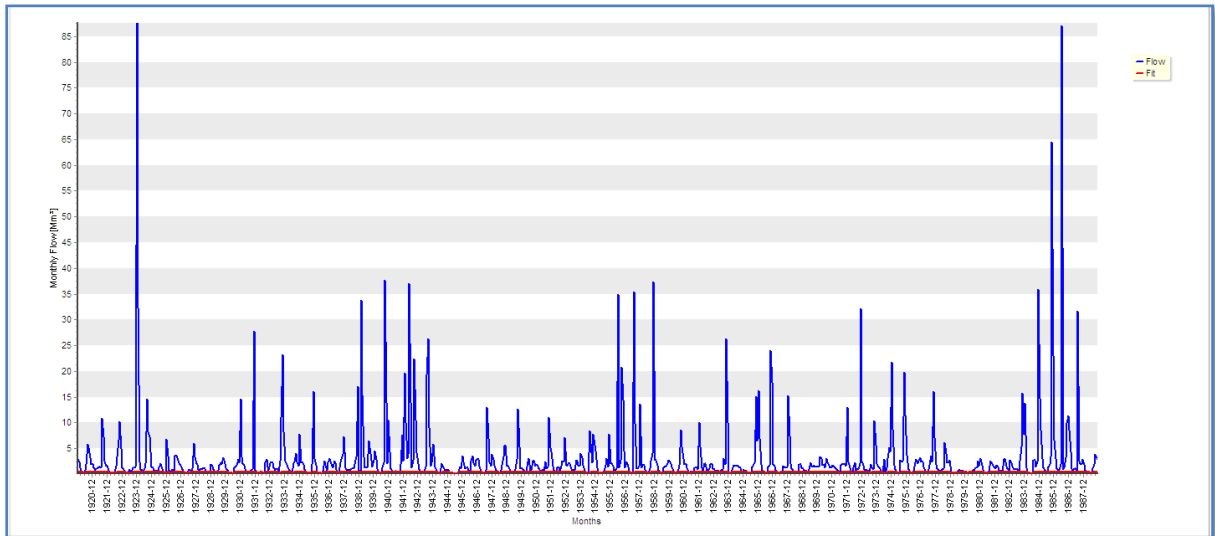


Figure 121: Baseflow separation for quaternary catchment V20H

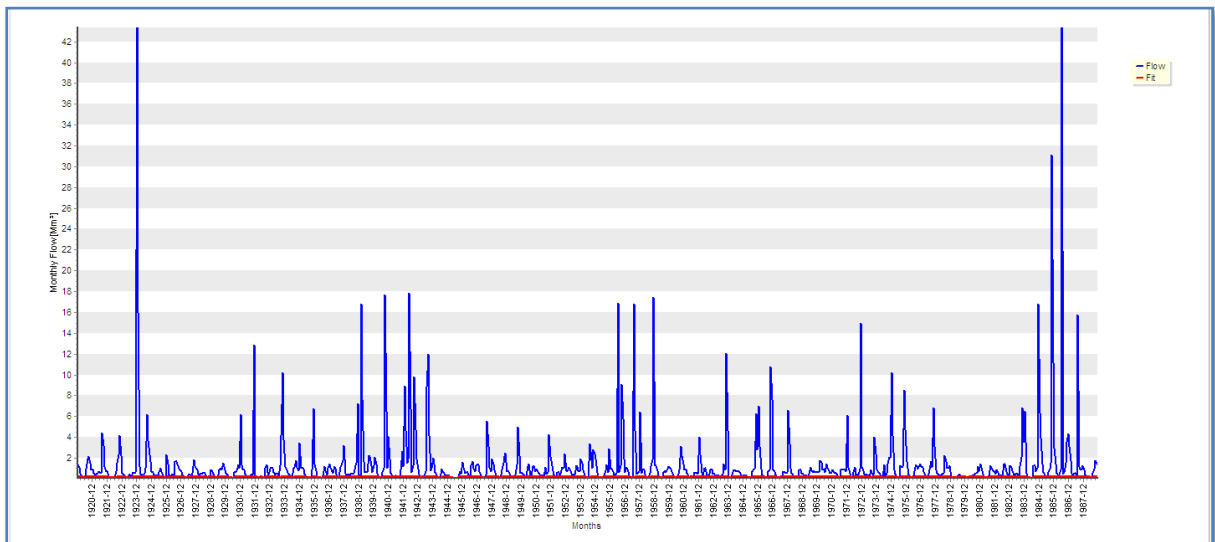


Figure 122: Baseflow separation for quaternary catchment V20J

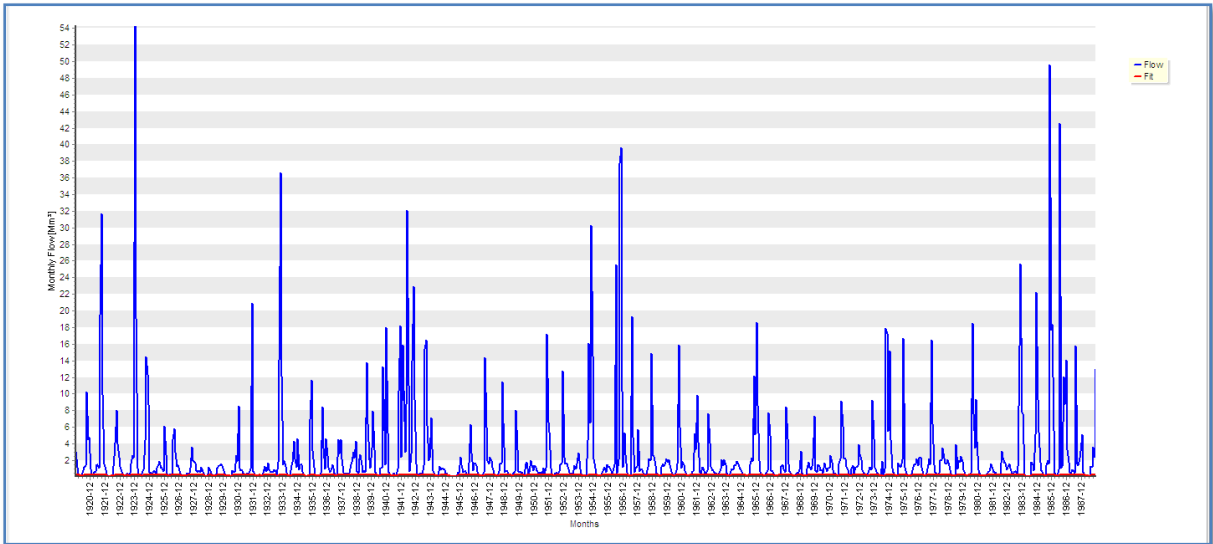


Figure 123: Baseflow separation for quaternary catchment V60F

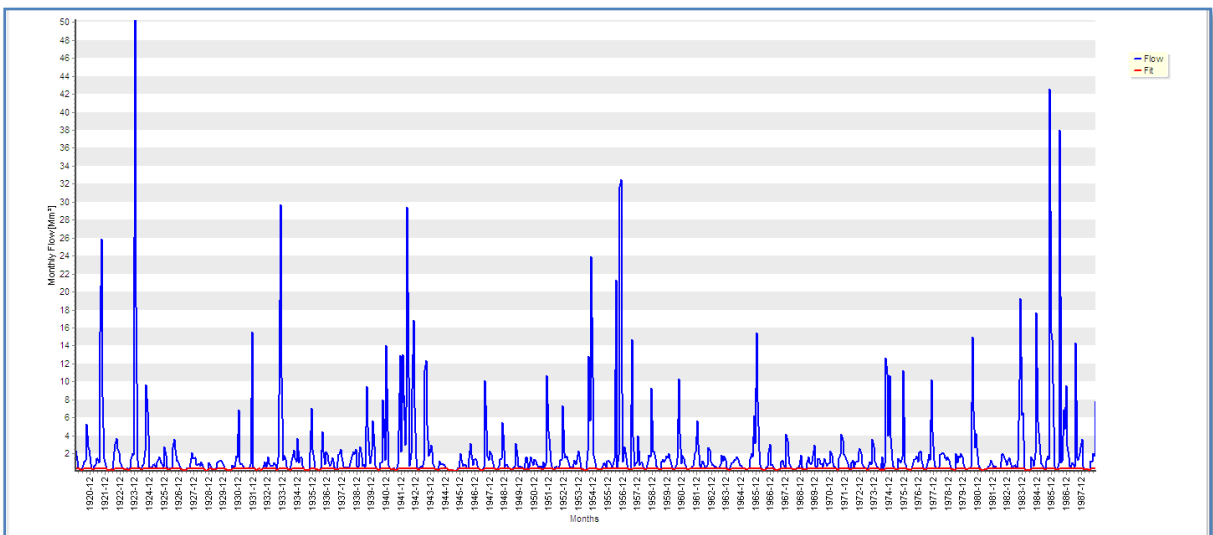


Figure 124: Baseflow separation for quaternary catchment V60G

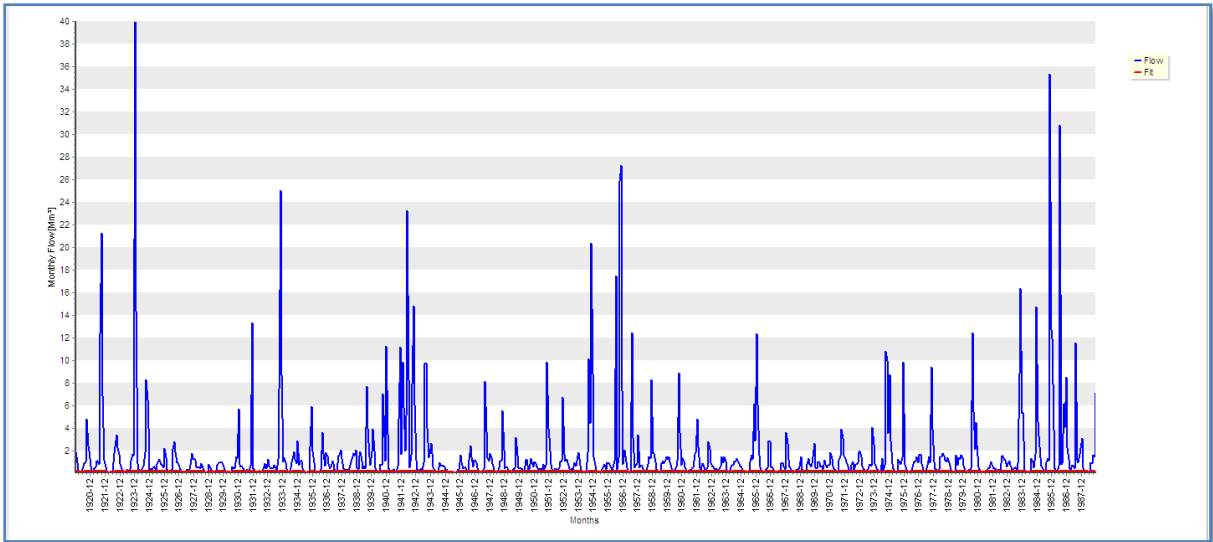


Figure 125: Baseflow separation for quaternary catchment V60H

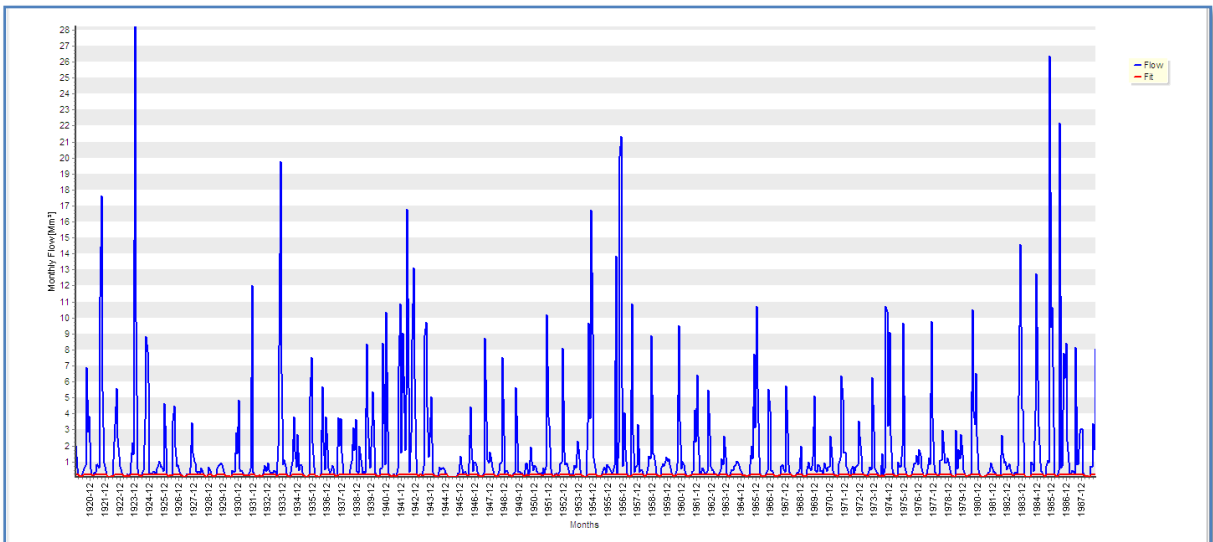


Figure 126: Baseflow separation for quaternary catchment V60J

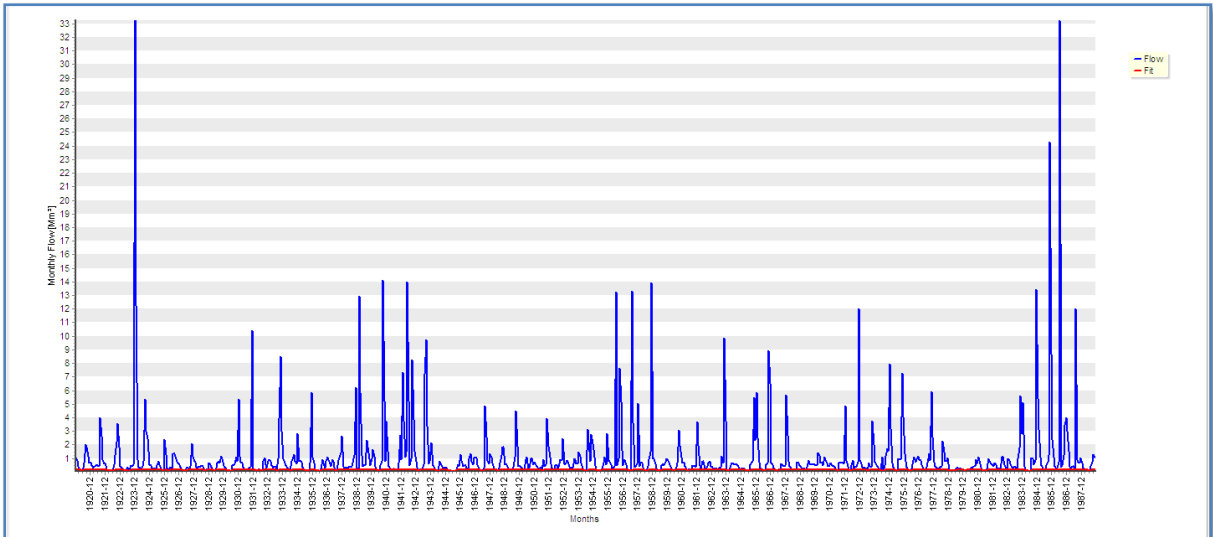


Figure 127: Baseflow separation for quaternary catchment V60K

The final groundwater contribution to baseflow values for the RU is highlighted in red in Table 103.

Table 103: Groundwater contribution to baseflow

Groundwater Contribution to Baseflow							
GRDM Mm ³ /a	Hughes Mm ³ /a	Shultz Mm ³ /a	Pitman Mm ³ /a	vTonder Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Herold Mm ³ /a
42.066	69.568	39.255	15.291	32.325	15.291	69.568	21.430

1.1.113 Groundwater use

The groundwater use for the RU is listed in Table 104.

Table 104: Groundwater use

Groundwater Use							
GRDM Mm ³ /a	WARMS Mm ³ /a	Hydrocensus Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Forrest Mm ³ /a	Crops Mm ³ /a	TOTAL Mm ³ /a
0.840	0.049	1.462	0.049	5.847	0.382	0.025	0.180

1.1.114 Groundwater quality

The TDS values for the RU are shown in Figure 128. They are classified according to SABS standards. Not all boreholes have quality data available but those that do can be used to identify possible hot spots with regard to quality in the resource unit. The overall quality of the resource unit is mostly within the drinking water guidelines with the exception of a number of boreholes. These areas should be treated as hotspots rather than penalising the whole resource unit with a poor classification. Treatment of the hotspot areas will be addressed under Resource Quality Objectives in Section 31.

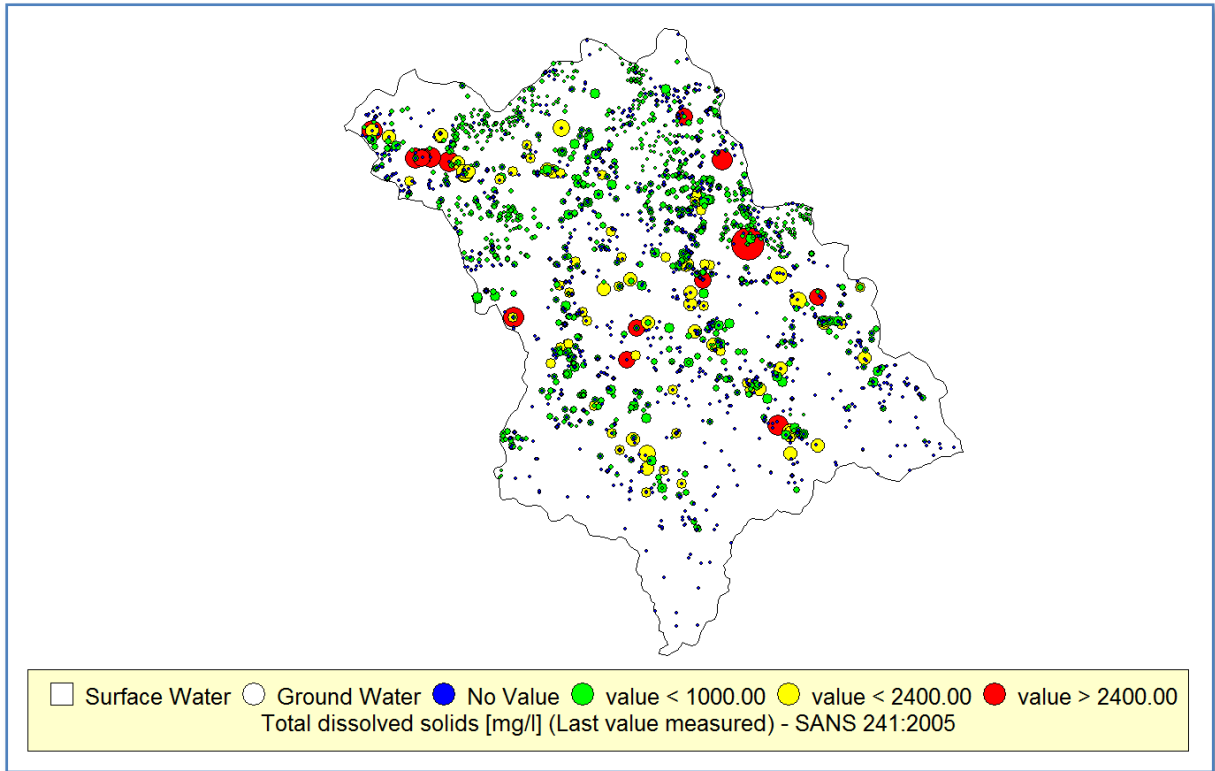


Figure 128: TDS values

1.1.115 Aquifer vulnerability

The aquifer vulnerability calculations are summarised in Table 105. The slope histogram is documented in Appendix B.

Table 105: Aquifer vulnerability

Aquifer Vulnerability						
Level mbgl	Recharge %	Slope %	Soil Texture	Aquifer Type	Vadose Zone	Vulnerability %
9.2	3.4%	1.2	SaClIm-SaCl	Weathered/Fractured	Karoo(southern)	53%

18.10 Classification

1.1.116 Groundwater usage

The stress index, defined as the ratio between total groundwater use and recharge, for the study area is calculated at 35%. Due to the uncertainty associated with the groundwater use component, the stress index was stochastically modelled through assigning a normal distribution curve with a standard deviation of 0.018 Mm³/a to the groundwater use estimate to account for the associated uncertainty. The stochastic results are shown in Figure 129. It is clear from the results that the stress index will vary between 35% and 35% with a certainty of 99.35%. Due to the small variability in the obtained range and high certainty, the uncertainty in the groundwater use component will not affect the calculated stress index significantly.

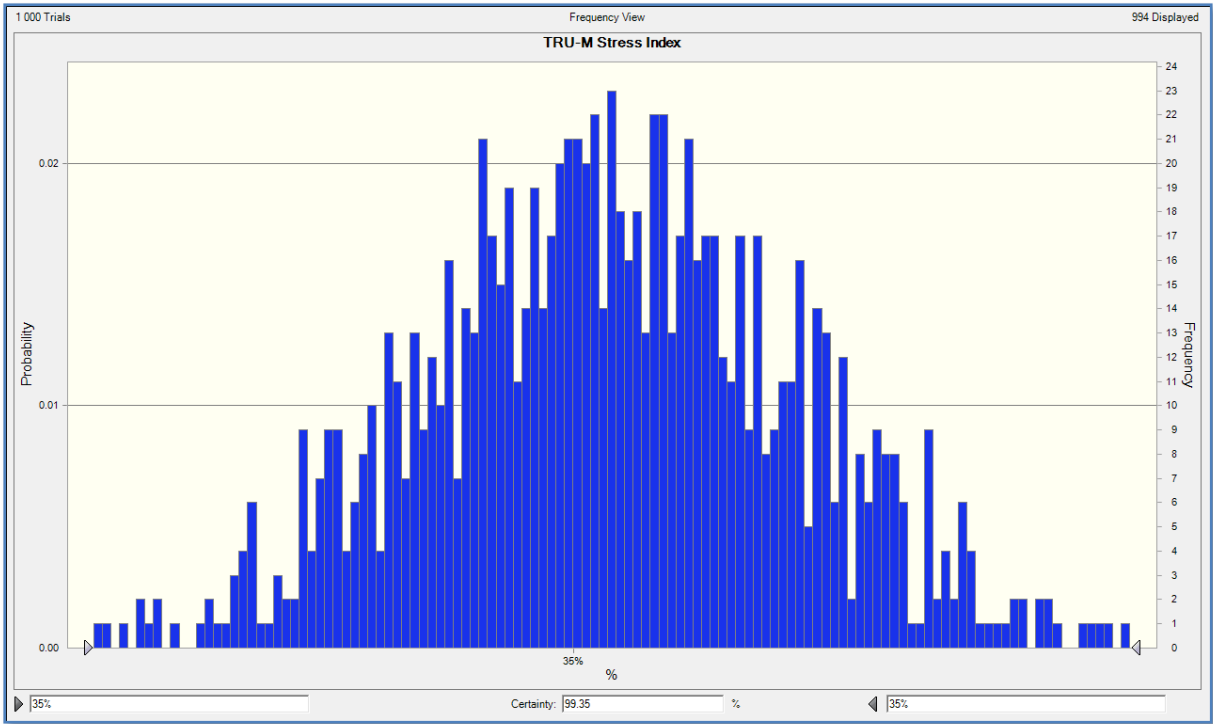


Figure 129: Stochastic results

1.1.117 Quality

The expanded Durov diagram with the groundwater quality is shown in Figure 130. An explanation of the classification process by means of the expanded Durov diagram is given in Section 2.3. There are numerous boreholes in categories A and C, however the overall water quality is not so good therefore the final category was set as a C.

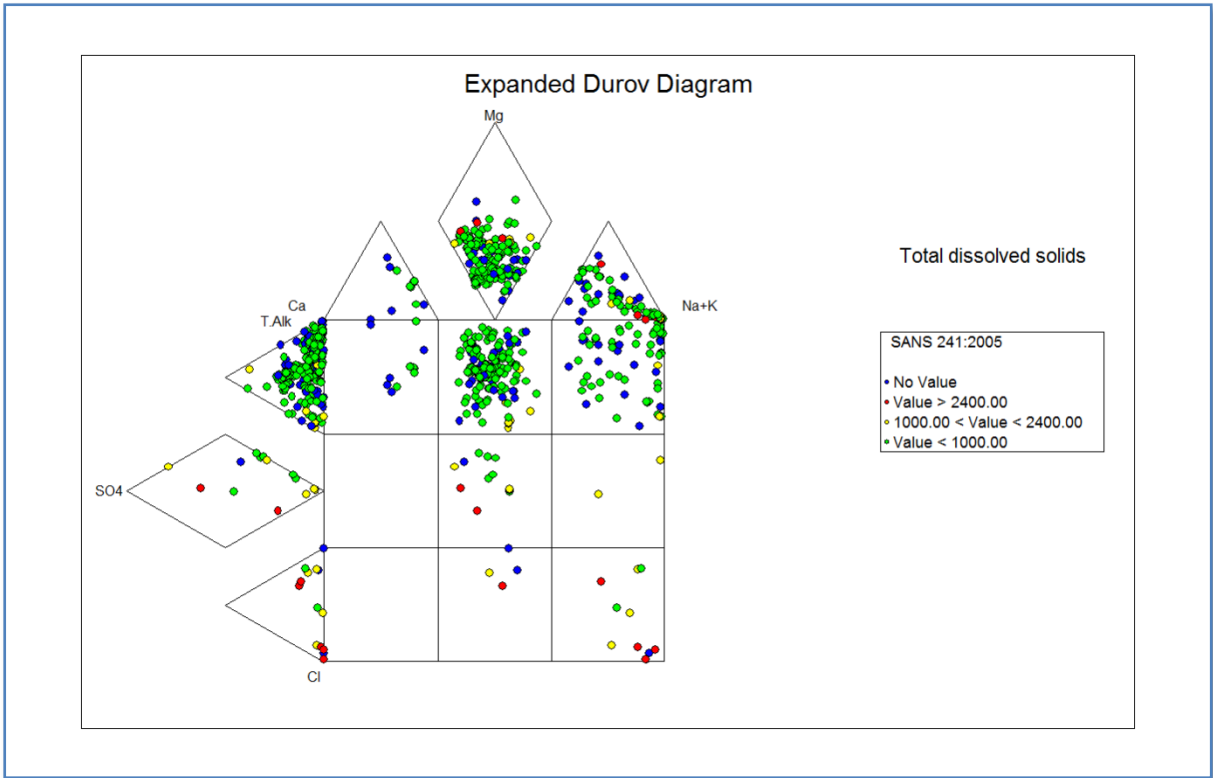


Figure 130: Expanded Durov diagram for RU

As documented in the vulnerability 53%. The impact of potential contamination according to Section 2.3 is moderate due to mines and agriculture.

1.1.118 Final category

The final category for the RU is summarised in Table 106.

Table 106: Category for RU

Impact	Present status category	Water resource category
Groundwater usage	C	Good/Fair
Groundwater contamination	C	Good/Fair
Potential groundwater contamination (vulnerability and impact)	C	Good/Fair
FINAL	C	Fair

18.11 Quantification of the Reserve

The groundwater Reserve for the RU is summarised in Table 107.

Table 107: Reserve

Reserve			Allocation	
Baseflow Mm ³ /a	BHN Mm ³ /a	Reserve % Recharge	Allocation Mm ³ /a	Current Use Mm ³ /a
21.430	0.227	35%	40.191	0.180

19. Classification and the for Resource Unit N

19.1 Location

The quaternary catchments included in the RU are: V70A, V70B, V70C, V70D and V70E. The main town in the study area is Estcourt. The only other town is Rock Mount. There are the following protected areas within the RU namely: Giants Castle which forms part of the Ukhahlamba Drakensberg Park and Moor Park surrounding Wagendrift Dam. Giant's Castle is a mountain peak in the southern African Drakensberg in KwaZulu Natal. The location of RUN is shown in Figure 131.

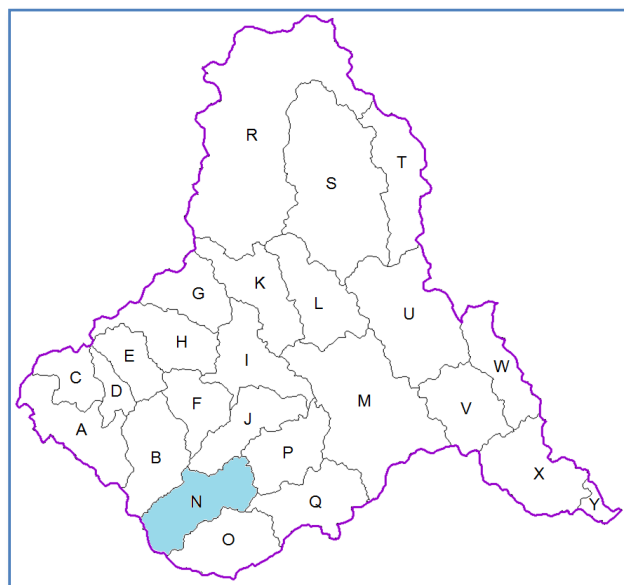


Figure 131: Location of RUN

19.2 Climate

Precipitation is often in the form of thunderstorms. The annual precipitation is between 770 and 1200 mm on the escarpment, precipitation between November to March accounting for 70% of the annual total with the winter months accounting for less than 10%. The mean annual temperature of the area is about 16°C, but both seasonal and diurnal variations are considerable. The highest temperatures (up to 35°C) occur during summer on north-facing slopes at lower latitudes, while the lowest temperatures (down to about -20°C) occur during winter nights on the summit plateau.

Frost is common in winter with about 180 days between mid April and October at higher elevations, but the local topography controls its distribution and intensity. It also occurs lower down when cold air from the high plateaus drains into lower-lying valleys.

19.3 Vegetation (taken from www.deat.gov.za)

The vegetation reflects the effects of climate and fire and the variety of the topography, elevation, geology, soils, slopes and drainage. It is largely grassland (Photo 33) and occurs in three main belts: the river valleys, the spurs and the summit plateau which is an island of Afro-alpine flora.

The fauna includes a total of 48 mammals, 299 birds, 48 reptiles, 26 amphibians and 8 species of fish. Large populations of several antelopes are present and include the endemic grey rhebok, reedbuck *and* eland.

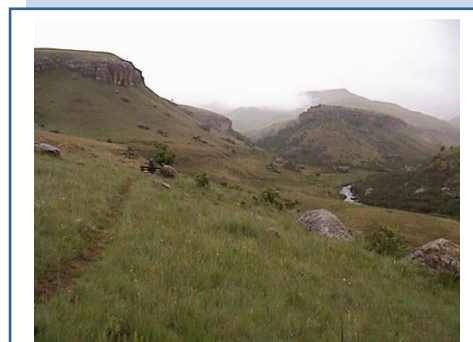


Photo 33: Grasslands found in RU
(Source: www.panoramio.com)

The invertebrate fauna of the area is less well known but includes many species endemic to the region. These include for example 21 species of millipedes, and 32 species of craneflies. Of the 156 South African species of dragonflies, 44 have been found in the area, one being endemic, and 74 butterfly species which is 11.7% of the butterflies found in the country.

19.4 Demography and Landcover

The Drakensberg is renowned for the quantity, quality and variety of rock art painted by now extinct

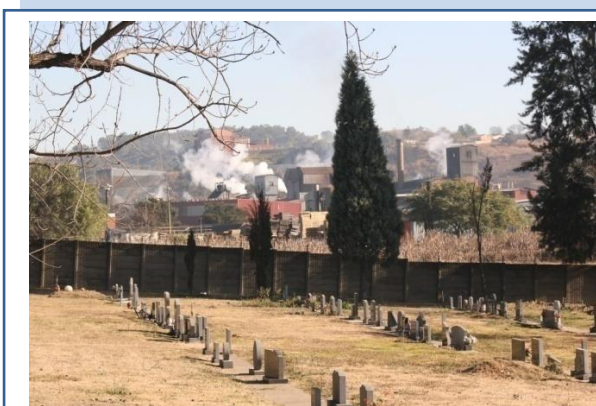


Photo 34: Industry and graveyard situated on shallow groundwaters

Bushman. Various activities are currently taking place in the area surrounding the protected area. These include commercial and subsistence farming, as well as various recreation activities. Many private accommodation facilities like chalets, lodges, hotels and camp sites have been developed to cater for the tourist market. Forest plantations also occur within the RU. The total population in the study area is 140000 (2001 census data).

The main hub of industrial activity is Estcourt (Photo 34). The main economic activity is farming with large bacon and processed food factories situated around the town. Industrial companies located in Estcourt include: Karobek, Mooi River Textiles, Estcourt Pet Products, Knight Engineering, Agrico, Freemans, Masonite Africa Limited and Milo (Nestle). The landcover within the RU is shown in Figure 132.

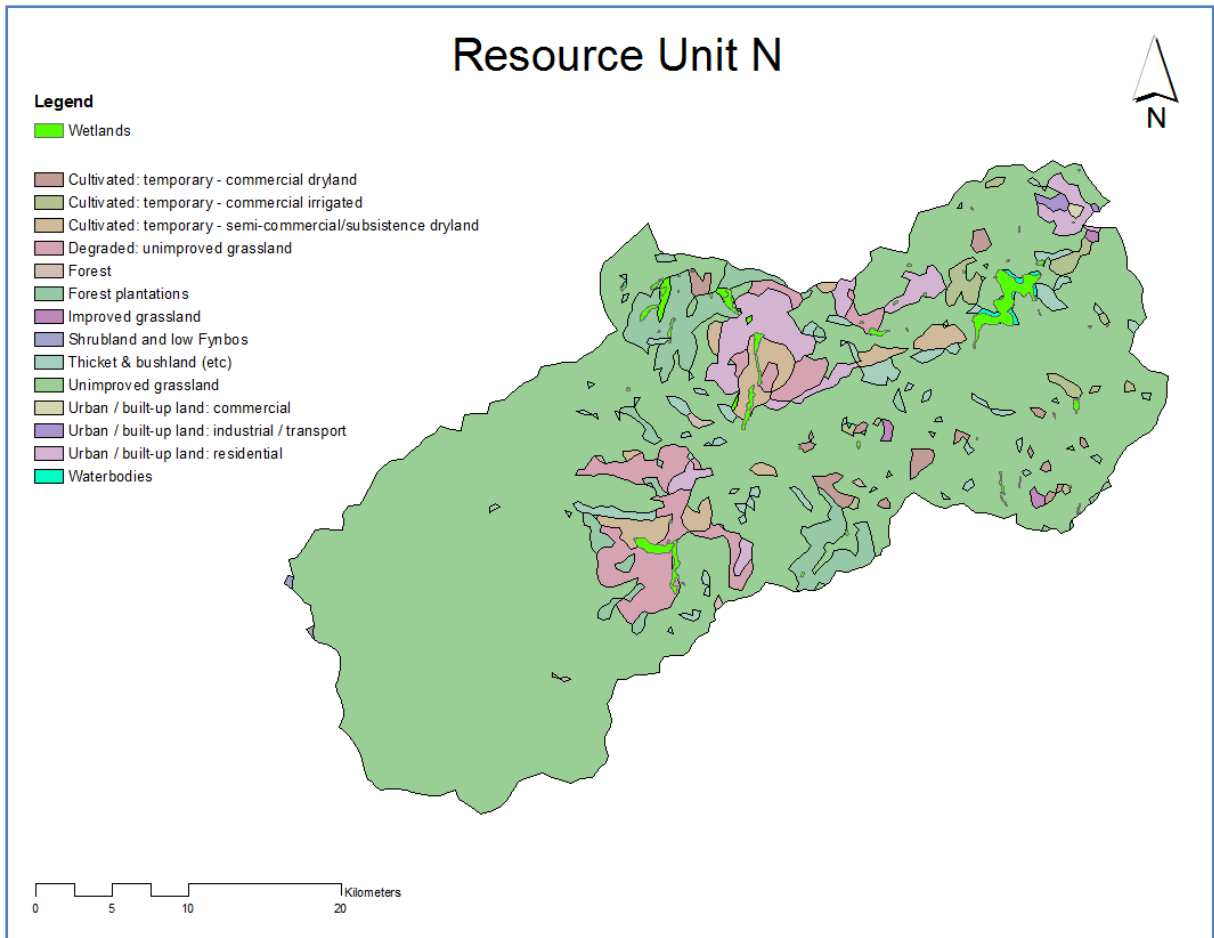


Figure 132: Landcover within RUN

19.5 Surface Water

This RU forms the headwaters of the Bushmans River. The Wagendrift Dam is included in the RU.

19.6 Wetlands

The wetlands in the study area are shown in Figure 132.

19.7 Soils (taken from www.deat.gov.za)

The channel substrate at high altitudes (generally > 1850 m) consists of basalt bedrock and boulders, while at lower altitudes, sandstone bedrock and boulders dominate. In the lowest parts of the study, sand and silt substrates become evident. Although mineral soils are more common, some of the wetland areas, particularly those on south-facing slopes and at higher altitudes have organic soils (which tend to have a minerotrophic water supply).

19.8 Geology (summarised from Woodford and Chevallier, 2002)

The Beaufort Group dominates in this RU and is stratigraphically divided into two major units, the upper Tarkastad Subgroup and the lower Adelaide Subgroup. The Tarkastad Subgroup is subdivided into the upper Burgersdorp Formation with its brightly coloured red, blue and green mudstones and the lower Katberg Formation, that can be up to 900 m thick. The Katberg Formation also contains brightly coloured shales and mudstones, but mainly consists of thick layers of coarse-grained sandstone. The Adelaide Subgroup mainly consists of green, bluish, grey and red mudstones and fine-grained sandstones that form thick lens-shaped units. The central basin mainly consists of mudstones, shales and fine-grained sandstones. These fine-grained sediments were mainly deposited where the braided rivers began to meander. The sedimentary units in the Group therefore usually have very low primary hydraulic conductivities. Since the Beaufort Group was also deposited in a fluvial environment, one can expect that aquifers in these formations will, like those in the Ecca Group, be anisotropic. The geometry of these aquifers, however, is further complicated by the migration of the braided and meandering streams. Aquifers in the Beaufort Group will therefore not only be multi-layered, but also multi-porous with variable thicknesses. The contact plane between two different sedimentary layers will cause a discontinuity in the hydraulic properties of an aquifer. The lifespan of a high-yielding borehole in the Beaufort Group may therefore be limited if the aquifer is not recharged frequently. Since these shales are very dense, they were often neglected as sources of groundwater in the past. The prodelta sandstones represent another formation of the Ecca Group in which one would expect to find high-yielding aquifers. Unfortunately, the permeabilities of these sandstones are also usually very low.

The Volksrust Formation (of the Ecca Group) is a predominantly argillaceous unit, which interfingers with the overlying Beaufort Group and underlying Vryheid Formation. The Formation consists of grey to black, silty shale with thin, usually bioturbated, siltstone or sandstone lenses and beds, particularly towards its upper and lower boundaries. Thin phosphate and carbonate beds and concretions are relatively common. Since these shales are very dense, they were often neglected as sources of groundwater in the past. The prodelta sandstones represent another formation of the Ecca Group in which one would expect to find high-yielding aquifers. Unfortunately, the permeabilities of these sandstones are also usually very low.

Sills in the Karoo formations are sheetlike forms of dolerite intrusions that tend to follow the bedding planes of the formations concordantly. These structures, whose thicknesses vary from less than a metre to hundreds of metres, represent the dominant form in which dolerite is emplaced in the Karoo Supergroup. Dolerite sills in the Karoo Supergroup often have very complex forms. The linear dykes are also usually thinner than ring dykes and are confined to the Ecca and Beaufort Groups. This is a clear indication that the magmatic activity at the time the linear dykes intruded was less than when the ring dykes and sills intruded.

19.9 Geohydrology

1.1.119 Groundwater levels

It is clear the groundwater levels follow the topography as seen from Figure A1 in Appendix A and therefore groundwater contour maps were generated using Bayesian interpolation. The

groundwater levels for the study area are shown in Figure 133. The most probable depth to groundwater level in the RU is 5.8 mbgl according to the histogram of water levels in the RU shown in Appendix A. Groundwater levels are expected to be lower than normal due to the prevailing drought conditions. Unfortunately very little time series water level data are available to quantify the overall impact.

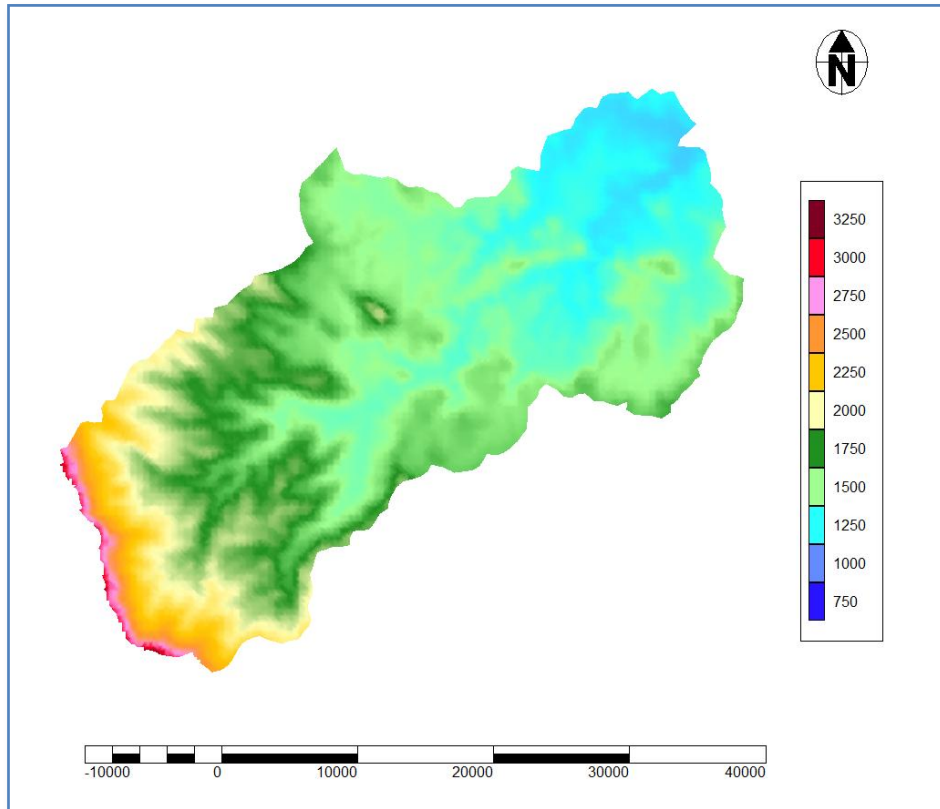


Figure 133: Groundwater levels in RUN

19.9.1 Groundwater recharge

The groundwater recharge calculated from the different methods is listed in Table 108. The different recharge methods applied are discussed in Section 2.3. The final recharge values for the RU are highlighted in red.

Table 108: Recharge values

Recharge							
MAP Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Volume Mm ³ /a	Calculated %	CMB %	Land Cover %	Geology %
1001.634	66.728	94.116	80.922	8.1%	8.1%	2.3%	2.6%

1.1.120 Basic human needs

The method for determining BHNs is discussed in Section 2.3. The final value for the study area is highlighted in red in Table 109.

Table 109: Basic human needs

Basic Human Need		
Census(2001) Adjusted	Dependence 18%	Estimate Mm ³ /a
161858	29134	0.262

1.1.121 Groundwater contribution to baseflow

The baseflow separation curves for the RU are shown in Figures 134 – 138.

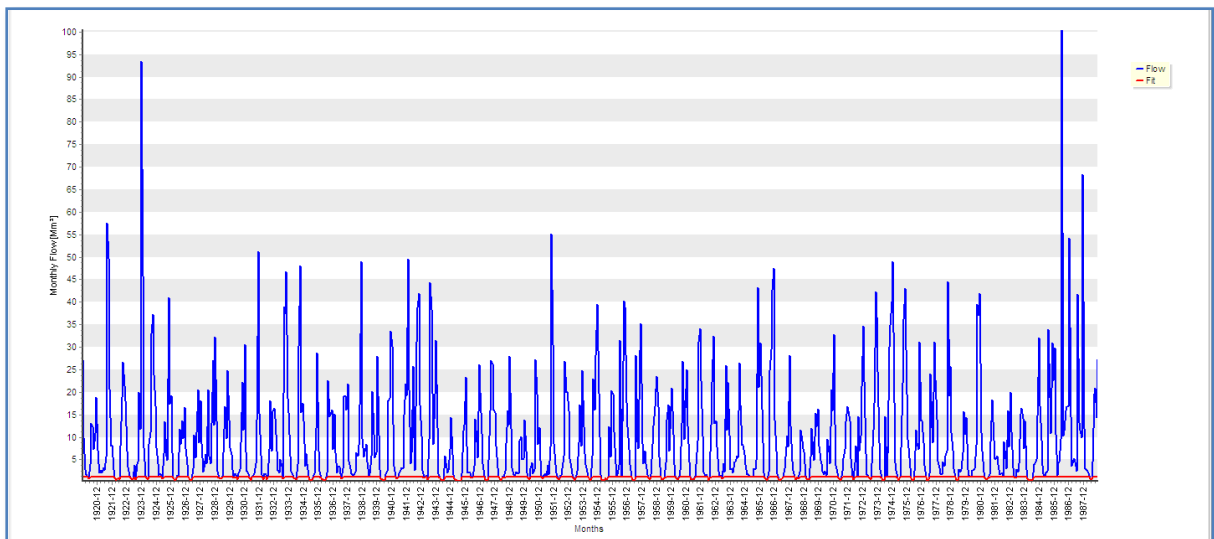


Figure 134: Baseflow separation for quaternary catchment V70A

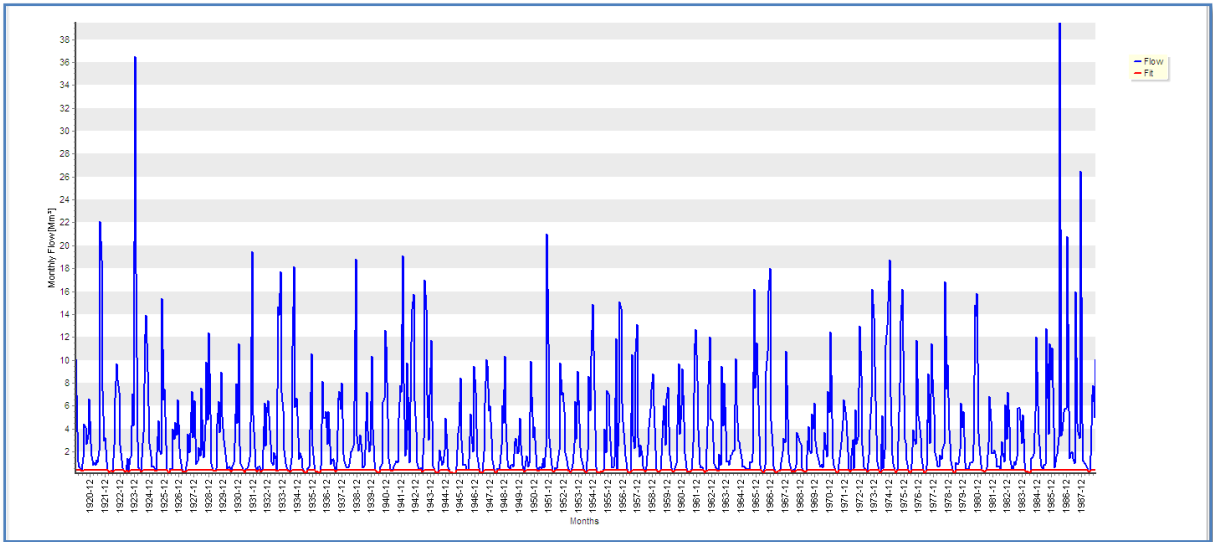


Figure 135: Baseflow separation for quaternary catchment V70B

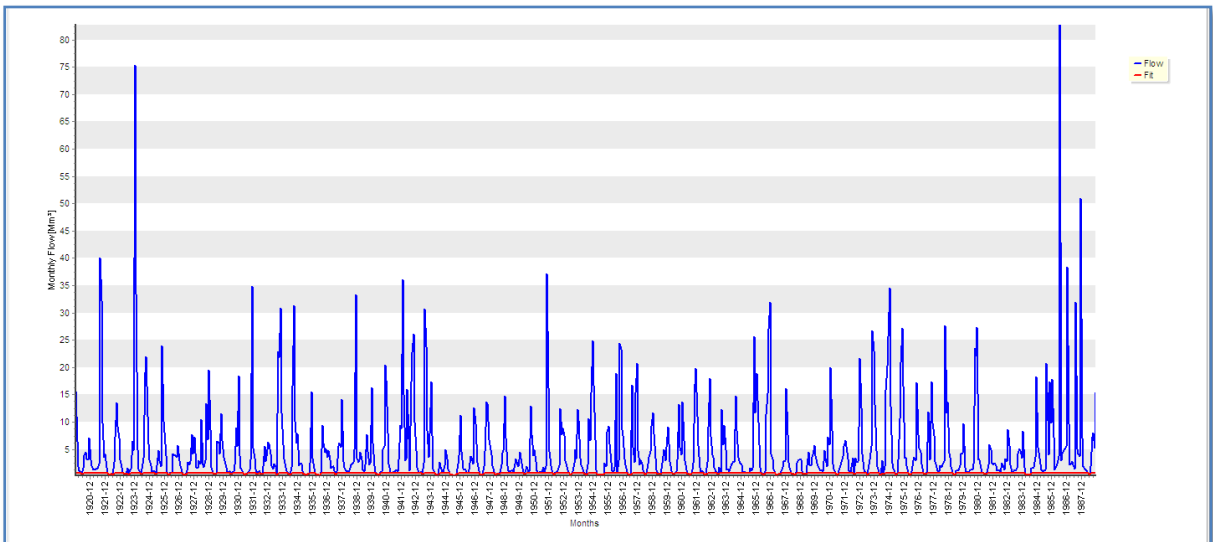


Figure 136: Baseflow separation for quaternary catchment V70C

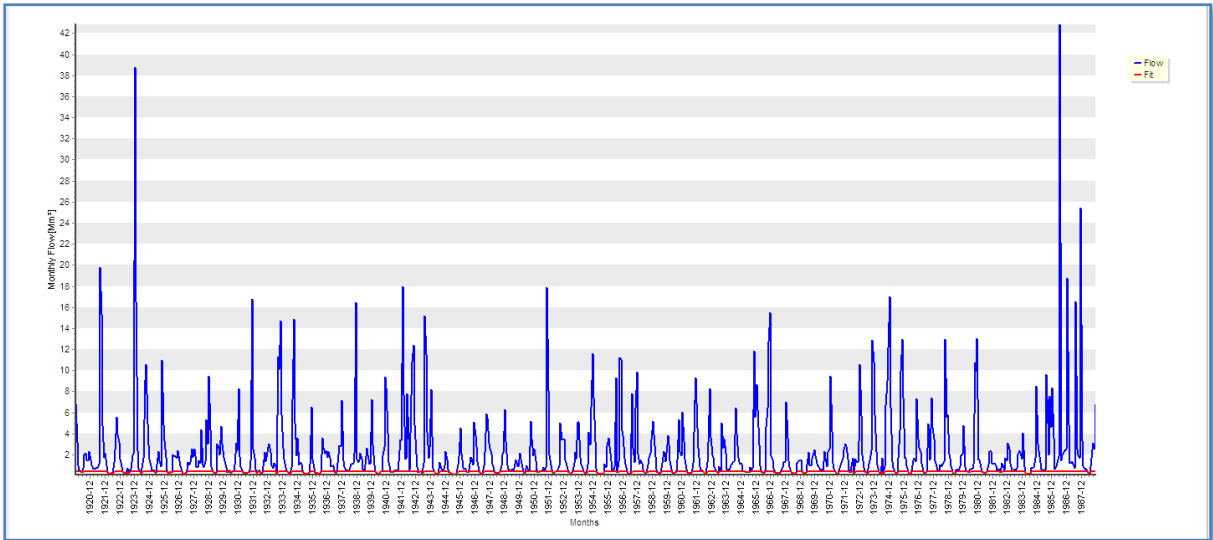


Figure 137: Baseflow separation for quaternary catchment V70D

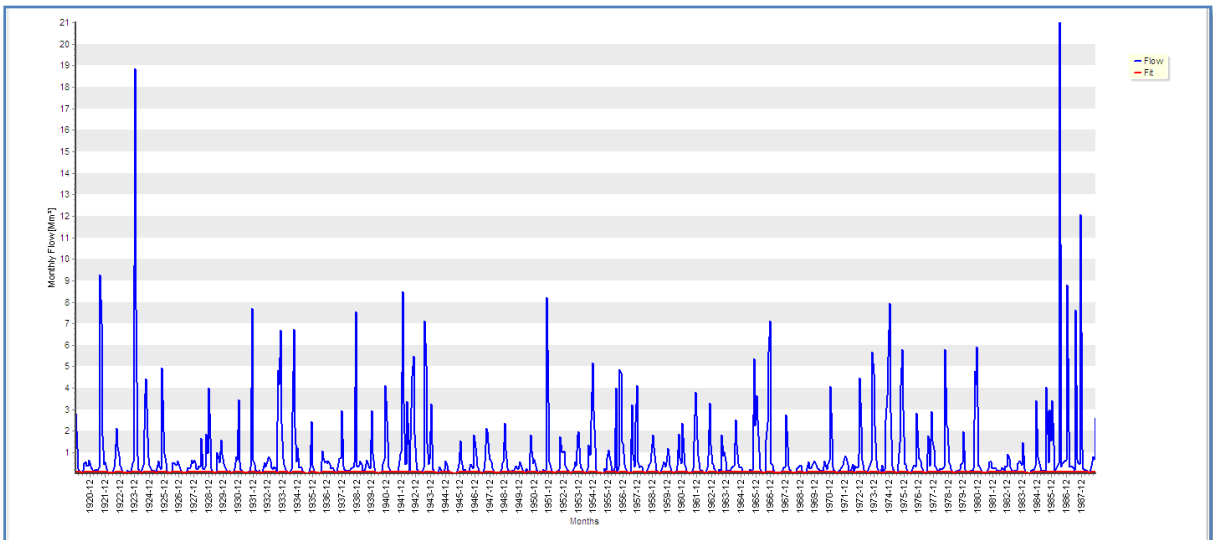


Figure 138: Baseflow separation for quaternary catchment V70E

The final groundwater contribution to baseflow values for the RU is highlighted in red in Table 110.

Table 110: Groundwater contribution to baseflow

Groundwater Contribution to Baseflow							
GRDM Mm ³ /a	Hughes Mm ³ /a	Shultz Mm ³ /a	Pitman Mm ³ /a	vTonder Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Herold Mm ³ /a
19.247	102.158	46.872	25.691	45.496	19.247	102.158	29.340

1.1.122 Groundwater use

The groundwater use for the RU is listed in Table 111.

Table 111: Groundwater use

Groundwater Use							
GRDM Mm ³ /a	WARMS Mm ³ /a	Hydrocensus Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Forrest Mm ³ /a	Crops Mm ³ /a	TOTAL Mm ³ /a
0.420	0.002	0.453	0.002	1.810	14.602	0.041	14.380

1.1.123 Groundwater quality

The TDS values for the RU are shown in Figure 139. They are classified according to SABS standards. Not all boreholes have quality data available but those that do can be used to identify possible hot spots with regard to quality in the resource unit. The overall quality of the resource unit is well within the drinking water guidelines with the exception of two boreholes. These areas should be treated as hotspots rather than penalising the whole resource unit with a poor classification. Treatment of the hotspot areas will be addressed under Resource Quality Objectives in Section 31.

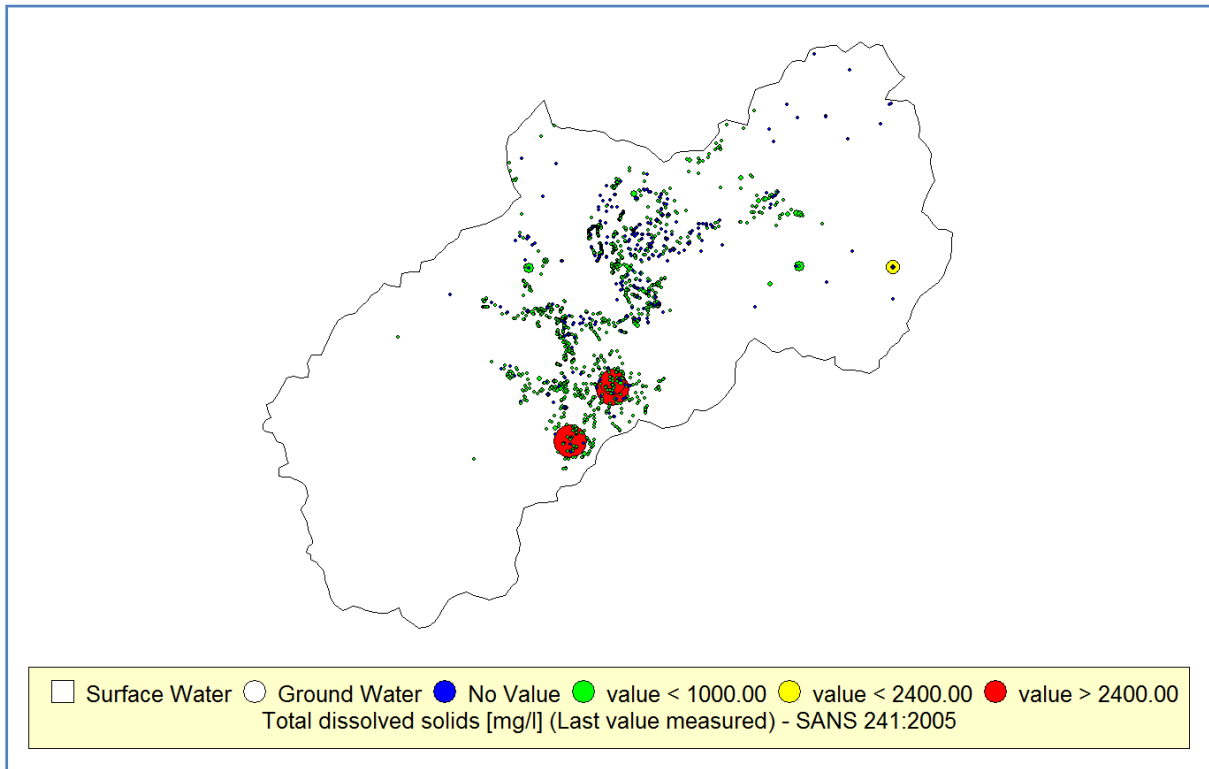


Figure 139: TDS values

1.1.124 Aquifer vulnerability

The aquifer vulnerability calculations are summarised in Table 112. The slope histogram is documented in Appendix B.

Table 112: Aquifer vulnerability

Aquifer Vulnerability						
Level mbgl	Recharge %	Slope %	Soil Texture	Aquifer Type	Vadose Zone	Vulnerability %
5.8	8.1%	2.0	SaCLm-SaCl	Weathered/Fractured	Karoo(southern)	63%

19.10 Classification

1.1.125 Groundwater usage

The stress index, defined as the ratio between total groundwater use and recharge, for the study area is calculated at 54%. Due to the uncertainty associated with the groundwater use component, the stress index was stochastically modelled through assigning a normal distribution curve with a standard deviation of 1.438 Mm³/a to the groundwater use estimate to account for the associated uncertainty. The stochastic results are shown in Figure 140. It is clear from the results that the stress index will vary between 50% and 59% with a certainty of 98.66%. Due to the small variability in the obtained range and high certainty, the uncertainty in the groundwater use component will not affect the calculated stress index significantly.

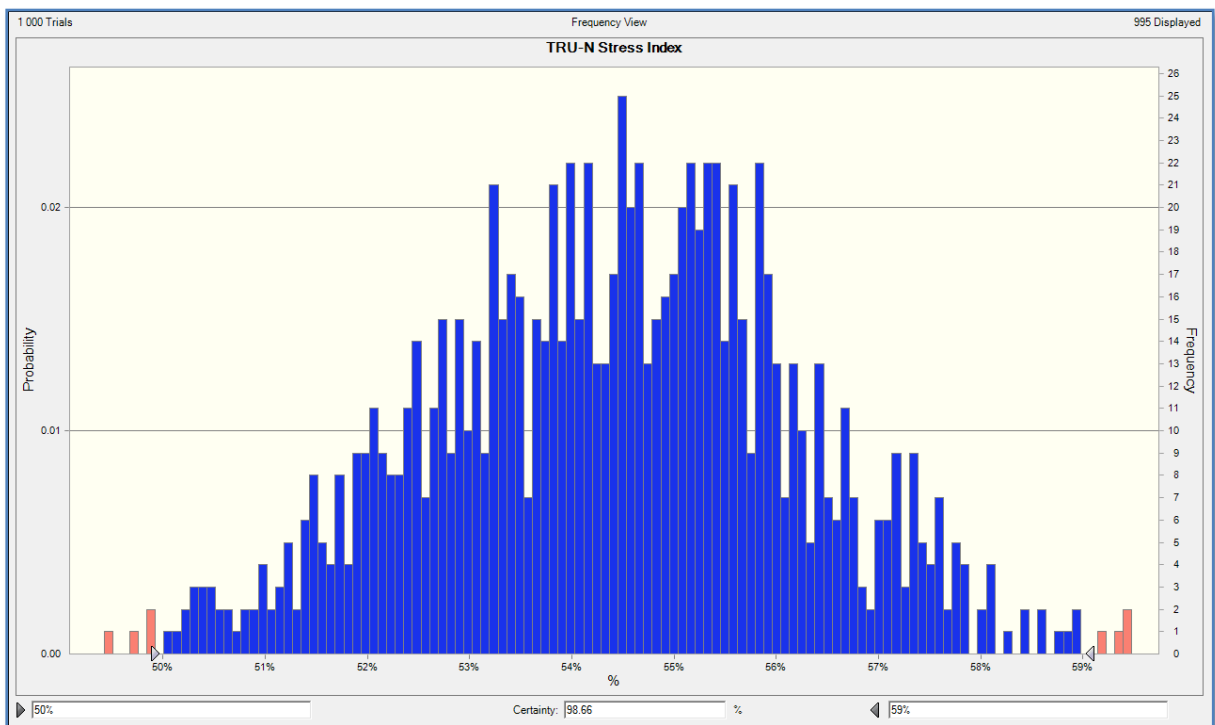


Figure 140: Stochastic results

1.1.126 Quality

The expanded Durov diagram with the groundwater quality is shown in Figure 141. An explanation of the classification process by means of the expanded Durov diagram is given in Section 2.3. It is apparent that the contamination category according to the explanation is an A/B.

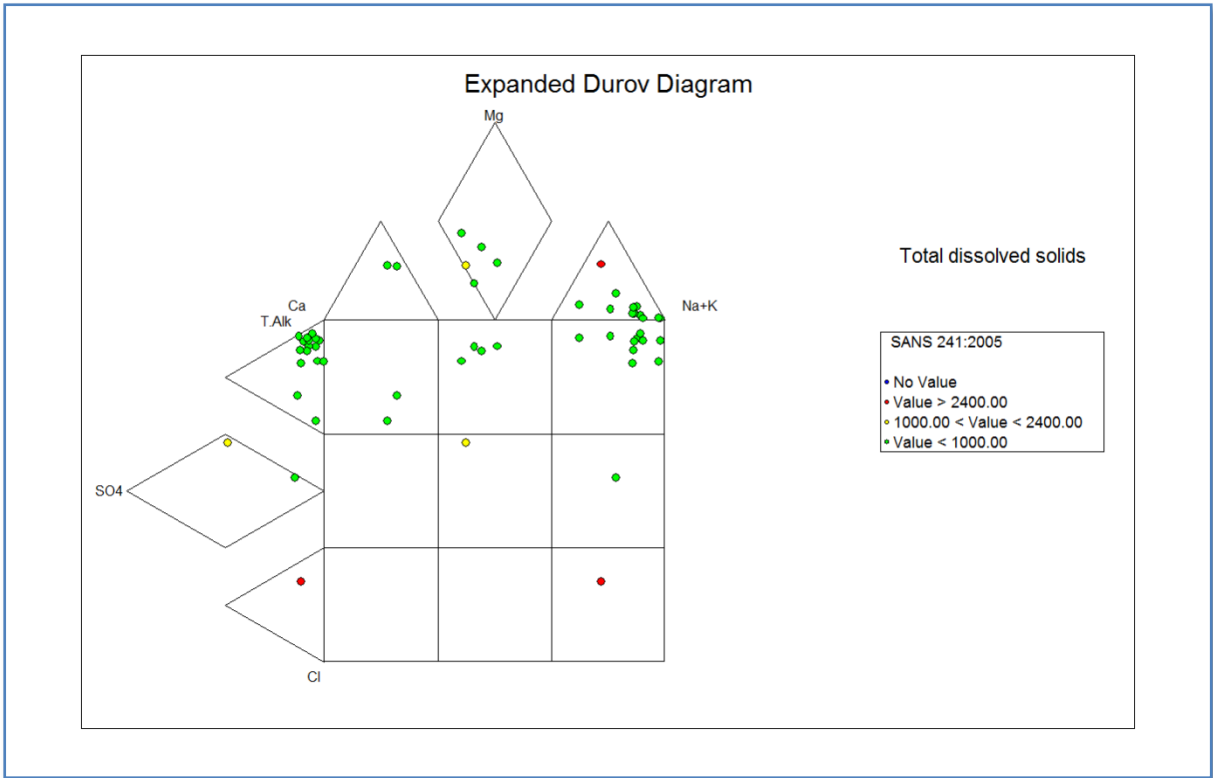


Figure 141: Expanded Durov diagram for RU

As documented in the vulnerability is 63%. The impact of potential contamination according to Section 2.3 is low.

1.1.127 Final category

The final category for the RU is summarised in Table 113.

Table 113: Category for RU

Impact	Present status category	Water resource category
Groundwater usage	D	Fair
Groundwater contamination	A/B	Natural/Fair
Potential groundwater contamination (vulnerability and impact)	B	Fair
FINAL	B/C	Good/Fair

19.11 Quantification of the Reserve

The groundwater Reserve for the RU is summarised in Table 114.

Table 114: Reserve

Reserve			Allocation	
Baseflow Mm ³ /a	BHN Mm ³ /a	Reserve % Recharge	Allocation Mm ³ /a	Current Use Mm ³ /a
29.340	0.262	37%	36.940	14.380

20. Classification and the Reserve for Resource Unit O

20.1 Location

The quaternary catchments located in RUO are: V20A, V20B, V20C and V20D. The main towns included in this area are: Redcliffe, Nottingham Road and Rosetta. The Highmoor and Kamberg (Photo 35) protected areas are included in the RU. These form part of the Ukhahlamba Drakensberg Park. The location of this RU is shown in Figure 142.

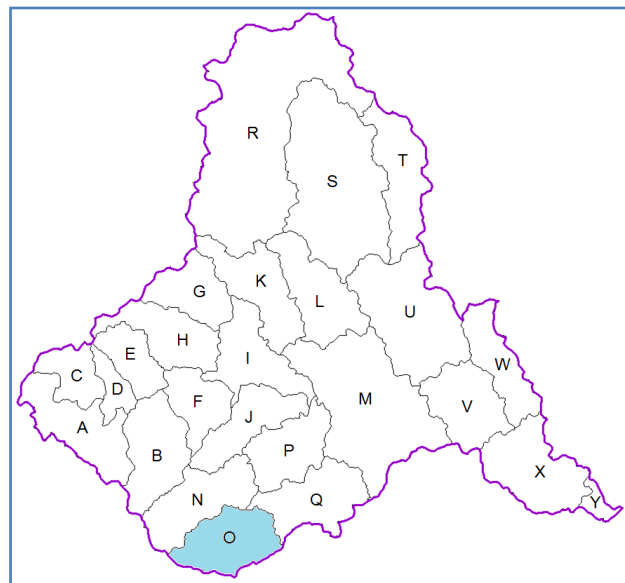


Figure 142: Location of RO

20.2 Climate

The rainfall is 850 to 1300 mm per year, in summer. Mean temperatures for January are around 22°C with a mean maximum of 29°C. In winter mean annual temperatures in July are about 10°C with a mean minimum of about 3°C.

20.3 Vegetation (taken from www.deat.gov.za)

The Grassland Biome is found chiefly on the high central plateau of South Africa. The topography is mainly flat and rolling, but includes the escarpment itself. Altitude varies from near sea level to 2 850 m above sea level. Grasslands are dominated by a single layer of grasses. The amount of cover depends on rainfall and the degree of grazing. Trees are absent, except in a few localized habitats. Geophytes are often abundant. Frosts, fire and grazing maintain the grass dominance and prevent the establishment of trees. There are two categories of grass plants: sweet grasses and sour grasses.

20.4 Demography and Landcover

The total population of 1700 people (2001 census data). The Grassland Biome is the mainstay of dairy, beef (Photo 36) and wool production in South Africa. Pastures may be augmented in wetter areas by the addition of legumes and sweet grasses. The Grassland Biome is the cornerstone of the maize crop, and many grassland types have been converted to this crop. Sorghum, wheat and sunflowers are also farmed on a smaller scale. Forest plantation also occur within the RU. The landcover for this RU is shown in Figure 143.



Photo 36: Cattle farming
(Source: www.panoramio.com)

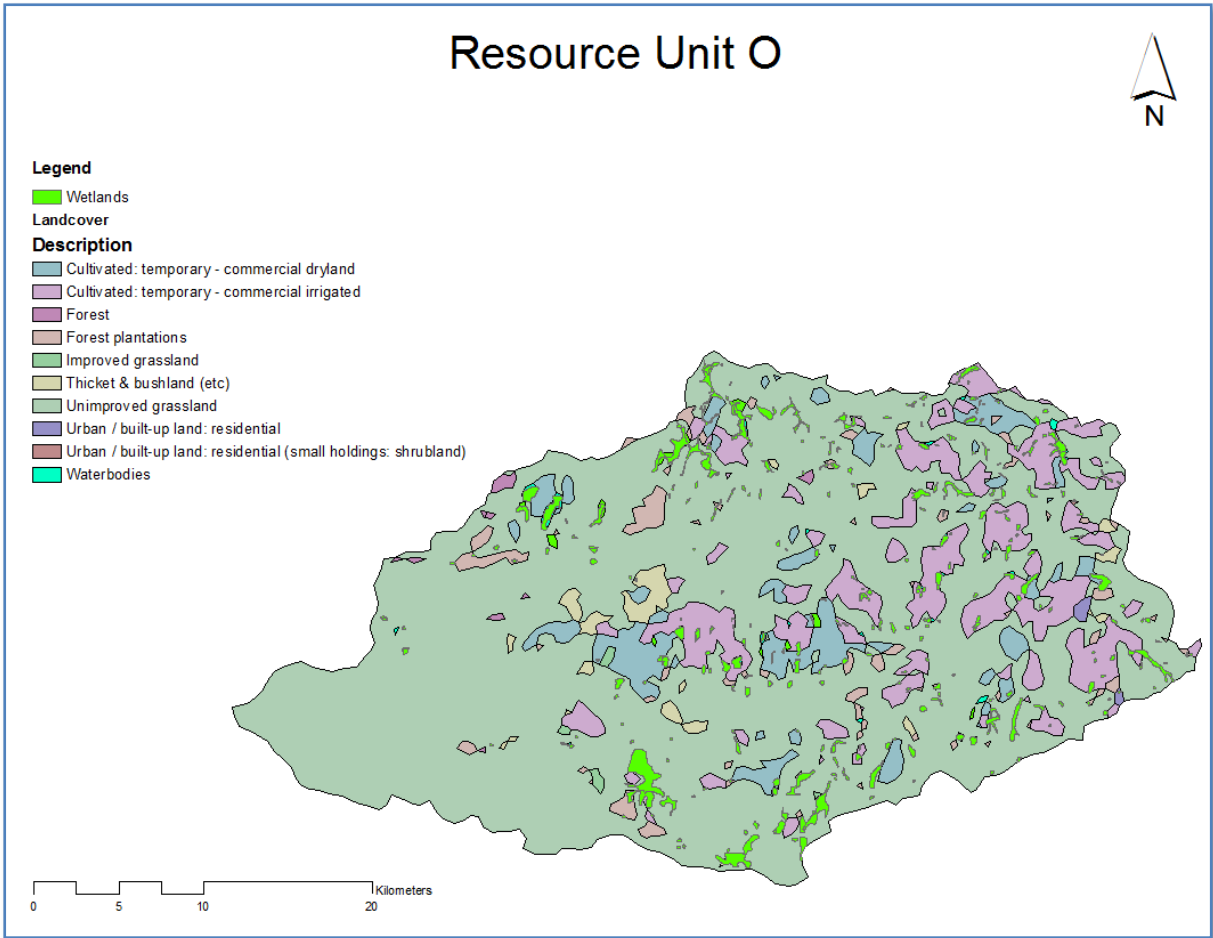


Figure 143: Landcover for RUO

20.5 *Surface Water*

This RU forms the head waters of the Mooi River. The main tributaries being the Little Mooi (Photo 37) and Hlatikulu Rivers.



20.6 Wetlands

Three well-known wetlands occur in this RU, namely the Hlatikulu, Nsonge, Stillerust and Highmoor Wetlands. The wetlands for the RU are shown in Figure 143. Hlatikulu Wetland is of high significance for biodiversity conservation and water supply and quality. It is considered a priority wetland in the province. The wetland and its surrounds provide living and breeding habitat for several important bird species, including Wattled crane, Southern Bald ibis and Blue crane.

The Nsonge Floodplain is a 67 ha floodplain wetland draining northeast into the Mooi River. Land use in its catchment is agriculture, conservation and recreation, and the wetland is used for grazing livestock. It is characterised by an alluvial ridge that rises up to 1 m above the surrounding hummocky swamp. Meander scars and ox-bow lakes occur mostly in the lower end of the floodplain.

20.7 Soils (taken from www.deat.gov.za)

The soil is often shallow, rocky and leached, derived from Karoo Sequence sediments and dolerite. Where deep, the soils may be leached due to the high rainfall and are fairly erodible forming large dongas in some parts.

20.8 Geology (summarised from Woodford and Chevallier, 2002)

The Beaufort Group dominates in this RU and is stratigraphically divided into two major units, the upper Tarkastad Subgroup and the lower Adelaide Subgroup. The Tarkastad Subgroup is subdivided into the upper Burgersdorp Formation with its brightly coloured red, blue and green mudstones and the lower Katberg Formation, that can be up to 900 m thick. The Katberg Formation also contains brightly coloured shales and mudstones, but mainly consists of thick layers of coarse-grained sandstone. The Adelaide Subgroup mainly consists of green, bluish, grey and red mudstones and fine-grained sandstones that form thick lens-shaped units. The central basin mainly consists of mudstones, shales and fine-grained sandstones. These fine-grained sediments were mainly deposited where the braided rivers began to meander. The sedimentary units in the Group therefore usually have very low primary hydraulic conductivities. Since the Beaufort Group was also deposited in a fluvial environment, one can expect that aquifers in these formations will, like those in the Ecca Group, be anisotropic. The geometry of these aquifers, however, is further complicated by the migration of the braided and meandering streams. Aquifers in the Beaufort Group will therefore not only be multi-layered, but also multi-porous with variable thicknesses. The contact plane between two different sedimentary layers will cause a discontinuity in the hydraulic properties of an aquifer.

The lifespan of a high-yielding borehole in the Beaufort Group may therefore be limited if the aquifer is not recharged frequently. Since these shales are very dense, they were often neglected as sources of groundwater in the past. The prodelta sandstones represent another formation of the Ecca Group in which one would expect to find high-yielding aquifers. Unfortunately, the permeabilities of these sandstones are also usually very low.

Sills in the Karoo formations are sheetlike forms of dolerite intrusions that tend to follow the bedding planes of the formations concordantly. These structures, whose thicknesses vary from less

than a metre to hundreds of metres, represent the dominant form in which dolerite is emplaced in the Karoo Supergroup. Dolerite sills in the Karoo Supergroup often have very complex forms. The linear dykes are also usually thinner than ring dykes and are confined to the Ecca and Beaufort Groups. This is a clear indication that the magmatic activity at the time the linear dykes intruded was less than when the ring dykes and sills intruded.

20.9 Geohydrology

1.1.128 Groundwater levels

It is clear the groundwater levels follow the topography as seen from Figure A1 in Appendix A and therefore groundwater contour maps were generated using Bayesian interpolation. The groundwater levels for the study area are shown in Figure 144. The most probable depth to groundwater level in the RU is 2.9 mbgl according to the histogram of water levels in the RU shown in Appendix A. Groundwater levels are expected to be lower than normal due to the prevailing drought conditions. Unfortunately very little time series water level data are available to quantify the overall impact.

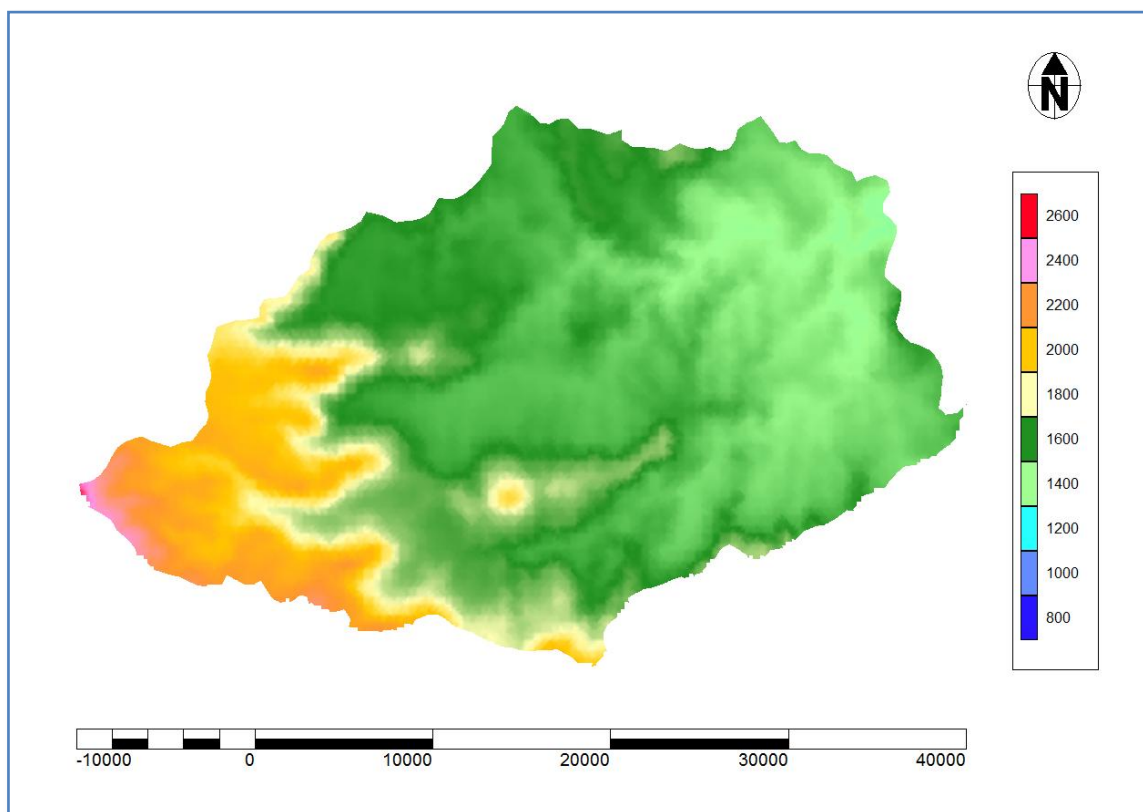


Figure 144: Groundwater levels in RUO

20.9.1 Groundwater recharge

The groundwater recharge calculated from the different methods is listed in Table 115. The different recharge methods applied are discussed in Section 2.3. The final recharge values for the RU are highlighted in red.

Table 115: Recharge values

Recharge							
MAP Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Volume Mm ³ /a	Calculated %	CMB %	Land Cover %	Geology %
894.232	62.346	89.728	69.793	7.8%	7.8%	1.0%	2.8%

1.1.129 Basic human needs

The method for determining BHNs is discussed in Section 2.3. The final value for the study area is highlighted in red in Table 116.

Table 116: Basic human needs

Basic Human Need		
Census(2001) Adjusted	Dependence 18%	Estimate Mm ³ /a
2915	525	0.005

1.1.130 Groundwater contribution to baseflow

The baseflow separation curves for the RU are shown in Figures 145 – 148.

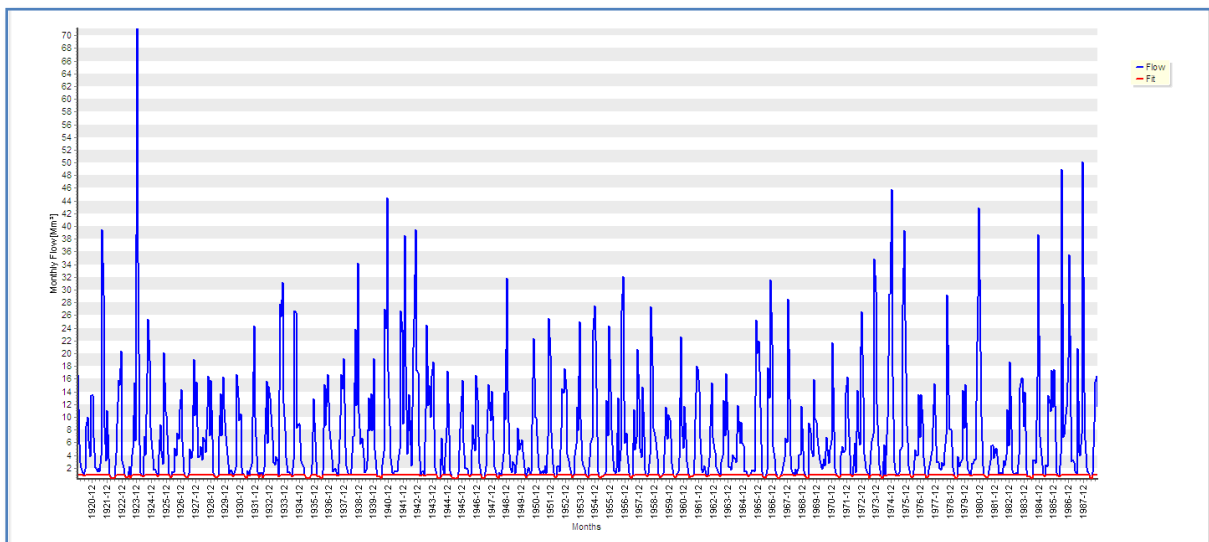


Figure 145: Baseflow separation for quaternary catchment V20A

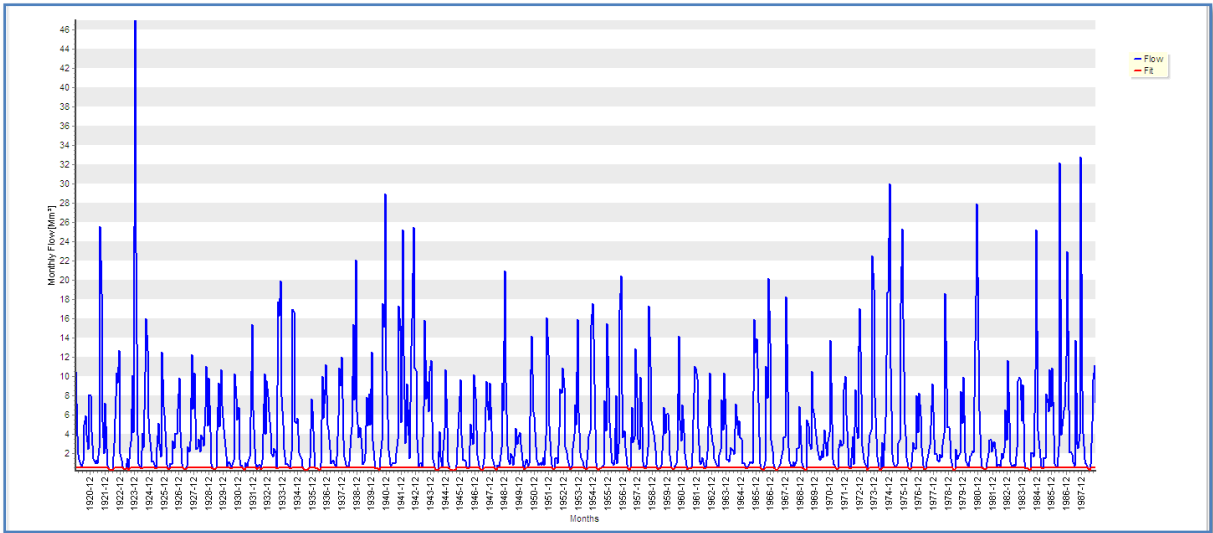


Figure 146: Baseflow separation for quaternary catchment V20B

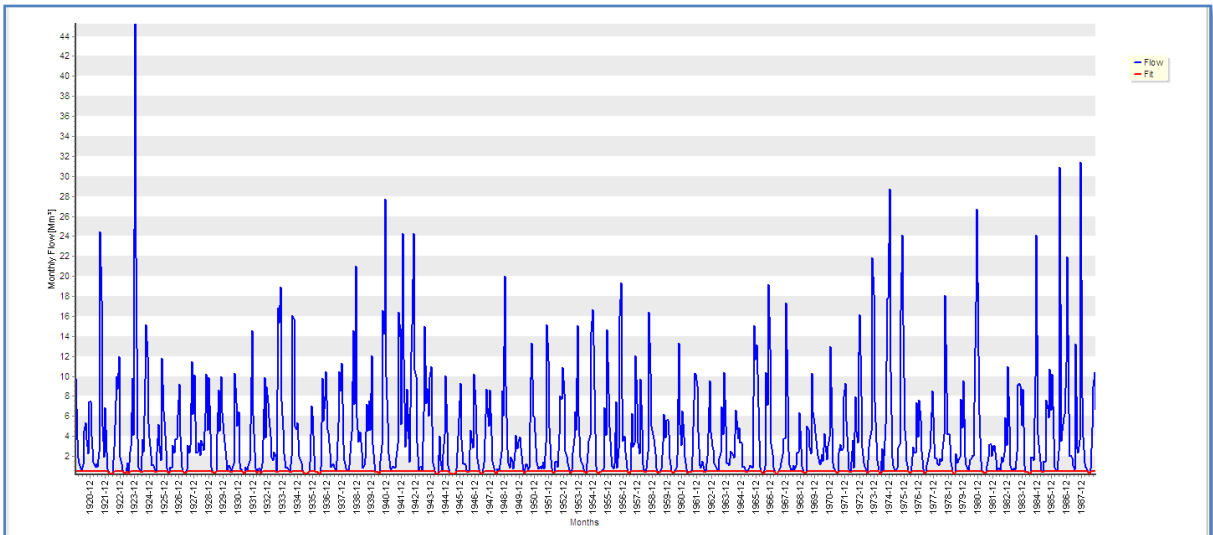


Figure 147: Baseflow separation for quaternary catchment V20C

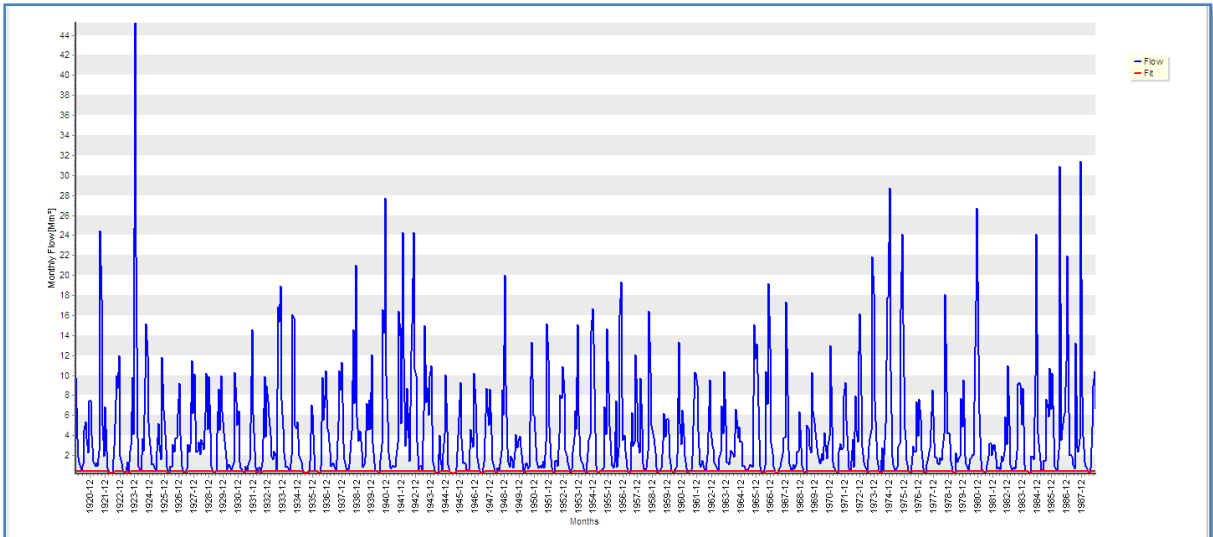


Figure 148: Baseflow separation for quaternary catchment V20D

The final groundwater contribution to baseflow values for the RU is highlighted in red in Table 117.

Table 117: Groundwater contribution to baseflow

Groundwater Contribution to Baseflow							
GRDM Mm ³ /a	Hughes Mm ³ /a	Shultz Mm ³ /a	Pitman Mm ³ /a	vTonder Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Herold Mm ³ /a
15.533	97.119	49.571	26.518	45.969	15.533	97.119	26.450

1.1.131 Groundwater use

The groundwater use for the RU is listed in Table 118.

Table 118: Groundwater use

Groundwater Use							
GRDM Mm ³ /a	WARMS Mm ³ /a	Hydrocensus Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Forrest Mm ³ /a	Crops Mm ³ /a	TOTAL Mm ³ /a
0.030	0.359	1.710	0.030	6.840	26.370	4.099	30.464

1.1.132 Groundwater quality

The TDS values for the RU are shown in Figure 149. They are classified according to SABS standards. Not all boreholes have quality data available but those that do can be used to identify possible hot spots with regard to quality in the resource unit. The overall quality of the resource unit is well within the drinking water guidelines.

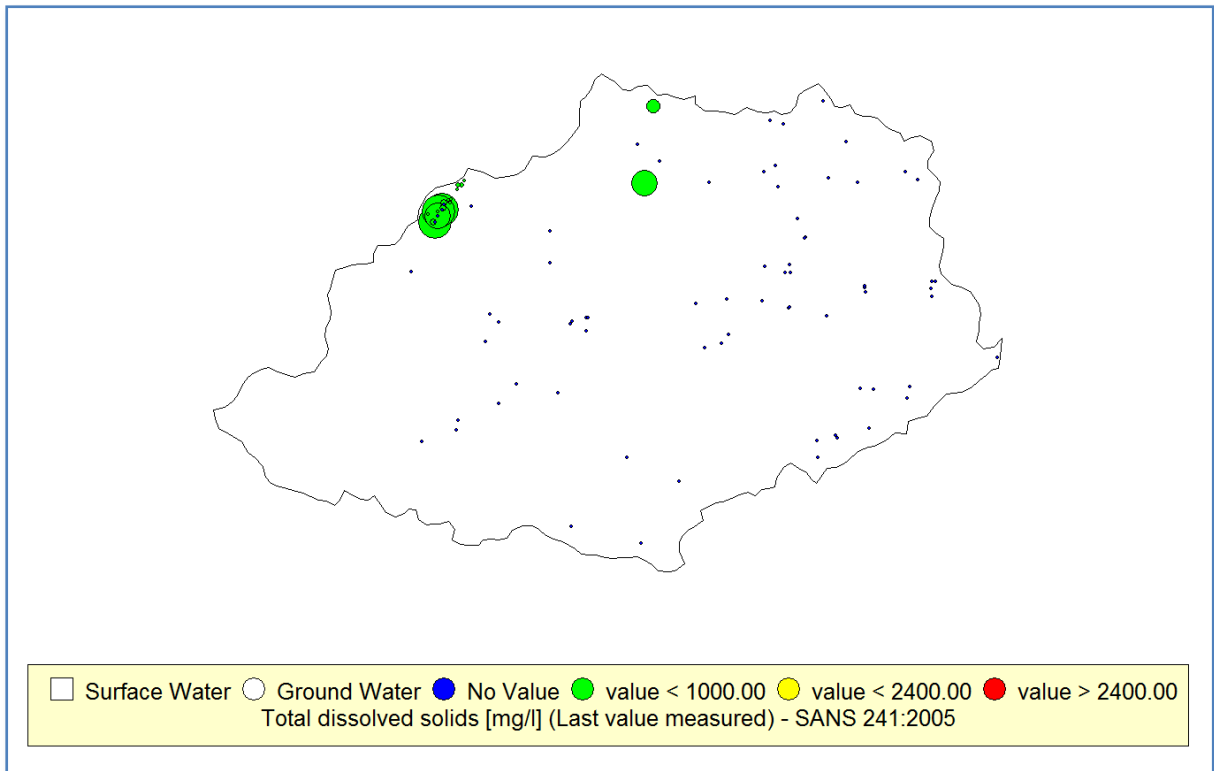


Figure 149: TDS values

1.1.133 Aquifer vulnerability

The aquifer vulnerability calculations are summarised in Table 119. The slope histogram is documented in Appendix B.

Table 119: Aquifer vulnerability

Aquifer Vulnerability						
Level mbgl	Recharge %	Slope %	Soil Texture	Aquifer Type	Vadose Zone	Vulnerability %
2.9	7.8%	1.1	SaClIm-SaCl	Weathered/Fractured	Karoo(southern)	62%

20.10 Classification

1.1.134 Groundwater usage

The stress index, defined as the ratio between total groundwater use and recharge, for the study area is calculated at 82%. Due to the uncertainty associated with the groundwater use component, the stress index was stochastically modelled through assigning a normal distribution curve with a standard deviation of 3.046 Mm³/a to the groundwater use estimate to account for the associated uncertainty. The stochastic results are shown in Figure 150. It is clear from the results that the stress index will vary between 69% and 91% with a certainty of 99.14%. Due to the large variability in the range obtained, it is recommended that the uncertainty in the groundwater use be reduced by detailed studies focusing on groundwater use within the RU. Due to the relatively high stress index this RU should be flagged as an area which requires further investigation.

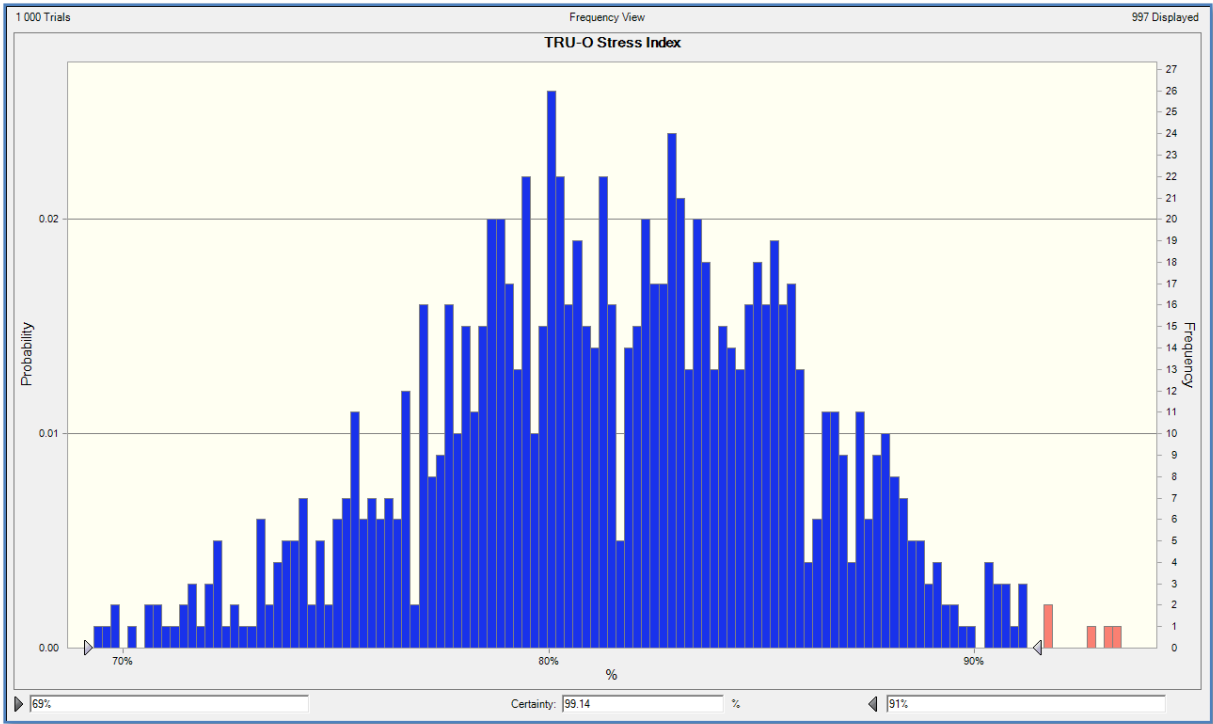


Figure 150: Stochastic results

1.1.135 Quality

The expanded Durov diagram with the groundwater quality is shown in Figure 151. An explanation of the classification process by means of the expanded Durov diagram is given in Section 2.3. There are numerous boreholes in categories A and C, however the overall water quality is relatively good therefore the final category was set as a A/B.

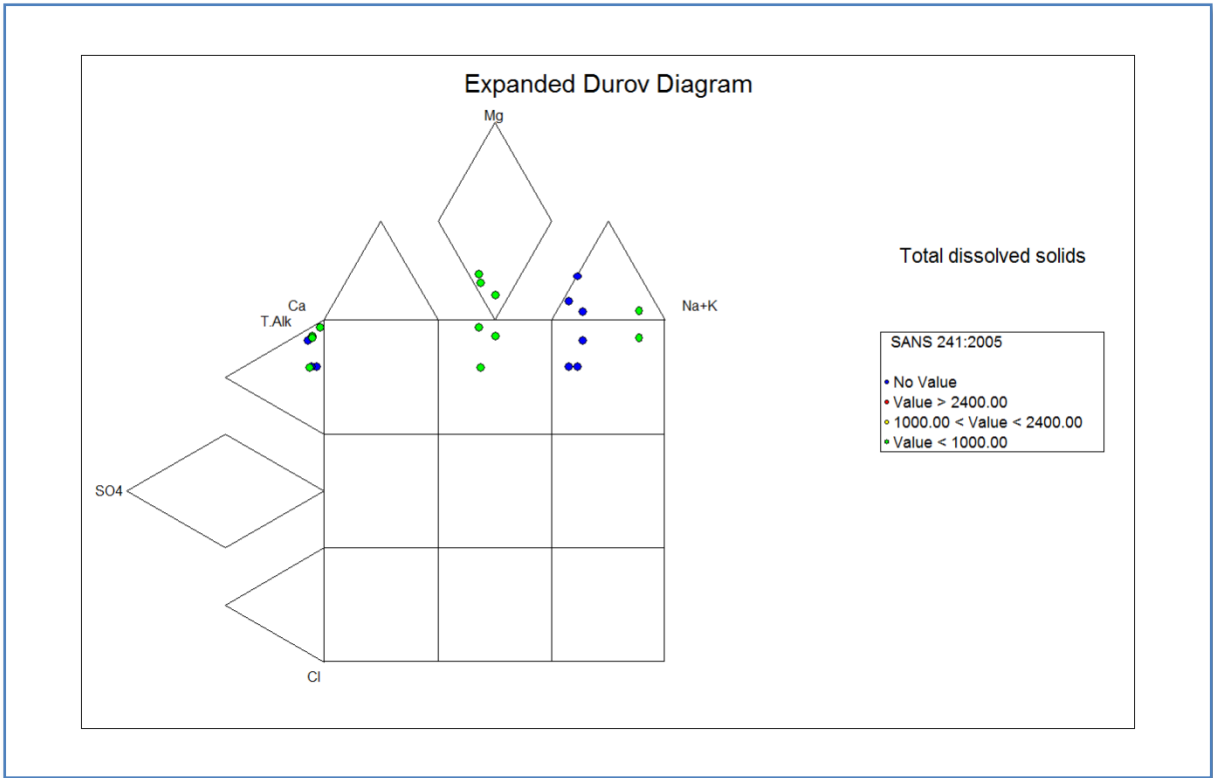


Figure 151: Expanded Durov diagram for RU

As documented the vulnerability is 62%. The impact of potential contamination according to Section 2.3 is low.

1.1.136 Final category

The final category for the RU is summarised in Table 120.

Table 120: Category for RU

Impact	Present status category	Water resource category
Groundwater usage	E	Poor
Groundwater contamination	A/B	Natural/Good
Potential groundwater contamination (vulnerability and impact)	B	Good
FINAL	B/C	Good/Fair

20.11 Quantification of the Reserve

The groundwater Reserve for the RU is summarised in Table 121.

Table 121: Reserve

Reserve			Allocation	
Baseflow Mm ³ /a	BHN Mm ³ /a	Reserve % Recharge	Allocation Mm ³ /a	Current Use Mm ³ /a
26.450	0.005	38%	12.875	30.464

21. Classification and the for Resource Unit P

21.1 Location

This RU includes quaternary catchments V70F and V70G. Weenen is the main town included in the area. Weenen (Dutch for "to weep") is the second oldest European settlement in KwaZulu-Natal, South Africa. It is situated on the banks of the Bushman River. The area includes the Weenen Game Reserve. The location of the RU is shown in Figure 152.

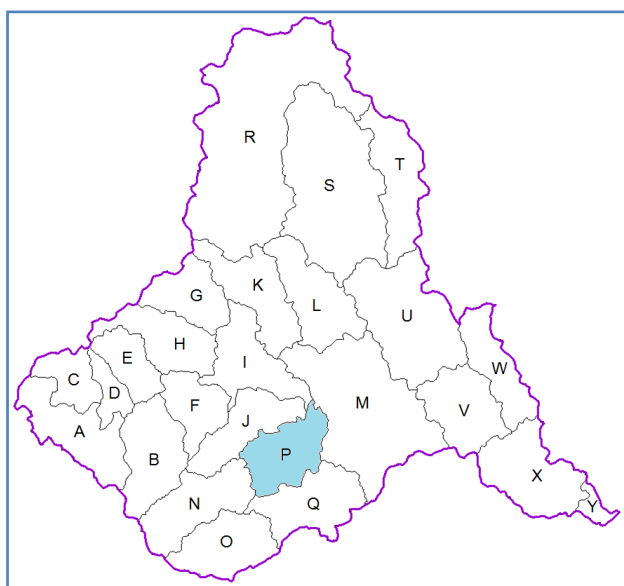


Figure 152: Location of RUP

21.2 Climate

The average rainfall for the RU is 660 mm/a. Weenen normally receives about 659 mm of rain per year, with most rainfall occurring mainly during mid-summer. It receives the lowest rainfall (3mm) in June and the highest (130mm) in January. The monthly distribution of average daily maximum temperatures shows that the average midday temperatures for Weenen range from 20.6°C in June to 28.5°C in January. The region is the coldest during June when the mercury drops to 3.5°C on average during the night.

21.3 Vegetation (taken from www.deat.gov.za)

This area is an open savanna, with scattered trees of Paperbark Thorn *Acacia sieberiana*, Sweet Thorn *A. karroo*, Scented Thorn *A. nilotica* and *A. caffra*. The herbaceous layer is quite variable, with secondary grassland, dominated by patches of tall Common Thatchgrass *Hyparrhenia hirta*, and sour grassland, dominated by Hairy Tridentgrass *Tristachya leucothrix*.

21.4 *Demography and Landcover*

The total population for the RU is 18420 (2001 census data). This area is known for its cattle and game farming, forestry (Photo 38) and agriculture. The farms in the vicinity of Weenen grow vegetables, lucerne, groundnuts, and citrus fruit (Photo 39). The landcover for the RU is shown in Figure 153.



Photo 38: Wattle plantation



Photo 39: Orange Groove Plantation

(Source: www.panoramio.com)

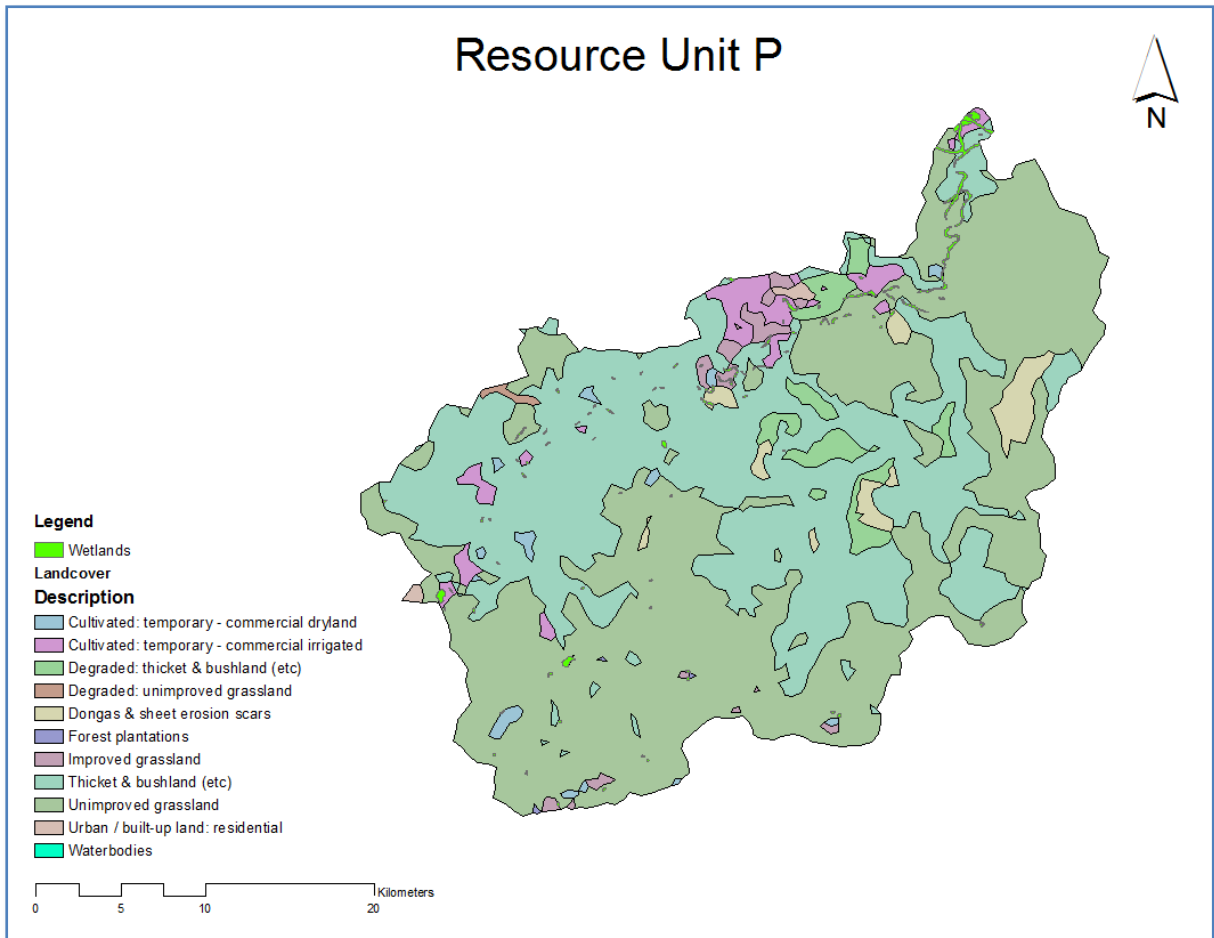


Figure 153: Landcover for RUP

21.5 *Surface Water*

The Rensburgspruit and Umngwenya River join the Bushmans River in the area.

21.6 *Wetlands*

The wetlands within the study area are shown in Figure 153.

21.7 *Soils (taken from www.deat.gov.za)*

The soil is shallow, derived from shales and mudstones of the Ecca Group of the Karoo Sequence.

21.8 *Geology (summarised from Woodford and Chevallier, 2002)*

The Beaufort Group dominates in this RU and is stratigraphically divided into two major units, the upper Tarkastad Subgroup and the lower Adelaide Subgroup. The Tarkastad Subgroup is subdivided into the upper Burgersdorp Formation with its brightly coloured red, blue and green mudstones and the lower Katberg Formation, that can be up to 900 m thick. The Katberg Formation also contains brightly coloured shales and mudstones, but mainly consists of thick layers of coarse-grained

sandstone. The Adelaide Subgroup mainly consists of green, bluish, grey and red mudstones and fine-grained sandstones that form thick lens-shaped units. The central basin mainly consists of mudstones, shales and fine-grained sandstones. These fine-grained sediments were mainly deposited where the braided rivers began to meander. The sedimentary units in the Group therefore usually have very low primary hydraulic conductivities. Since the Beaufort Group was also deposited in a fluvial environment, one can expect that aquifers in these formations will, like those in the Eccca Group, be anisotropic. The geometry of these aquifers, however, is further complicated by the migration of the braided and meandering streams. Aquifers in the Beaufort Group will therefore not only be multi-layered, but also multi-porous with variable thicknesses. The contact plane between two different sedimentary layers will cause a discontinuity in the hydraulic properties of an aquifer. The lifespan of a high-yielding borehole in the Beaufort Group may therefore be limited if the aquifer is not recharged frequently. Since these shales are very dense, they were often neglected as sources of groundwater in the past. The prodelta sandstones represent another formation of the Eccca Group in which one would expect to find high-yielding aquifers. Unfortunately, the permeabilities of these sandstones are also usually very low.

The Volksrust Formation (of the Eccca Group) is a predominantly argillaceous unit, which interfingers with the overlying Beaufort Group and underlying Vryheid Formation. The Formation consists of grey to black, silty shale with thin, usually bioturbated, siltstone or sandstone lenses and beds, particularly towards its upper and lower boundaries. Thin phosphate and carbonate beds and concretions are relatively common.

Since these shales are very dense, they were often neglected as sources of groundwater in the past. The prodelta sandstones represent another formation of the Eccca Group in which one would expect to find high-yielding aquifers. Unfortunately, the permeabilities of these sandstones are also usually very low.

Sills in the Karoo formations are sheetlike forms of dolerite intrusions that tend to follow the bedding planes of the formations concordantly. These structures, whose thicknesses vary from less than a metre to hundreds of metres, represent the dominant form in which dolerite is emplaced in the Karoo Supergroup. Dolerite sills in the Karoo Supergroup often have very complex forms. The linear dykes are also usually thinner than ring dykes and are confined to the Eccca and Beaufort Groups. This is a clear indication that the magmatic activity at the time the linear dykes intruded was less than when the ring dykes and sills intruded.

21.9 *Geohydrology*

1.1.137 Groundwater levels

It is clear the groundwater levels follow the topography as seen from Figure A1 in Appendix A and therefore groundwater contour maps were generated using Bayesian interpolation. The groundwater levels for the study area are shown in Figure 154. The most probable depth to groundwater level in the RU is 7.2 mbgl according to the histogram of water levels in the RU shown in Appendix A. Groundwater levels are expected to be lower than normal due to the prevailing

drought conditions. Unfortunately very little time series water level data are available to quantify the overall impact.

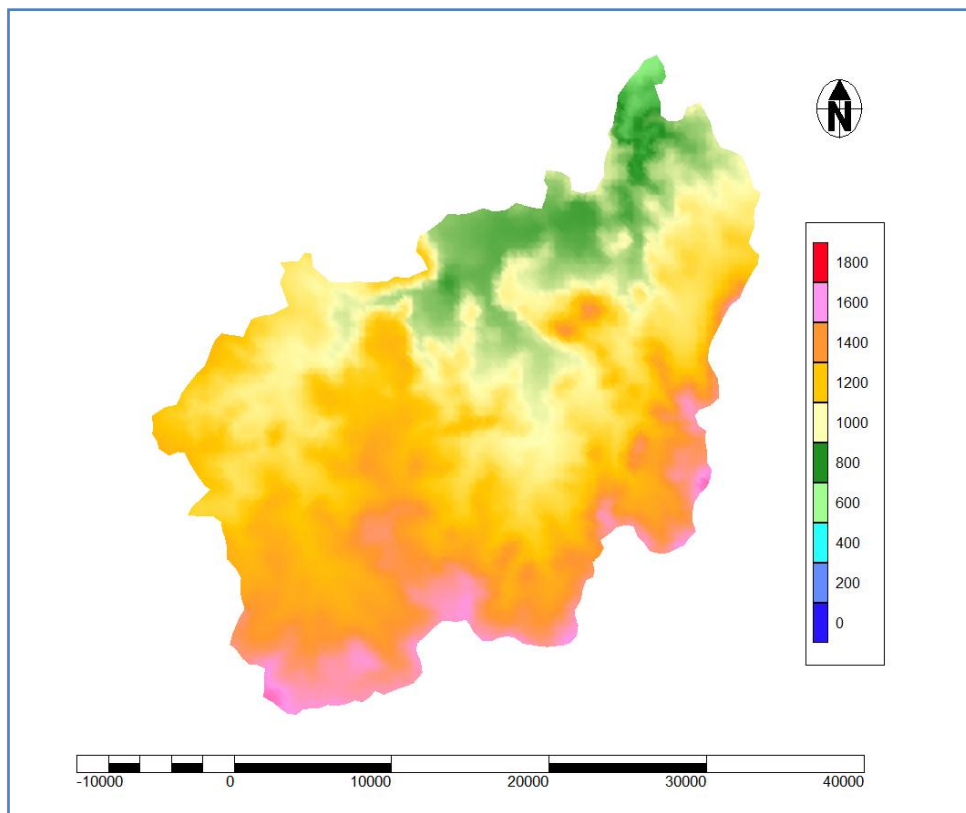


Figure 154: Groundwater levels in RUP

21.9.1 Groundwater recharge

The groundwater recharge calculated from the different methods is listed in Table 122. The different recharge methods applied are discussed in Section 2.3. The final recharge values for the RU are highlighted in red.

Table 122: Recharge values

Recharge							
MAP Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Volume Mm ³ /a	Calculated %	CMB %	Land Cover %	Geology %
579.343	27.648	46.395	28.148	4.9%	4.9%	3.2%	2.6%

1.1.138 Basic human needs

The method for determining BHNs is discussed in Section 2.3. The final value for the study area is highlighted in red in Table 123.

Table 123: Basic human needs

Basic Human Need		
Census(2001) Adjusted	Dependence 18%	Estimate Mm ³ /a
21183	3813	0.034

1.1.139 Groundwater contribution to baseflow

The baseflow separation curves for the RU are shown in Figures 155 & 156.

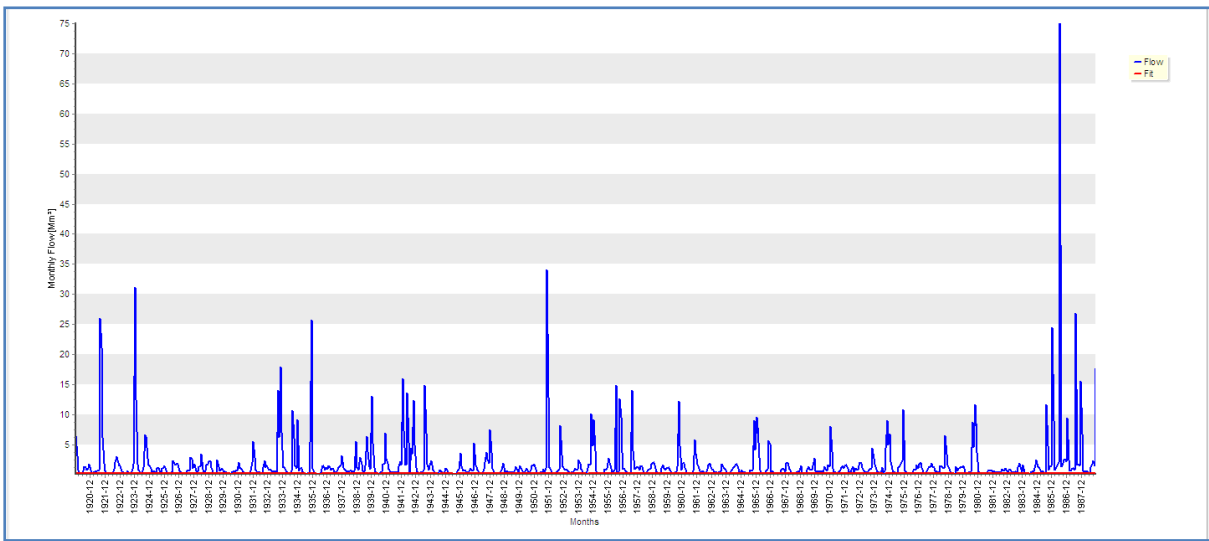


Figure 155: Baseflow separation for quaternary catchment V70F

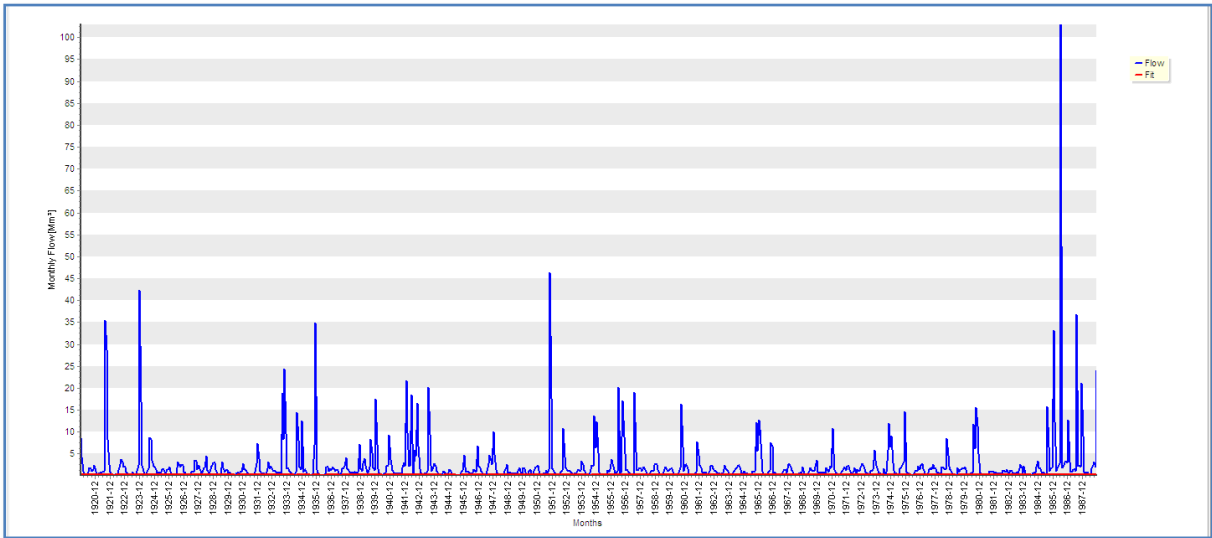


Figure 156: Baseflow separation for quaternary catchment V70G

The final groundwater contribution to baseflow values for the RU is highlighted in red in Table 124.

Table 124: Groundwater contribution to baseflow

Groundwater Contribution to Baseflow							
GRDM Mm ³ /a	Hughes Mm ³ /a	Shultz Mm ³ /a	Pitman Mm ³ /a	vTonder Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Herold Mm ³ /a
12.376	21.085	12.166	5.196	10.168	5.196	21.085	5.870

1.1.140 Groundwater use

The groundwater use for the RU is listed in Table 125.

Table 125: Groundwater use

Groundwater Use							
GRDM Mm ³ /a	WARMS Mm ³ /a	Hydrocensus Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Forrest Mm ³ /a	Crops Mm ³ /a	TOTAL Mm ³ /a
0.020	0.068	0.564	0.020	2.257	2.052	0.145	2.162

1.1.141 Groundwater quality

The TDS values for the RU are shown in Figure 157. They are classified according to SABS standards. Not all boreholes have quality data available but those that do can be used to identify possible hot spots with regard to quality in the resource unit. The overall quality of the resource unit is well within the drinking water guidelines with the exception one borehole which is classified as allowable.

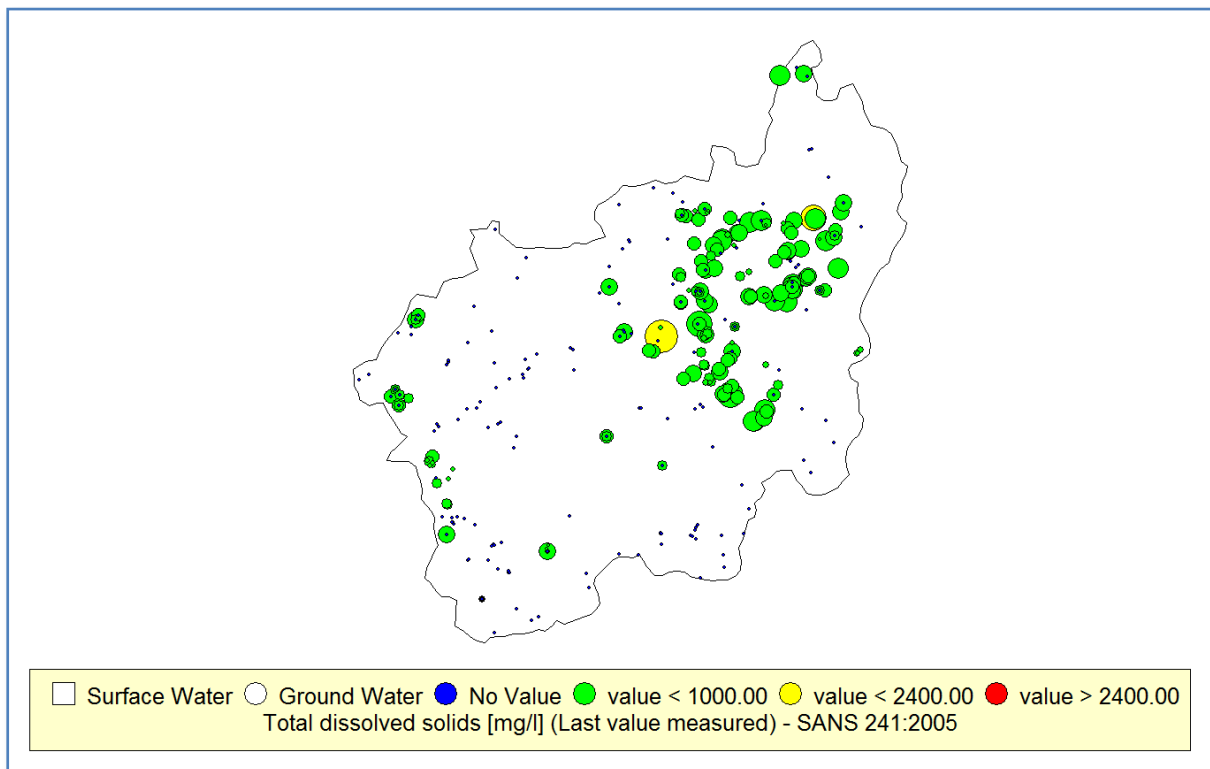


Figure 157: TDS values

1.1.142 Aquifer vulnerability

The aquifer vulnerability calculations are summarised in Table 126. The slope histogram is documented in Appendix B.

Table 126: Aquifer vulnerability

Aquifer Vulnerability						
Level mbgl	Recharge %	Slope %	Soil Texture	Aquifer Type	Vadose Zone	Vulnerability %
7.2	4.9%	1.3	SaClLm-SaCl	Weathered/Fractured	Karoo(southern)	56%

21.10 Classification

1.1.143 Groundwater usage

The stress index, defined as the ratio between total groundwater use and recharge, for the study area is calculated at 29%. Due to the uncertainty associated with the groundwater use component, the stress index was stochastically modelled through assigning a normal distribution curve with a standard deviation of 0.216 Mm³/a to the groundwater use estimate to account for the associated uncertainty. The stochastic results are shown in Figure 158. It is clear from the results that the stress index will vary between 27% and 31% with a certainty of 98.99%. Due to the small variability in the obtained range and high certainty, the uncertainty in the groundwater use component will not affect the calculated stress index significantly.

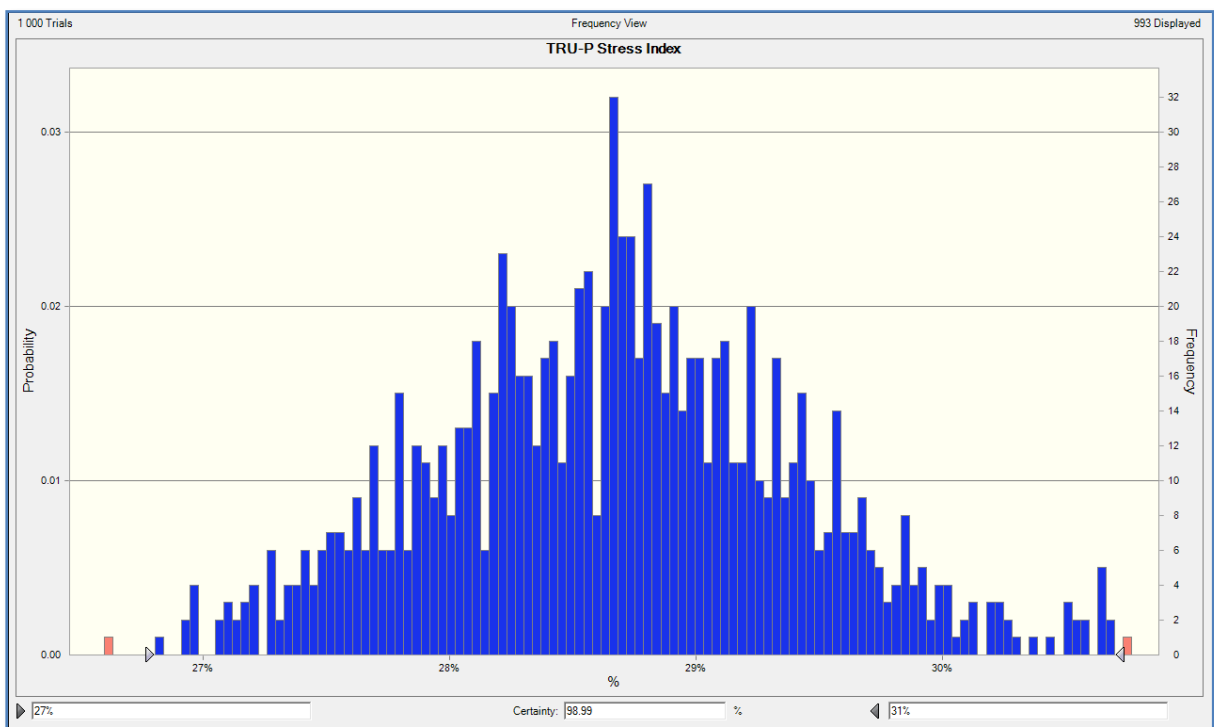


Figure 158: Stochastic results

1.1.144 Quality

The expanded Durov diagram with the groundwater quality is shown in Figure 159. An explanation of the classification process by means of the expanded Durov diagram is given in Section 2.3. There are numerous boreholes in categories A and C, however the overall water quality is relatively good therefore the final category was set as a B.

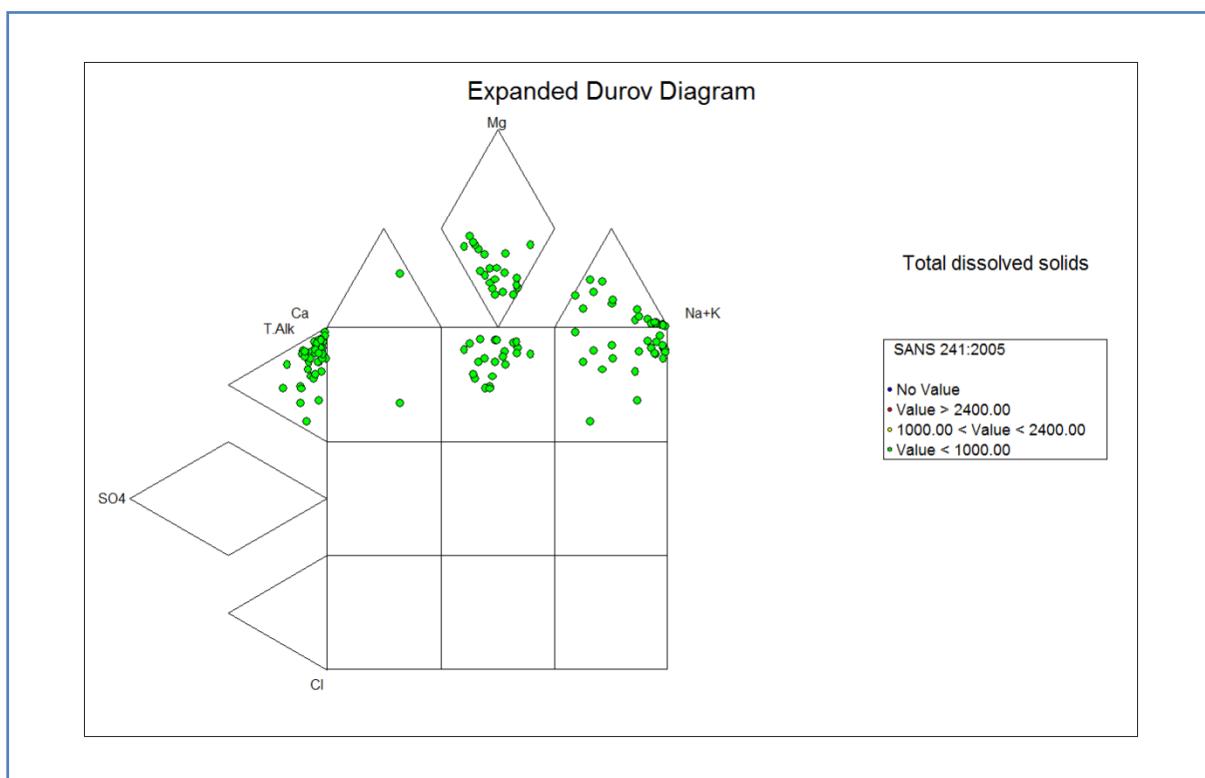


Figure 159: Expanded Durov diagram for RU

As documented the vulnerability is 56%. The impact of potential contamination according to Section 2.3 is low.

1.1.145 Final category

The final category for the RU is summarised in Table 127.

Table 127: Category for RU

Impact	Present status category	Water resource category
Groundwater usage	C	Good/Fair
Groundwater contamination	B	Good
Potential groundwater contamination (vulnerability and impact)	B	Good
FINAL	B/C	Good/Fair

21.11 Quantification of the Reserve

The groundwater Reserve for the RU is summarised in Table 128.

Table 128: Reserve

Reserve			Allocation	
Baseflow Mm ³ /a	BHN Mm ³ /a	Reserve % Recharge	Allocation Mm ³ /a	Current Use Mm ³ /a
5.870	0.034	21%	20.082	2.162

22. Classification and the for Resource Unit Q

22.1 Location

This RU encompasses the following quaternary catchments: V20E, V20F and V20G, with the main town in the RU being Mooi River (Photo 40). Mooi River is a small town situated at 1389m above sea level. The protected area of Karkloof is included in the RU. The location of the RU is shown in Figure 160.



Photo 40: Mooi River
(Source: www.panoramio.com)

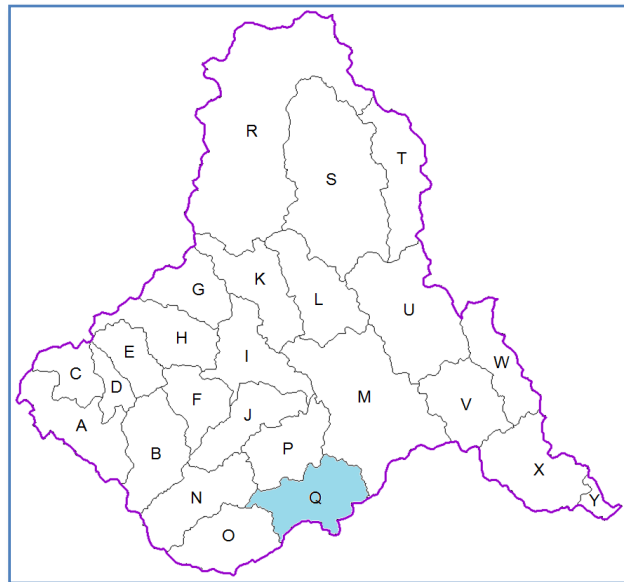


Figure 160: Location of RUQ

22.2 Climate

Mooi River normally receives about 648 mm of rain per year, with most rainfall occurring mainly during mid-summer. It receives the lowest rainfall (2 mm) in June and the highest (113 mm) in January. The monthly distribution of average daily maximum temperatures shows that the average midday temperatures for Mooi River range from 16.3°C in June to 24.2°C in January. The region is the coldest during June when the mercury drops to 0.6°C on average during the night.

22.3 Vegetation (taken from www.deat.gov.za)

This vegetation type is a dense, sour grassland with Redgrass. The tall-growing Common Thatchgrass *Hypparrhenia hirta* and Catstail Dropseed *Sporobolus pyramidalis* are often prominent in

the north. Trees and shrubs that occur on sheltered sites, rocky hills and ridges, include Common Spikethorn *Maytenus heterophylla*, Small Knobwood *Zanthoxylum capense*, Buffalo Thorn *Ziziphus mucronata*, *Rhus rehmanniana* and *Acacia sieberiana* in the north. Overgrazing encourages unpalatable Wire Grass *Elionurus muticus* and herbaceous weeds such as Staggersweed *Senecio retrorsus* and Doll Rose *Helichrysum argyrophyllum*.

22.4 Demography and Landcover

The total population for the study area is 16800 (2001 census data). The area is mainly used for grazing, though crop-farming (maize and potatoes) and forestry are also important economic activities. Mooi River also has a large number of piggeries and dairies. The landcover in the study area is shown in Figure 161.

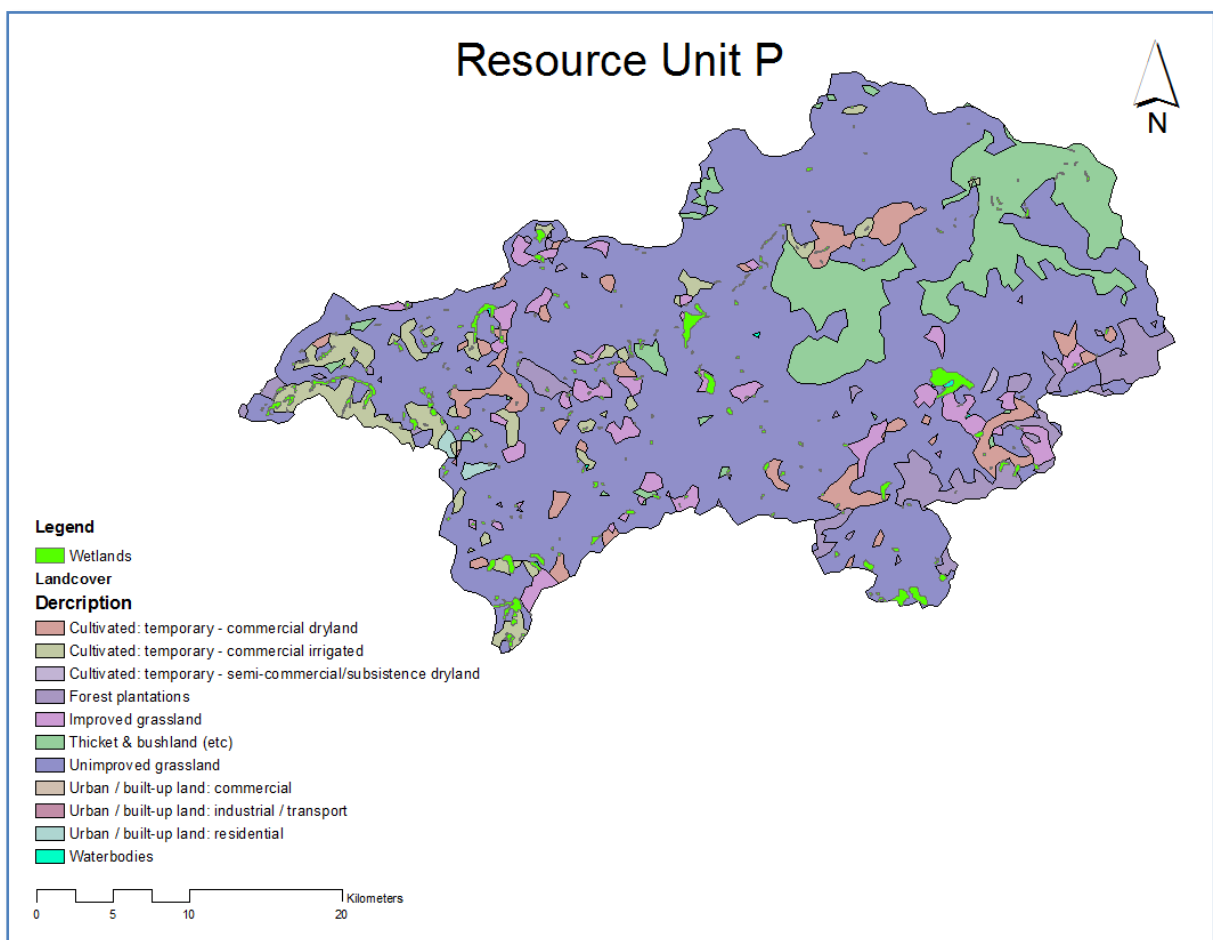


Figure 161: Landcover in RU

22.5 Surface Water

The Mooi River flows through most of the study area. The Mnyamvubu and Mpatheni join. The Craigie Burn Dam is included in the study area.

22.6 Wetlands

The wetlands in the study area are shown in Figure 161. There are numerous wetlands upstream of the Craigie Burn Dam.

22.7 Soils (taken from www.deat.gov.za)

The soil is often shallow, rocky and leached, derived from Karoo Sequence sediments and dolerite. Where deep, the soils may be leached due to the high rainfall and are fairly erodible forming large dongas in some parts.

22.1 Geology (summarised from Woodford and Chevallier, 2002)

The Beaufort Group dominates in this RU and is stratigraphically divided into two major units, the upper Tarkastad Subgroup and the lower Adelaide Subgroup. The Tarkastad Subgroup is subdivided into the upper Burgersdorp Formation with its brightly coloured red, blue and green mudstones and the lower Katberg Formation, that can be up to 900 m thick. The Katberg Formation also contains brightly coloured shales and mudstones, but mainly consists of thick layers of coarse-grained sandstone. The Adelaide Subgroup mainly consists of green, bluish, grey and red mudstones and fine-grained sandstones that form thick lens-shaped units. The central basin consist mainly of mudstones, shales and fine-grained sandstones. These fine-grained sediments were mainly deposited where the braided rivers began to meander. The sedimentary units in the Group therefore usually have very low primary hydraulic conductivities. Since the Beaufort Group was also deposited in a fluvial environment, one can expect that aquifers in these formations will, like those in the Ecca Group, be anisotropic. The geometry of these aquifers, however, is further complicated by the migration of the braided and meandering streams. Aquifers in the Beaufort Group will therefore not only be multi-layered, but also multi-porous with variable thicknesses. The contact plane between two different sedimentary layers will cause a discontinuity in the hydraulic properties of an aquifer. The lifespan of a high-yielding borehole in the Beaufort Group may therefore be limited if the aquifer is not recharged frequently.

The Volksrust Formation (of the Ecca Group) is a predominantly argillaceous unit, which interfingers with the overlying Beaufort Group and underlying Vryheid Formation. The Formation consists of grey to black, silty shale with thin, usually bioturbated, siltstone or sandstone lenses and beds, particularly towards its upper and lower boundaries. Thin phosphate and carbonate beds and concretions are relatively common.

The Vryheid Formation (of the Ecca Group) comprises mudrock, rhythmite, siltstone and fine- to coarse-grained sandstone (pebbly in places). The Formation contains up to five (mineable) coal seams. The different lithofacies are mainly arranged in upward coarsening deltaic cycles (up to 80m thick in the southeast). Linear coastline cycles are, however, fairly common particularly in the thin northwestern part where they constitute the entire Vryheid in places. A relatively thin fluvial interval (60 m thick) which grades distally into deltaic deposits towards the southwest and south occurs approximately in the middle of the formation in the east and northeast. Fining upward fluvial cycles, of which up to six are present in the east, are typically sheet like in geometry, although some

form valley-fill deposits. They comprise coarse grained to pebbly, immature sandstones - with an abrupt upward transition into fine grained sediments and coal seams.

Since these shales are very dense, they were often neglected as sources of groundwater in the past. The prodelta sandstones represent another formation of the Ecca Group in which one would expect to find high-yielding aquifers. Unfortunately, the permeabilities of these sandstones are also usually very low.

Sills in the Karoo formations are sheetlike forms of dolerite intrusions that tend to follow the bedding planes of the formations concordantly. These structures, whose thicknesses vary from less than a metre to hundreds of metres, represent the dominant form in which dolerite is emplaced in the Karoo Supergroup. Dolerite sills in the Karoo Supergroup often have very complex forms.

The linear dykes are also usually thinner than ring dykes and are confined to the Ecca and Beaufort Groups. This is a clear indication that the magmatic activity at the time the linear dykes intruded was less than when the ring dykes and sills intruded.

22.2 *Geohydrology*

1.1.146 Groundwater levels

It is clear the groundwater levels follow the topography as seen from Figure A1 in Appendix A and therefore groundwater contour maps were generated using Bayesian interpolation. The groundwater levels for the study area are shown in Figure 162. The most probable depth to groundwater level in the RU is 7.4 mbgl according to the histogram of water levels in the RU shown in Appendix A. Groundwater levels are expected to be lower than normal due to the prevailing drought conditions. Unfortunately very little time series water level data are available to quantify the overall impact.

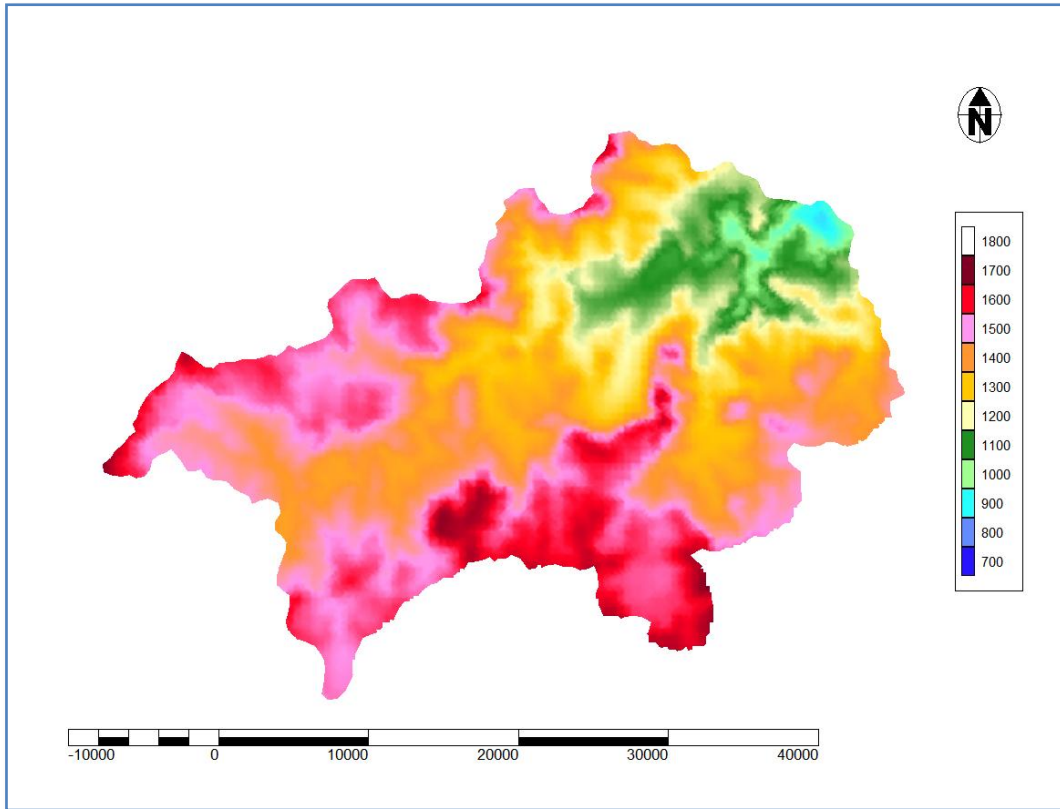


Figure 162: Groundwater levels in RUQ

22.2.1 Groundwater recharge

The groundwater recharge calculated from the different methods is listed in Table 129. The different recharge methods applied are discussed in Section 2.3. The final recharge values for the RU are highlighted in red.

Table 129: Recharge values

Recharge							
MAP Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Volume Mm ³ /a	Calculated %	CMB %	Land Cover %	Geology %
778.186	34.199	87.981	51.900	6.7%	6.7%	1.4%	2.8%

1.1.147 Basic human needs

The method for determining BHNs is discussed in Section 2.3. The final value for the study area is highlighted in red in Table 130.

Table 130: Basic human needs

Basic Human Need		
Census(2001) Adjusted	Dependence 18%	Estimate Mm ³ /a
19334	3480	0.031

1.1.148 Groundwater contribution to baseflow

The baseflow separation curves for the RU are shown in Figures 163 – 165.

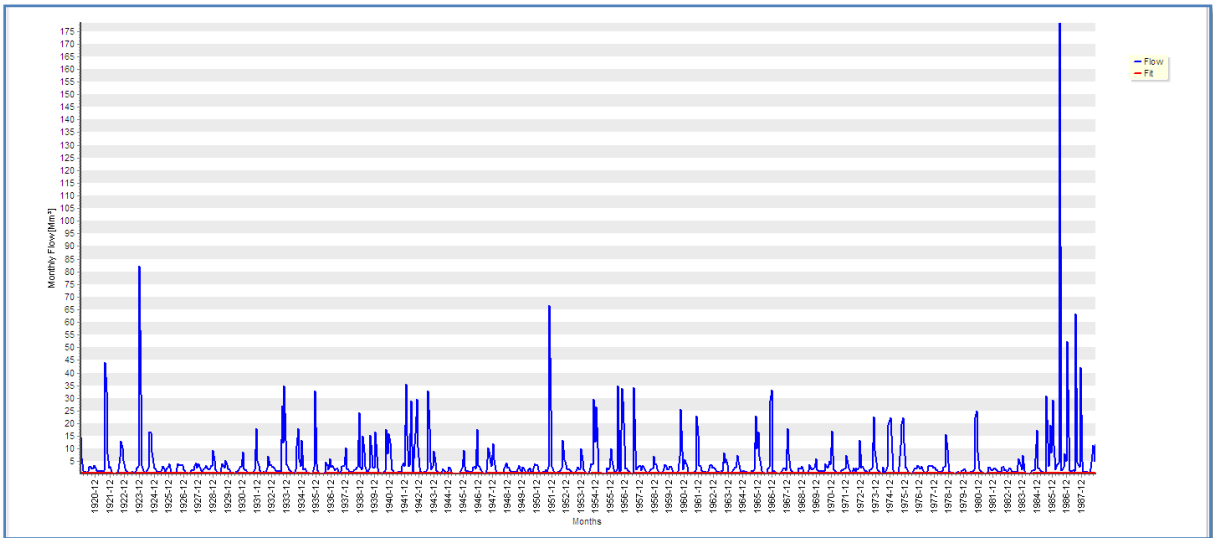


Figure 163: Baseflow separation for quaternary catchment V20E

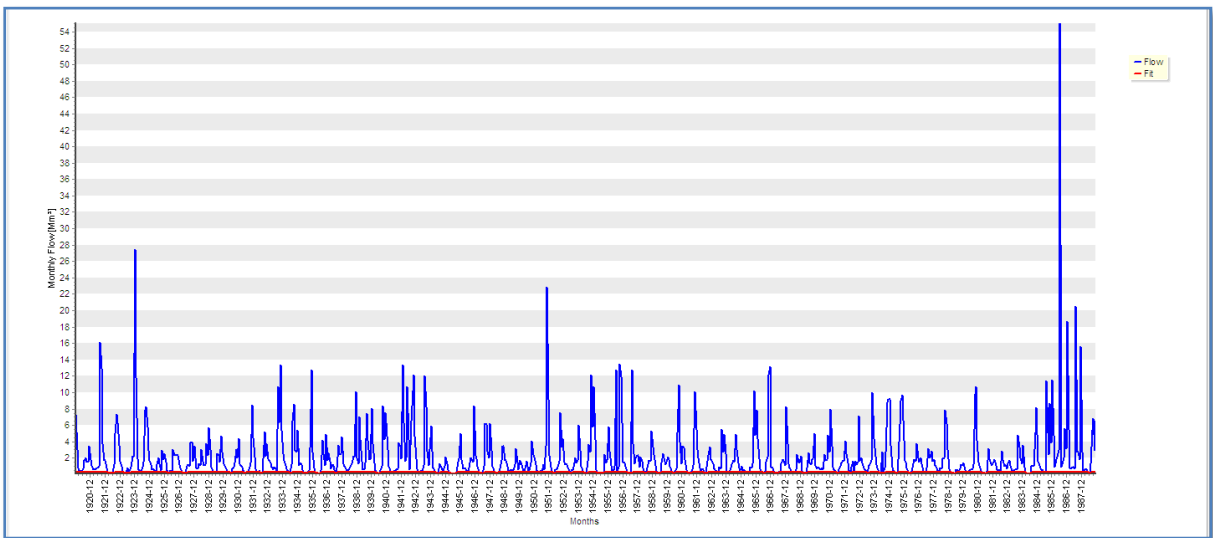


Figure 164: Baseflow separation for quaternary catchment V20F

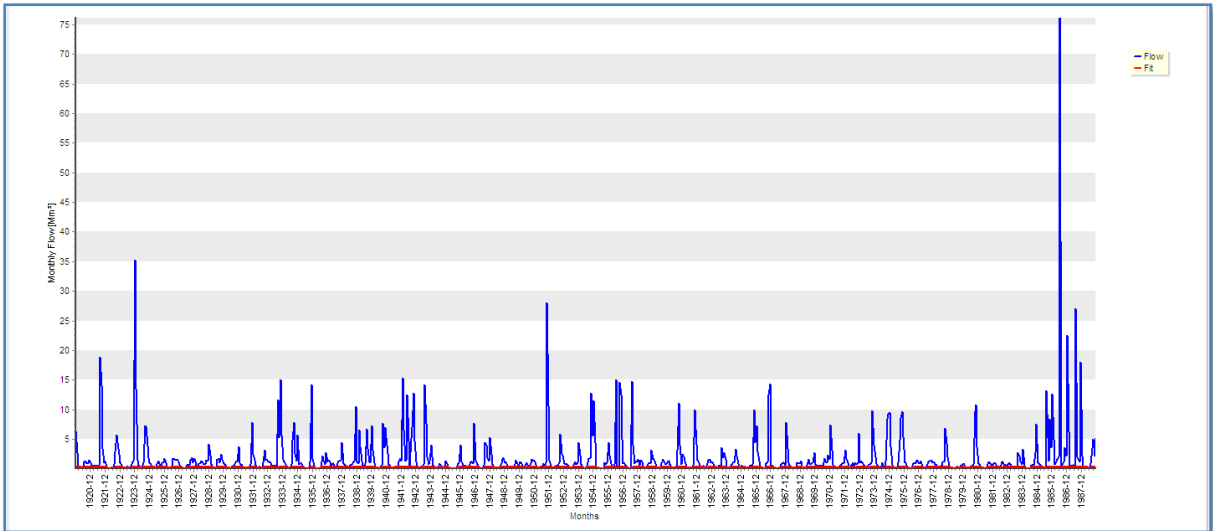


Figure 165: Baseflow separation for quaternary catchment V20G

The final groundwater contribution to baseflow values for the RU is highlighted in red in Table 131.

Table 131: Groundwater contribution to baseflow

Groundwater Contribution to Baseflow							
GRDM Mm ³ /a	Hughes Mm ³ /a	Shultz Mm ³ /a	Pitman Mm ³ /a	vTonder Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Herold Mm ³ /a
19.688	41.112	19.637	9.217	18.006	9.217	41.112	12.530

1.1.149 Groundwater use

The groundwater use for the RU is listed in Table 132.

Table 132: Groundwater use

Groundwater Use							
GRDM Mm ³ /a	WARMs Mm ³ /a	Hydrocensus Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Forrest Mm ³ /a	Crops Mm ³ /a	TOTAL Mm ³ /a
0.070	0.038	0.664	0.038	2.656	20.599	0.433	21.000

1.1.150 Groundwater quality

The TDS values for the RU are shown in Figure 166. They are classified according to SABS standards for Figure 20. Not all boreholes have quality data available but those that do can be used to identify possible hot spots with regard to quality in the resource unit. There is however very little water quality data to assess water quality within RU.

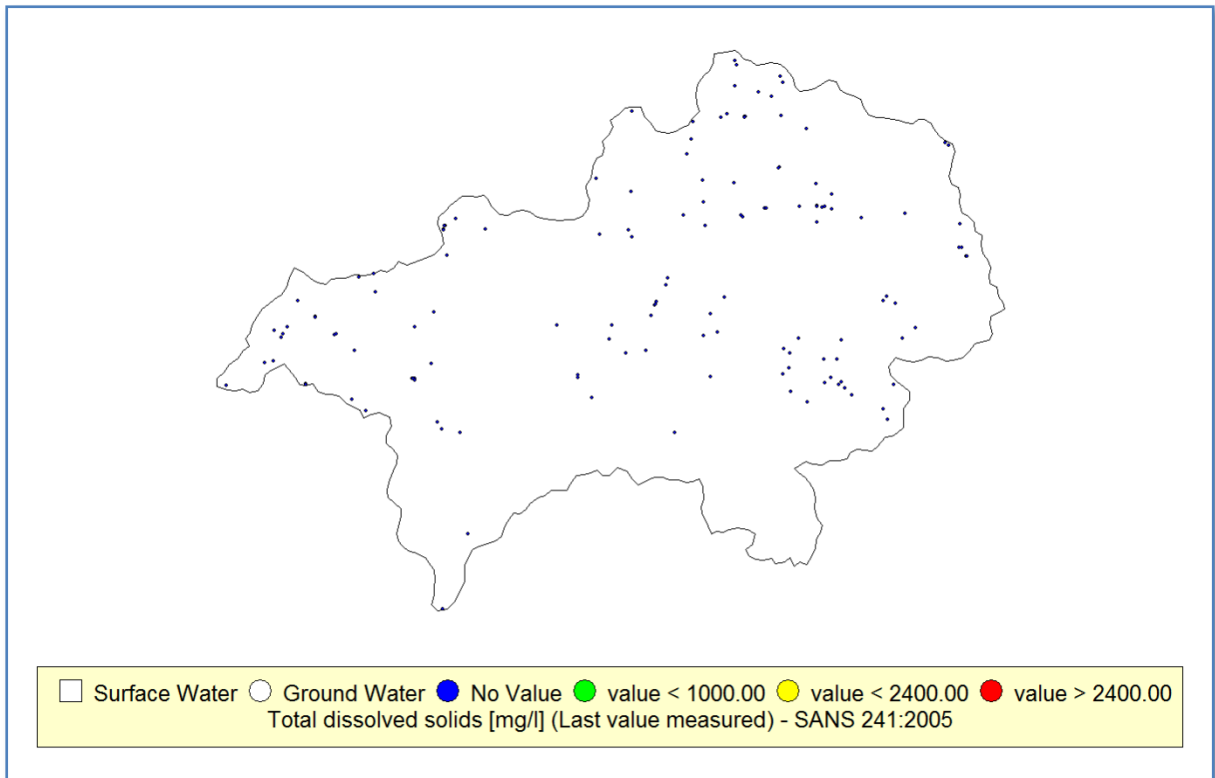


Figure 166: TDS values

1.1.151 Aquifer vulnerability

The aquifer vulnerability calculations are summarised in Table 133. The slope histogram is documented in Appendix B.

Table 133: Aquifer vulnerability

Aquifer Vulnerability						
Level mbgl	Recharge %	Slope %	Soil Texture	Aquifer Type	Vadose Zone	Vulnerability %
7.4	6.7%	1.1	SaClLm-SaCl	Weathered/Fractured	Karoo(southern)	60%

22.3 Classification

1.1.152 Groundwater usage

The stress index, defined as the ratio between total groundwater use and recharge, for the study area is calculated at 65%. Due to the uncertainty associated with the groundwater use component, the stress index was stochastically modelled through assigning a normal distribution curve with a standard deviation of 2.1 Mm³/a to the groundwater use estimate to account for the associated uncertainty. The stochastic results are shown in Figure 167. It is clear from the results that the stress index will vary between 55% and 75% with a certainty of 98.52%. Due to the large variability in the range obtained, it is recommended that the uncertainty in the groundwater use be reduced by detailed studies focusing on groundwater use within the RU. Due to the relatively high stress index this RU should be flagged as an area which requires further investigation.

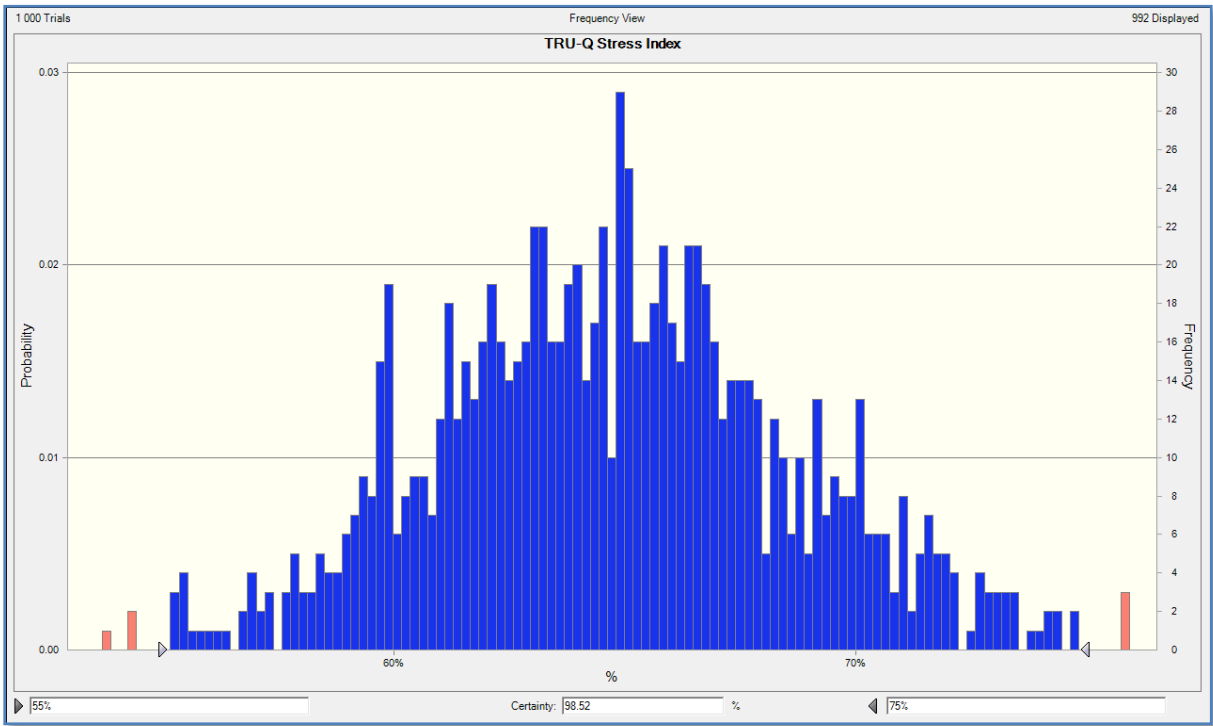


Figure 167: Stochastic results

1.1.153 Quality

The expanded Durov diagram with the groundwater quality is shown in Figure 168. An explanation of the classification process by means of the expanded Durov diagram is given in Section 2.3. Two boreholes plot in category A, two in category C and one in category E, therefore it was decided to set the final quality category as C.

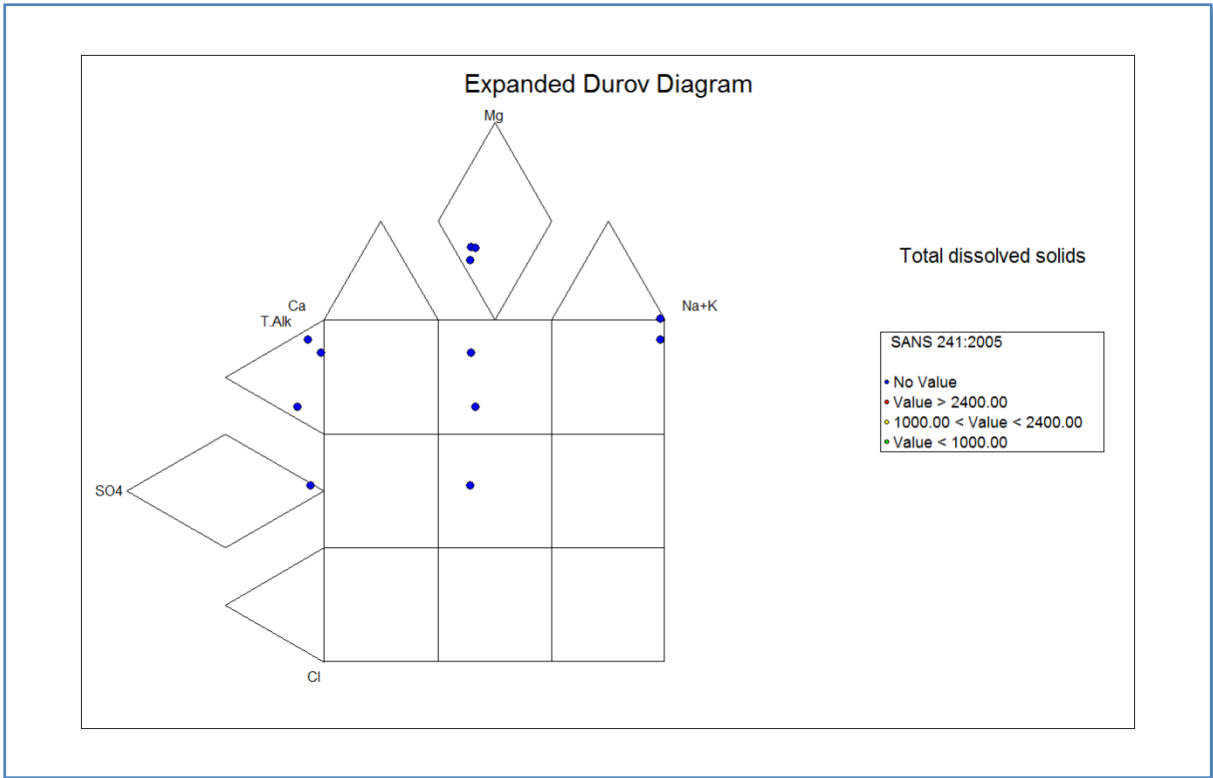


Figure 168: Expanded Durov diagram for RU

As documented in Section 6.11.7 the vulnerability is 60%. The impact of potential contamination according to Section 2.3 is low.

1.1.154 Final category

The final category for the RU is summarised in Table 134.

Table 134: Category for RU

Impact	Present status category	Water resource category
Groundwater usage	E	Poor
Groundwater contamination	C	Good/Fair
Potential groundwater contamination (vulnerability and impact)	B	Good
FINAL	C	Fair

22.4 Quantification of the Reserve

The groundwater Reserve for the RU is summarised in Table 135.

Table 135: Reserve

Reserve			Allocation	
Baseflow Mm ³ /a	BHN Mm ³ /a	Reserve % Recharge	Allocation Mm ³ /a	Current Use Mm ³ /a
12.530	0.031	24%	18.338	21.000

23. Classification and the Reserve for Resource Unit R

23.1 Location

This RU is located in the coalfields of KZN. The towns in the study area include Wakkerstroom, Volksrust, New Castle and Dannhauser. The quaternary catchments include: V31A, V31B, V31C, V31D, V31E, V31F, V31G, V31H, V31I, V31J, V31K and V32A. The location of this RU is shown in Figure 169.

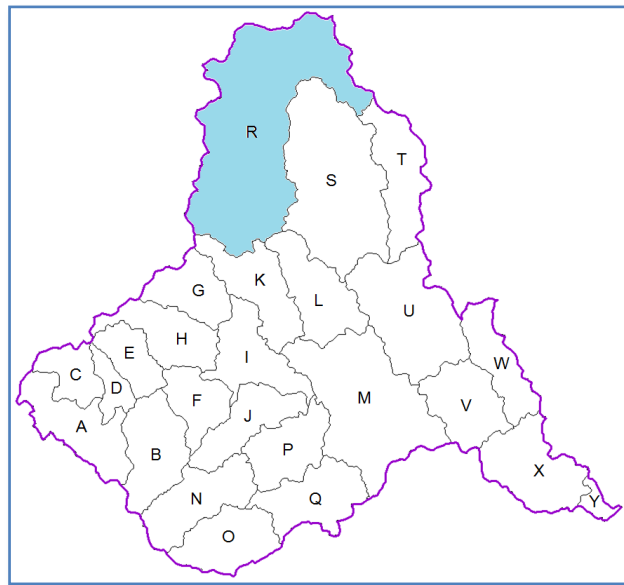


Figure 169: Location of RUR

23.2 Climate

The rainfall in the study area varies between 680 – 940 mm/a. Newcastle normally receives about 687mm of rain per year, with most rainfall occurring mainly during mid-summer. It receives the lowest rainfall (0 mm) in June and the highest (132 mm) in January. The monthly distribution of average daily maximum temperatures shows that the average midday temperatures for Newcastle range from 19.5°C in June to 27.6°C in January. The region is the coldest during July when the mercury drops to 2.2°C on average during the night.

23.3 Vegetation (taken from www.deat.gov.za)

This area is an open savanna, with scattered trees of Paperbark Thorn *Acacia sieberiana*, Sweet Thorn *A. karroo*, Scented Thorn *A. nilotica* and *A. caffra*. The herbaceous layer is quite variable, with secondary grassland, dominated by patches of tall Common Thatchgrass *Hyparrhenia hirta*, and sour grassland, dominated by Hairy Tridentgrass *Tristachya leucothrix*.

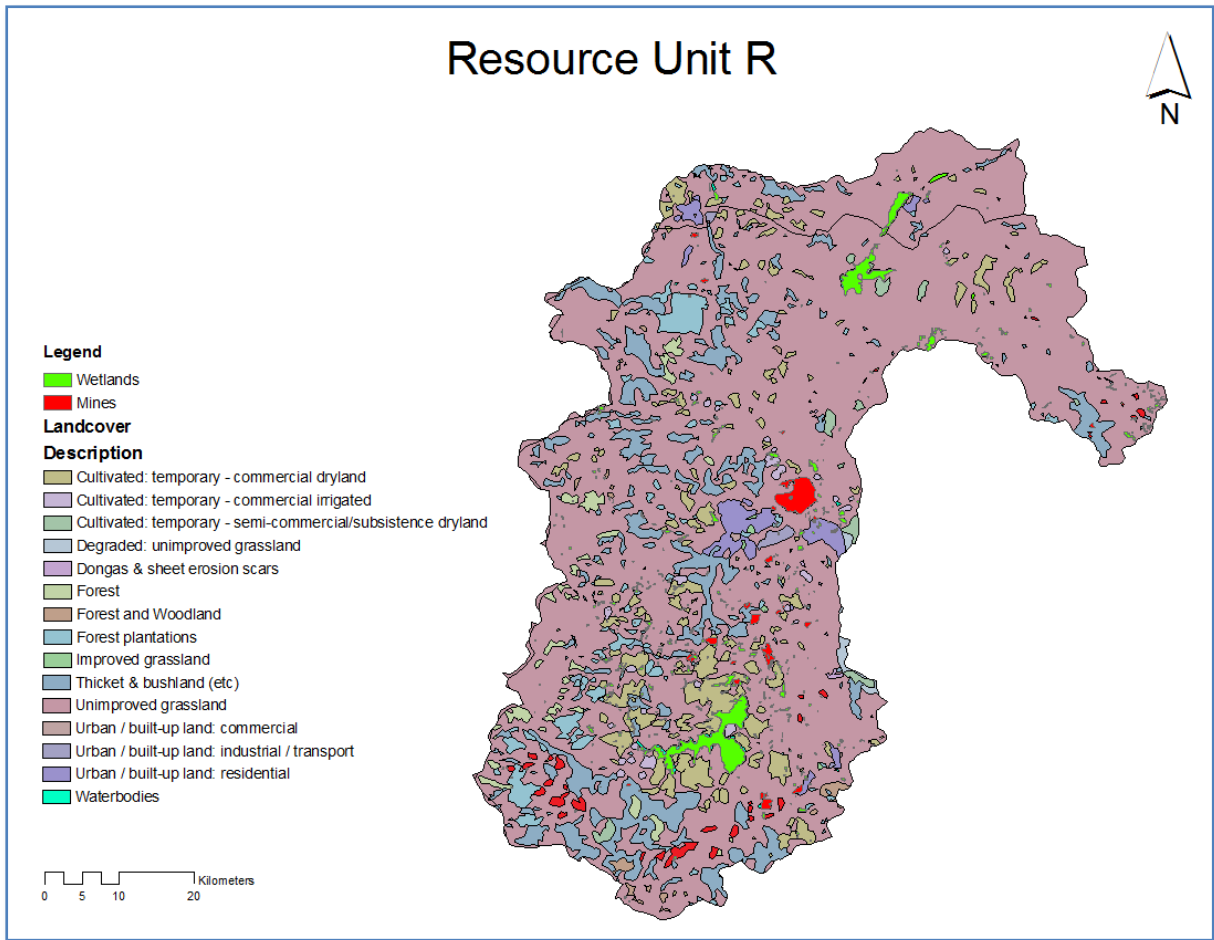


Figure 170: Land use within RUR

23.5 Surface Water

The Harte, Ngogo, Ncandu, Slang, Ngagane and Doringspruit Rivers form the headwaters of the Buffalo River. The Zaaiohoek, Hattingspruit and Ntshigwayo (Clemsford) Dams are included in the study area.

23.6 Wetlands

Wakkerstroom Wetland in South Africa is predominantly a mosaic of different marshes and forms part of the bigger wetland system in the Wakkerstroom/Luneburg region. Although the Wakkerstroom wetland contains very little open water, the centre of the wetland (vlei) is permanently wet. The site is well endowed with rare species, such as the globally threatened blue crane (*Anthropoides paradisea*), rare bush blackcaps, yellow-breasted pipits and more than 85 per cent of the world's Rudd's larks population. The Wakkerstroom / Luneburg area is also



the source of four major rivers and is vitally important from a water security perspective in South Africa.

The Wakkerstroom Wetland's hydrological functioning is currently largely disrupted by invasive alien vegetation in the surrounding catchment. Furthermore, deforestation has resulted in soil erosion, altering the character of the site. Burning of adjacent grasslands to improve grazing for cattle frequently causes fires to cross into the wetland at times of year that are highly disruptive to the ecosystem. The site is also coveted as rich grazing land by surrounding landowners and there is increasing pressure to open up the wetland reserve and allow cattle to graze. The wetland is also threatened by coal mining activities in the RU.

Groenvlei is situated in the vicinity of the Zaaihoek Dam. There are also a number of smaller wetlands in the upper catchment of the Slang River.

23.7 *Soils (taken from www.deat.gov.za)*

The soil is shallow, derived from shales and mudstones of the Ecca Group of the Karoo Sequence.

23.8 *Geology (summarised from Woodford and Chevallier, 2002)*

The Beaufort Group dominates in this RU and is stratigraphically divided into two major units, the upper Tarkastad Subgroup and the lower Adelaide Subgroup. The Tarkastad Subgroup is subdivided into the upper Burgersdorp Formation with its brightly coloured red, blue and green mudstones and the lower Katberg Formation, that can be up to 900 m thick. The Katberg Formation also contains brightly coloured shales and mudstones, but mainly consists of thick layers of coarse-grained sandstone. The Adelaide Subgroup mainly consists of green, bluish, grey and red mudstones and fine-grained sandstones that form thick lens-shaped units. The central basin mainly consists of mudstones, shales and fine-grained sandstones. These fine-grained sediments were mainly deposited where the braided rivers began to meander. The sedimentary units in the Group therefore usually have very low primary hydraulic conductivities. Since the Beaufort Group was also deposited in a fluvial environment, one can expect that aquifers in these formations will, like those in the Ecca Group, be anisotropic. The geometry of these aquifers, however, is further complicated by the migration of the braided and meandering streams. Aquifers in the Beaufort Group will therefore not only be multi-layered, but also multi-porous with variable thicknesses. The contact plane between two different sedimentary layers will cause a discontinuity in the hydraulic properties of an aquifer. The lifespan of a high-yielding borehole in the Beaufort Group may therefore be limited if the aquifer is not recharged frequently.

The Volksrust Formation (of the Ecca Group) is a predominantly argillaceous unit, which interfingers with the overlying Beaufort Group and underlying Vryheid Formation. The Formation consists of grey to black, silty shale with thin, usually bioturbated, siltstone or sandstone lenses and beds, particularly towards its upper and lower boundaries. Thin phosphate and carbonate beds and concretions are relatively common.

The Vryheid Formation (of the Ecca Group) comprises mudrock, rhythmite, siltstone and fine- to coarse-grained sandstone (pebbly in places). The Formation contains up to five (mineable) coal seams. The different lithofacies are mainly arranged in upward-coarsening deltaic cycles (up to 80m thick in the southeast). Linear coastline cycles are, however, fairly common particularly in the thin northwestern part where they constitute the entire Vryheid in places. A relatively thin fluvial interval (60 m thick) which grades distally into deltaic deposits towards the southwest and south occurs approximately in the middle of the formation in the east and northeast. Fining-upward fluvial cycles, of which up to six are present in the east, are typically sheet-like in geometry, although some form valley-fill deposits. They comprise coarse-grained to pebbly, immature sandstones - with an abrupt upward transition into fine-grained sediments and coal seams.

Since these shales are very dense, they were often neglected as sources of groundwater in the past. The prodelta sandstones represent another formation of the Ecca Group in which one would expect to find high-yielding aquifers. Unfortunately, the permeabilities of these sandstones are also usually very low.

Sills in the Karoo formations are sheetlike forms of dolerite intrusions that tend to follow the bedding planes of the formations concordantly. These structures, whose thicknesses vary from less than a metre to hundreds of metres, represent the dominant form in which dolerite is emplaced in the Karoo Supergroup. Dolerite sills in the Karoo Supergroup often have very complex forms. The linear dykes are also usually thinner than ring dykes and are confined to the Ecca and Beaufort Groups. This is a clear indication that the magmatic activity at the time the linear dykes intruded was less than when the ring dykes and sills intruded.

23.9 *Geohydrology*

1.1.155 Groundwater levels

It is clear the groundwater levels follow the topography as seen from Figure A1 in Appendix A and therefore groundwater contour maps were generated using Bayesian interpolation. The groundwater levels for the study area are shown in Figure 171. The most probable depth to groundwater level in the RU is 8 mbgl according to the histogram of water levels in the RU shown in Appendix A. Groundwater levels are expected to be lower than normal due to the prevailing drought conditions. Unfortunately very little time series water level data are available to quantify the overall impact.

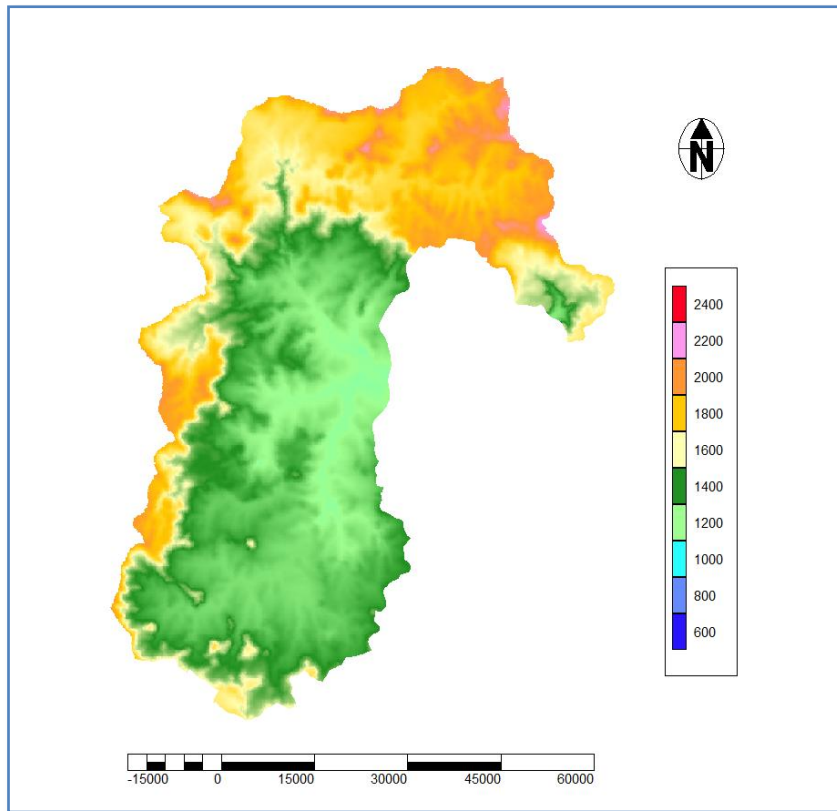


Figure 171: Groundwater levels in RUR

23.9.1 Groundwater recharge

The groundwater recharge calculated from the different methods is listed in Table 136. The different recharge methods applied are discussed in Section 2.3. The final recharge values for the RU are highlighted in red.

Table 136: Recharge values

Recharge							
MAP Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Volume Mm ³ /a	Calculated %	CMB %	Land Cover %	Geology %
3542.911	206.239	269.243	295.926	8.4%	8.4%	3.5%	3.2%

1.1.156 Basic human needs

The method for determining BHNs is discussed in Section 2.3. The final value for the study area is highlighted in red in Table 137.

Table 137: Basic human needs

Basic Human Need		
Census(2001) Adjusted	Dependence 18%	Estimate Mm ³ /a
367158	66088	0.595

1.1.157 Groundwater contribution to baseflow

The baseflow separation curves for the RU are shown in Figures 172 – 182.

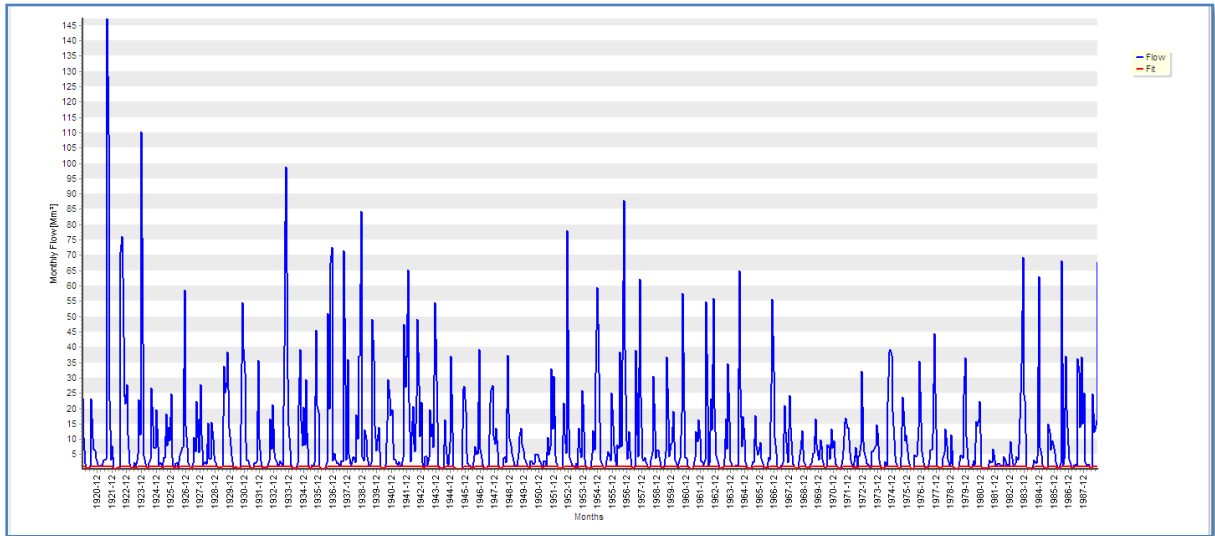


Figure 172: Baseflow separation for quaternary catchment V31A

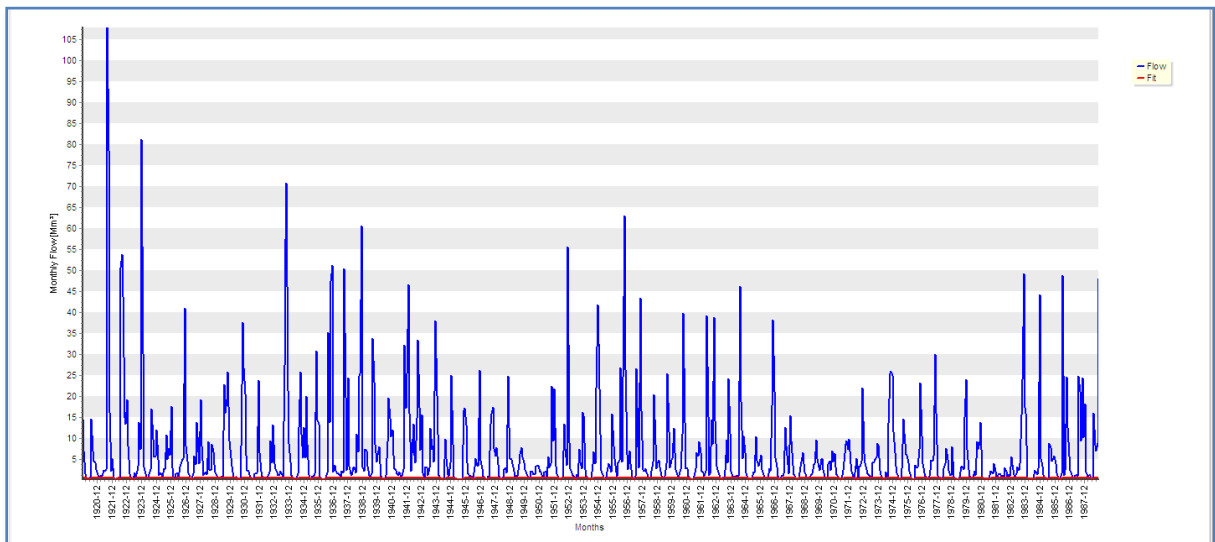


Figure 173: Baseflow separation for quaternary catchment V31B

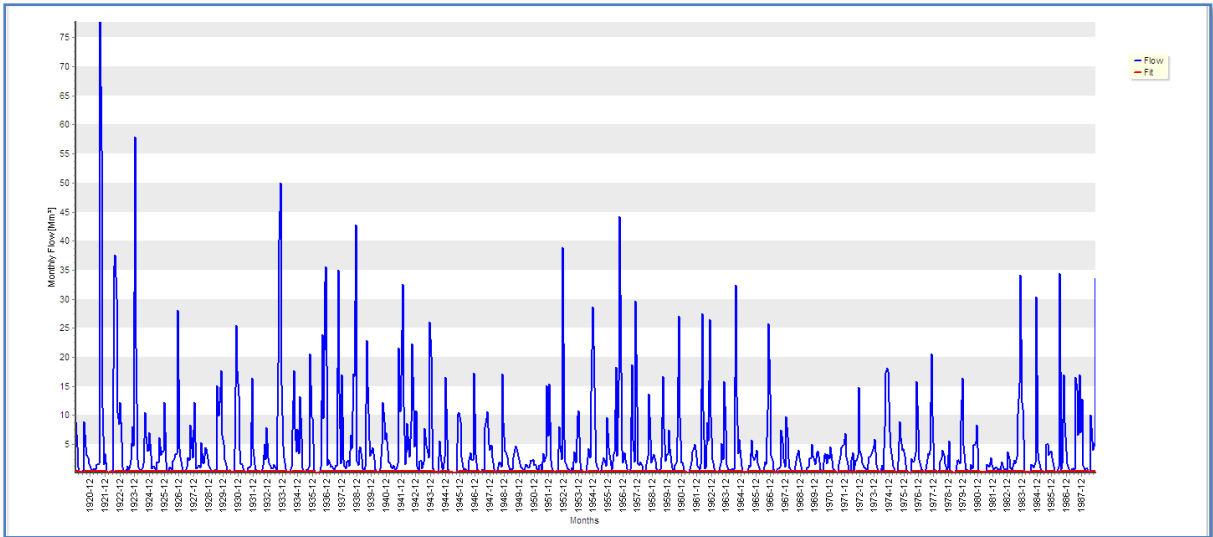


Figure 174: Baseflow separation for quaternary catchment V31C

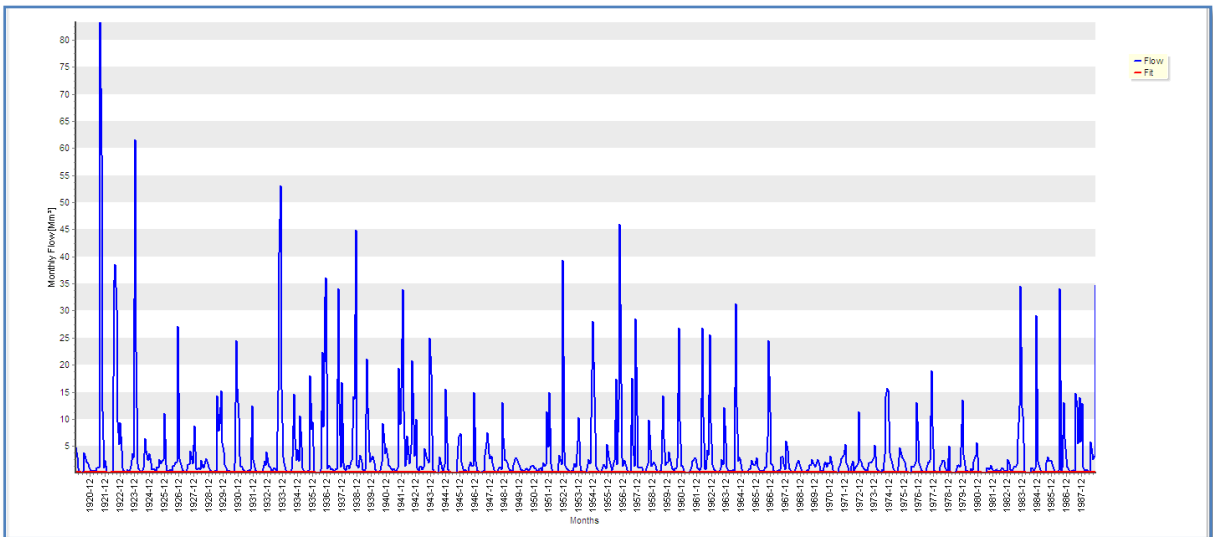


Figure 175: Baseflow separation for quaternary catchment V31D

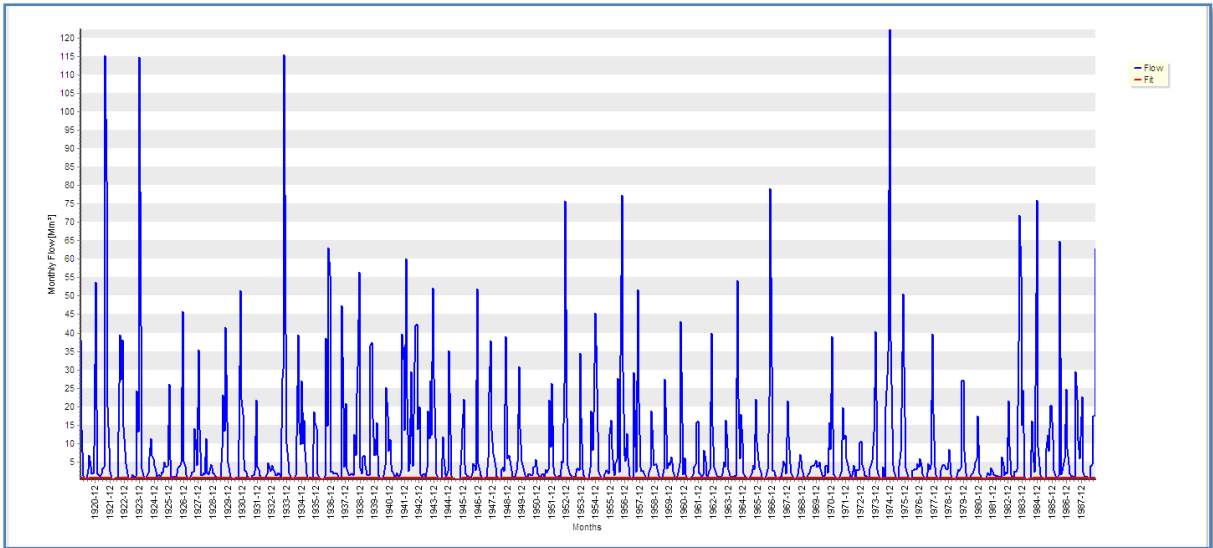


Figure 176: Baseflow separation for quaternary catchment V31E

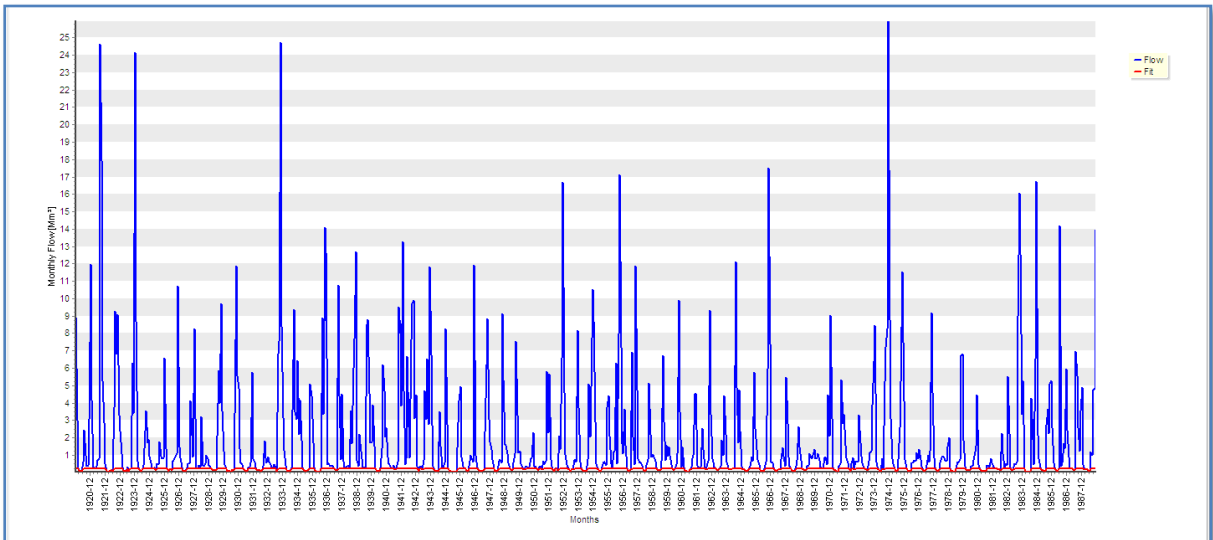


Figure 177: Baseflow separation for quaternary catchment V31F

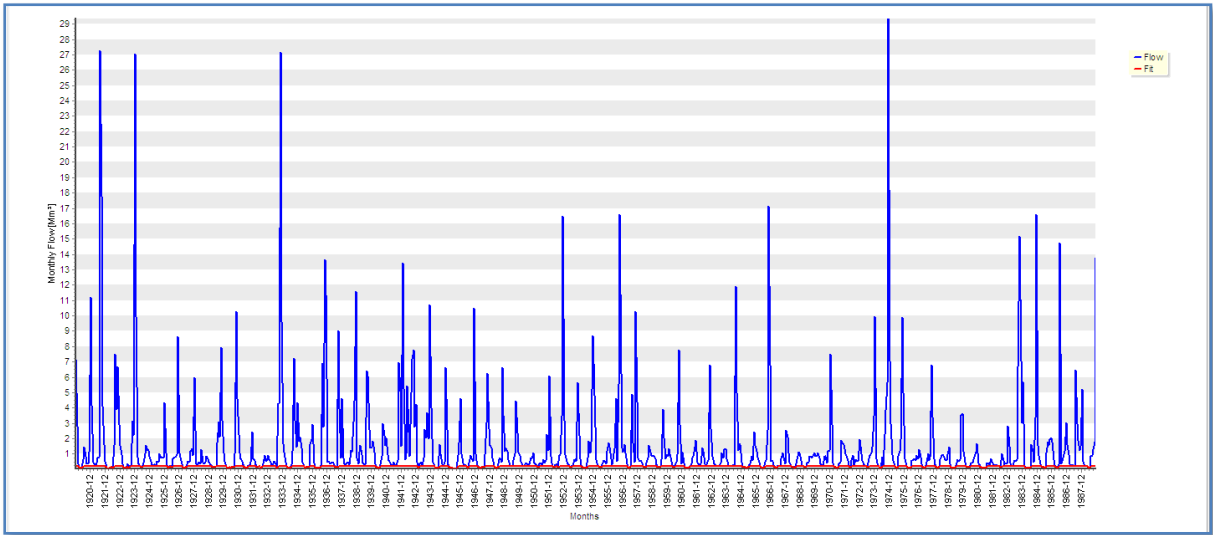


Figure 178: Baseflow separation for quaternary catchment V31G

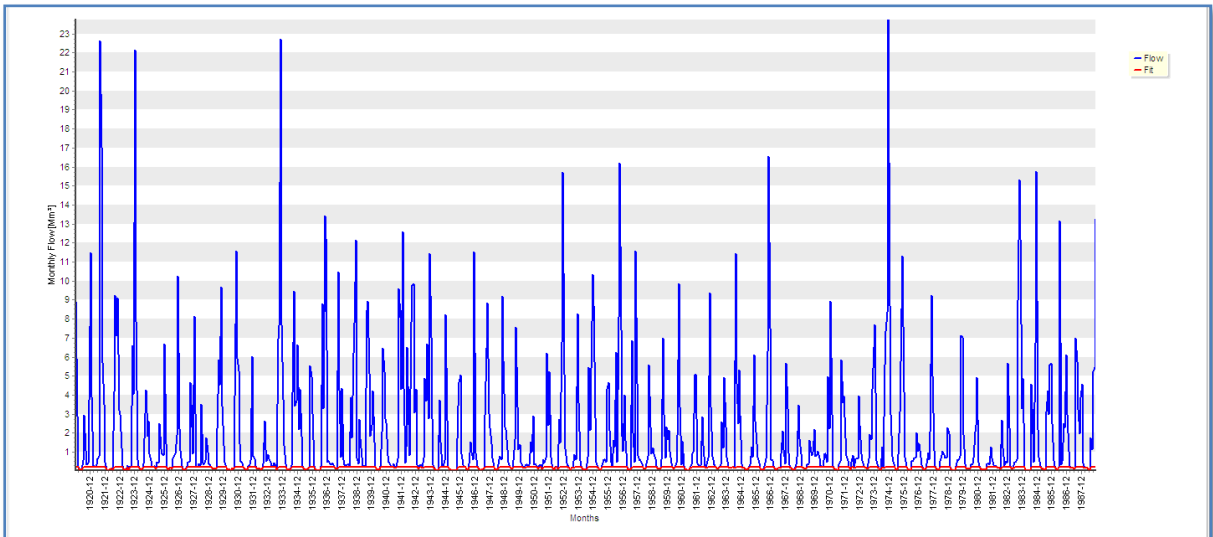


Figure 179: Baseflow separation for quaternary catchment V31H

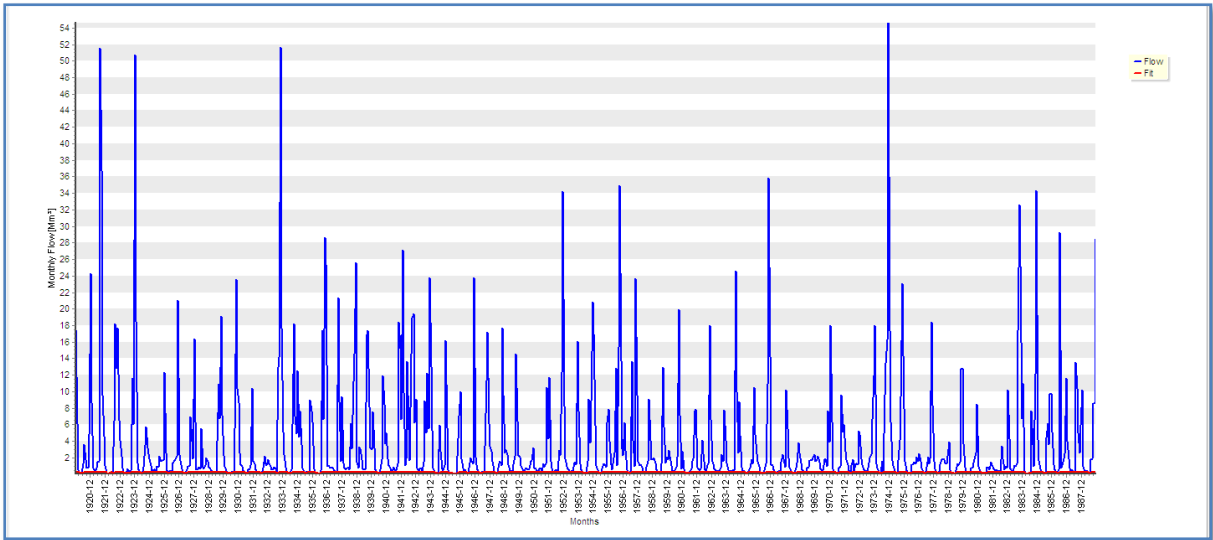


Figure 180: Baseflow separation for quaternary catchment V31J

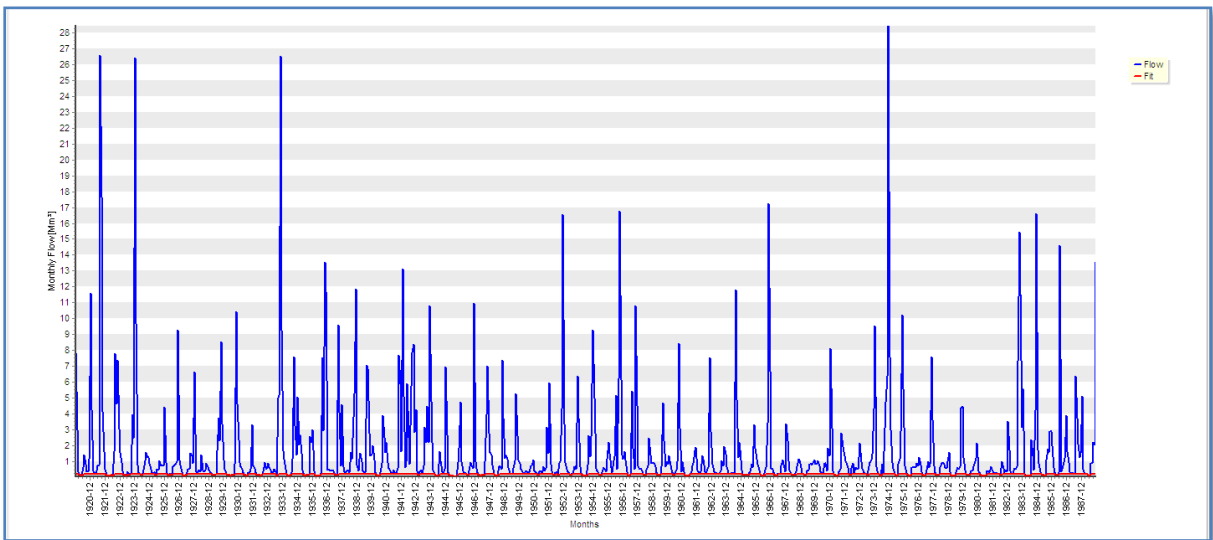


Figure 181: Baseflow separation for quaternary catchment V31K

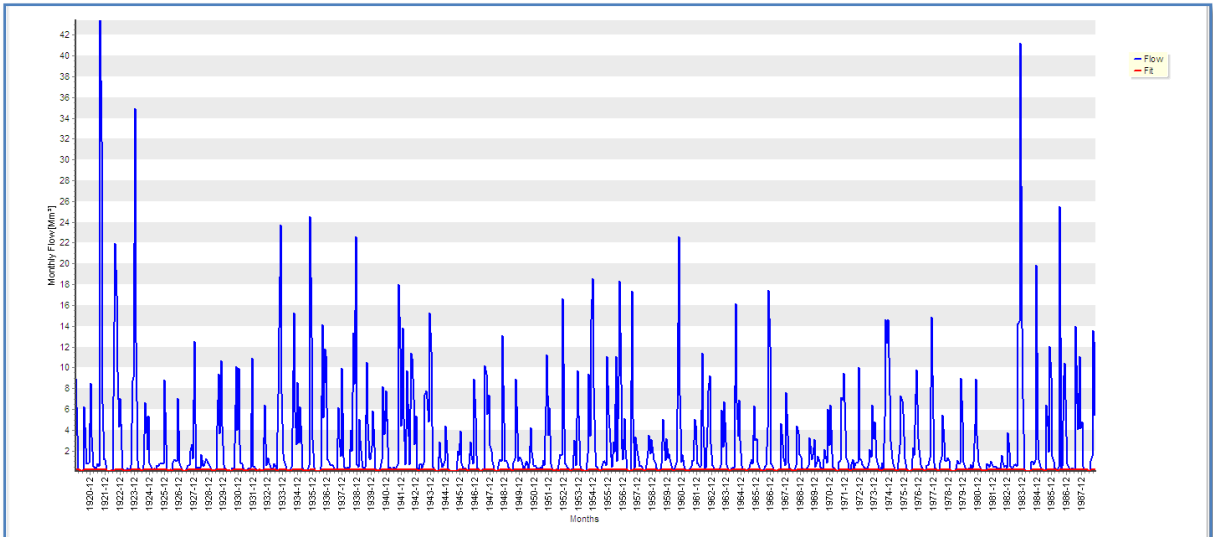


Figure 182: Baseflow separation for quaternary catchment V32A

The final groundwater contribution to baseflow values for the RU is highlighted in red in Table 138.

Table 138: Groundwater contribution to baseflow

Groundwater Contribution to Baseflow							
GRDM Mm ³ /a	Hughes Mm ³ /a	Shultz Mm ³ /a	Pitman Mm ³ /a	vTonder Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Herold Mm ³ /a
105.634	201.354	95.131	36.574	83.557	36.574	201.354	47.170

1.1.158 Groundwater use

The groundwater use for the RU is listed in Table 139.

Table 139: Groundwater use

Groundwater Use							
GRDM Mm ³ /a	WARMS Mm ³ /a	Hydrocensus Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Forrest Mm ³ /a	Crops Mm ³ /a	TOTAL Mm ³ /a
0.830	0.275	1.292	0.275	5.168	80.388	3.845	83.638

1.1.159 Groundwater quality

The TDS values for the RU are shown in Figure 183. They are classified according to SABS standards. Not all boreholes have quality data available but those that do can be used to identify possible hot spots with regard to quality in the resource unit. The overall quality of the resource unit is well within the drinking water guidelines with the exception of a couple of boreholes that are allowable. However there are numerous coal mines within the study area that are associated with poor

groundwater quality. These mines should be treated as hotspots rather than penalising the whole resource unit with a poor classification. Treatment of the hotspot areas will be addressed under Resource Quality Objectives in Section 31.

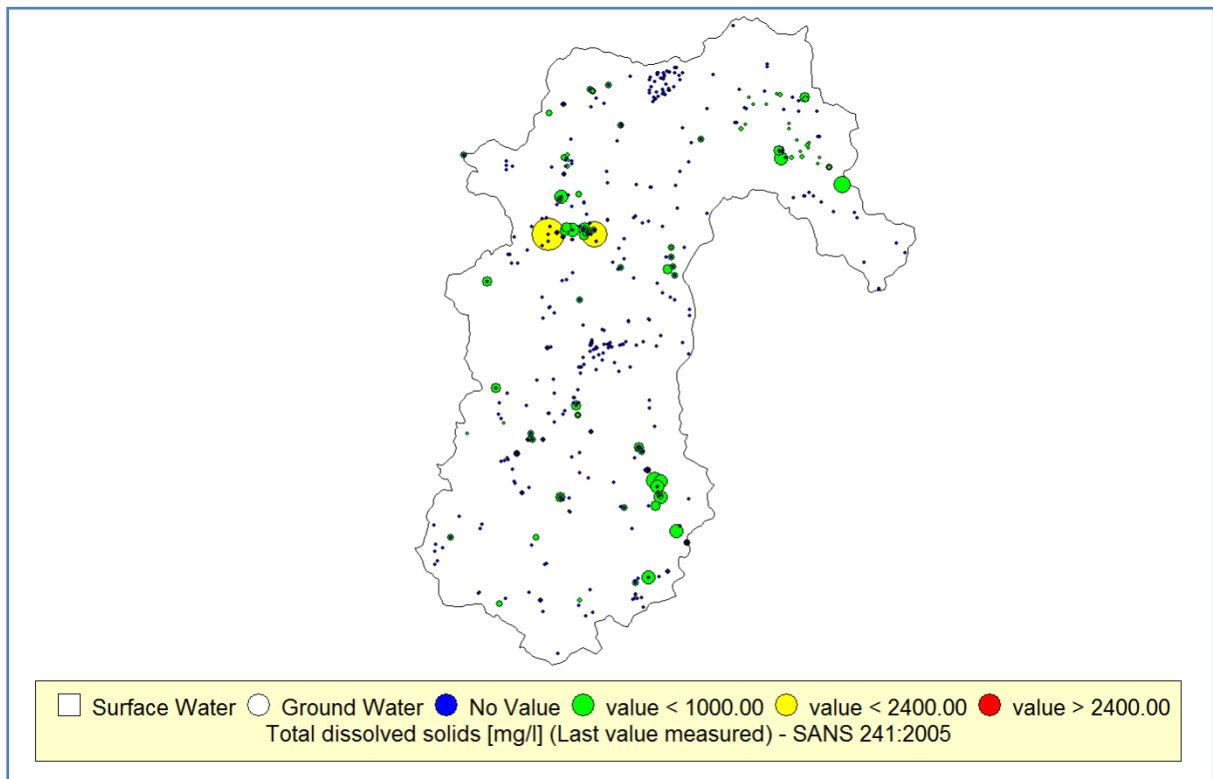


Figure 183: TDS values

1.1.160 Aquifer vulnerability

The aquifer vulnerability calculations are summarised in Table 140. The slope histogram is documented in Appendix B.

Table 140: Aquifer vulnerability

Aquifer Vulnerability						
Level mbgl	Recharge %	Slope %	Soil Texture	Aquifer Type	Vadose Zone	Vulnerability %
8.0	8.4%	1.0	SaClLm-SaCl, LmSa-SaLm, SaLm	Weathered/Fractured	Karoo(southern)	61%

23.10 Classification

1.1.161 Groundwater usage

The stress index, defined as the ratio between total groundwater use and recharge, for the study area is calculated at 44%. Due to the uncertainty associated with the groundwater use component, the stress index was stochastically modelled through assigning a normal distribution curve with a standard deviation of 8.364 Mm³/a to the groundwater use estimate to account for the associated uncertainty. The stochastic results are shown in Figure 184. It is clear from the results that the stress

index will vary between 37% and 52% with a certainty of 99.42%. Due to the large variability in the range obtained, it is recommended that the uncertainty in the groundwater use be reduced by detailed studies focusing on groundwater use within the RU. Due to the relatively high stress index this RU should be flagged as an area which requires further investigation.

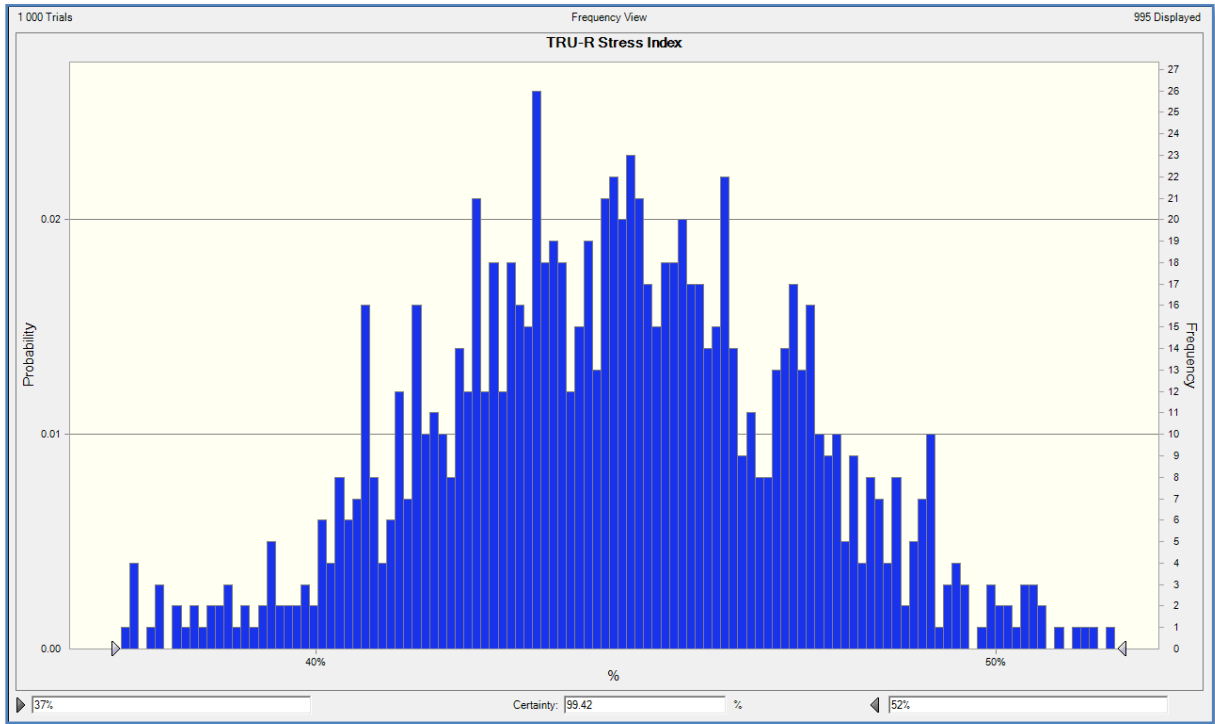


Figure 184: Stochastic results

1.1.162 Quality

The expanded Durov diagram with the groundwater quality is shown in Figure 185. An explanation of the classification process by means of the expanded Durov diagram is given in Section 2.3. There are numerous boreholes in categories A and C, however the overall water quality is not so good therefore the final category was set as a C.

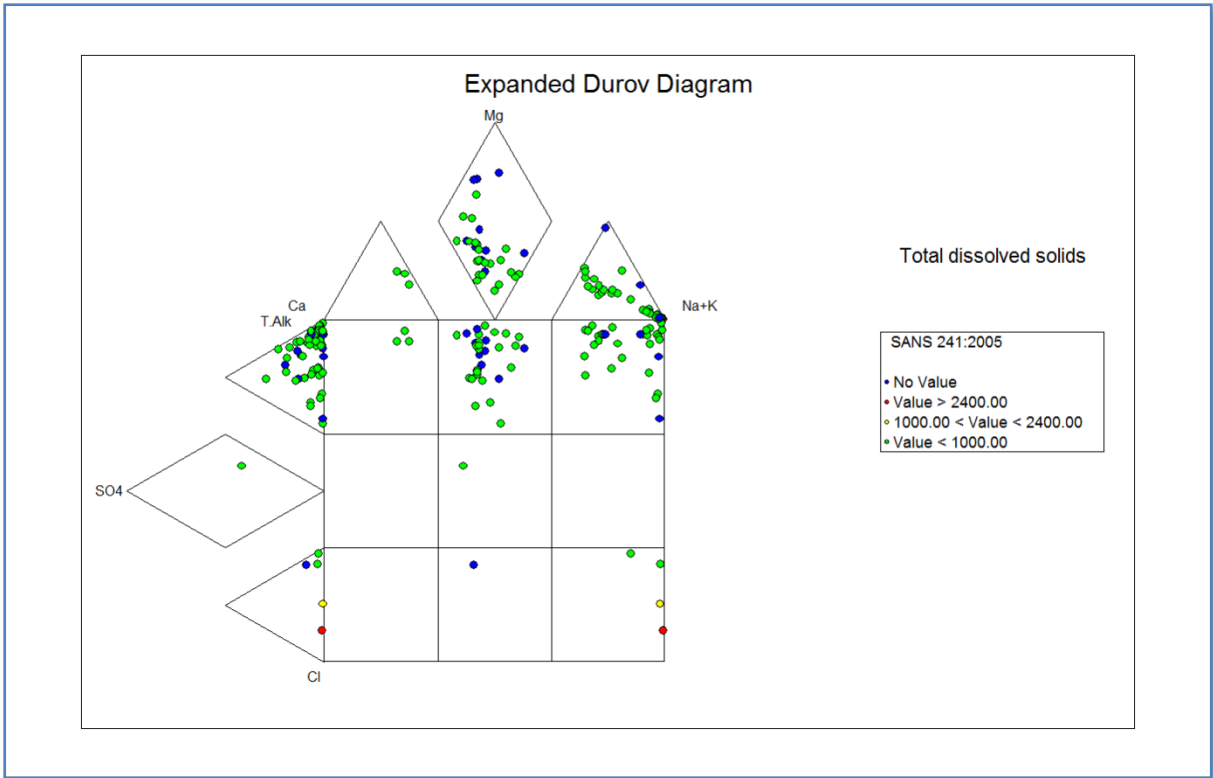


Figure 185: Expanded Durov diagram for RU

As documented the vulnerability is 62%. The impact of potential contamination according to Section 2.3 is moderate due to all the mining activities and industry.

1.1.163 Final category

The final category for the RU is summarised in Table 141.

Table 141: Category for RU

Impact	Present status category	Water resource category
Groundwater usage	D	Fair
Groundwater contamination	C	Good/Fair
Potential groundwater contamination (vulnerability and impact)	C	Good/Fair
FINAL	C/D	Fair

23.11 Quantification of the Reserve

The groundwater Reserve for the RU is summarised in Table 142.

Table 142: Reserve

Reserve			Allocation	
Baseflow Mm ³ /a	BHN Mm ³ /a	Reserve % Recharge	Allocation Mm ³ /a	Current Use Mm ³ /a
47.170	0.595	16%	164.523	83.638

24. Classification and the Reserve for Resource Unit S

24.1 Location

The quaternary catchments included in the RU are: V32B, V32C, V32D, V32E and V32F. Utrecht is a small town in the foothills of the Balele Mountains. Dundee is one of the centres of northern KwaZulu-Natal. The location of the RU is shown in Figure 186.

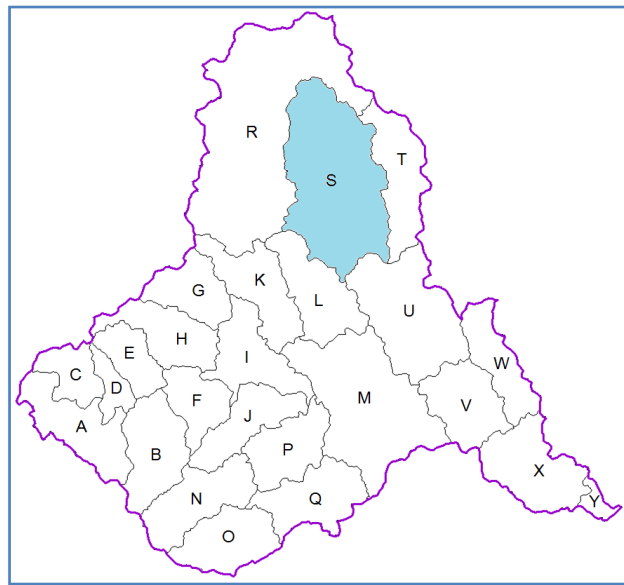


Figure 186: Location of RUS

24.2 Climate

The average rainfall for the RU is 720 – 800 mm/a. Dundee normally receives about 725 mm of rain per year, with most rainfall occurring mainly during mid-summer. It receives the lowest rainfall (1 mm) in June and the highest (134 mm) in January. The monthly distribution of average daily maximum temperatures shows that the average midday temperatures for Dundee range from 18.6°C in June to 25.9°C in January. The region is the coldest during July when the mercury drops to 2.7°C on average during the night.

24.3 Vegetation (taken from www.deat.gov.za)

This area is an open savanna, with scattered trees of Paperbark Thorn *Acacia sieberiana*, Sweet Thorn *A. karroo*, Scented Thorn *A. nilotica* and *A. caffra*. The herbaceous layer is quite variable, with secondary grassland, dominated by patches of tall Common Thatchgrass *Hyparrhenia hirta*, and sour grassland, dominated by Hairy Tridentgrass *Tristachya leucothrix*.

24.4 Demography and Landcover

The total population is 281500 (2001 census data). Coal mining (Photo 44) and cattle farming (including dairies) are the predominant economic activities. One of the main manufacturing plants of animal feeds is situated in Dundee. There are numerous forests in the RU. The landcover within RUS is shown in Figure 187.



Photo 44: Transport of coal in Dundee

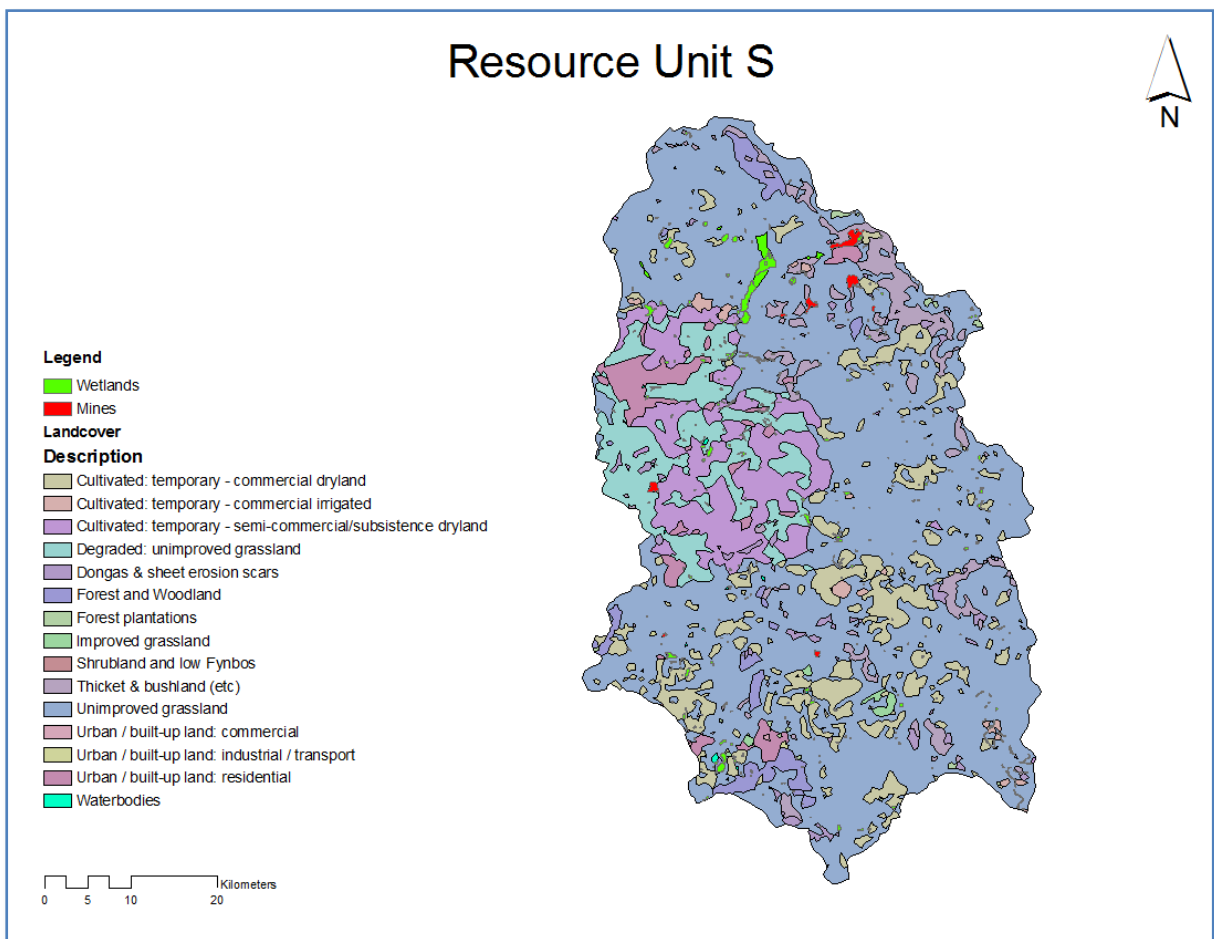


Figure 187: Landcover within RUS

24.5 Surface Water

The Wasbankspruit, Dorpspruit, Kweekspruit Mabababe River and Eerstelingspruit all join the Buffalo River. The Donald McHardy and Tom Worthington Dams are located within this RU.

24.6 Wetlands

The wetlands within the RU are shown in Figure 187.

24.7 Soils (taken from www.deat.gov.za)

The soil is shallow, derived from shales and mudstones of the Ecca Group of the Karoo Sequence.

24.8 Geology (summarised from Woodford and Chevallier, 2002)

The Vryheid Formation (of the Ecca Group) comprises mudrock, rhythmite, siltstone and fine- to coarse-grained sandstone (pebbly in places). The Formation contains up to five (mineable) coal seams. The different lithofacies are mainly arranged in upward-coarsening deltaic cycles (up to 80m thick in the southeast). Linear coastline cycles are, however, fairly common particularly in the thin northwestern part where they constitute the entire Vryheid in places. A relatively thin fluvial interval (60 m thick) which grades distally into deltaic deposits towards the southwest and south occurs approximately in the middle of the formation in the east and northeast. Fining-upward fluvial cycles, of which up to six are present in the east, are typically sheet-like in geometry, although some form valley-fill deposits. They comprise coarse-grained to pebbly, immature sandstones - with an abrupt upward transition into fine-grained sediments and coal seams. Since these shales are very dense, they were often neglected as sources of groundwater in the past. The prodelta sandstones represent another formation of the Ecca Group in which one would expect to find high-yielding aquifers. Unfortunately, the permeabilities of these sandstones are also usually very low.

Sills in the Karoo formations are sheetlike forms of dolerite intrusions that tend to follow the bedding planes of the formations concordantly. These structures, whose thicknesses vary from less than a metre to hundreds of metres, represent the dominant form in which dolerite is emplaced in the Karoo Supergroup. Dolerite sills in the Karoo Supergroup often have very complex forms. The linear dykes are also usually thinner than ring dykes and are confined to the Ecca and Beaufort Groups. This is a clear indication that the magmatic activity at the time the linear dykes intruded was less than when the ring dykes and sills intruded.

24.9 Geohydrology

1.1.164 Groundwater levels

It is clear the groundwater levels follow the topography as seen from Figure A1 in Appendix A and therefore groundwater contour maps were generated using Bayesian interpolation. The groundwater levels for the study area are shown in Figure 188. The most probable depth to groundwater level in the RU is 13.2 mbgl according to the histogram of water levels in the RU shown in Appendix A. Groundwater levels are expected to be lower than normal due to the prevailing

drought conditions. Unfortunately very little time series water level data are available to quantify the overall impact.

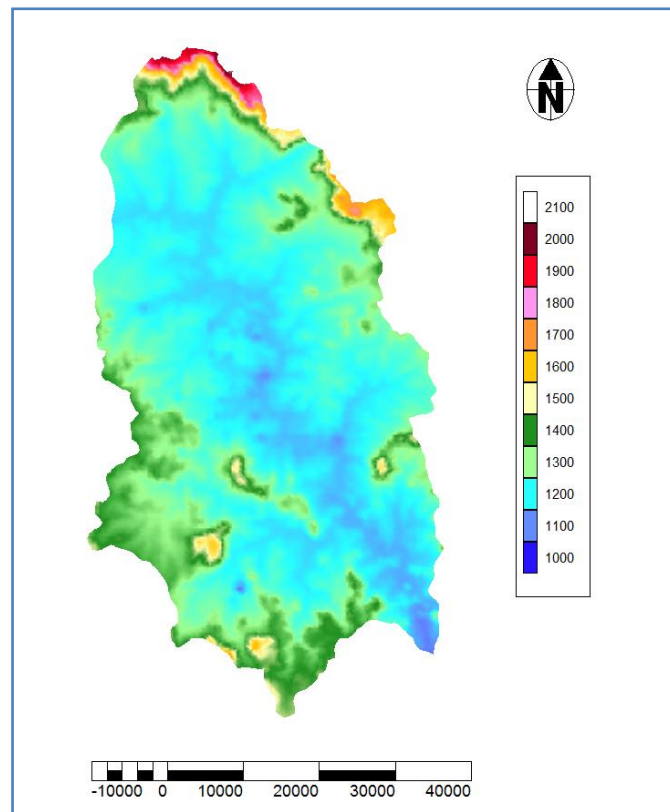


Figure 188: Groundwater levels in RUS

24.9.1 Groundwater recharge

The groundwater recharge calculated from the different methods is listed in Table 143. The different recharge methods applied are discussed in Section 2.3. The final recharge values for the RU are highlighted in red.

Table 143: Recharge values

Recharge							
MAP Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Volume Mm ³ /a	Calculated %	CMB %	Land Cover %	Geology %
2101.465	97.295	163.665	97.261	4.6%	4.6%	1.4%	4.1%

1.1.165 Basic human needs

The method for determining BHNs is discussed in Section 2.3. The final value for the study area is highlighted in red in Table 144.

Table 144: Basic human needs

Basic Human Need		
Census(2001) Adjusted	Dependence 18%	Estimate Mm ³ /a
324026	58325	0.525

1.1.166 Groundwater contribution to baseflow

The baseflow separation curves for the RU are shown in Figures 189 – 193.

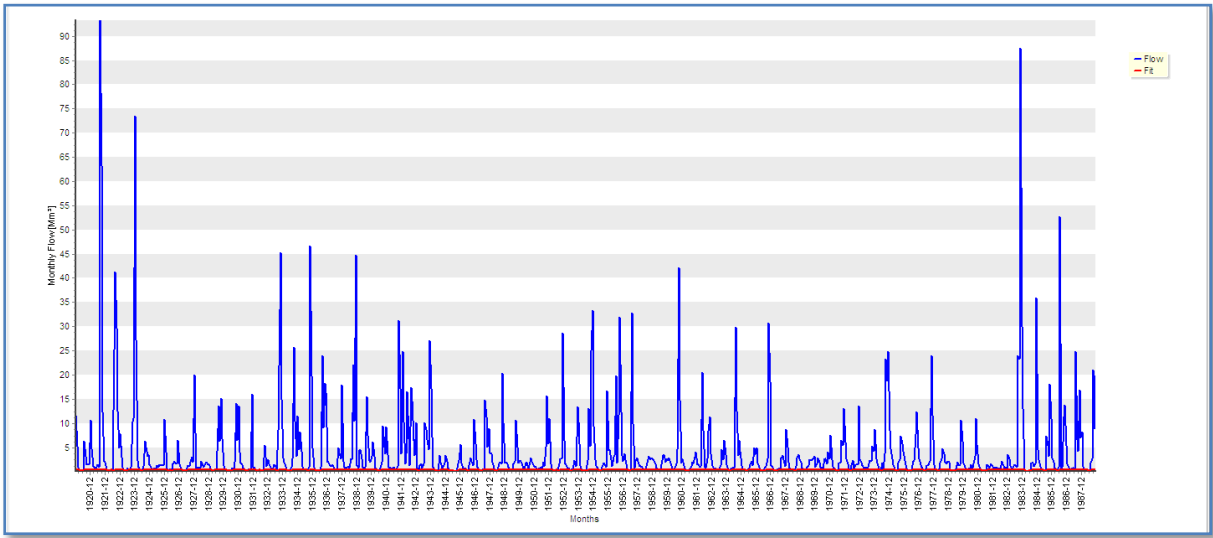


Figure 189: Baseflow separation for quaternary catchment V32B

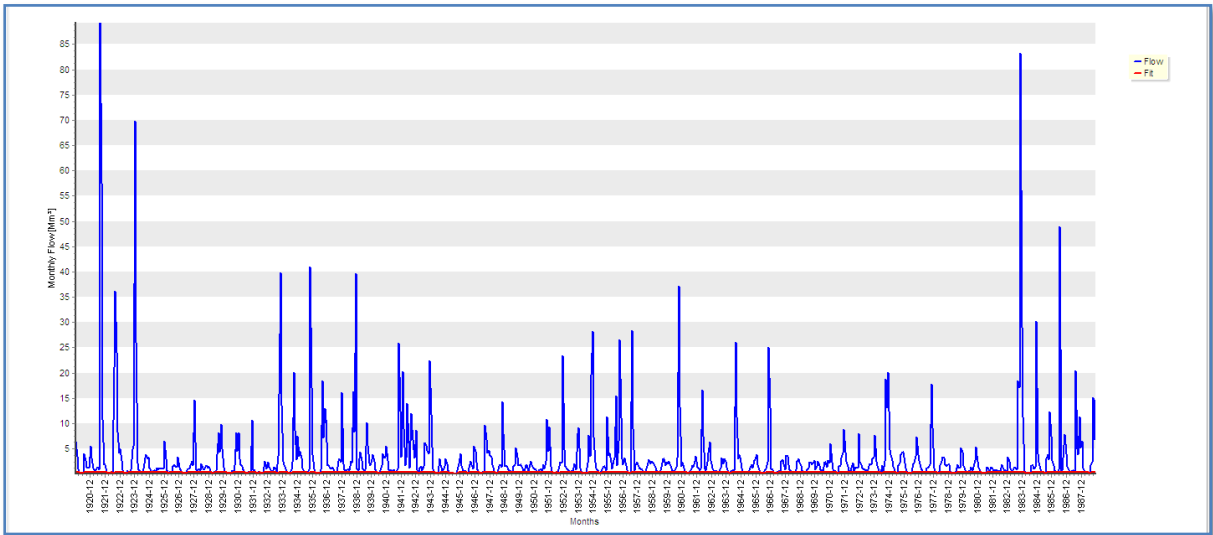


Figure 190: Baseflow separation for quaternary catchment V32C

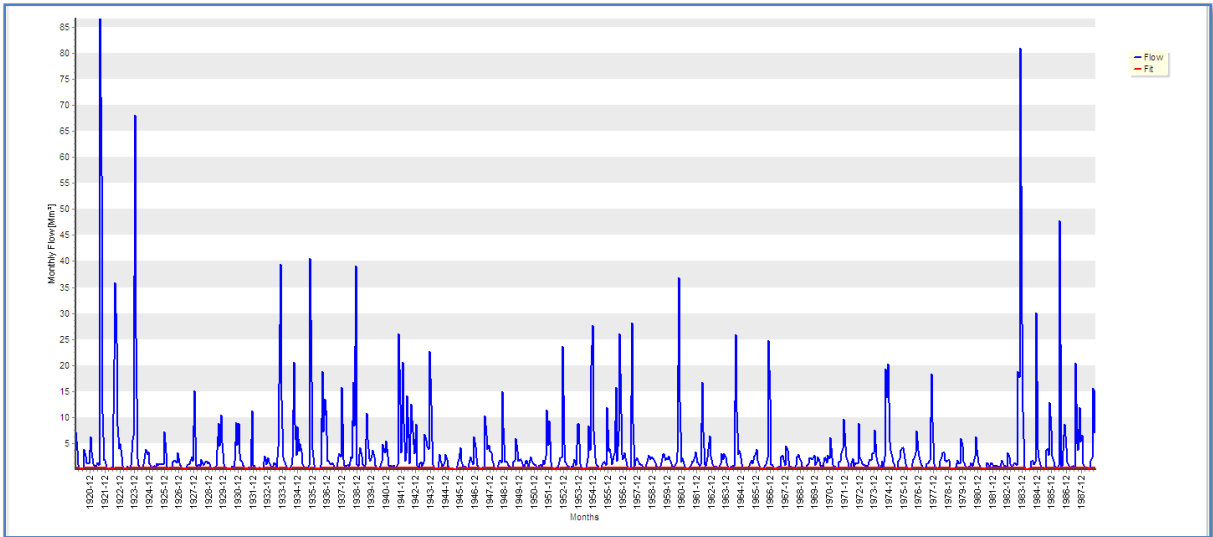


Figure 191: Baseflow separation for quaternary catchment V32D

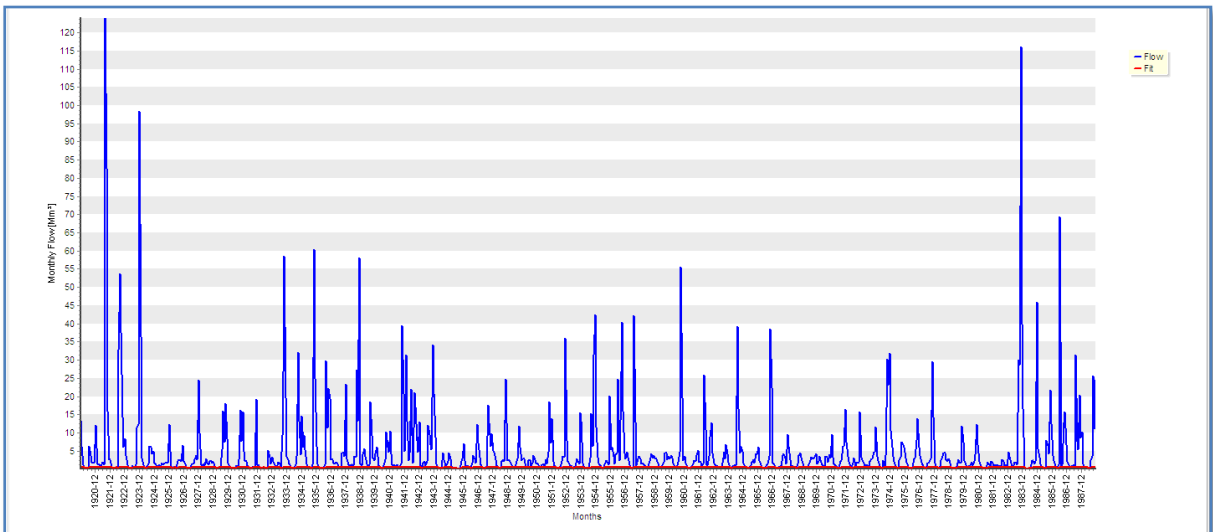


Figure 192: Baseflow separation for quaternary catchment V32E

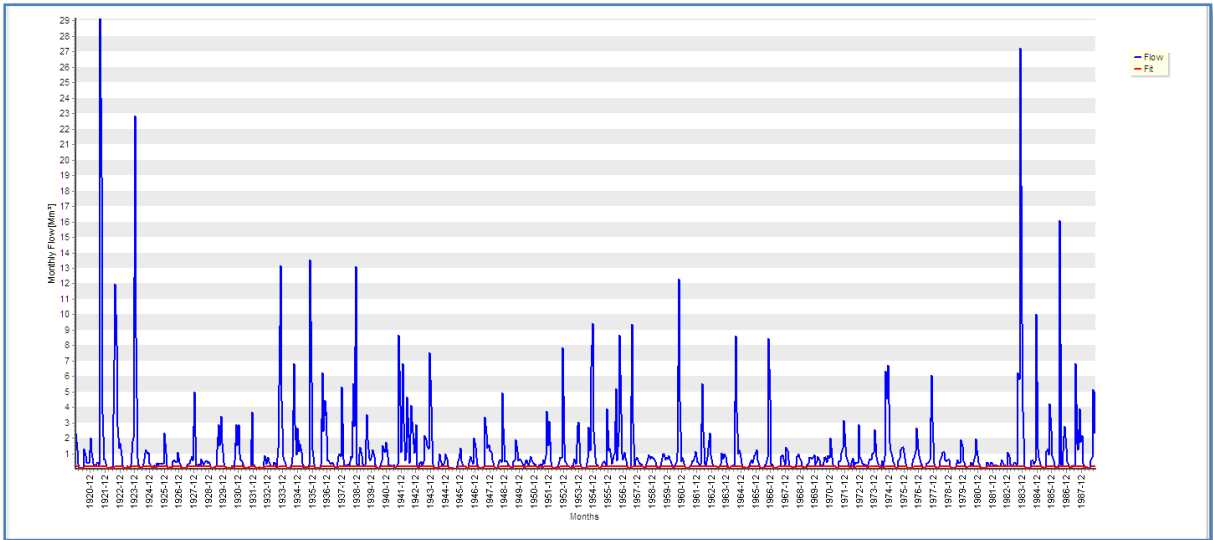


Figure 193: Baseflow separation for quaternary catchment V32F

The final groundwater contribution to baseflow values for the RU is highlighted in red in Table 145.

Table 145: Groundwater contribution to baseflow

Groundwater Contribution to Baseflow							
GRDM Mm ³ /a	Hughes Mm ³ /a	Shultz Mm ³ /a	Pitman Mm ³ /a	vTonder Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Herold Mm ³ /a
67.758	78.086	47.288	18.048	37.801	18.048	78.086	21.530

1.1.167 Groundwater use

The groundwater use for the RU is listed in Table 146.

Table 146: Groundwater use

Groundwater Use							
GRDM Mm ³ /a	WARMS Mm ³ /a	Hydrocensus Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Forrest Mm ³ /a	Crops Mm ³ /a	TOTAL Mm ³ /a
0.700	0.146	0.884	0.146	3.534	67.730	4.905	72.110

1.1.168 Groundwater quality

The TDS values for the RU are shown in Figure 20. They are classified according to SABS standards. Not all boreholes have quality data available but those that do can be used to identify possible hot spots with regard to quality in the resource unit. The overall quality of the resource unit relatively poor – however there are not many water quality data to perform the assessment. These areas should be treated as hotspots rather than penalising the whole resource unit with a poor classification. Treatment of the hotspot areas will be addressed under Resource Quality Objectives in Section 31.

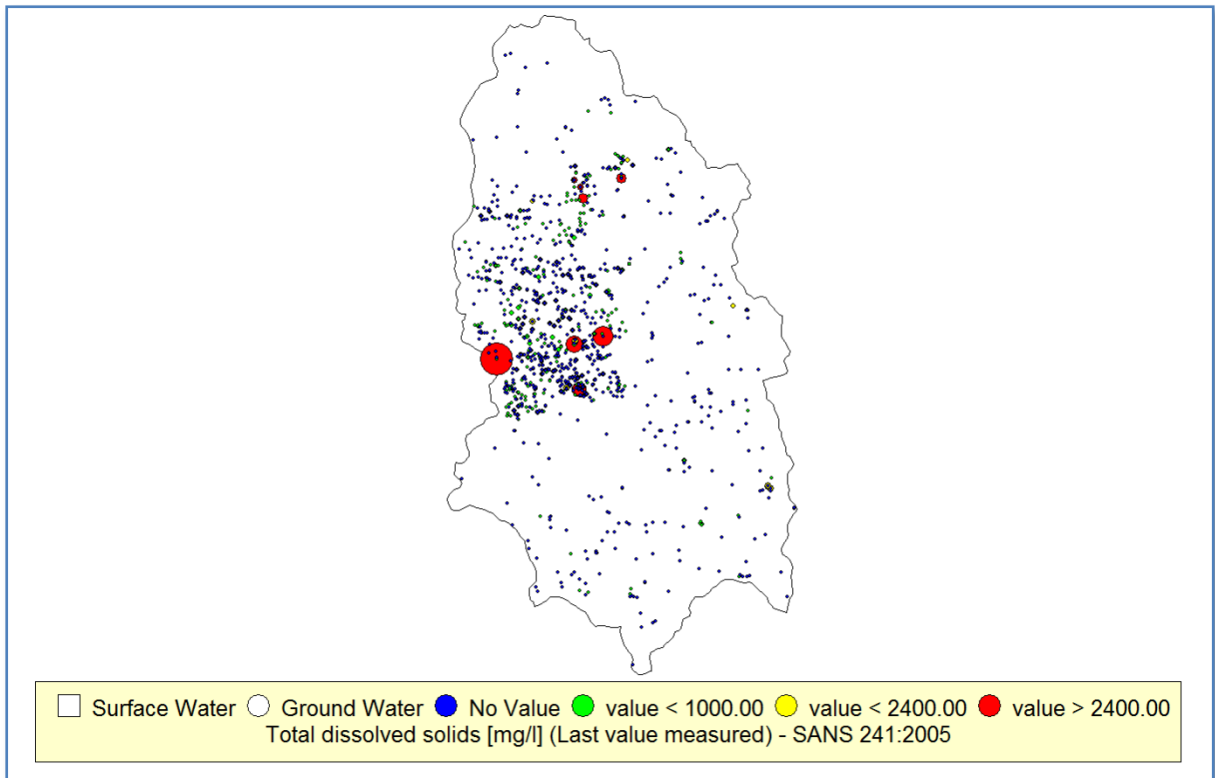


Figure 194: TDS values

1.1.169 Aquifer vulnerability

The aquifer vulnerability calculations are summarised in Table 147. The slope histogram is documented in Appendix B.

Table 147: Aquifer vulnerability

Aquifer Vulnerability						
Level mbgl	Recharge %	Slope %	Soil Texture	Aquifer Type	Vadose Zone	Vulnerability %
13.2	4.6%	2.2	SaClLm-SaCl, LmSa-SaLm	Weathered/Fractured	Karoo(southern)	50%

24.10 Classification

1.1.170 Groundwater usage

The stress index, defined as the ratio between total groundwater use and recharge, for the study area is calculated at 97%. Due to the uncertainty associated with the groundwater use component, the stress index was stochastically modelled through assigning a normal distribution curve with a standard deviation of 7.211 Mm³/a to the groundwater use estimate to account for the associated uncertainty. The stochastic results are shown in Figure 195. It is clear from the results that the stress index will vary between 77% and 100% with a certainty of 67.2%. Due to the large variability in the range obtained, it is recommended that the uncertainty in the groundwater use be reduced by detailed studies focusing on groundwater use within the RU. Due to the relatively high stress index this RU should be flagged as an area which requires further investigation.

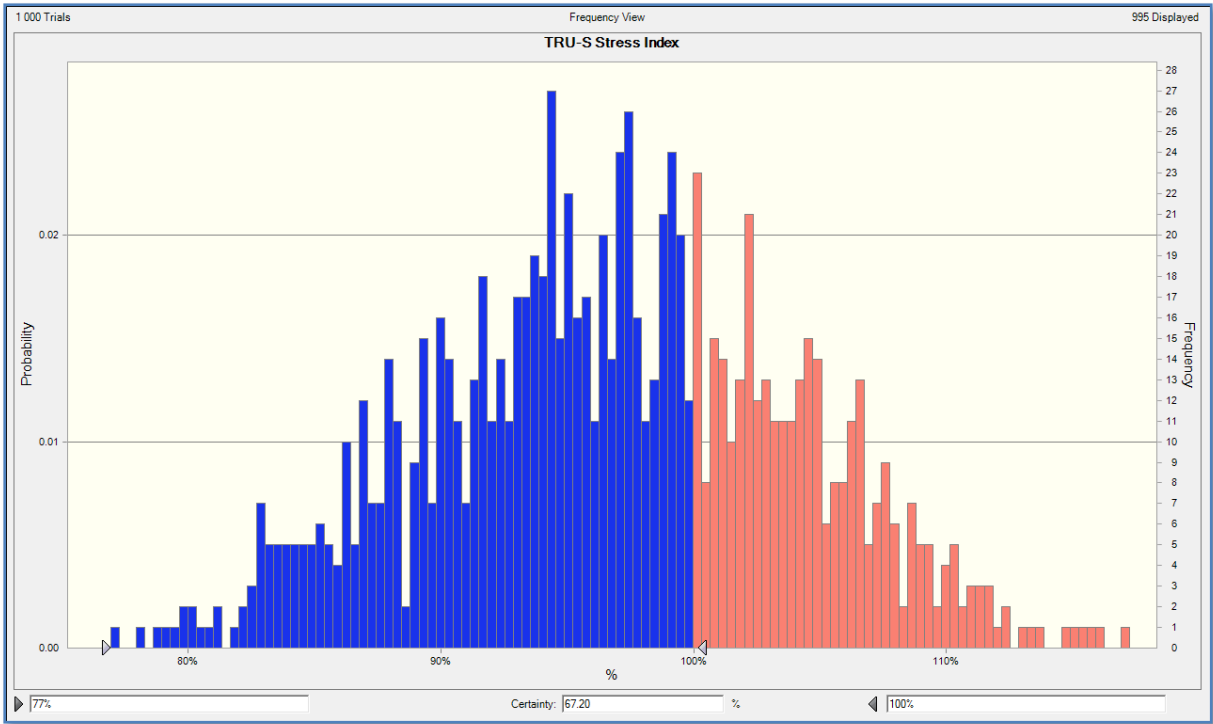


Figure 195: Stochastic results

1.1.171 Quality

The expanded Durov diagram with the groundwater quality is shown in Figure 196. An explanation of the classification process by means of the expanded Durov diagram is given in Section 2.3. There are numerous boreholes in categories A, C and E, however the overall water quality is not so good therefore the final category was set as a C/D.

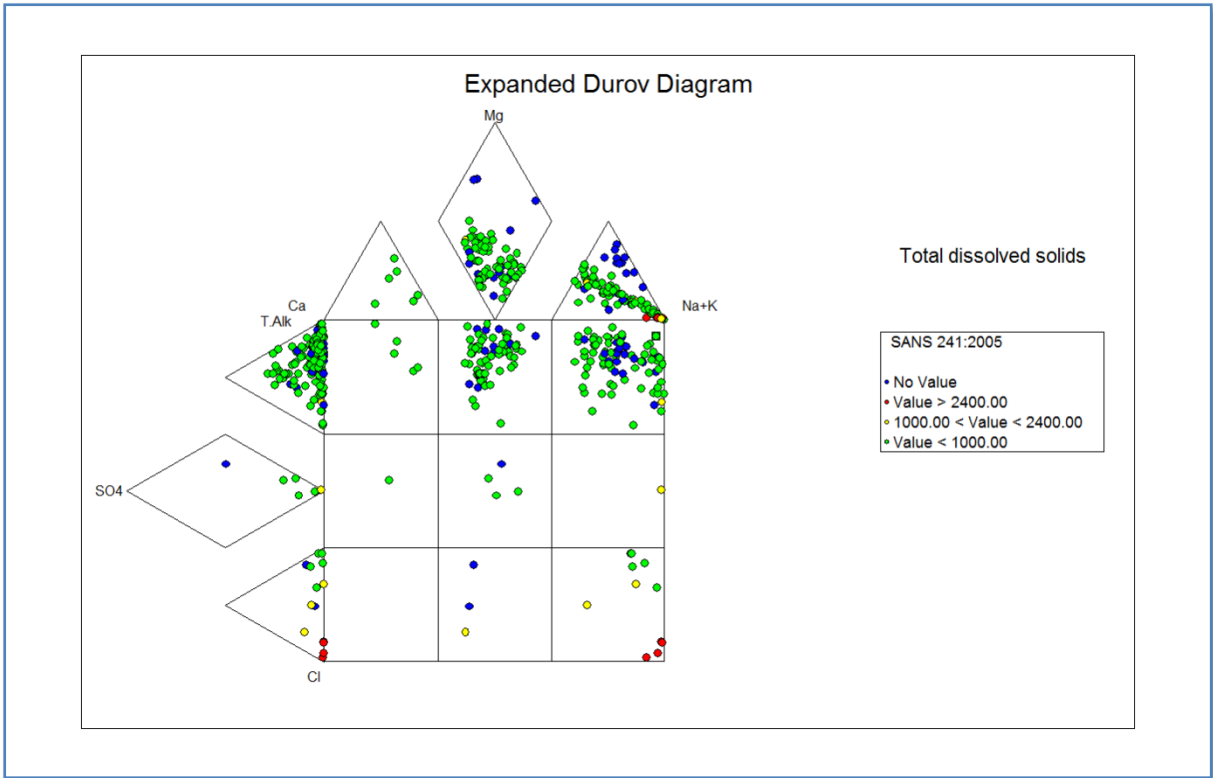


Figure 196: Expanded Durov diagram for RU

As documented in the vulnerability is 50%. The impact of potential contamination according to Section 2.3 is moderate due to the coal mining activities.

1.1.172 Final category

The final category for the RU is summarised in Table 148.

Table 148: Category for RU

Impact	Present status category	Water resource category
Groundwater usage	F	Poor
Groundwater contamination	C/D	Fair
Potential groundwater contamination (vulnerability and impact)	C	Good/Fair
FINAL	D	Fair

24.11 Quantification of the Reserve

The groundwater Reserve for the RU is summarised in Table 149.

Table 149: Reserve

Reserve			Allocation	
Baseflow Mm ³ /a	BHN Mm ³ /a	Reserve % Recharge	Allocation Mm ³ /a	Current Use Mm ³ /a
21.530	0.525	23%	3.096	72.110

25. Classification and the Reserve for Resource Unit T

25.1 Location

The quaternary catchments included in the RU are: V32G and V32H on the eastern edge of the coalfields. The location of the RU is shown in Figure 197.

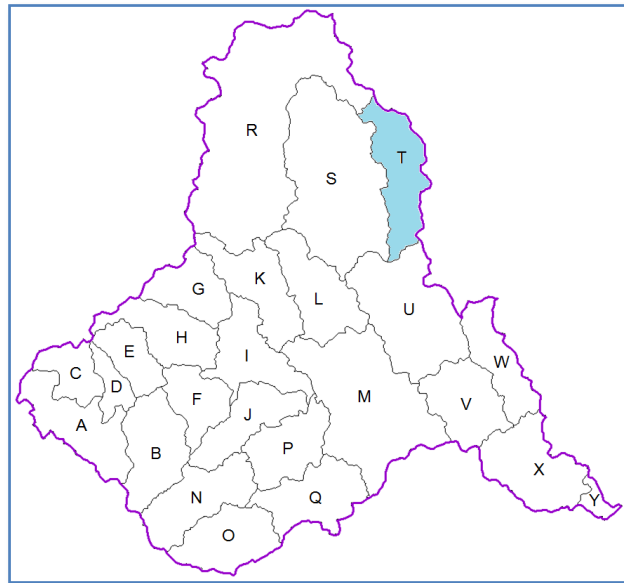


Figure 197: Location of RUT

25.2 Climate

The average rainfall for the area is 720 – 860 mm/a, with most rainfall occurring mainly during mid-summer. It receives the lowest rainfall in June and the highest in January. The monthly distribution of average daily maximum temperatures indicates that the average midday temperatures range from 18.6°C in June to 25.9°C in January. The region is the coldest during July when the mercury drops to 2.7°C on average during the night.

25.3 Vegetation (taken from www.deat.gov.za)

This grassland type contains many endemic plant species. No forest species are endemic to the vegetation type. Typical species, always present, include the grasses Common Russetgrass *Loudetia simplex*, Giant Speargrass *Trachypogon spicatus*, Threadleaf Bluestem *Diheteropogon filifolius*, *Aristida junciformis*, *Tristachya leucothrix*, *Alloteropsis semialata*, *Eragrostis racemosa*, *Sporobolus pectinatus* and *Microchloa caffra*, and forbs such as *Aeschynomene nodulosa*, *Geelkeurtjie* *Eriosema angustifolium*, *Bracken* *Pteridium aquilinum*, *Berkheya echinacea*, *Pearsonia sessilifolia*, *Crassula alba*, *Vernonia centauroides*, *V natalensis*, *Clutia monticola*, *Stiburus alopecuroides*, *Helichrysum wilmsii*, *H. cephaloideum*, *H. acutatatum* and *H. pilosellum*. A number of species are, however,

restricted to the mist belt zone of high mountain peaks and summits (exceeding 1 700 m). At relatively lower altitudes, below 1 700 m, grass species and the woody species are common. Forest-related bush clumps are at the edge of the escarpment in this area.

25.4 *Demography and Landcover*

The total population is approximately 45300 (2001 census data). Forestry (Photo 45), grazing, crops and ecotourism are the most important economic activities. The landcover is shown in Figure 198.



Photo 45: Forests in RU
(Source: www.panoramio.com)

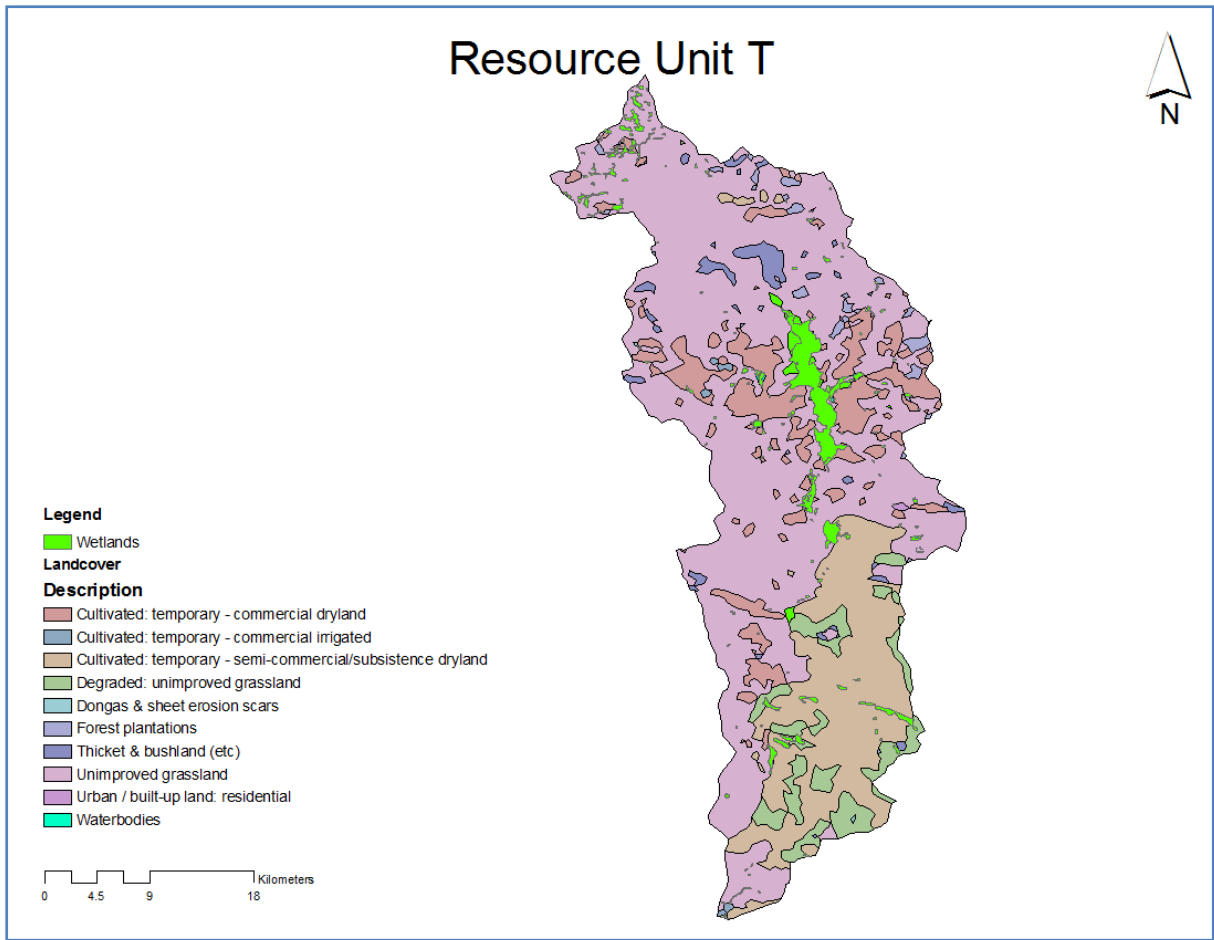


Figure 198: Landcover within RUT

25.5 Surface Water

The Blood River flows through this RU.

25.6 Wetlands

The KZN North wetland on the Blood River near Scheepersneck has been identified as a priority wetland in the province. It is one of the largest inland marshes in the country and of high importance for biodiversity conservation. Its main beneficiaries are commercial farmers and the Mondlo community downstream who rely on it for water. It provides a number of important ecosystem services including livestock grazing, streamflow regulation, flood attenuation, water assimilation and sediment trapping.

The wetland formed in a depression below the Skurweberg plateau, an area of high ground that is capped and protected from weathering and erosion by an extensive dolerite sill. It has four main tributary arms, the Blood River flowing from the north, the Lynspruit from the northeast, and the Spartspruit and Bloubankspruit from the south. The wetlands located in the RU are shown in Figure 198.

25.7 Soils (taken from www.deat.gov.za)

Soils are mostly shallow lithosols derived from a variety of rock types.

25.8 Geology (summarised from Woodford and Chevallier, 2002)

The Pietermaritzburg Formation (of the Ecca Group) comprises dark, upward coarsening, silty mudrock, which is heavily bioturbated. Pene-contemporaneously deformed sandy and silty beds appear near the top of the formation.

The Vryheid Formation (of the Ecca Group) comprises mudrock, rhythmite, siltstone and fine- to coarse-grained sandstone (pebbly in places). The Formation contains up to five (mineable) coal seams. The different lithofacies are mainly arranged in upward-coarsening deltaic cycles (up to 80m thick in the southeast). Linear coastline cycles are, however, fairly common particularly in the thin northwestern part where they constitute the entire Vryheid in places. A relatively thin fluvial interval (60 m thick) which grades distally into deltaic deposits towards the southwest and south occurs approximately in the middle of the formation in the east and northeast. Fining-upward fluvial cycles, of which up to six are present in the east, are typically sheet-like in geometry, although some form valley-fill deposits. They comprise coarse-grained to pebbly, immature sandstones - with an abrupt upward transition into fine-grained sediments and coal seams.

Since these shales are very dense, they were often neglected as sources of groundwater in the past. The prodelta sandstones represent another formation of the Ecca Group in which one would expect to find high-yielding aquifers. Unfortunately, the permeabilities of these sandstones are also usually very low.

Sills in the Karoo formations are sheetlike forms of dolerite intrusions that tend to follow the bedding planes of the formations concordantly. These structures, whose thicknesses vary from less than a metre to hundreds of metres, represent the dominant form in which dolerite is emplaced in the Karoo Supergroup. Dolerite sills in the Karoo Supergroup often have very complex forms. The linear dykes are also usually thinner than ring dykes and are confined to the Ecca and Beaufort Groups. This is a clear indication that the magmatic activity at the time the linear dykes intruded was less than when the ring dykes and sills intruded.

25.9 Geohydrology

1.1.173 Groundwater levels

It is clear the groundwater levels follow the topography as seen from Figure A1 in Appendix A and therefore groundwater contour maps were generated using Bayesian interpolation. The groundwater levels for the study area are shown in Figure 199. The most probable depth to groundwater level in the RU is 6.4 mbgl according to the histogram of water levels in the RU shown in Appendix A. Groundwater levels are expected to be lower than normal due to the prevailing drought conditions. Unfortunately very little time series water level data are available to quantify the overall impact.

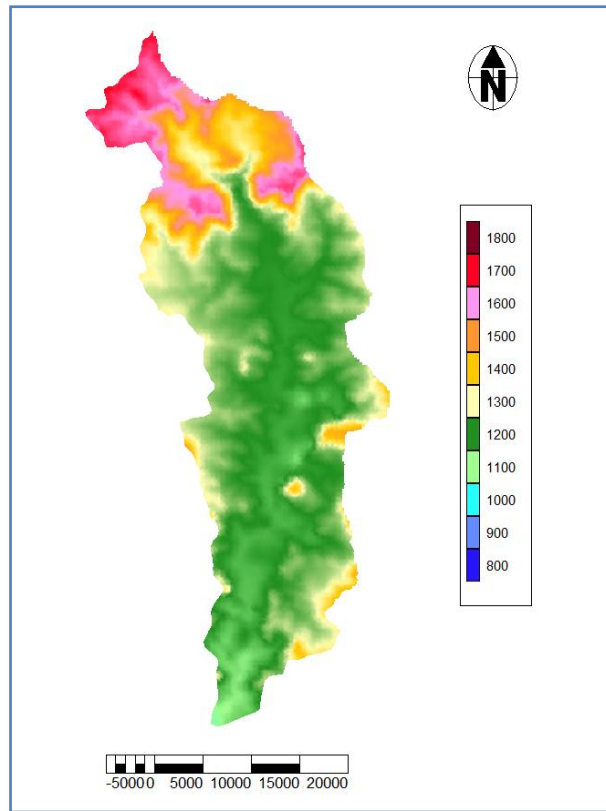


Figure 199: Groundwater levels in RUT

25.9.1 Groundwater recharge

The groundwater recharge calculated from the different methods is listed in Table 150. The different recharge methods applied are discussed in Section 2.3. The final recharge values for the RU are highlighted in red.

Table 150: Recharge values

Recharge							
MAP Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Volume Mm ³ /a	Calculated %	CMB %	Land Cover %	Geology %
841.117	41.050	58.663	41.378	4.9%	4.9%	3.4%	4.5%

1.1.174 Basic human needs

The method for determining BHNs is discussed in Section 2.3. The final value for the study area is highlighted in red in Table 151.

Table 151: Basic human needs

Basic Human Need		
Census(2001) Adjusted	Dependence 18%	Estimate Mm ³ /a
52095	9377	0.084

1.1.175 Groundwater contribution to baseflow

The baseflow separation curves for the RU are shown in Figures 200 & 201.

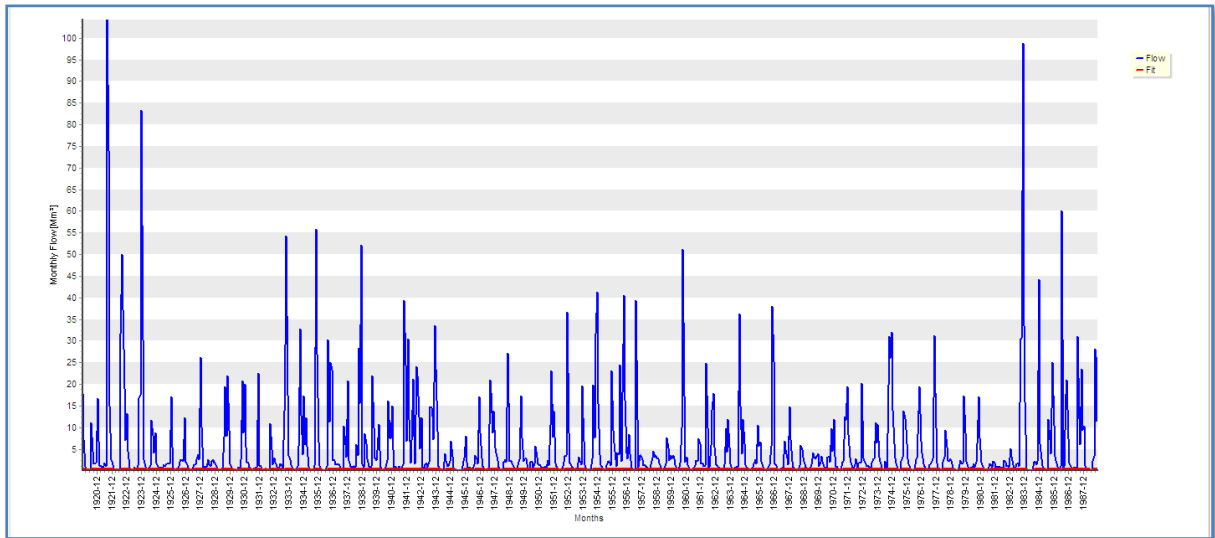


Figure 200: Baseflow separation for quaternary catchment V32G

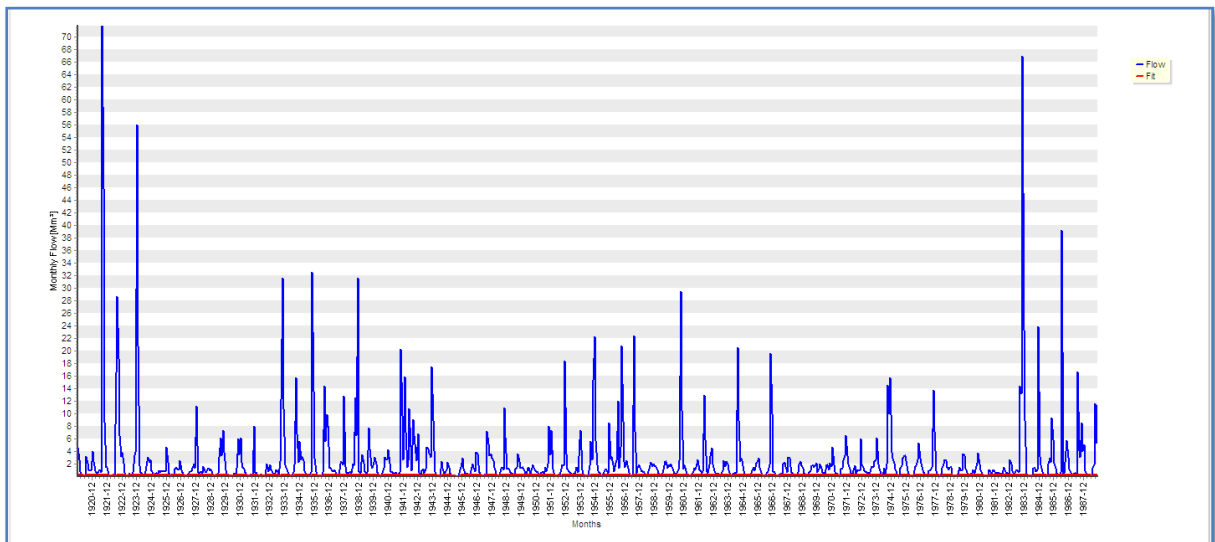


Figure 201: Baseflow separation for quaternary catchment V32H

The final groundwater contribution to baseflow values for the RU is highlighted in red in Table 152.

Table 152: Groundwater contribution to baseflow

Groundwater Contribution to Baseflow							
GRDM Mm ³ /a	Hughes Mm ³ /a	Shultz Mm ³ /a	Pitman Mm ³ /a	vTonder Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Herold Mm ³ /a
24.638	35.918	19.439	6.897	15.915	6.897	35.918	8.040

1.1.176 Groundwater use

The groundwater use for the RU is listed in Table 153.

Table 153: Groundwater use

Groundwater Use							
GRDM Mm ³ /a	WARMS Mm ³ /a	Hydrocensus Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Forrest Mm ³ /a	Crops Mm ³ /a	TOTAL Mm ³ /a
0.180	0.058	0.919	0.058	3.676	20.221	0.501	20.637

1.1.177 Groundwater quality

The TDS values for the RU are shown in Figure 202. They are classified according to SABS standards. Not all boreholes have quality data available but those that do can be used to identify possible hot spots with regard to quality in the resource unit. The overall quality of the resource unit is well within the drinking water guidelines with the exception of two boreholes. These areas should be treated as hotspots rather than penalising the whole resource unit with a poor classification. Treatment of the hotspot areas will be addressed under Resource Quality Objectives in Section 31.

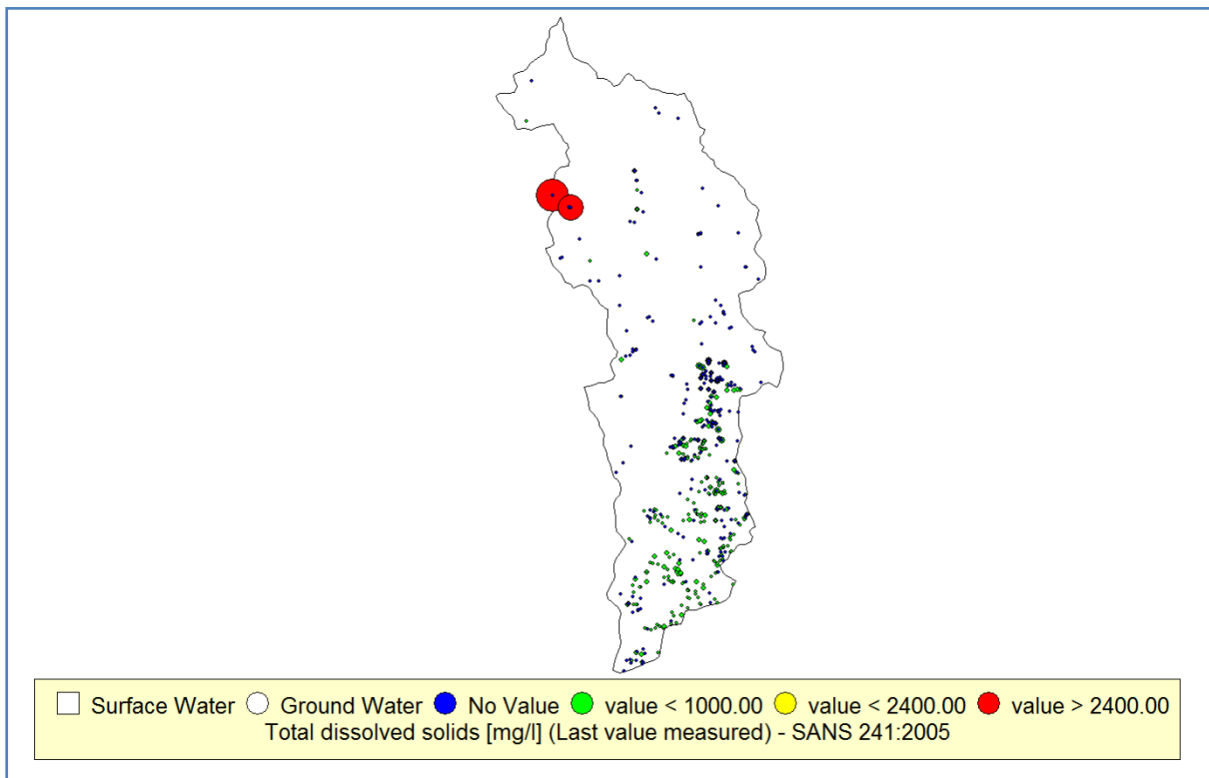


Figure 202: TDS values

1.1.178 Aquifer vulnerability

The aquifer vulnerability calculations are summarised in Table 154. The slope histogram is documented in Appendix B.

Table 154: Aquifer vulnerability

Aquifer Vulnerability						
Level mbgl	Recharge %	Slope %	Soil Texture	Aquifer Type	Vadose Zone	Vulnerability %
6.4	4.9%	1.2	SaCLm-SaCl, LmSa-SaLm	Weathered/Fractured	Karoo(southern)	58%

25.10 Classification

1.1.179 Groundwater usage

The stress index, defined as the ratio between total groundwater use and recharge, for the study area is calculated at 70%. Due to the uncertainty associated with the groundwater use component, the stress index was stochastically modelled through assigning a normal distribution curve with a standard deviation of 2.064 Mm³/a to the groundwater use estimate to account for the associated uncertainty. The stochastic results are shown in Figure 203. It is clear from the results that the stress index will vary between 57% and 83% with a certainty of 99.31%. Due to the large variability in the range obtained, it is recommended that the uncertainty in the groundwater use be reduced by detailed studies focusing on groundwater use within the RU. Due to the relatively high stress index this RU should be flagged as an area which requires further investigation.

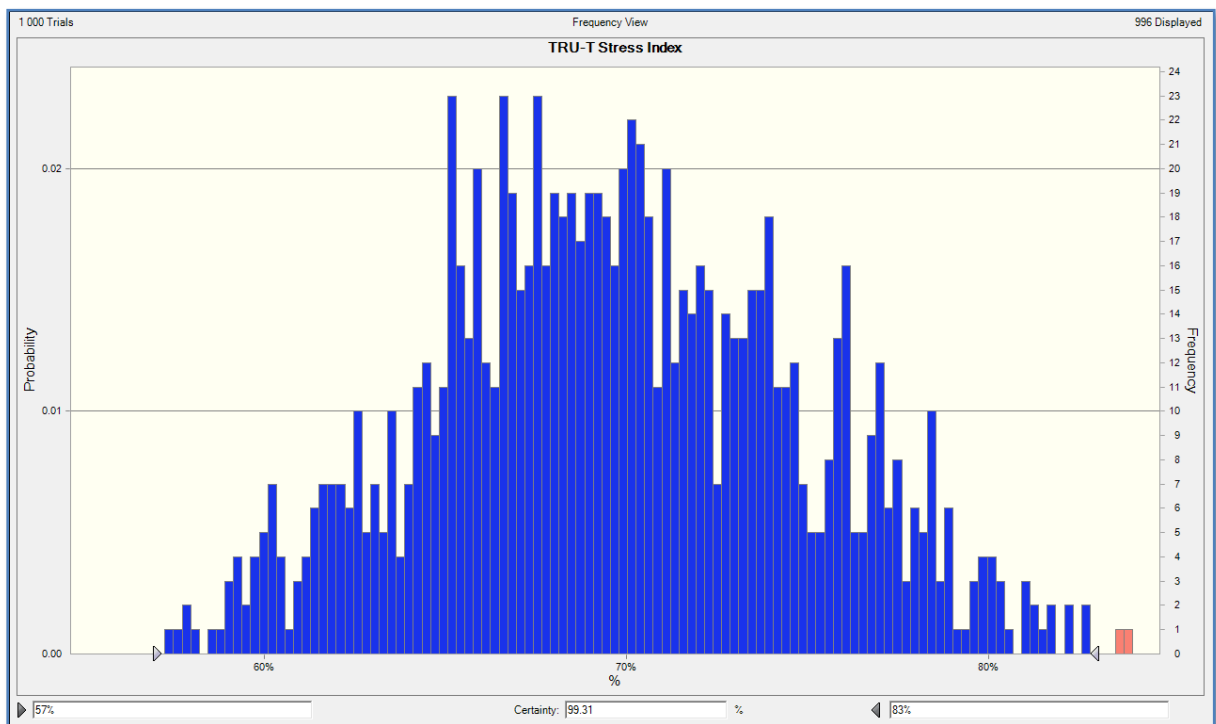


Figure 203: Stochastic results

1.1.180 Quality

The expanded Durov diagram with the groundwater quality is shown in Figure 204. An explanation of the classification process by means of the expanded Durov diagram is given in Section 2.3. There

are numerous boreholes in categories A and C, however the overall water quality is relatively good therefore the final category was set as a B.

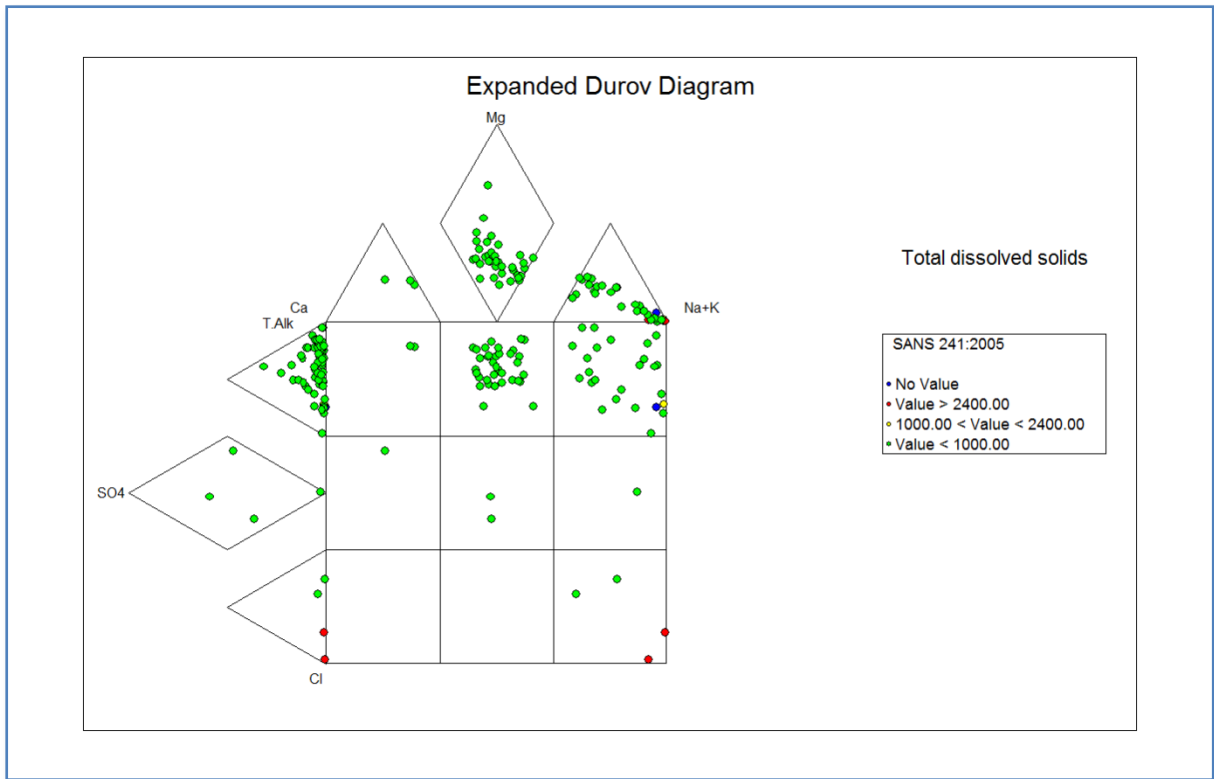


Figure 204: Expanded Durov diagram for RU

As documented the vulnerability is 58%. The impact of potential contamination according to Section 2.3 is low.

1.1.181 Final category

The final category for the RU is summarised in Table 155.

Table 155: Category for RU

Impact	Present status category	Water resource category
Groundwater usage	E	Poor
Groundwater contamination	B	Good
Potential groundwater contamination (vulnerability and impact)	B	Good
FINAL	C	Fair

25.11 *Quantification of the Reserve*

The groundwater Reserve for the RU is summarised in Table 156.

Table 156: Reserve

Reserve			Allocation	
Baseflow Mm ³ /a	BHN Mm ³ /a	Reserve % Recharge	Allocation Mm ³ /a	Current Use Mm ³ /a
8.040	0.084	20%	12.616	20.637

26. Classification and the Reserve for Resource Unit U

26.1 Location

The quaternary catchments V33A, V33B, V33C and V33D are included in the RU. The protected area of Islandlwana occurs in the centre of the RU. There are no major towns in the area and the only landmark is Rorke's Drift which was a mission station is situated near a natural ford (drift) on the Buffalo River. The location of the RU is shown in Figure 205.

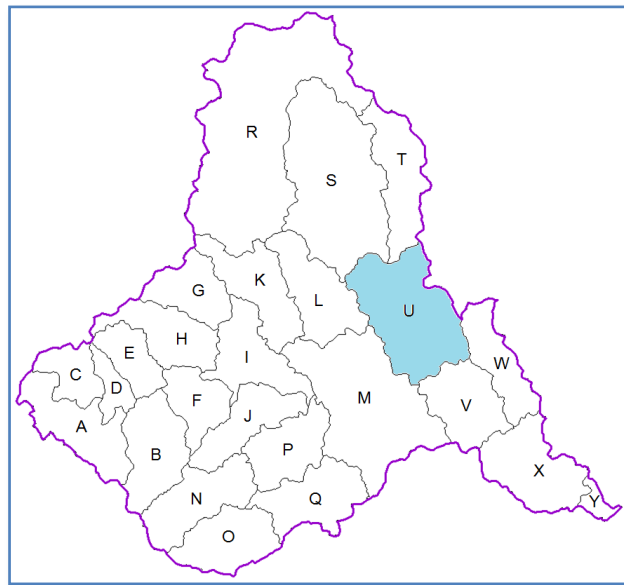


Figure 205: Location of RUU

26.2 Climate

These areas are moist, cold montane grasslands with rainfall of 650 to 800 mm per year and little snow except on the tops of mountains. Rainfall occurs mainly in summer in the east and less seasonal in the west. Temperatures vary between -3°C and 40°C, with an average of 16°C.

26.3 Vegetation (taken from www.deat.gov.za)

This vegetation type is a dense, sour grassland with Redgrass. Trees and shrubs that occur on sheltered sites, rocky hills and ridges. Overgrazing encourages unpalatable Wire Grass *Elionurus muticus* and herbaceous weeds such as Staggersweed *Senecio retrorsus* and Doll Rose *Helichrysum argyrophyllum*.

26.4 Demography and Landcover

The average population is 93000 (2001 census data). The area is mainly used for grazing, though crop-farming (maize) and forestry are also important economic activities. The landcover is shown in Figure 206.

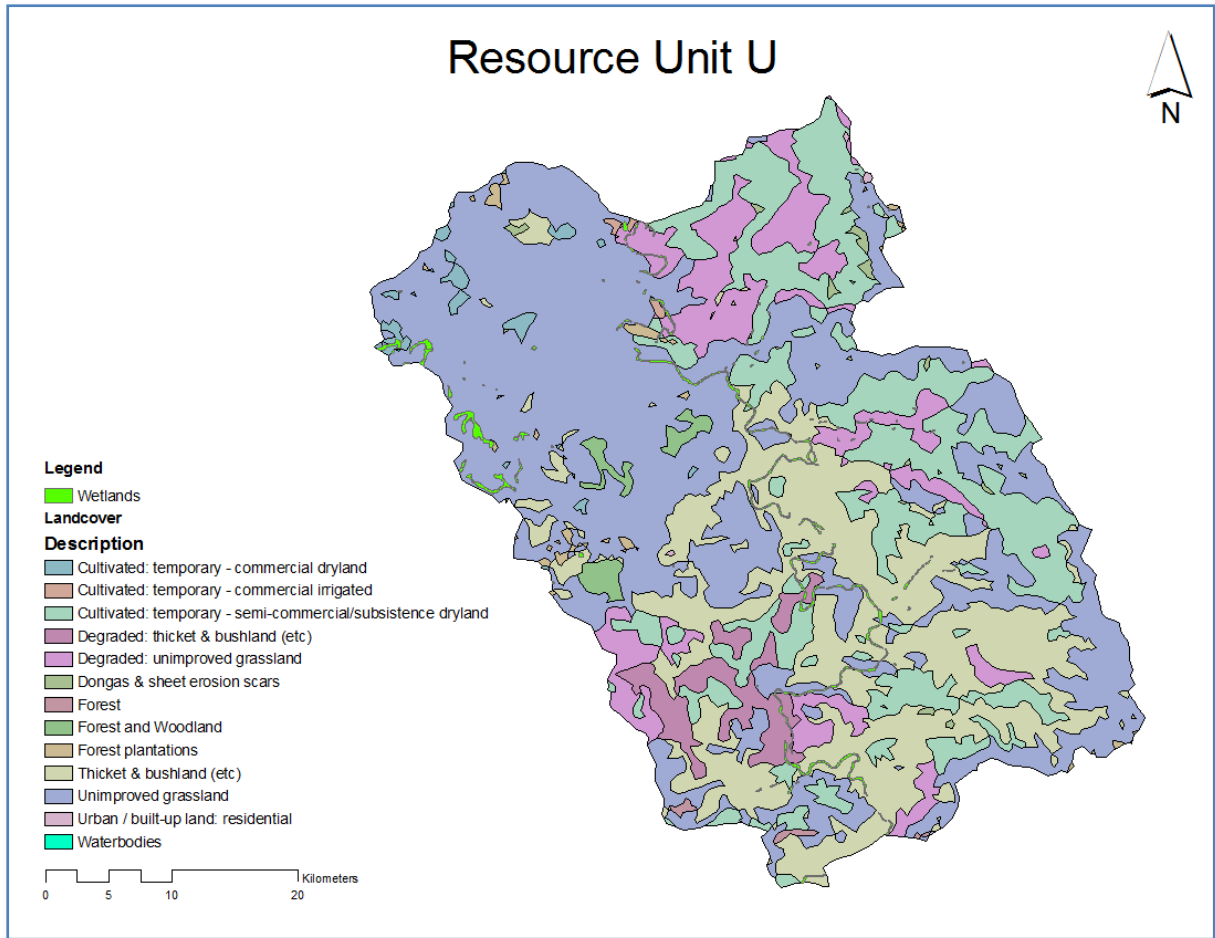


Figure 206: Landcover within the RU

26.5 Surface Water

The Totololo, Batshe, Ngoxobongo, Mazabeko, Mangeni and Gubazi Rivers join the Buffalo River.

26.6 Wetlands

The wetlands within the study area are shown in Figure 206.

26.7 Soils (taken from www.deat.gov.za)

The soil is often shallow, rocky and leached, derived from Karoo Sequence sediments and dolerite. Where deep, the soils may be leached due to the high rainfall and are fairly erodible forming large dongas in some parts.

26.8 *Geology (summarised from Woodford and Chevallier, 2002)*

The Dwyka sediments, which are situated at the base of the Karoo Supergroup, have been deposited on older Precambrian granitic rocks in the north and sedimentary rocks, associated with the Cape Fold Belt in the south. The Dwyka Formation mainly consists of Dwyka diamictite—angular to rounded clasts of the basement rocks, embedded in a clay and silt matrix. However, varved shales, sandstone layers and conglomerates, typical of a fluvio-glacial environment, are also present. The Dwyka diamictite, shales and tillites have very low hydraulic conductivities [$\sim 10^{-11}$ to 10^{-12} m/s], and virtually no primary voids. They therefore tend to form more aquitards than aquifers. The few sandstone bodies deposited in the glacial valleys of the northern facies are very limited in extent, and sealed off by the diamictite. The aquifers in them are therefore limited and often only contain fossil water. Since the Dwyka sediments were deposited mainly under marine conditions, the water in these aquifers tends to be saline.

The Pietermaritzburg Formation (of the Ecca Group) comprises dark, upward coarsening, silty mudrock, which is heavily bioturbated. Pene-contemporaneously deformed sandy and silty beds appear near the top of the formation.

The Vryheid Formation (of the Ecca Group) comprises mudrock, rhythmite, siltstone and fine- to coarse-grained sandstone (pebbly in places). The Formation contains up to five (mineable) coal seams. The different lithofacies are mainly arranged in upward-coarsening deltaic cycles (up to 80m thick in the southeast). Linear coastline cycles are, however, fairly common particularly in the thin northwestern part where they constitute the entire Vryheid in places. A relatively thin fluvial interval (60 m thick) which grades distally into deltaic deposits towards the southwest and south occurs approximately in the middle of the formation in the east and northeast. Fining-upward fluvial cycles, of which up to six are present in the east, are typically sheet-like in geometry, although some form valley-fill deposits. They comprise coarse-grained to pebbly, immature sandstones - with an abrupt upward transition into fine-grained sediments and coal seams.

The Volksrust Formation (of the Ecca Group) is a predominantly argillaceous unit, which interfingers with the overlying Beaufort Group and underlying Vryheid Formation. The Formation consists of grey to black, silty shale with thin, usually bioturbated, siltstone or sandstone lenses and beds, particularly towards its upper and lower boundaries. Thin phosphate and carbonate beds and concretions are relatively common.

Since these shales are very dense, they were often neglected as sources of groundwater in the past. The prodelta sandstones represent another formation of the Ecca Group in which one would expect to find high-yielding aquifers. Unfortunately, the permeabilities of these sandstones are also usually very low.

Sills in the Karoo formations are sheetlike forms of dolerite intrusions that tend to follow the bedding planes of the formations concordantly. These structures, whose thicknesses vary from less than a metre to hundreds of metres, represent the dominant form in which dolerite is emplaced in the Karoo Supergroup. Dolerite sills in the Karoo Supergroup often have very complex forms. The

linear dykes are also usually thinner than ring dykes and are confined to the Ecca and Beaufort Groups. This is a clear indication that the magmatic activity at the time the linear dykes intruded was less than when the ring dykes and sills intruded.

26.9 *Geohydrology*

1.1.182 Groundwater levels

It is clear the groundwater levels follow the topography as seen from Figure A1 in Appendix A and therefore groundwater contour maps were generated using Bayesian interpolation. The groundwater levels for the study area are shown in Figure 207. The most probable depth to groundwater level in the RU is 7.7 mbgl according to the histogram of water levels in the RU shown in Appendix A. Groundwater levels are expected to be lower than normal due to the prevailing drought conditions. Unfortunately very little time series water level data are available to quantify the overall impact.

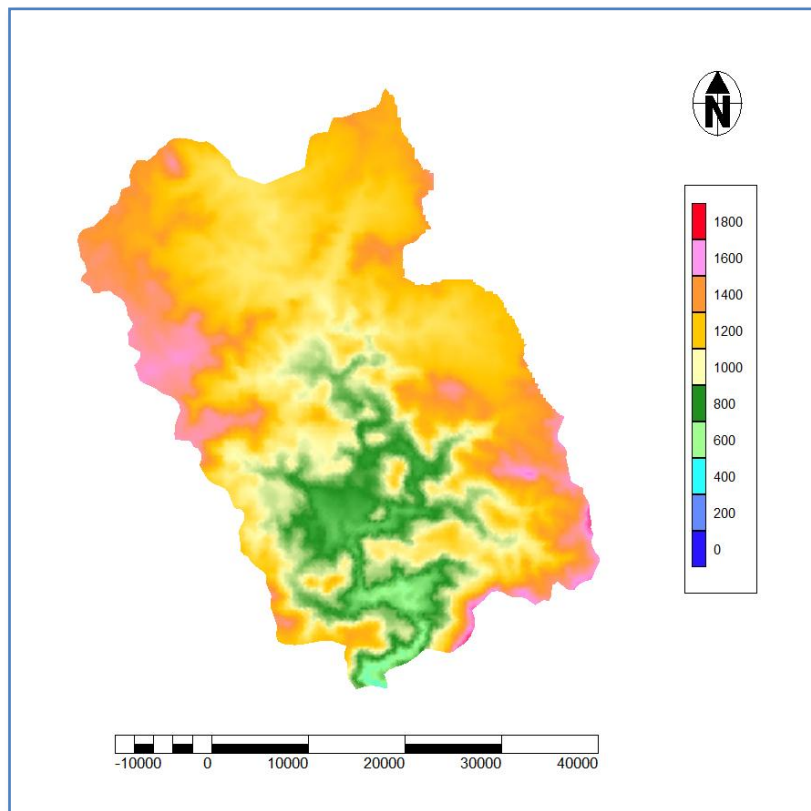


Figure 207: Groundwater levels in RUU

26.9.1 Groundwater recharge

The groundwater recharge calculated from the different methods is listed in Table 157. The different recharge methods applied are discussed in Section 2.3. The final recharge values for the RU are highlighted in red.

Table 157: Recharge values

Recharge							
MAP Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Volume Mm ³ /a	Calculated %	CMB %	Land Cover %	Geology %
1371.466	58.778	87.161	67.968	5.0%	5.0%	3.4%	3.2%

1.1.183 Basic human needs

The method for determining BHNs is discussed in Section 2.3. The final value for the study area is highlighted in red in Table 158.

Table 158: Basic human needs

Basic Human Need		
Census(2001) Adjusted	Dependence 18%	Estimate Mm ³ /a
106690	19204	0.173

1.1.184 Groundwater contribution to baseflow

The baseflow separation curves for the RU are shown in Figures 208 – 211.

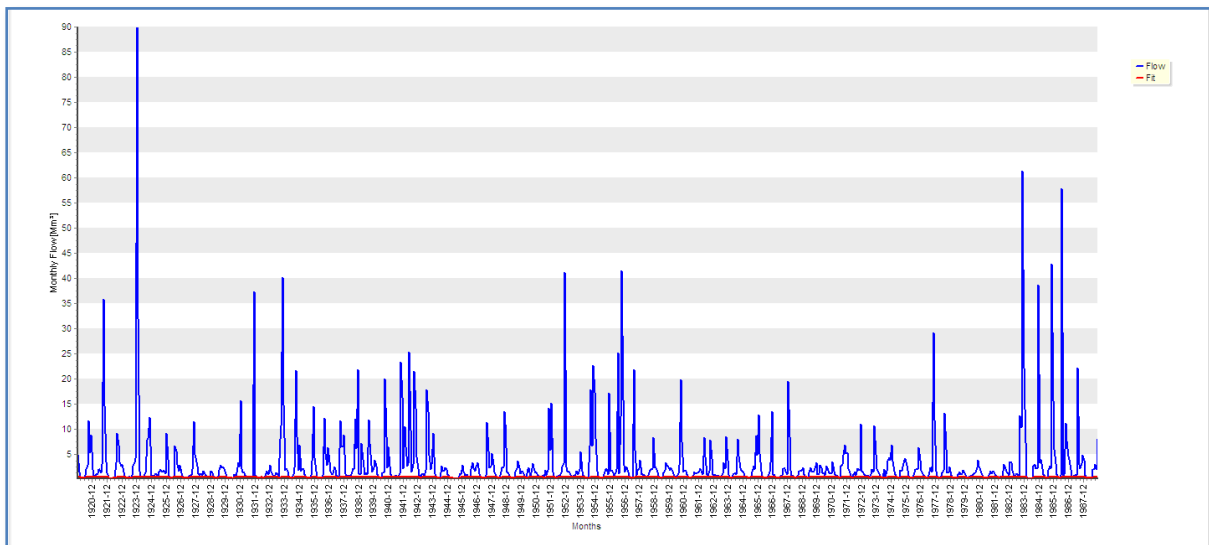


Figure 208: Baseflow separation for quaternary catchment V33A

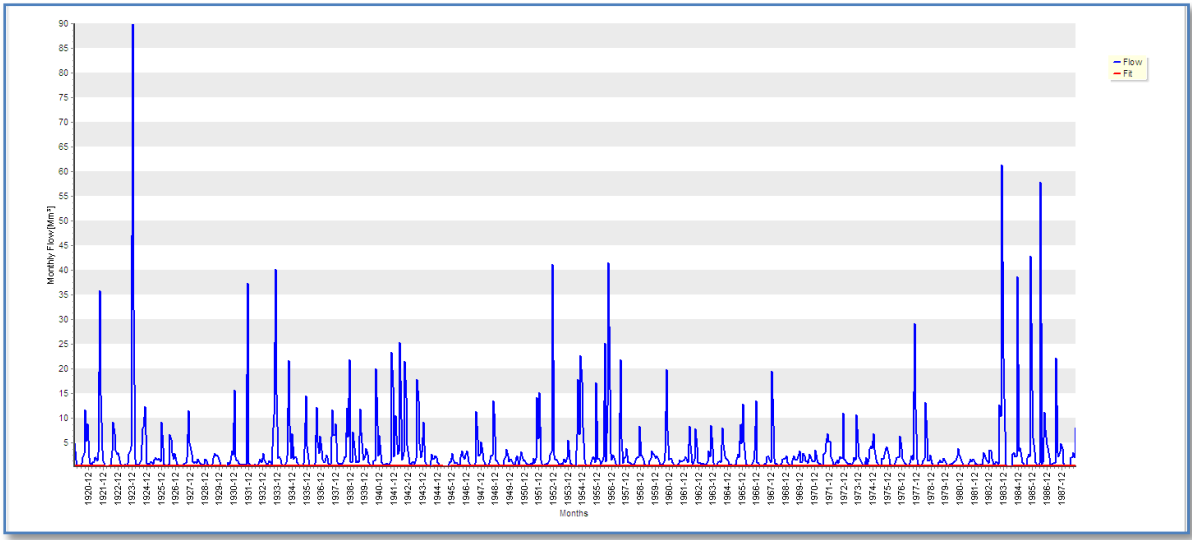


Figure 209: Baseflow separation for quaternary catchment V33B

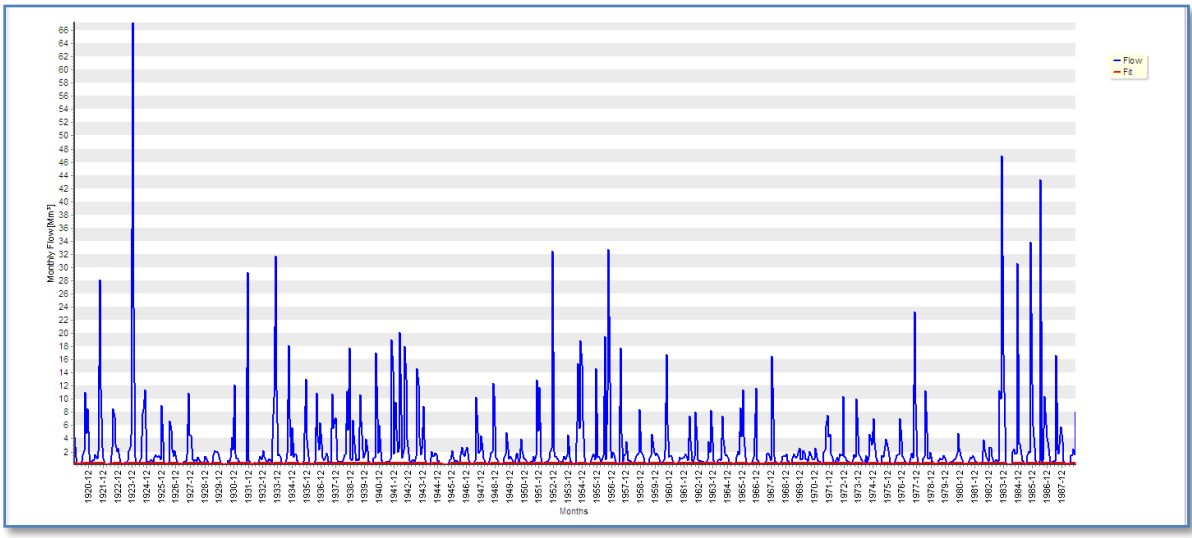


Figure 210: Baseflow separation for quaternary catchment V33C

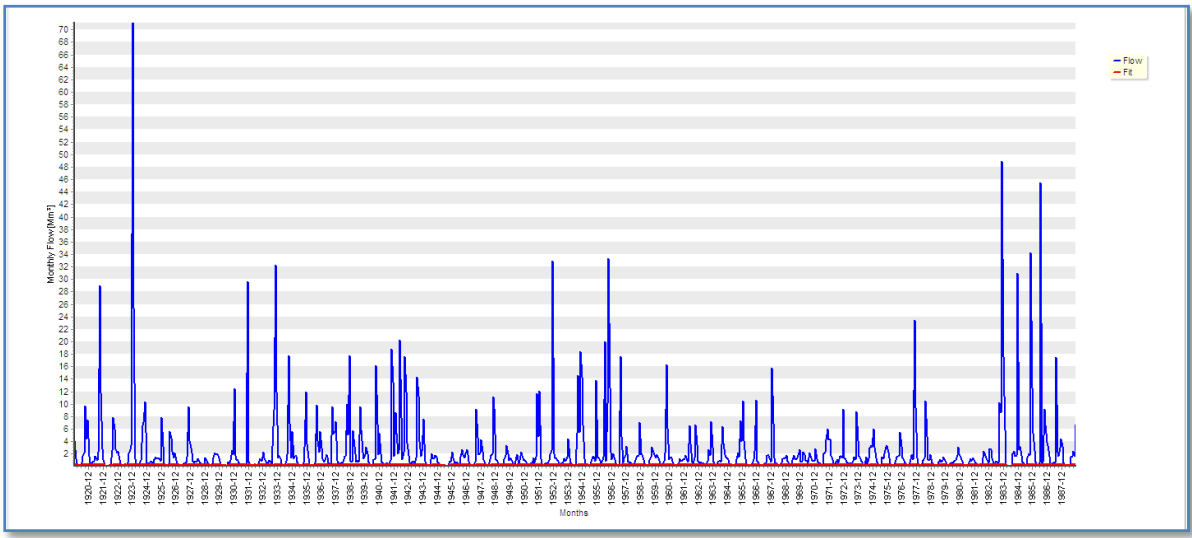


Figure 211: Baseflow separation for quaternary catchment V33D

The final groundwater contribution to baseflow values for the RU is highlighted in red in Table 159.

Table 159: Groundwater contribution to baseflow

Groundwater Contribution to Baseflow							
GRDM Mm ³ /a	Hughes Mm ³ /a	Shultz Mm ³ /a	Pitman Mm ³ /a	vTonder Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Herold Mm ³ /a
34.745	51.743	30.469	11.823	24.691	11.823	51.743	14.860

1.1.185 Groundwater use

The groundwater use for the RU is listed in Table 160.

Table 160: Groundwater use

Groundwater Use							
GRDM Mm ³ /a	WARMS Mm ³ /a	Hydrocensus Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Forrest Mm ³ /a	Crops Mm ³ /a	TOTAL Mm ³ /a
0.570	0.000	0.733	0.000	2.933	0.360	0.000	0.187

1.1.186 Groundwater quality

The TDS values for the RU are shown in Figure 212. They are classified according to SABS standards. Not all boreholes have quality data available but those that do can be used to identify possible hot spots with regard to quality in the resource unit. The overall quality of the resource unit is within the drinking water guidelines with the exception of a couple boreholes most probably due to agricultural activities. These areas should be treated as hotspots rather than penalising the whole resource unit with a poor classification. Treatment of the hotspot areas will be addressed under Resource Quality Objectives in Section 31.

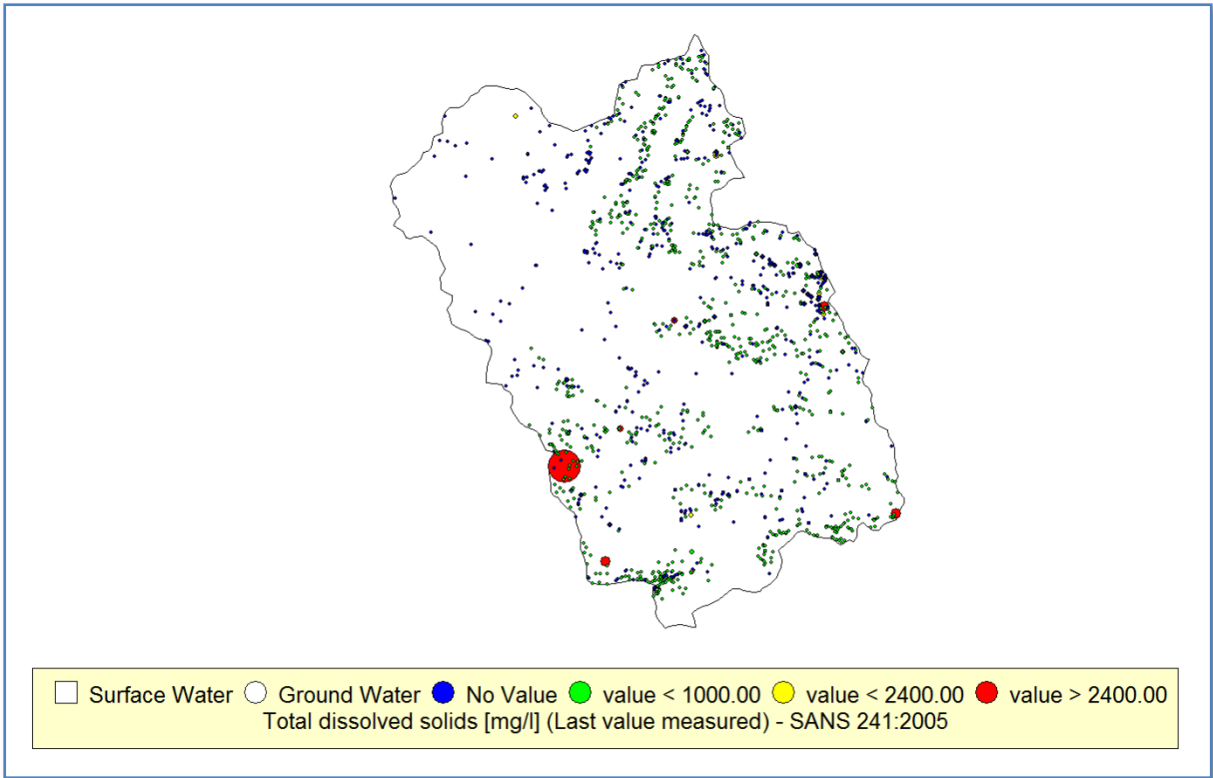


Figure 212: TDS values

1.1.187 Aquifer vulnerability

The aquifer vulnerability calculations are summarised in Table 161. The slope histogram is documented in Appendix B.

Table 161: Aquifer vulnerability

Aquifer Vulnerability						
Level mbgl	Recharge %	Slope %	Soil Texture	Aquifer Type	Vadose Zone	Vulnerability %
7.7	5.0%	0.001	SaClLm-SaCl	Weathered/Fractured	Karoo(southern)	57%

26.10 Classification

1.1.188 Groundwater usage

The stress index, defined as the ratio between total groundwater use and recharge, for the study area is calculated at 22%. Due to the uncertainty associated with the groundwater use component, the stress index was stochastically modelled through assigning a normal distribution curve with a standard deviation of 0.019 Mm³/a to the groundwater use estimate to account for the associated uncertainty. The stochastic results are shown in Figure 213. It is clear from the results that the stress index will vary between 22% and 22% with a certainty of 99.6%. Due to the small variability in the obtained range and high certainty, the uncertainty in the groundwater use component will not affect the calculated stress index significantly.

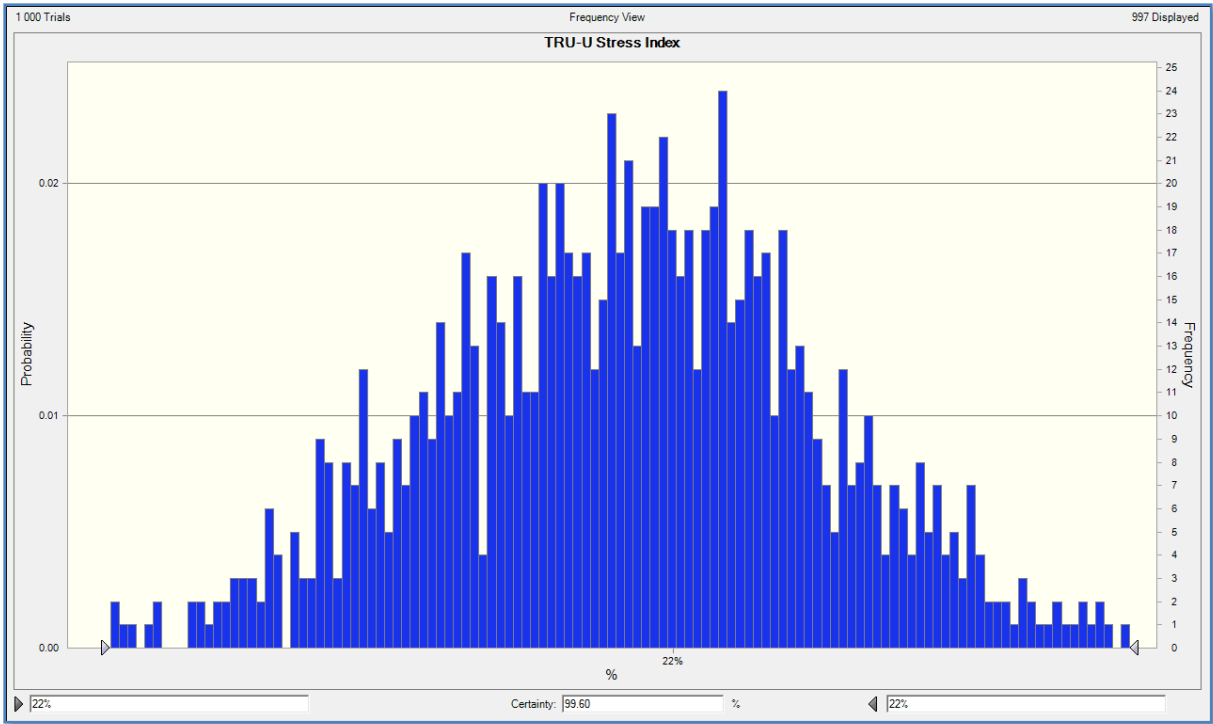


Figure 213: Stochastic results

1.1.189 Quality

The expanded Durov diagram with the groundwater quality is shown in Figure 214. An explanation of the classification process by means of the expanded Durov diagram is given in Section 2.3. There are numerous boreholes in categories A and C, however the overall water quality is average therefore the final category was set as a B/C.

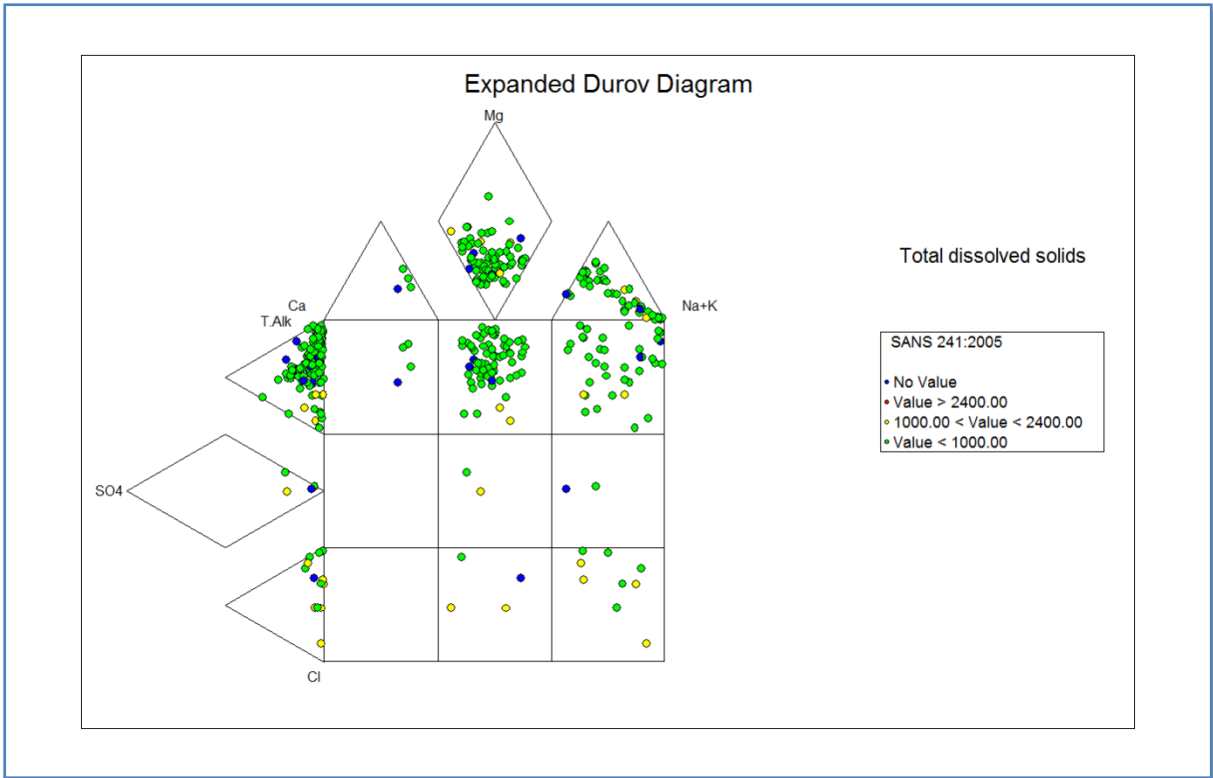


Figure 214: Expanded Durov diagram for RU

As documented the vulnerability is 57%. The impact of potential contamination according to Section 2.3 is low.

1.1.190 Final category

The final category for the RU is summarised in Table 162.

Table 162: Category for RU

Impact	Present status category	Water resource category
Groundwater usage	C	Good/Fair
Groundwater contamination	B/C	Good/Fair
Potential groundwater contamination (vulnerability and impact)	B	Good
FINAL	B/C	Good/Fair

26.11 Quantification of the Reserve

The groundwater Reserve for the RU is summarised in Table 163.

Table 163: Reserve

Reserve			Allocation	
Baseflow Mm ³ /a	BHN Mm ³ /a	Reserve % Recharge	Allocation Mm ³ /a	Current Use Mm ³ /a
14.860	0.173	22%	52.748	0.187

27. Classification and the Reserve for Resource Unit V

27.1 Location

This RU encompasses the following quaternary catchments: V40A, V40B and V40E. The protected areas within the study area include: Qudeni Forest, Hlatikulu (also known as Cederberge) and Kranskop. The towns within the area include: Ekombe, Dolwana, Jameson’s Drift and Kranskop. Kranskop is a small town that is situated on the edge of the Thukela River Valley. Kranskop is named after two cliff faces that rise 1175 m above the Thukela Valley near the town. The location of the study area is shown in Figure 215.

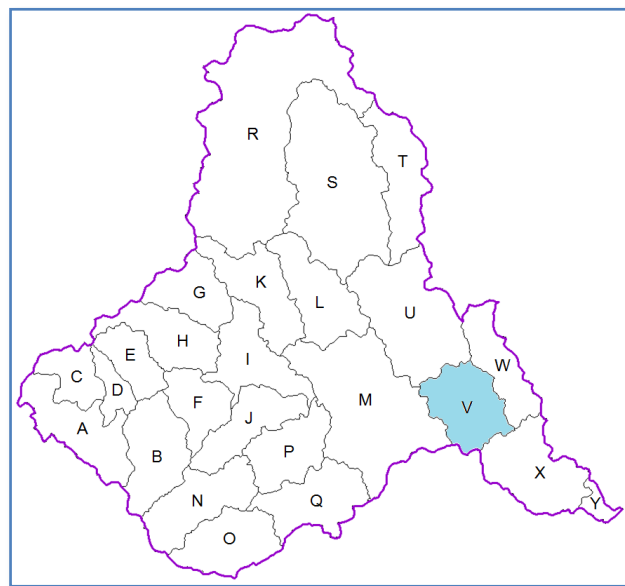


Figure 215: Location of RUV

27.2 Climate

Rainfall ranges from 700 to 900 mm per year and temperatures are mild or subtropical.

27.3 Vegetation (taken from www.deat.gov.za)

The flora has transitional Tongoland-Pondoland and Afromontane affinities. The closed canopy is up to 6 m in height and woody evergreen species are dominant, rather than succulent trees or shrubs. There is a great diversity of species in this thicket type.

27.4 Demography and Landcover

The total population is 27250 (2001 census data). There are cultivated lands (including sugar cane) which are mostly semi-commercial or subsistence farmers. There are numerous forests with the study area. The landcover is shown Figure 216.

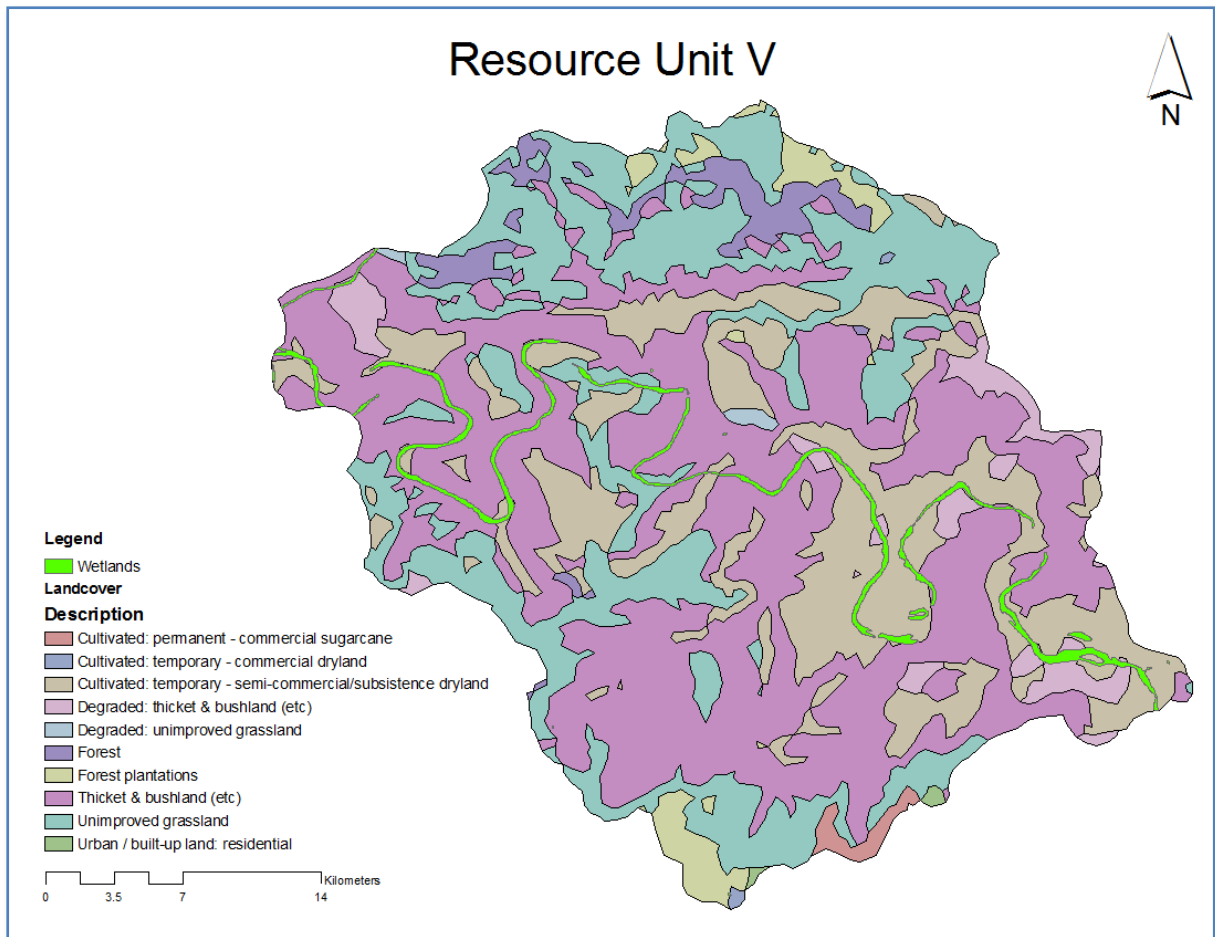


Figure 216: Landcover within RU

27.5 Surface Water

The main river flowing through the study area is the Thukela River. The main tributaries of the Thukela River include: Mfongosi, Manyane, Ngcaza and Mamdeni Rivers.

27.6 Wetlands

The wetlands in the study area are shown in Figure 216.

27.7 Soils (taken from www.deat.gov.za)

The soils vary from sandy clays and lithosols of the Dwyka and Ecca Formations, to deep solonetic soils derived from dolerites of the Beaufort Group.

27.8 *Geology (summarised from Woodford and Chevallier, 2002)*

The Dwyka sediments, which are situated at the base of the Karoo Supergroup, have been deposited on older Precambrian granitic rocks in the north and sedimentary rocks, associated with the Cape Fold Belt in the south. The Dwyka Formation mainly consists of Dwyka diamictite—angular to rounded clasts of the basement rocks, embedded in a clay and silt matrix. However, varved shales, sandstone layers and conglomerates, typical of a fluvio-glacial environment, are also present. The Dwyka diamictite, shales and tillites have very low hydraulic conductivities [$\sim 10^{-11}$ to 10^{-12} m/s], and virtually no primary voids. They therefore tend to form more aquitards than aquifers. The few sandstone bodies deposited in the glacial valleys of the northern facies are very limited in extent, and sealed off by the diamictite. The aquifers in them are therefore limited and often only contain fossil water. Since the Dwyka sediments were deposited mainly under marine conditions, the water in these aquifers tends to be saline.

The Pietermaritzburg Formation (of the Ecca Group) comprises dark, upward coarsening, silty mudrock, which is heavily bioturbated. Pene-contemporaneously deformed sandy and silty beds appear near the top of the formation.

The Vryheid Formation (of the Ecca Group) comprises mudrock, rhythmite, siltstone and fine- to coarse-grained sandstone (pebbly in places). The Formation contains up to five (mineable) coal seams. The different lithofacies are mainly arranged in upward-coarsening deltaic cycles (up to 80m thick in the southeast). Linear coastline cycles are, however, fairly common particularly in the thin northwestern part where they constitute the entire Vryheid in places. A relatively thin fluvial interval (60 m thick) which grades distally into deltaic deposits towards the southwest and south occurs approximately in the middle of the formation in the east and northeast. Fining-upward fluvial cycles, of which up to six are present in the east, are typically sheet-like in geometry, although some form valley-fill deposits. They comprise coarse-grained to pebbly, immature sandstones - with an abrupt upward transition into fine-grained sediments and coal seams.

The Volksrust Formation (of the Ecca Group) is a predominantly argillaceous unit, which interfingers with the overlying Beaufort Group and underlying Vryheid Formation. The Formation consists of grey to black, silty shale with thin, usually bioturbated, siltstone or sandstone lenses and beds, particularly towards its upper and lower boundaries. Thin phosphate and carbonate beds and concretions are relatively common.

Since these shales are very dense, they were often neglected as sources of groundwater in the past. The prodelta sandstones represent another formation of the Ecca Group in which one would expect to find high-yielding aquifers. Unfortunately, the permeabilities of these sandstones are also usually very low.

27.9 Geohydrology

1.1.191 Groundwater levels

It is clear the groundwater levels follow the topography as seen from Figure A1 in Appendix A and therefore groundwater contour maps were generated using Bayesian interpolation. The groundwater levels for the study area are shown in Figure 217. The most probable depth to groundwater level in the RU is 8.9 mbgl according to the histogram of water levels in the RU shown in Appendix A. Groundwater levels are expected to be lower than normal due to the prevailing drought conditions. Unfortunately very little time series water level data are available to quantify the overall impact.

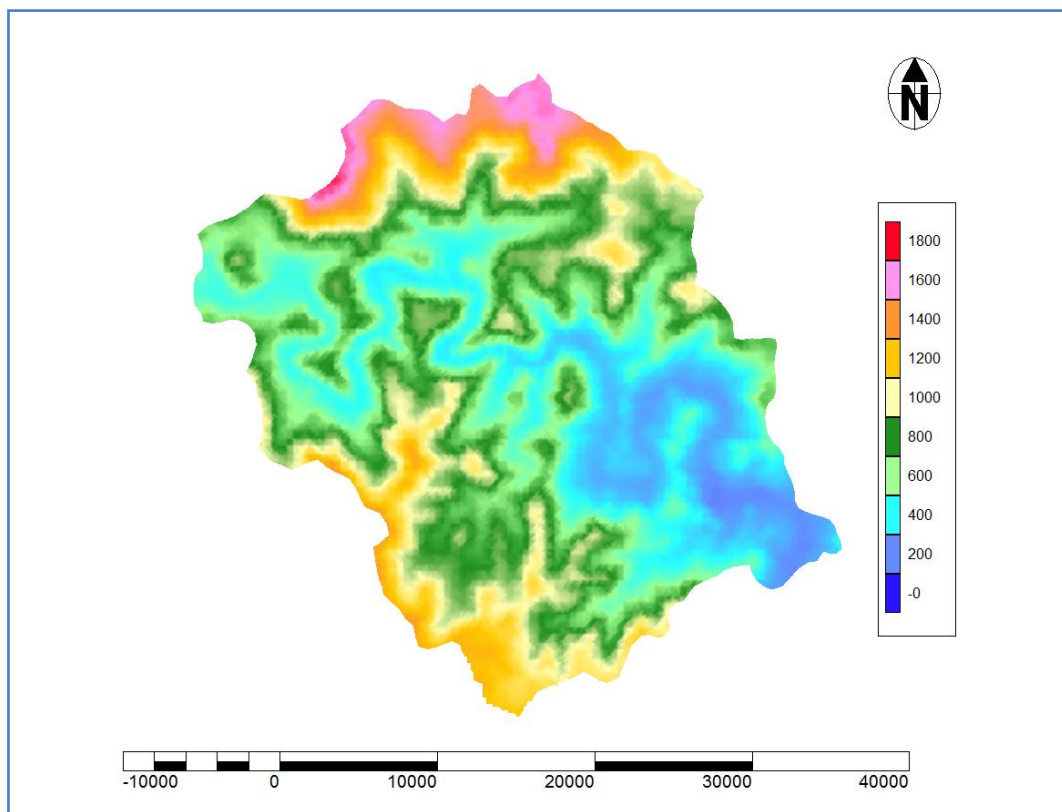


Figure 217: Groundwater levels in RUV

27.9.1 Groundwater recharge

The groundwater recharge calculated from the different methods is listed in Table 164. The different recharge methods applied are discussed in Section 2.3. The final recharge values for the RU are highlighted in red.

Table 164: Recharge values

Recharge							
MAP Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Volume Mm ³ /a	Calculated %	CMB %	Land Cover %	Geology %
781.802	30.893	62.751	52.764	6.7%	6.7%	3.1%	3.1%

1.1.192 Basic human needs

The method for determining BHNs is discussed in Section 2.3. The final value for the study area is highlighted in red in Table 165.

Table 165: Basic human needs

Basic Human Need		
Census(2001) Adjusted	Dependence 18%	Estimate Mm ³ /a
31338	5641	0.051

1.1.193 Groundwater contribution to baseflow

The baseflow separation curves for the RU are shown in Figures 218 – 220.

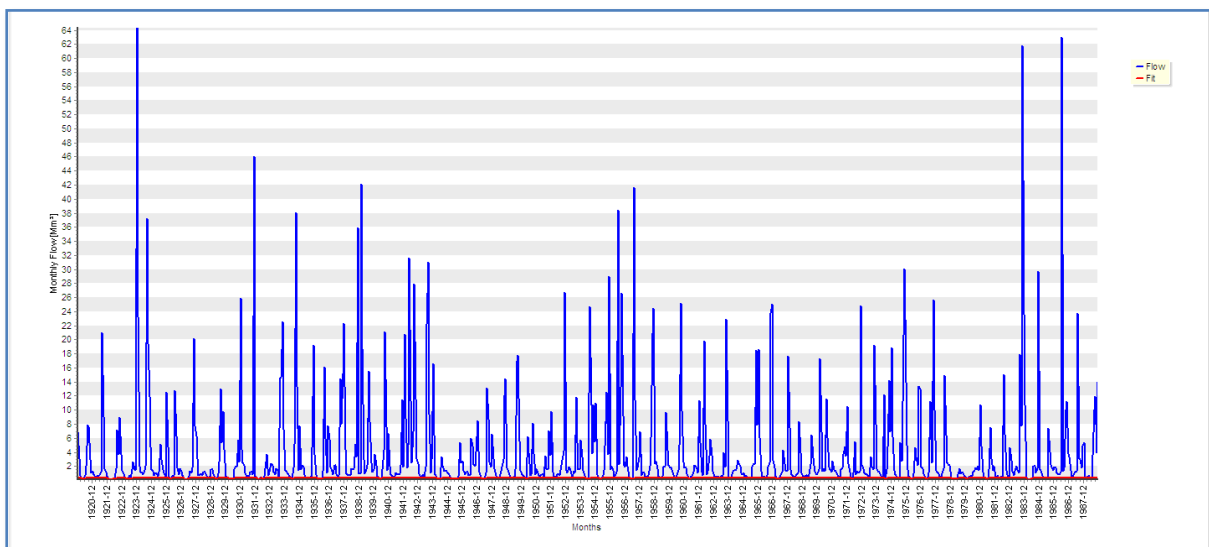


Figure 218: Baseflow separation for quaternary catchment V40A

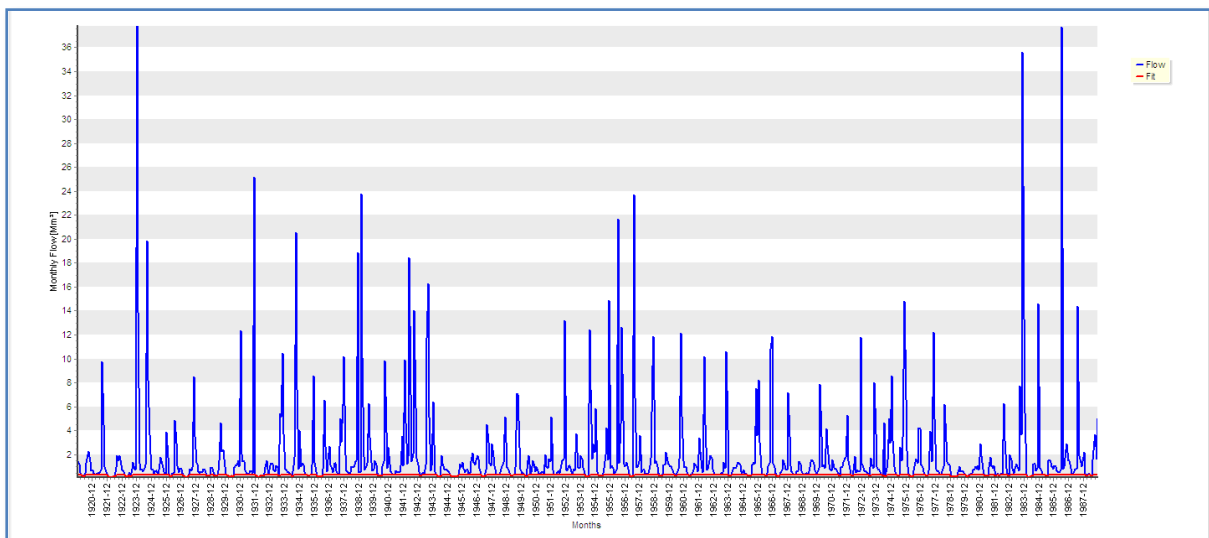


Figure 219: Baseflow separation for quaternary catchment V40B

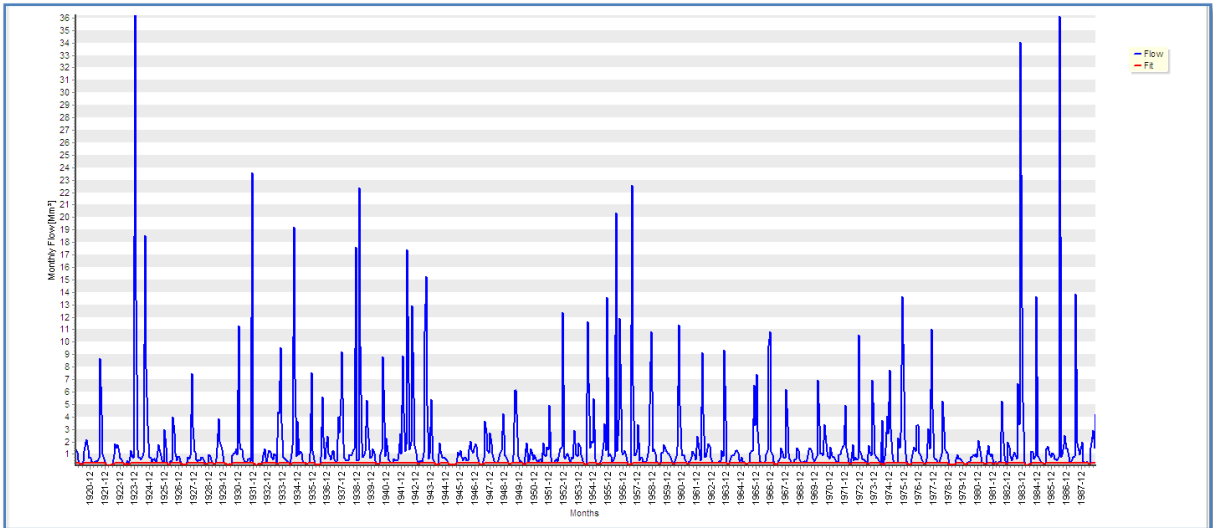


Figure 220: Baseflow separation for quaternary catchment V40E

The final groundwater contribution to baseflow values for the RU is highlighted in red in Table 166.

Table 166: Groundwater contribution to baseflow

Groundwater Contribution to Baseflow							
GRDM Mm ³ /a	Hughes Mm ³ /a	Shultz Mm ³ /a	Pitman Mm ³ /a	vTonder Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Herold Mm ³ /a
15.120	36.966	18.445	11.042	17.830	11.042	36.966	11.490

1.1.194 Groundwater use

The groundwater use for the RU is listed in Table 167.

Table 167: Groundwater use

Groundwater Use							
GRDM Mm ³ /a	WARMs Mm ³ /a	Hydrocensus Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Forrest Mm ³ /a	Crops Mm ³ /a	TOTAL Mm ³ /a
0.290	0.000	0.400	0.000	1.600	0.360	0.000	0.309

1.1.195 Groundwater quality

The TDS values for the RU are shown in Figure 221. They are classified according to SABS standards for Figure 20. Not all boreholes have quality data available but those that do can be used to identify possible hot spots with regard to quality in the resource unit. The overall quality of the resource unit is well within the drinking water guidelines with the exception of one borehole. These areas should be treated as hotspots rather than penalising the whole resource unit with a poor classification. Treatment of the hotspot areas will be addressed under Resource Quality Objectives in Section 31.

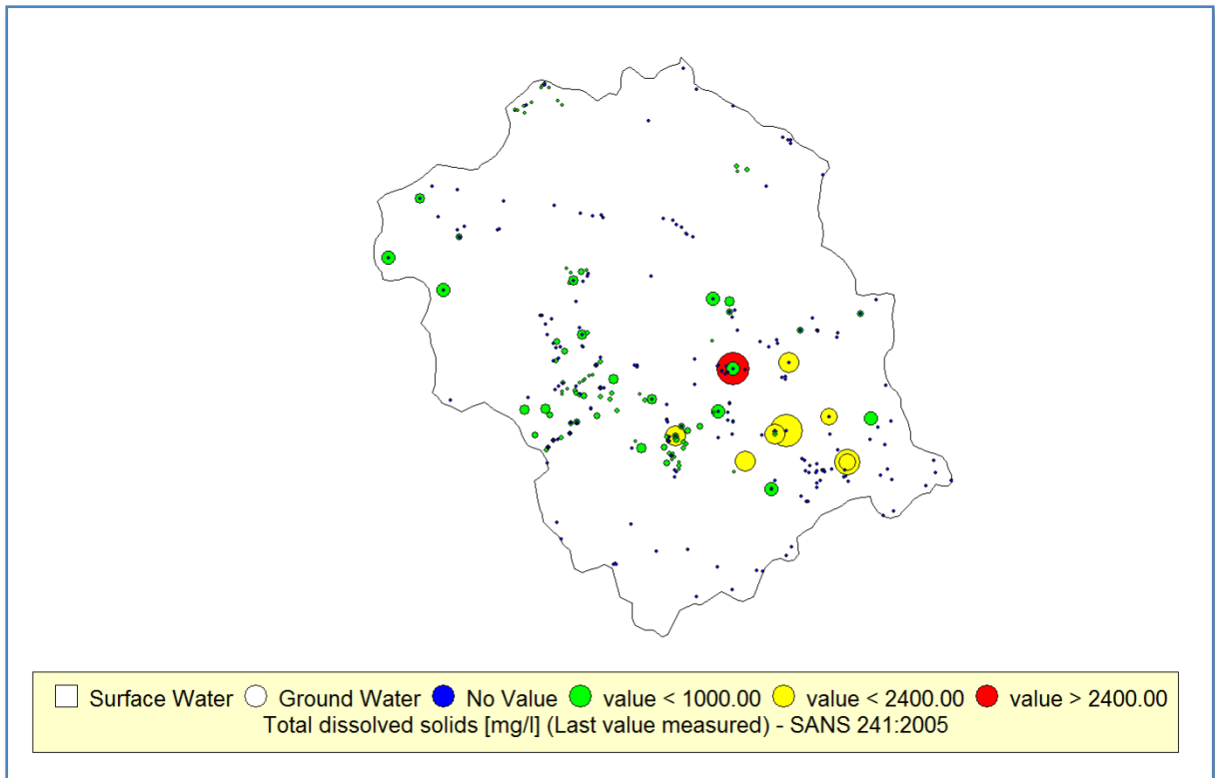


Figure 221: TDS values

1.1.196 Aquifer vulnerability

The aquifer vulnerability calculations are summarised in Table 168. The slope histogram is documented in Appendix B.

Table 168: Aquifer vulnerability

Aquifer Vulnerability						
Level mbgl	Recharge %	Slope %	Soil Texture	Aquifer Type	Vadose Zone	Vulnerability %
8.9	6.7%	2.0	SaClLm-SaCl	Weathered/Fractured	Karoo(southern)	56%

27.10 Classification

1.1.197 Groundwater usage

The stress index, defined as the ratio between total groundwater use and recharge, for the study area is calculated at 22%. Due to the uncertainty associated with the groundwater use component, the stress index was stochastically modelled through assigning a normal distribution curve with a standard deviation of 0.031 Mm³/a to the groundwater use estimate to account for the associated uncertainty. The stochastic results are shown in Figure 222. It is clear from the results that the stress index will vary between 22% and 23% with a certainty of 99.36%. Due to the small variability in the obtained range and high certainty, the uncertainty in the groundwater use component will not affect the calculated stress index significantly.

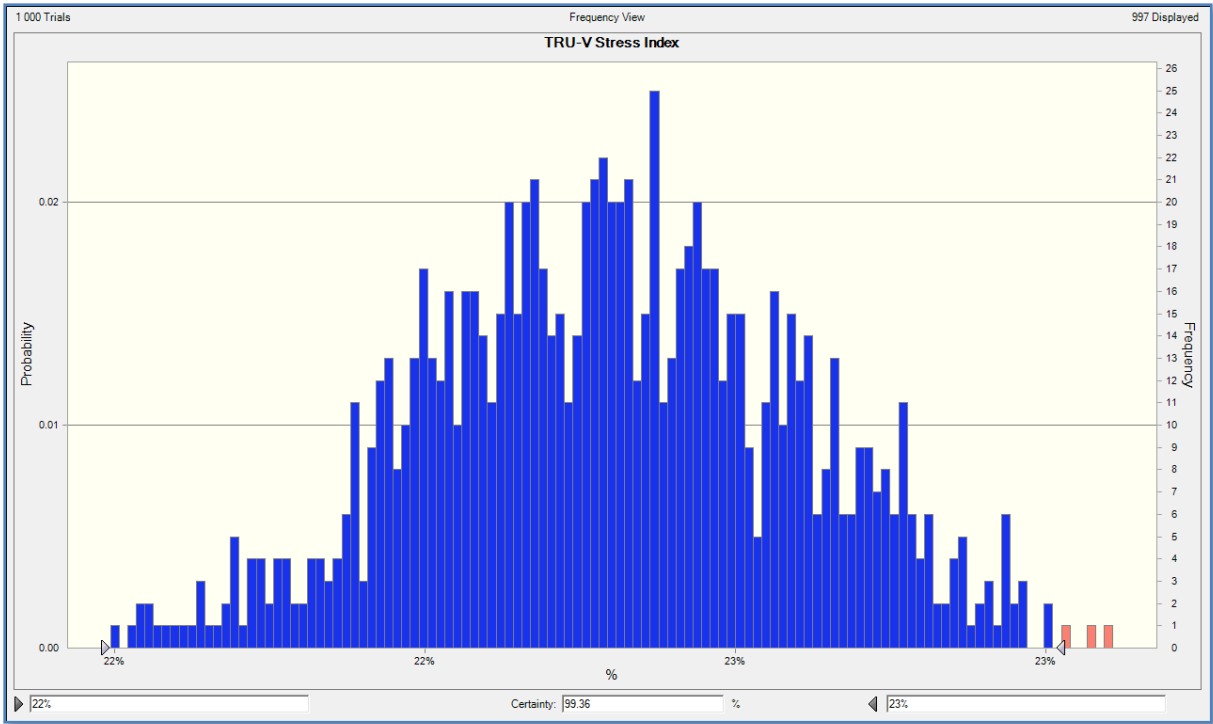


Figure 222: Stochastic results

1.1.198 Quality

The expanded Durov diagram with the groundwater quality is shown in Figure 223. An explanation of the classification process by means of the expanded Durov diagram is given in Section 2.3. There are numerous boreholes in categories A and C, however there are some boreholes in the E category overall water quality is relatively good therefore the final category was set as a C.

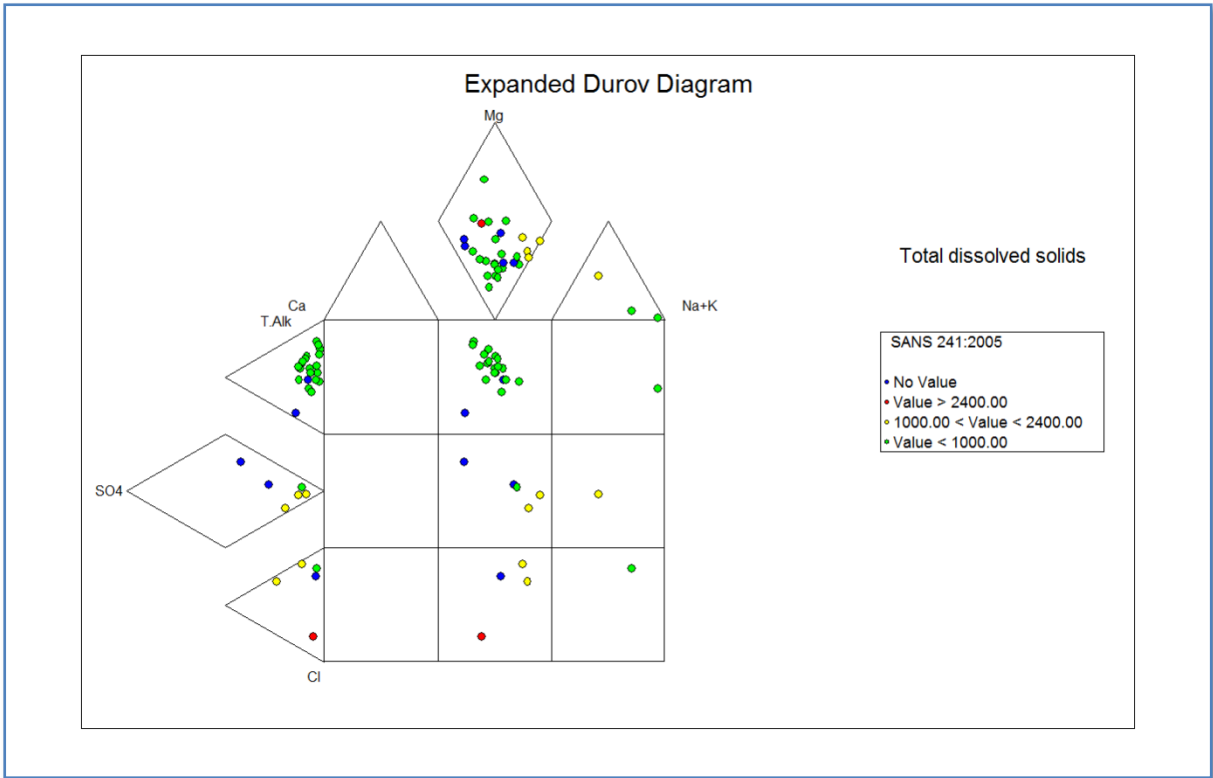


Figure 223: Expanded Durov diagram for RU

As documented in the vulnerability is 56%. The impact of potential contamination according to Section 2.3 is low.

1.1.199 Final category

The final category for the RU is summarised in Table 169.

Table 169: Category for RU

Impact	Present status category	Water resource category
Groundwater usage	C	Good/Fair
Groundwater contamination	C	Good/Fair
Potential groundwater contamination (vulnerability and impact)	B	Good
FINAL	B/C	Good/Fair

27.11 Quantification of the Reserve

The groundwater Reserve for the RU is summarised in Table 170.

Table 170: Reserve

Reserve			Allocation	
Baseflow Mm ³ /a	BHN Mm ³ /a	Reserve % Recharge	Allocation Mm ³ /a	Current Use Mm ³ /a
11.490	0.051	22%	40.914	0.309

28. Classification and the Reserve for Resource Unit W

28.1 Location

Quaternary catchments V40C and V40D are included in this RU. The Qudeni is the only town included in the area. The Nkandla protected area is located within the RU. The location of the RU is shown in Figure 224.

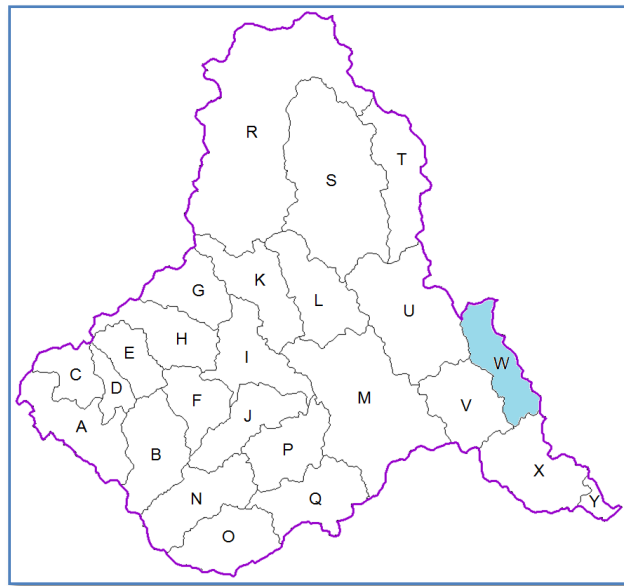


Figure 224: Location of RUW

28.2 Climate

The area is cooler and drier than the coastal belt, with a rainfall of 800 to 850 mm per year. Mean daily temperatures in January are around 22°C with a maximum of about 28°C. July mean temperatures are around 14°C with minima as low as 7°C.

28.3 Vegetation (taken from www.deat.gov.za)

The vegetation is an open Sweet Thorn *Acacia karroo* savanna or scrub, with Ngongoni Bristlegrass *Aristida junciformis* almost entirely dominant. At well preserved sites other species include Redgrass. Forbs such as Natal Vernonia *Vernonia natalensis*, Wild Verbena *Pentanisia prunelloides*, Rasp Thistlethorn *Berkheya setifera*, *Thunbergia atriplicifolia* and *Tephrosia macropoda* are abundantly present.

28.4 Demography and Landcover

The total population is 20650 (2001 census data). There are cultivated lands which are mostly semi-commercial or subsistence farmers. There are numerous forests with the study area. The landcover is shown in Figure 225.

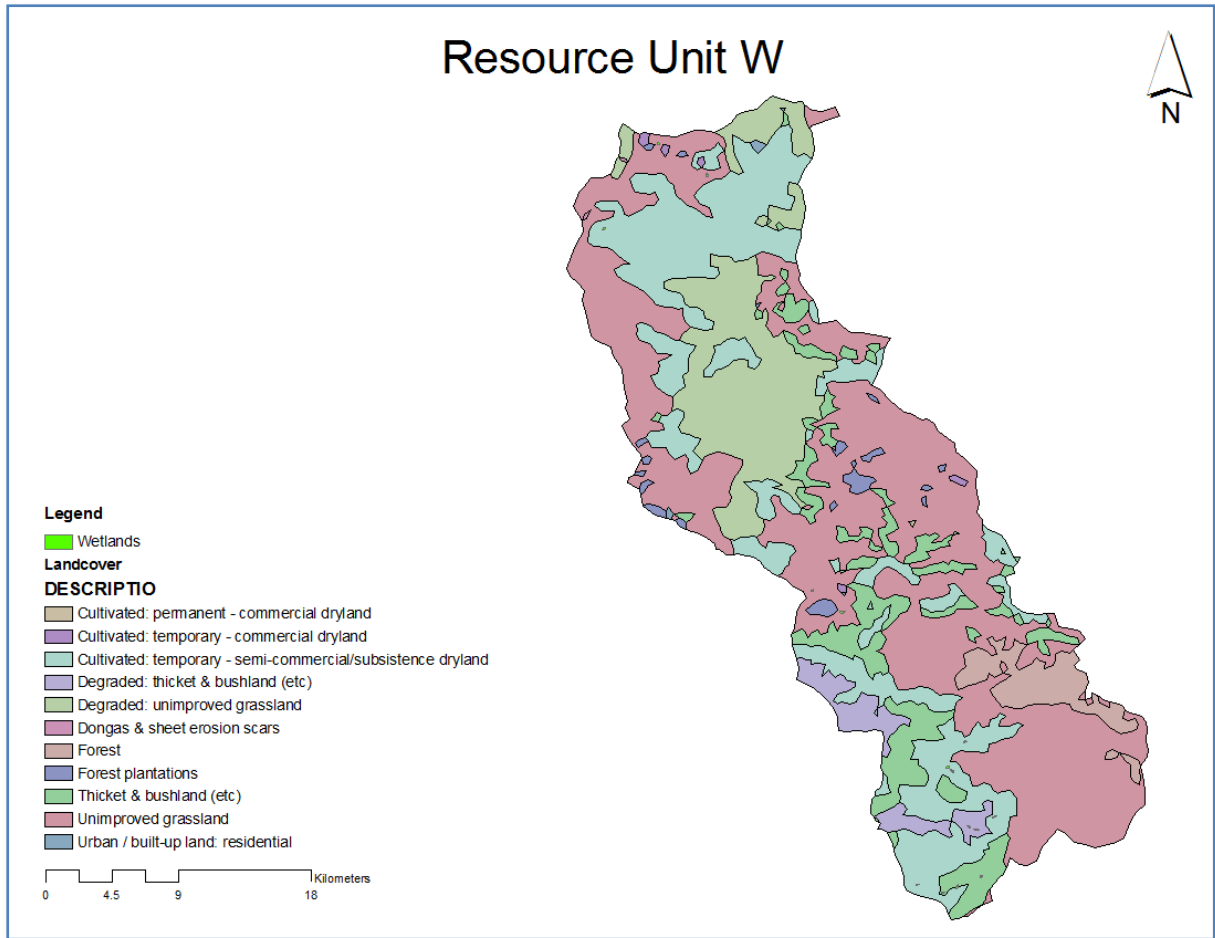


Figure 225: Landcover within the RU

28.5 Surface Water

The Nsuzi River flows through the study area.

28.6 Soils (taken from www.deat.gov.za)

Soils are weakly developed, with shallow topsoils underlain by a lithocutanic B horizon. Where soil development has proceeded further, red or black clays may characterise the subsoil.

28.7 Geology (summarised from Woodford and Chevallier, 2002)

The Dwyka sediments, which are situated at the base of the Karoo Supergroup, have been deposited on older Precambrian granitic rocks in the north and sedimentary rocks, associated with the Cape Fold Belt in the south. The Dwyka Formation mainly consists of Dwyka diamictite—angular to

rounded clasts of the basement rocks, embedded in a clay and silt matrix. However, varved shales, sandstone layers and conglomerates, typical of a fluvio-glacial environment, are also present. The Dwyka diamictite, shales and tillites have very low hydraulic conductivities [$\sim 10^{-11}$ to 10^{-12} m/s], and virtually no primary voids. They therefore tend to form more aquitards than aquifers. The few sandstone bodies deposited in the glacial valleys of the northern facies are very limited in extent, and sealed off by the diamictite. The aquifers in them are therefore limited and often only contain fossil water. Since the Dwyka sediments were deposited mainly under marine conditions, the water in these aquifers tends to be saline.

The Pietermaritzburg Formation (of the Ecca Group) comprises dark, upward coarsening, silty mudrock, which is heavily bioturbated. Pene-contemporaneously deformed sandy and silty beds appear near the top of the formation.

The Vryheid Formation (of the Ecca Group) comprises mudrock, rhythmite, siltstone and fine- to coarse-grained sandstone (pebbly in places). The Formation contains up to five (mineable) coal seams. The different lithofacies are mainly arranged in upward-coarsening deltaic cycles (up to 80m thick in the southeast). Linear coastline cycles are, however, fairly common particularly in the thin northwestern part where they constitute the entire Vryheid in places. A relatively thin fluvial interval (60 m thick) which grades distally into deltaic deposits towards the southwest and south occurs approximately in the middle of the formation in the east and northeast. Fining-upward fluvial cycles, of which up to six are present in the east, are typically sheet-like in geometry, although some form valley-fill deposits. They comprise coarse-grained to pebbly, immature sandstones - with an abrupt upward transition into fine-grained sediments and coal seams.

The Volksrust Formation (of the Ecca Group) is a predominantly argillaceous unit, which interfingers with the overlying Beaufort Group and underlying Vryheid Formation. The Formation consists of grey to black, silty shale with thin, usually bioturbated, siltstone or sandstone lenses and beds, particularly towards its upper and lower boundaries. Thin phosphate and carbonate beds and concretions are relatively common.

Since these shales are very dense, they were often neglected as sources of groundwater in the past. The prodelta sandstones represent another formation of the Ecca Group in which one would expect to find high-yielding aquifers. Unfortunately, the permeabilities of these sandstones are also usually very low.

The Tugela Terrane is an allochthonous ophiolite complex comprising of rocks of oceanic affinities which was thrust northwards onto the southern flank of the Kaapvaal Craton. This Group consists of quartzite, schists, gneisses, gabbros and norites.

28.8 Geohydrology

1.1.200 Groundwater levels

It is clear the groundwater levels follow the topography as seen from Figure A1 in Appendix A and therefore groundwater contour maps were generated using Bayesian interpolation. The groundwater levels for the study area are shown in Figure 226. The most probable depth to groundwater level in the RU is 5.5 mbgl according to the histogram of water levels in the RU shown in Appendix A. Groundwater levels are expected to be lower than normal due to the prevailing drought conditions. Unfortunately very little time series water level data are available to quantify the overall impact.

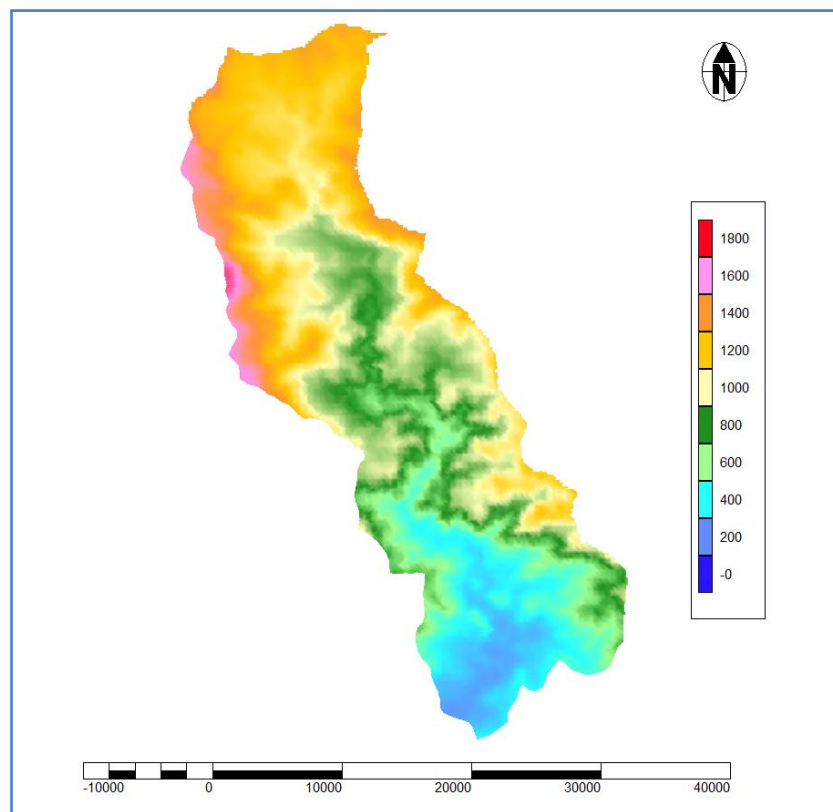


Figure 226: Groundwater levels in RUW

28.8.1 Groundwater recharge

The groundwater recharge calculated from the different methods is listed in Table 171. The different recharge methods applied are discussed in Section 2.3. The final recharge values for the RU are highlighted in red.

Table 171: Recharge values

Recharge							
MAP Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Volume Mm ³ /a	Calculated %	CMB %	Land Cover %	Geology %
651.634	34.309	51.233	26.065	4.0%	4.0%	3.2%	3.0%

1.1.201 Basic human needs

The method for determining BHNs is discussed in Section 2.3. The final value for the study area is highlighted in red in Table 172.

Table 172: Basic human needs

Basic Human Need		
Census(2001) Adjusted	Dependence 18%	Estimate Mm ³ /a
23748	4275	0.038

1.1.202 Groundwater contribution to baseflow

The baseflow separation curves for the RU are shown in Figures 227 & 228.

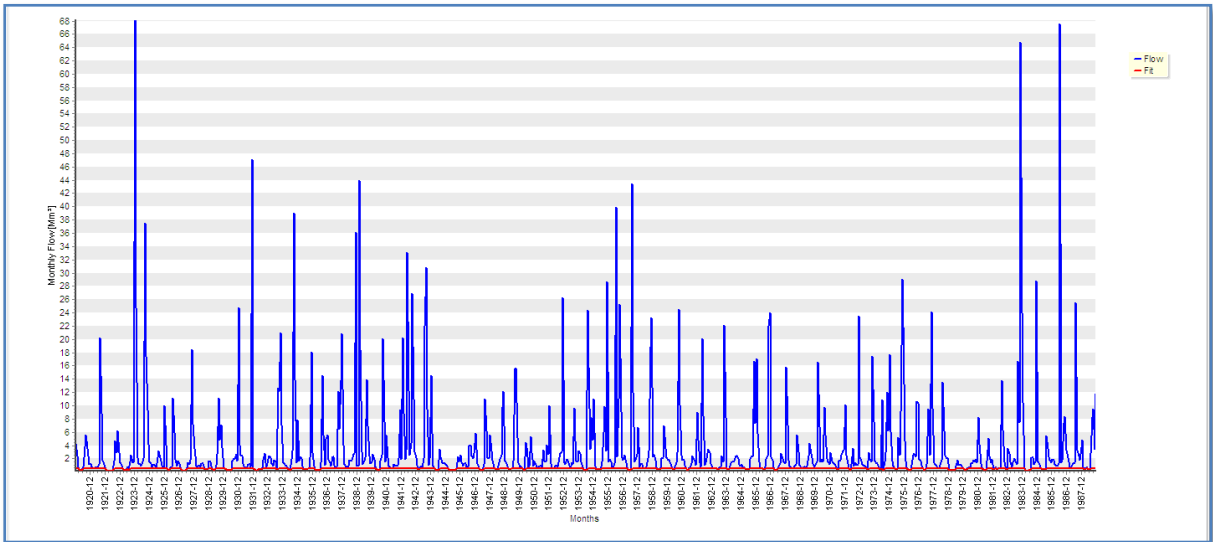


Figure 227: Baseflow separation for quaternary catchment V40C

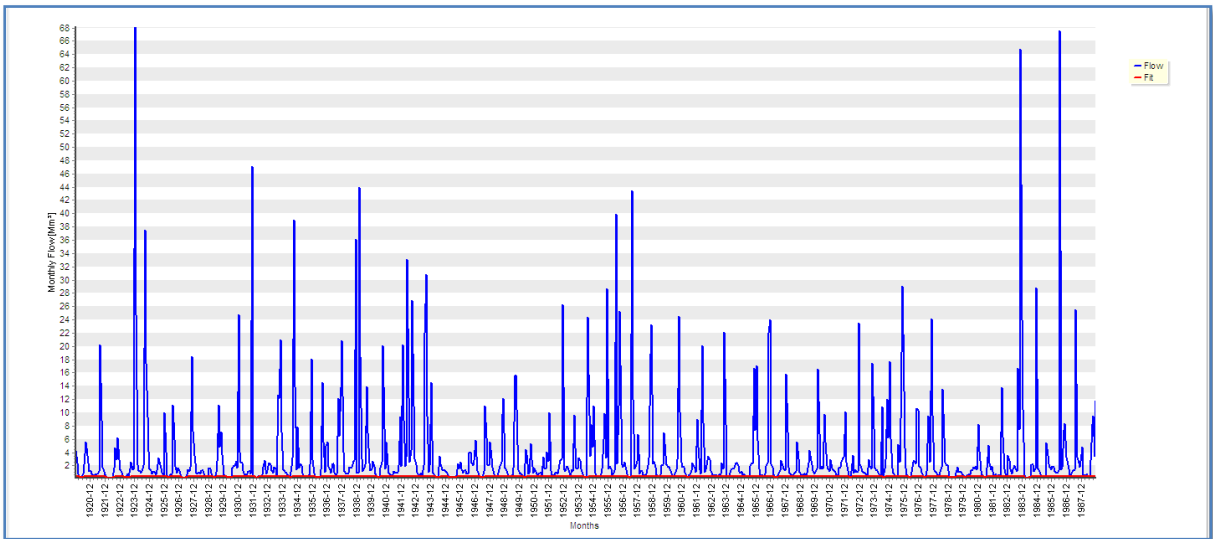


Figure 228: Baseflow separation for quaternary catchment V40D

The final groundwater contribution to baseflow values for the RU is highlighted in red in Table 173.

Table 173: Groundwater contribution to baseflow

Groundwater Contribution to Baseflow							
GRDM Mm ³ /a	Hughes Mm ³ /a	Shultz Mm ³ /a	Pitman Mm ³ /a	vTonder Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Herold Mm ³ /a
14.301	30.433	15.610	9.133	14.842	9.133	30.433	10.380

1.1.203 Groundwater use

The groundwater use for the RU is listed in Table 174.

Table 174: Groundwater use

Groundwater Use							
GRDM Mm ³ /a	WARMS Mm ³ /a	Hydrocensus Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Forrest Mm ³ /a	Crops Mm ³ /a	TOTAL Mm ³ /a
0.370	0.000	0.444	0.000	1.776	0.547	0.000	0.509

1.1.204 Groundwater quality

The TDS values for the RU are shown in Figure 229. They are classified according to SABS standards. Not all boreholes have quality data available but those that do can be used to identify possible hot spots with regard to quality in the resource unit. The overall quality of the resource unit is well within the drinking water guidelines with the exception of one borehole which is classified as allowable.

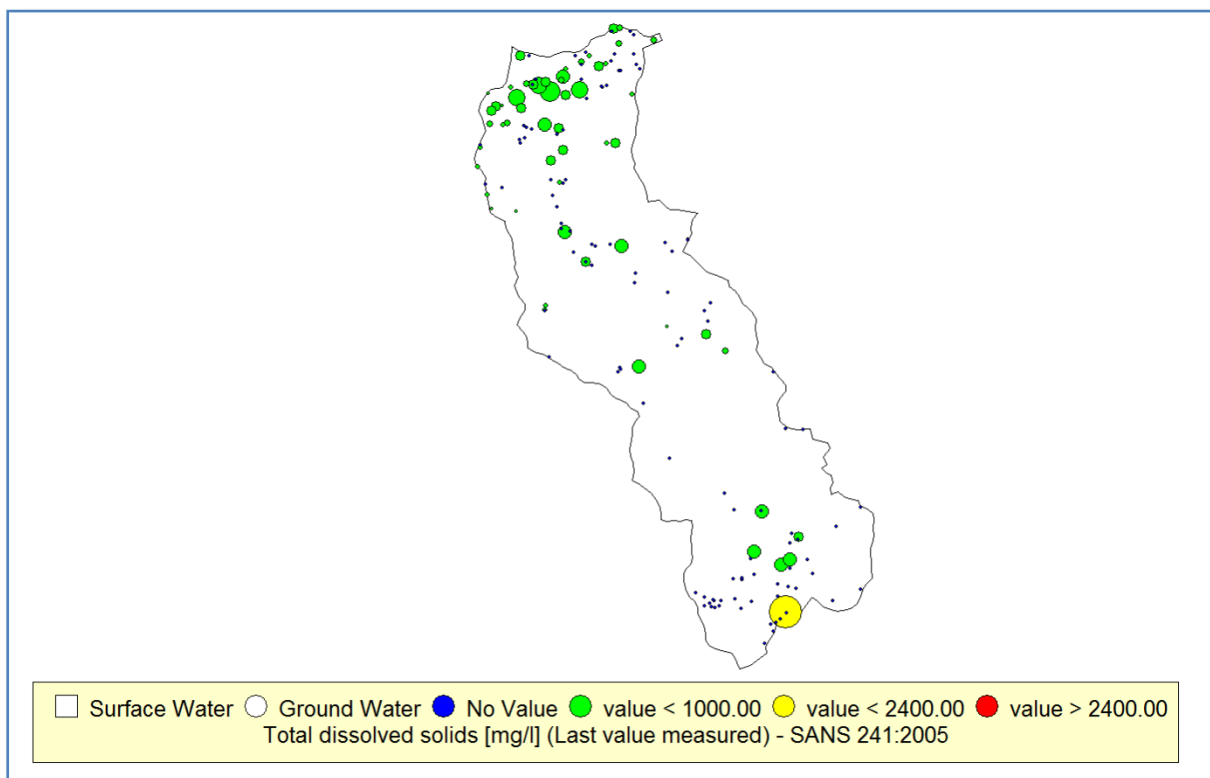


Figure 229: TDS values

1.1.205 Aquifer vulnerability

The aquifer vulnerability calculations are summarised in Table 175. The slope histogram is documented in Appendix B.

Table 175: Aquifer vulnerability

Aquifer Vulnerability						
Level mbgl	Recharge %	Slope %	Soil Texture	Aquifer Type	Vadose Zone	Vulnerability %
5.5	4.0%	2.0	SaClLm-SaCl	Weathered/Fractured	Karoo(southern)	56%

28.9 Classification

1.1.206 Groundwater usage

The stress index, defined as the ratio between total groundwater use and recharge, for the study area is calculated at 42%. Due to the uncertainty associated with the groundwater use component, the stress index was stochastically modelled through assigning a normal distribution curve with a standard deviation of 0.051 Mm³/a to the groundwater use estimate to account for the associated uncertainty. The stochastic results are shown in Figure 230. It is clear from the results that the stress index will vary between 41% and 42% with a certainty of 99.04%. Due to the small variability in the obtained range and high certainty, the uncertainty in the groundwater use component will not affect the calculated stress index significantly.

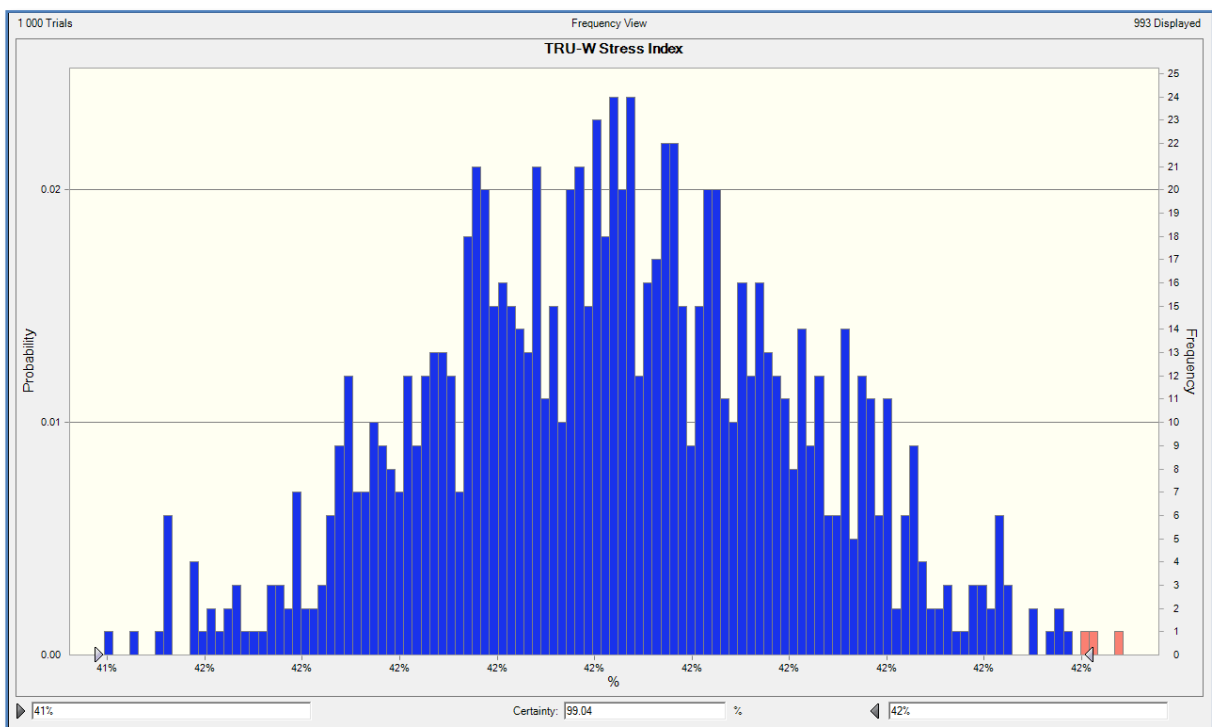


Figure 230: Stochastic results

1.1.207 Quality

The expanded Durov diagram with the groundwater quality is shown in Figure 231. An explanation of the classification process by means of the expanded Durov diagram is given in Section 2.3. There is not sufficient data to generate an expanded Durov diagram.

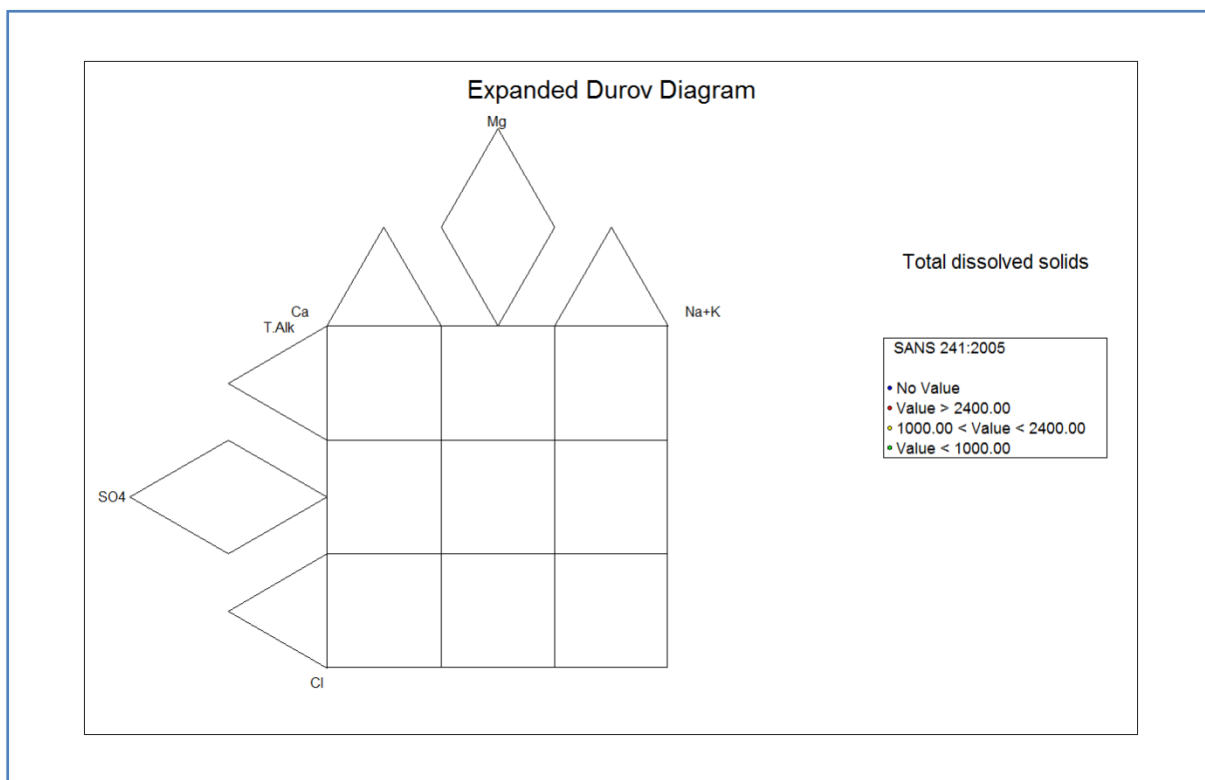


Figure 231: Expanded Durov diagram for RU

As documented the vulnerability is 56%. The impact of potential contamination according to Section 2.3 is low.

1.1.208 Final category

The final category for the RU is summarised in Table 176.

Table 176: Category for RU

Impact	Present status category	Water resource category
Groundwater usage	D	Fair
Groundwater contamination	-	-
Potential groundwater contamination (vulnerability and impact)	B	Good
FINAL	B/C	Good/Fair

28.10 Quantification of the Reserve

The groundwater Reserve for the RU is summarised in Table 177.

Table 177: Reserve

Reserve			Allocation	
Baseflow Mm ³ /a	BHN Mm ³ /a	Reserve % Recharge	Allocation Mm ³ /a	Current Use Mm ³ /a
10.380	0.038	40%	15.138	0.509

29. Classification and the Reserve for Resource Unit X

29.1 Location

The location of this RU is shown in Figure 232. There are no towns within this area. The quaternary catchments included in the area are: V50A, V50B and V50C.

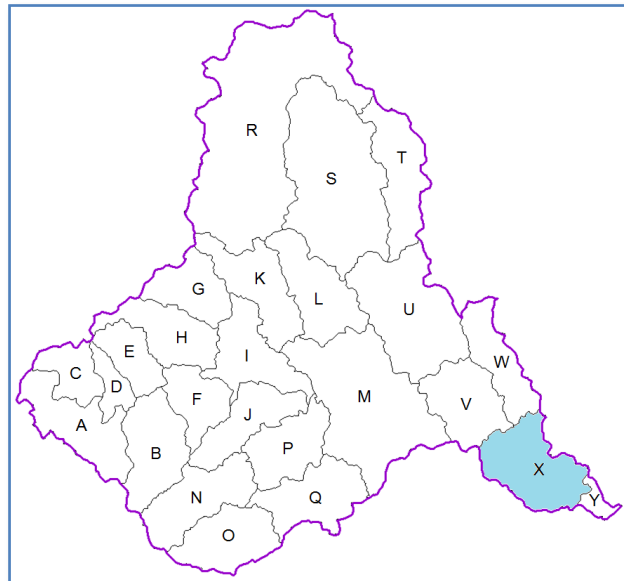


Figure 232: Location of RUX

29.2 Climate

The area is cooler and drier than the coastal belt, with a rainfall of 750 to 1000 mm per year. Mean daily temperatures in January are around 22°C with a maximum of about 28°C. July mean temperatures are around 14°C with minima as low as 7°C.

29.3 Vegetation (taken from www.deat.gov.za)

The vegetation is an open Sweet Thorn *Acacia karroo* savanna or scrub, with Ngongoni Bristlegrass *Aristida junciformis* almost entirely dominant. At well preserved sites other species include Redgrass. Forbs such as Natal Vernonia *Vernonia natalensis*, Wild Verbena *Pentanisia prunelloides*, Rasp Thistlethorn *Berkheya setifera*, *Thunbergia atriplicifolia* and *Tephrosia macropoda* are abundantly present.

29.4 Demography and Landcover

The total population is 77430 (2001 census data). There are cultivated lands (Photo 46) which are mostly semi-commercial or subsistence farmers. There are numerous forests with the study area. The landcover is shown in Figure 233.

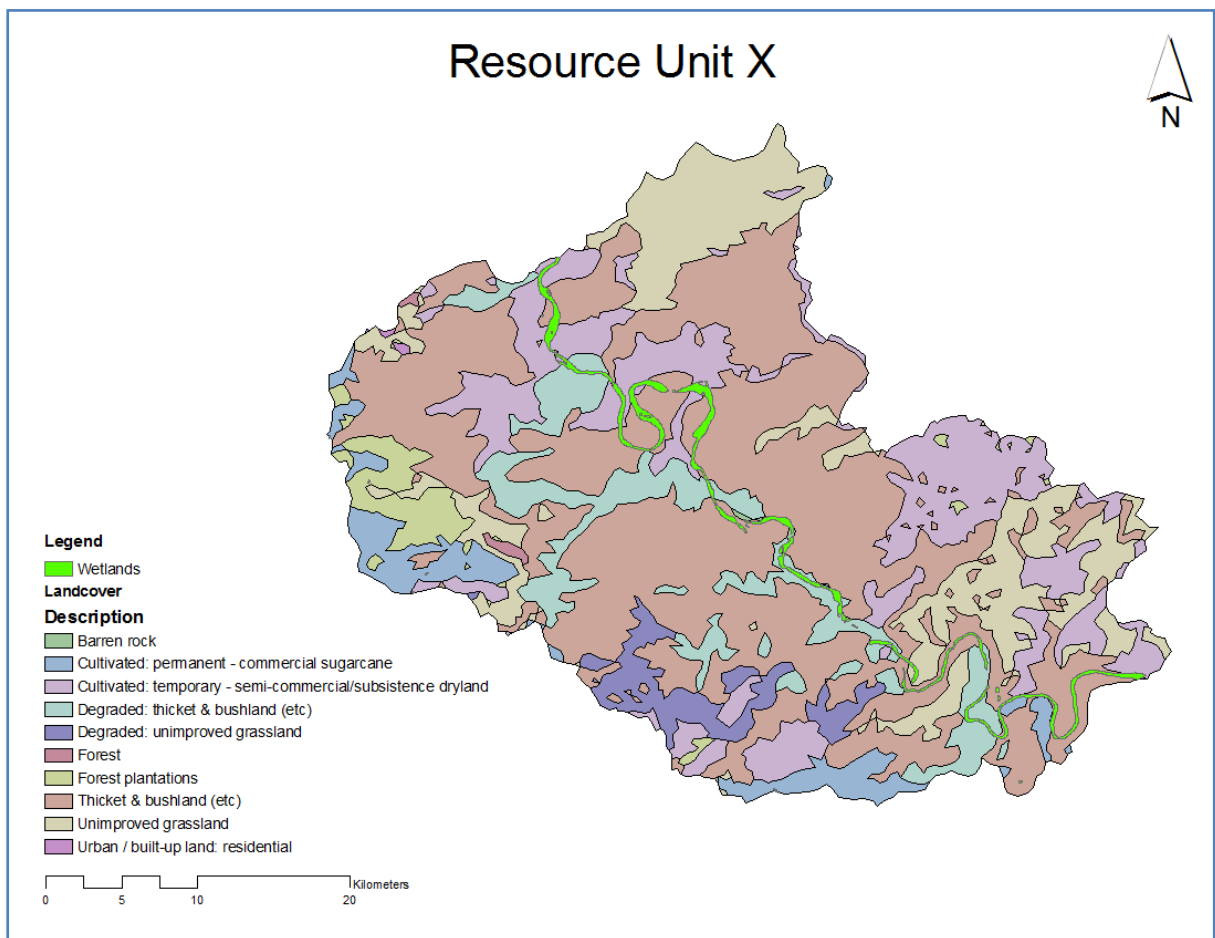


Figure 233: Landcover within RU

29.5 *Surface Water*

The Mamba, Mpisi, Nembe and Nsuze Rivers join the Thukela River.

29.6 *Wetlands*

The wetlands in the RU are shown in Figure 233.

29.7 *Soils (taken from www.deat.gov.za)*

Soils are weakly developed, with shallow topsoils underlain by a lithocutanic B horizon. Where soil development has proceeded further, red or black clays may characterise the subsoil.

29.8 *Geology (summarised from Woodford and Chevallier, 2002)*

The Dwyka sediments, which are situated at the base of the Karoo Supergroup, have been deposited on older Precambrian granitic rocks in the north and sedimentary rocks, associated with the Cape Fold Belt in the south. The Dwyka Formation mainly consists of Dwyka diamictite—angular to rounded clasts of the basement rocks, embedded in a clay and silt matrix. However, varved shales, sandstone layers and conglomerates, typical of a fluvio-glacial environment, are also present. The Dwyka diamictite, shales and tillites have very low hydraulic conductivities [$\sim 10^{-11}$ to 10^{-12} m/s], and virtually no primary voids. They therefore tend to form more aquitards than aquifers. The few sandstone bodies deposited in the glacial valleys of the northern facies are very limited in extent, and sealed off by the diamictite. The aquifers in them are therefore limited and often only contain fossil water. Since the Dwyka sediments were deposited mainly under marine conditions, the water in these aquifers tends to be saline.

The Pietermaritzburg Formation (of the Ecca Group) comprises dark, upward coarsening, silty mudrock, which is heavily bioturbated. Pene-contemporaneously deformed sandy and silty beds appear near the top of the formation.

The Vryheid Formation (of the Ecca Group) comprises mudrock, rhythmite, siltstone and fine- to coarse-grained sandstone (pebbly in places). The Formation contains up to five (mineable) coal seams. The different lithofacies are mainly arranged in upward coarsening deltaic cycles (up to 80m thick in the southeast). Linear coastline cycles are, however, fairly common particularly in the thin northwestern part where they constitute the entire Vryheid in places. A relatively thin fluvial interval (60 m thick) which grades distally into deltaic deposits towards the southwest and south occurs approximately in the middle of the formation in the east and northeast. Fining upward fluvial cycles, of which up to six are present in the east, are typically sheet like in geometry, although some form valley-fill deposits. They comprise coarse grained to pebbly, immature sandstones - with an abrupt upward transition into fine grained sediments and coal seams.

The Volksrust Formation (of the Ecca Group) is a predominantly argillaceous unit, which interfingers with the overlying Beaufort Group and underlying Vryheid Formation. The Formation consists of grey to black, silty shale with thin, usually bioturbated, siltstone or sandstone lenses and beds,

particularly towards its upper and lower boundaries. Thin phosphate and carbonate beds and concretions are relatively common.

Since these shales are very dense, they were often neglected as sources of groundwater in the past. The prodelta sandstones represent another formation of the Ecca Group in which one would expect to find high-yielding aquifers. Unfortunately, the permeabilities of these sandstones are also usually very low.

The Tugela Terrane is an allochthonous ophiolite complex comprising of rocks of oceanic affinities which was thrust northwards onto the southern flank of the Kaapvaal Craton. This Group consists of quartzite, schists, gneisses, gabbros and norites.

29.9 *Geohydrology*

1.1.209 *Groundwater levels*

It is clear the groundwater levels follow the topography as seen from Figure A1 in Appendix A and therefore groundwater contour maps were generated using Bayesian interpolation. The groundwater levels for the study area are shown in Figure 234. The most probable depth to groundwater level in the RU is 10 mbgl according to the histogram of water levels in the RU shown in Appendix A. Groundwater levels are expected to be lower than normal due to the prevailing drought conditions. Unfortunately very little time series water level data are available to quantify the overall impact.

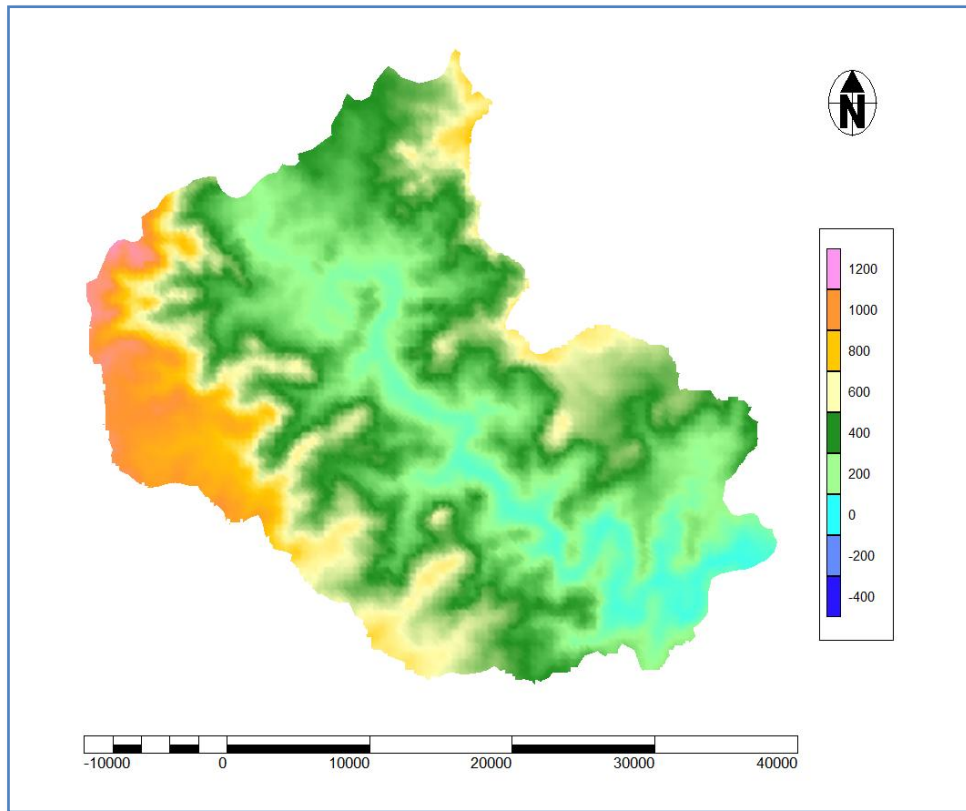


Figure 234: Groundwater levels in RUX

29.9.1 Groundwater recharge

The groundwater recharge calculated from the different methods is listed in Table 178. The different recharge methods applied are discussed in Section 2.3. The final recharge values for the RU are highlighted in red.

Table 178: Recharge values

Recharge							
MAP Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Volume Mm ³ /a	Calculated %	CMB %	Land Cover %	Geology %
1034.326	57.859	80.707	87.847	8.5%	8.5%	2.5%	3.5%

1.1.210 Basic human needs

The method for determining BHNs is discussed in Section 2.3. The final value for the study area is highlighted in red in Table 179.

Table 179: Basic human needs

Basic Human Need		
Census(2001) Adjusted	Dependence 18%	Estimate Mm ³ /a
89047	16028	0.144

1.1.211 Groundwater contribution to baseflow

The baseflow separation curves for the RU are shown in Figures 235 – 237.

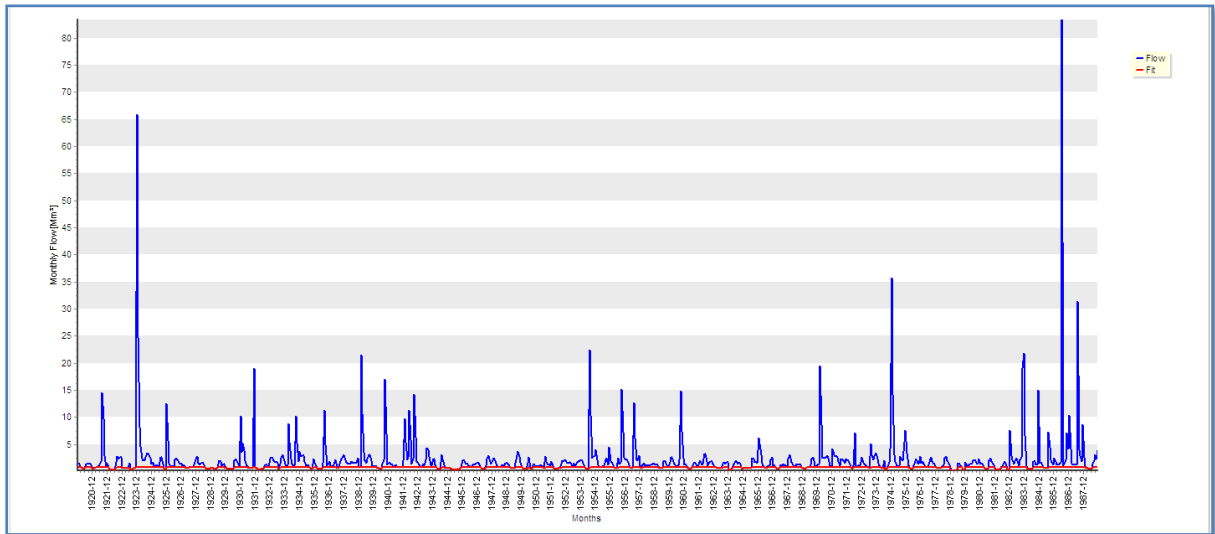


Figure 235: Baseflow separation for quaternary catchment V50A

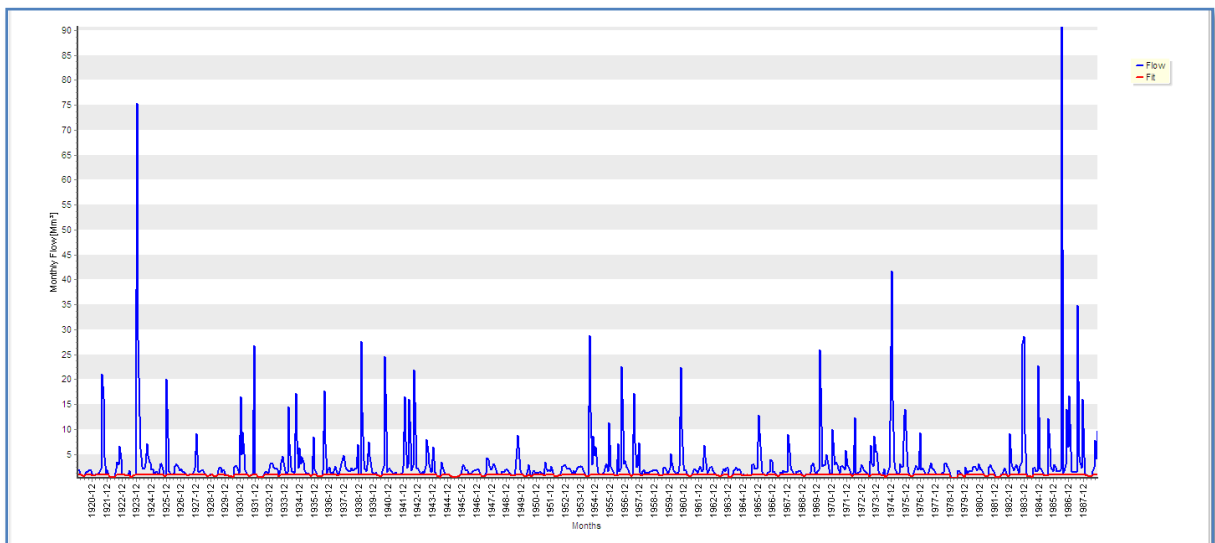


Figure 236: Baseflow separation for quaternary catchment V50B

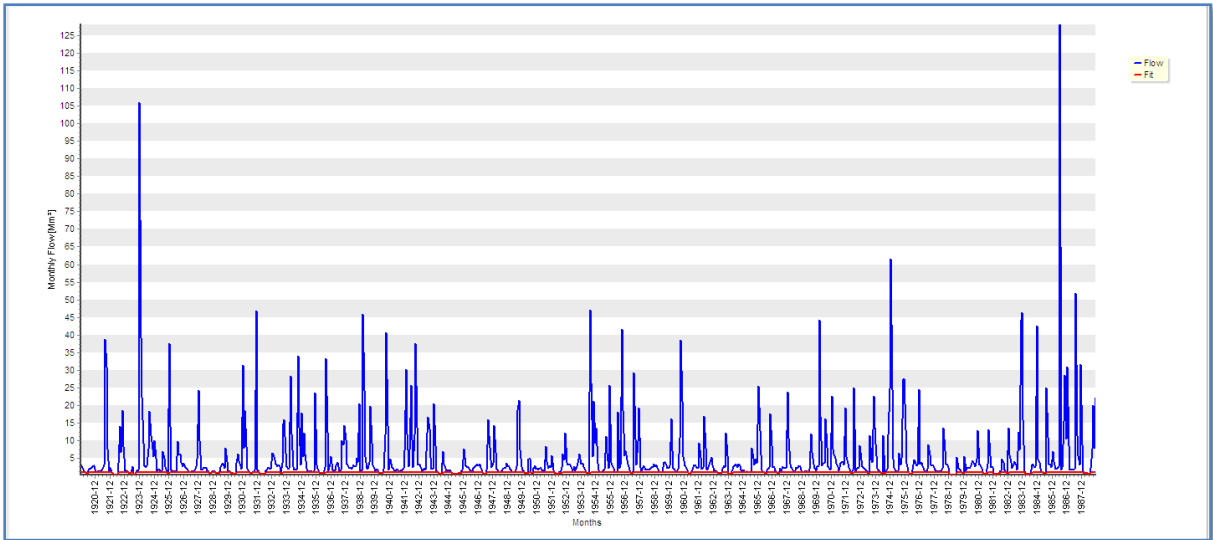


Figure 237: Baseflow separation for quaternary catchment V50D

The final groundwater contribution to baseflow values for the RU is highlighted in red in Table 180.

Table 180: Groundwater contribution to baseflow

Groundwater Contribution to Baseflow							
GRDM Mm ³ /a	Hughes Mm ³ /a	Shultz Mm ³ /a	Pitman Mm ³ /a	vTonder Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Herold Mm ³ /a
24.511	62.405	41.294	33.202	40.767	24.511	62.405	31.700

1.1.212 Groundwater use

The groundwater use for the RU is listed in Table 181.

Table 181: Groundwater use

Groundwater Use							
GRDM Mm ³ /a	WARMS Mm ³ /a	Hydrocensus Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Forrest Mm ³ /a	Crops Mm ³ /a	TOTAL Mm ³ /a
0.450	0.160	0.548	0.160	2.192	3.593	0.965	4.414

1.1.213 Groundwater quality

The TDS values for the RU are shown in Figure 238. They are classified according to SABS standards. Not all boreholes have quality data available but those that do can be used to identify possible hot spots with regard to quality in the resource unit. The overall quality of the resource unit is well within the drinking water guidelines with the exception of one borehole which is allowable.

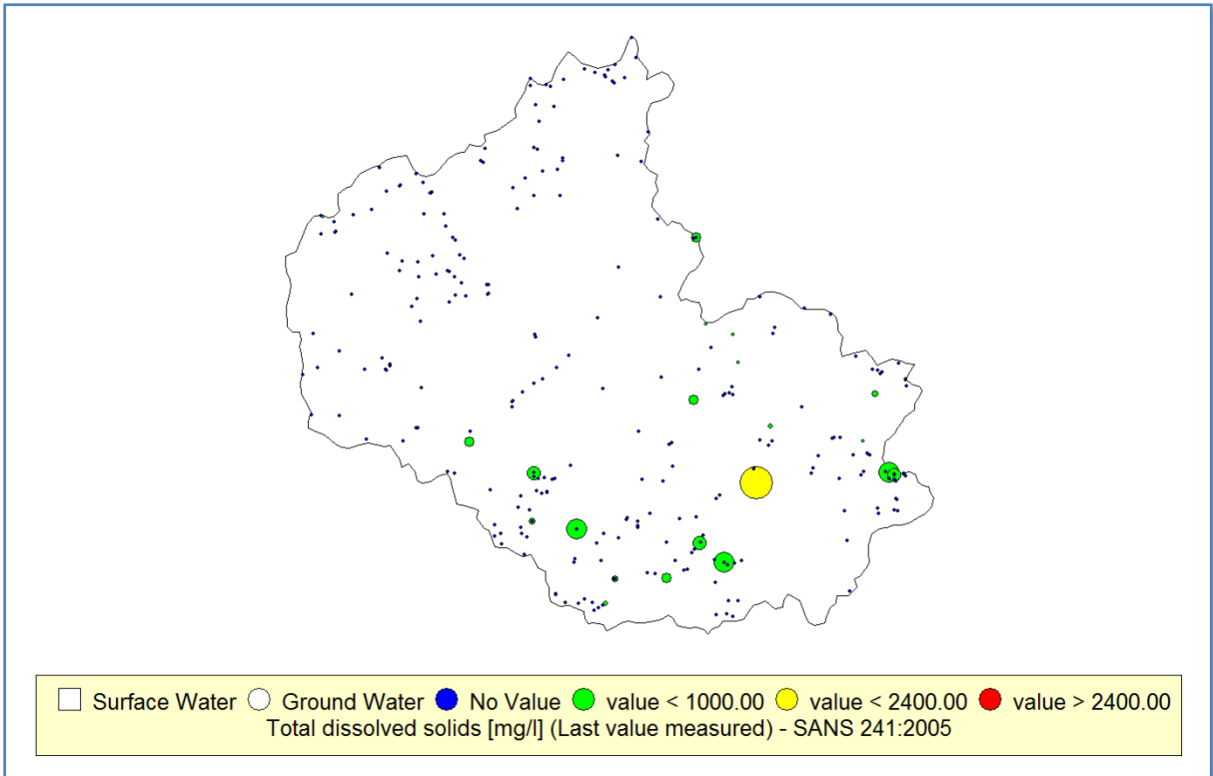


Figure 238: TDS values

1.1.214 Aquifer vulnerability

The aquifer vulnerability calculations are summarised in Table 182. The slope histogram is documented in Appendix B.

Table 182: Aquifer vulnerability

Aquifer Vulnerability						
Level mbgl	Recharge %	Slope %	Soil Texture	Aquifer Type	Vadose Zone	Vulnerability %
10.0	8.5%	1.1	SaCLlm-SaCl	Weathered/Fractured	Karoo(southern)	58%

29.10 Classification

1.1.215 Groundwater usage

The stress index, defined as the ratio between total groundwater use and recharge, for the study area is calculated at 41%. Due to the uncertainty associated with the groundwater use component, the stress index was stochastically modelled through assigning a normal distribution curve with a standard deviation of 0.441 Mm³/a to the groundwater use estimate to account for the associated uncertainty. The stochastic results are shown in Figure 239. It is clear from the results that the stress index will vary between 40% and 42% with a certainty of 98.45%. Due to the small variability in the obtained range and high certainty, the uncertainty in the groundwater use component will not affect the calculated stress index significantly.

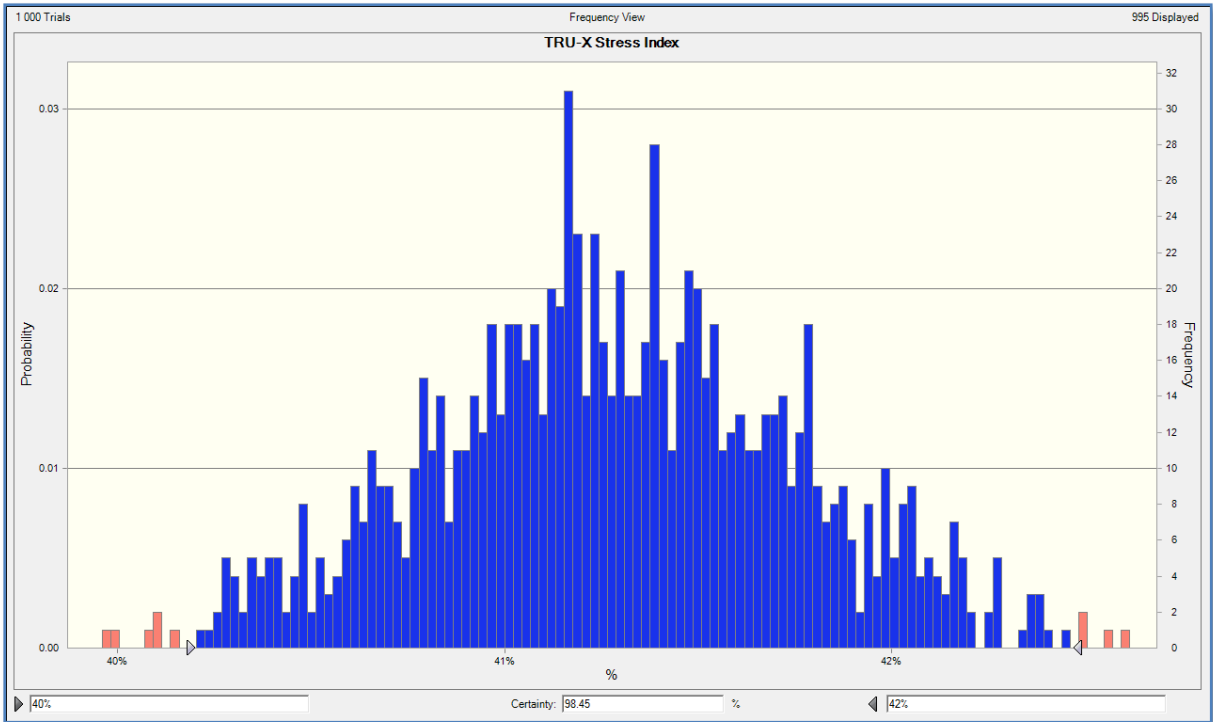


Figure 239: Stochastic results

1.1.216 Quality

The expanded Durov diagram with the groundwater quality is shown in Figure 240. An explanation of the classification process by means of the expanded Durov diagram is given in Section 2.3. There is not sufficient water quality data to generate an expanded Durov diagram.

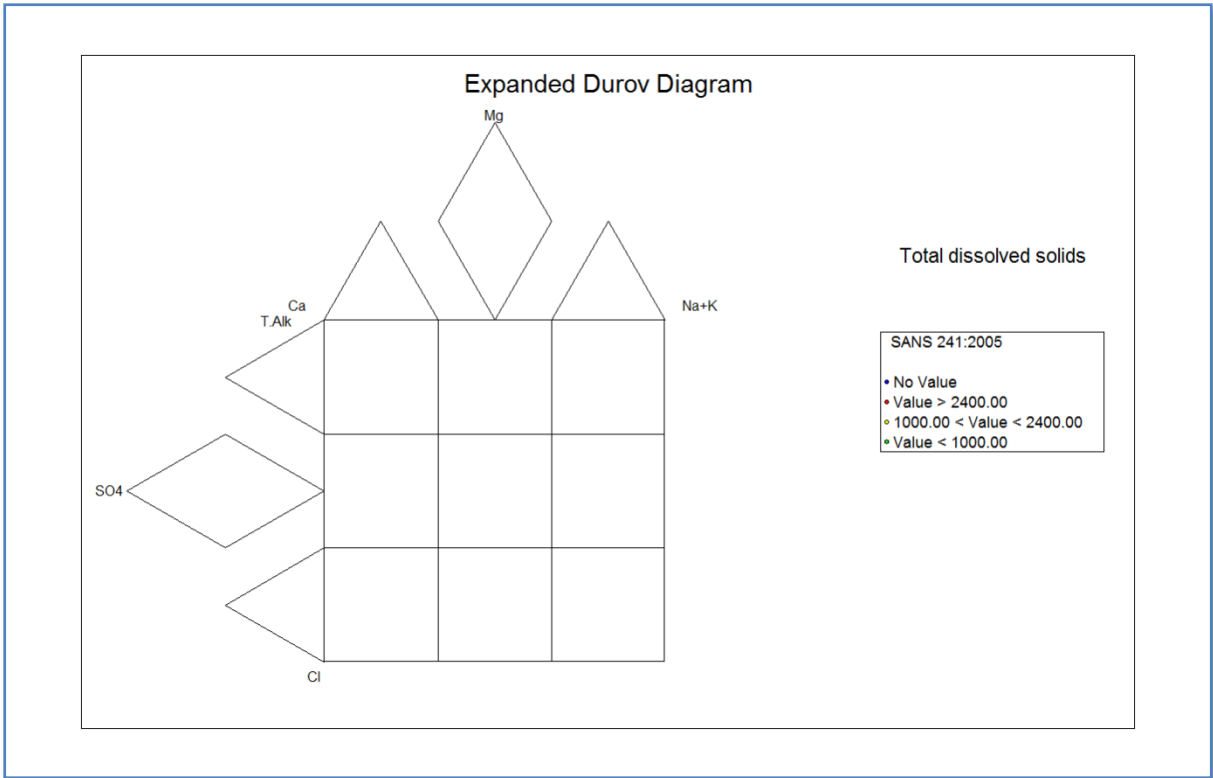


Figure 240: Expanded Durov diagram for RU

As documented the vulnerability is 58%. The impact of potential contamination according to Section 2.3 is low.

1.1.217 Final category

The final category for the RU is summarised in Table 183.

Table 183: Category for RU

Impact	Present status category	Water resource category
Groundwater usage	E	Fair
Groundwater contamination	-	-
Potential groundwater contamination (vulnerability and impact)	B	Good
FINAL	B/C	Good/Fair

29.11 Quantification of the Reserve

The groundwater Reserve for the RU is summarised in Table 184.

Table 184: Reserve

Reserve			Allocation	
Baseflow Mm ³ /a	BHN Mm ³ /a	Reserve % Recharge	Allocation Mm ³ /a	Current Use Mm ³ /a
31.700	0.144	36%	51.589	4.414

30. Classification and the Reserve for Resource Unit Y

30.1 Location

Quaternary catchment V50D constitutes RUY. Towns in the RU include Mandini and Tugela. There are 2 protected areas namely Harold Jonson and Amatikulu. The location of the RU is shown in Figure 241.

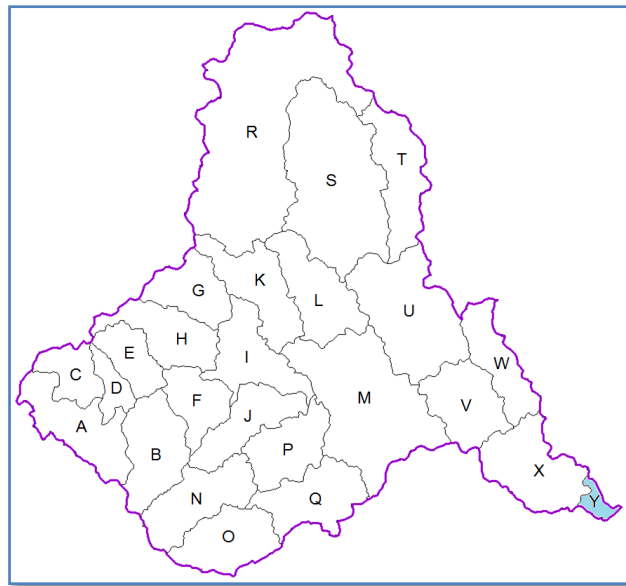


Figure 241: Location of RUY

30.2 Climate

The climate is humid with only one or two months experiencing very little or no rain. The rainfall exceeds 1 000 mm per year. Mean annual temperatures for January are around 25°C and those in July around 17°C.

30.3 Vegetation (taken from www.deat.gov.za)

Remaining forest patches are characterised by species such as: Forest Iron Plum *Drypetes gerrardii*, Umzimbeet *Millettia grandis*, White Ironwood *Vepris undulata*, *Protorhus longifolia*, *Trichilia emetica*, *Brachylaena spp.*, *Celtis spp.*, *Chaetacme aristata* and *Mimusops obovata*. These forest patches are also characterised by a large number of species of woody lianas. Much closer to the seashore, evergreen thicket occurs on littoral dunes. On the seaward side the canopy exhibits the typical clipped appearance of wind-pruning as a result of constant exposure to salt-laden easterly winds. The vegetation often has a shrubby appearance, due to many dwarf geoxylphytes. Locally, at swampy localities, the Illala Palm *Hyphaene coriacea*, is very prominent.

30.4 Demography and Landcover

The population is approximately 11800 (2001 census data). The area has numerous forests and sugarcane lands. As a result there are numerous paper (Photo 47) and saw mills. The landcover within the study area is shown in Figure 242.

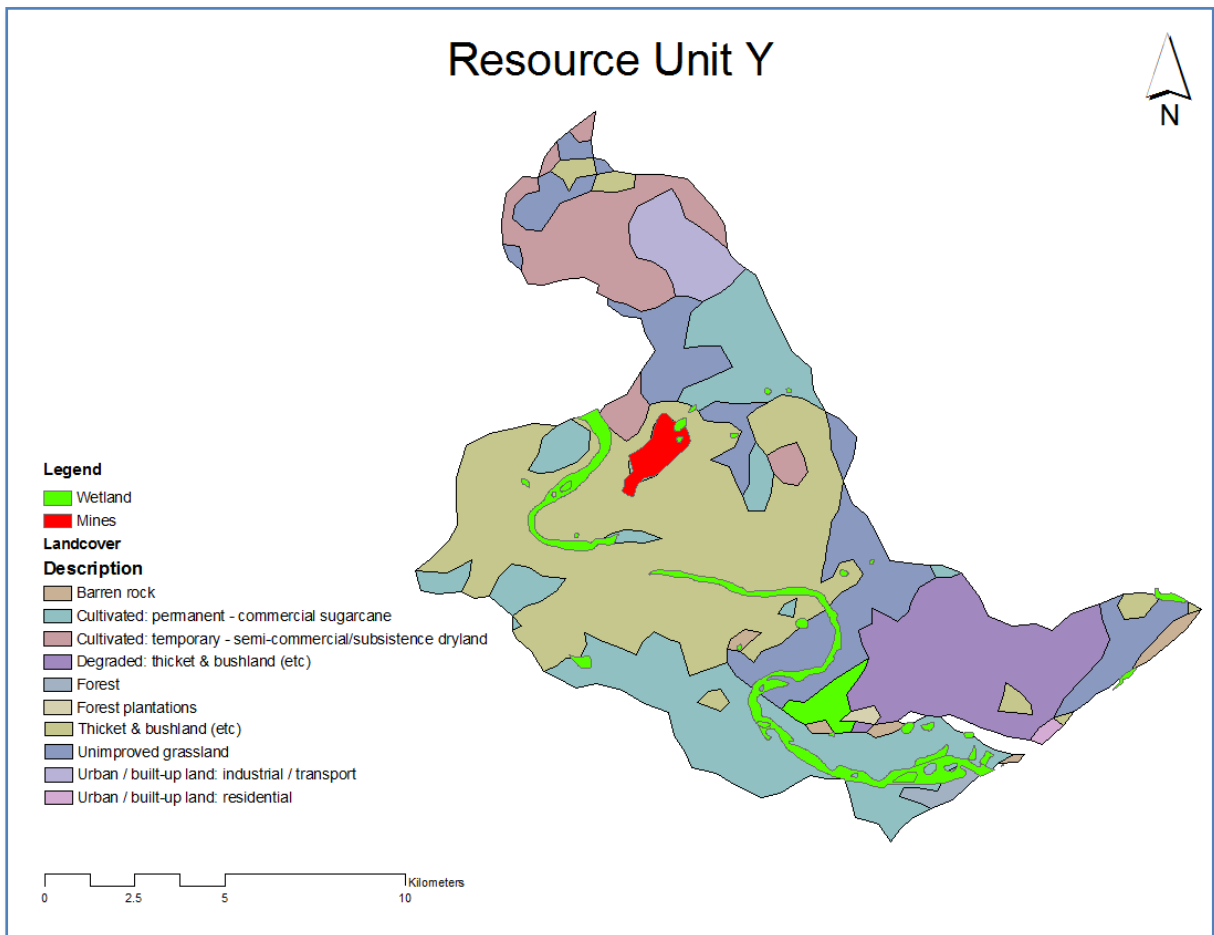
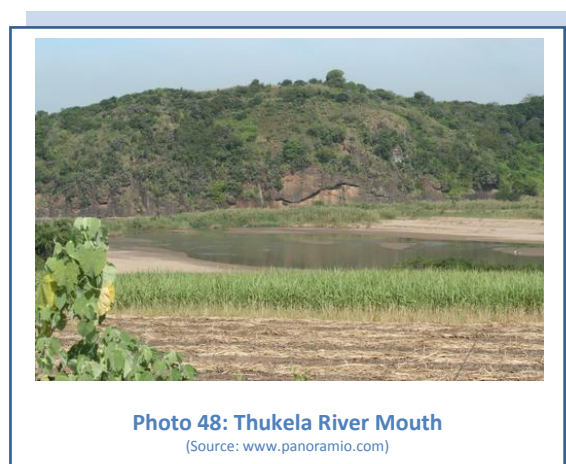


Figure 242: Landcover within RU

30.5 *Surface Water*

The Thukela River flows through this RU. The Thukela River Mouth (Photo 48) or estuary is included in this RU.



30.6 *Wetlands*

The wetlands in the study area are shown in Figure 242.

30.7 *Soils (taken from www.deat.gov.za)*

There are sandy soils of Quaternary aeolian and marine origin.

30.8 *Geology (summarised from Woodford and Chevallier, 2002)*

The Dwyka sediments, which are situated at the base of the Karoo Supergroup, have been deposited on older Precambrian granitic rocks in the north and sedimentary rocks, associated with the Cape Fold Belt in the south. The Dwyka Formation mainly consists of Dwyka diamictite—angular to rounded clasts of the basement rocks, embedded in a clay and silt matrix. However, varved shales, sandstone layers and conglomerates, typical of a fluvio-glacial environment, are also present. The Dwyka diamictite, shales and tillites have very low hydraulic conductivities [$\sim 10^{-11}$ to 10^{-12} m/s], and virtually no primary voids. They therefore tend to form more aquitards than aquifers. The few sandstone bodies deposited in the glacial valleys of the northern facies are very limited in extent, and sealed off by the diamictite. The aquifers in them are therefore limited and often only contain fossil water. Since the Dwyka sediments were deposited mainly under marine conditions, the water in these aquifers tends to be saline.

The Pietermaritzburg Formation (of the Ecca Group) comprises dark, upward coarsening, silty mudrock, which is heavily bioturbated. Pene-contemporaneously deformed sandy and silty beds appear near the top of the formation.

The Vryheid Formation (of the Ecca Group) comprises mudrock, rhythmite, siltstone and fine- to coarse-grained sandstone (pebbly in places). The Formation contains up to five (mineable) coal

seams. The different lithofacies are mainly arranged in upward coarsening deltaic cycles (up to 80m thick in the southeast). Linear coastline cycles are, however, fairly common particularly in the thin northwestern part where they constitute the entire Vryheid in places. A relatively thin fluvial interval (60 m thick) which grades distally into deltaic deposits towards the southwest and south occurs approximately in the middle of the formation in the east and northeast. Fining upward fluvial cycles, of which up to six are present in the east, are typically sheet like in geometry, although some form valley-fill deposits. They comprise coarse grained to pebbly, immature sandstones - with an abrupt upward transition into fine grained sediments and coal seams.

The Volksrust Formation (of the Ecca Group) is a predominantly argillaceous unit, which interfingers with the overlying Beaufort Group and underlying Vryheid Formation. The Formation consists of grey to black, silty shale with thin, usually bioturbated, siltstone or sandstone lenses and beds, particularly towards its upper and lower boundaries. Thin phosphate and carbonate beds and concretions are relatively common.

Since these shales are very dense, they were often neglected as sources of groundwater in the past. The prodelta sandstones represent another formation of the Ecca Group in which one would expect to find high-yielding aquifers. Unfortunately, the permeabilities of these sandstones are also usually very low.

The Tugela Terrane is an allochthonous ophiolite complex comprising of rocks of oceanic affinities which was thrust northwards onto the southern flank of the Kaapvaal Craton. This Group consists of quartzite, schists, gneisses, gabbros and norites.

The Cenozoic deposits comprise mainly of tertiary and quaternary aeolian sand deposits.

30.9 *Geohydrology*

1.1.218 Groundwater levels

It is clear the groundwater levels follow the topography as seen from Figure A1 in Appendix A and therefore groundwater contour maps were generated using Bayesian interpolation. The groundwater levels for the study area are shown in Figure 243. The most probable depth to groundwater level in the RU is 7.3 mbgl according to the histogram of water levels in the RU shown in Appendix A. Groundwater levels are expected to be lower than normal due to the prevailing drought conditions. Unfortunately very little time series water level data are available to quantify the overall impact.

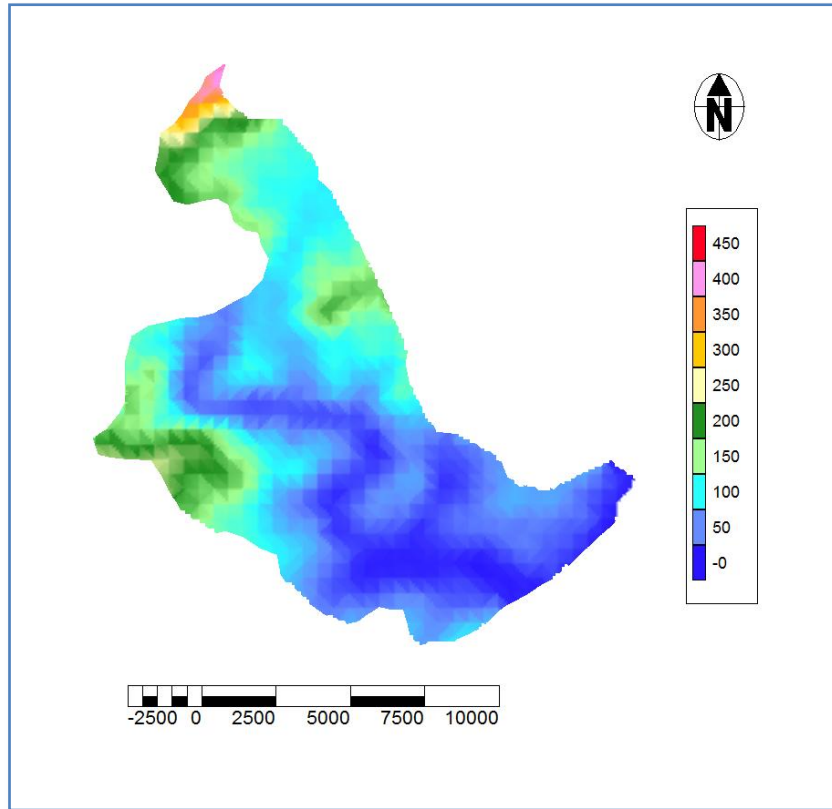


Figure 243: Groundwater levels in RUY

30.9.1 Groundwater recharge

The groundwater recharge calculated from the different methods is listed in Table 185. The different recharge methods applied are discussed in Section 2.3. The final recharge values for the RU are highlighted in red.

Table 185: Recharge values

Recharge							
MAP Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Volume Mm ³ /a	Calculated %	CMB %	Land Cover %	Geology %
149.589	9.542	11.757	8.822	5.9%	5.9%	1.6%	2.5%

1.1.219 Basic human needs

The method for determining BHNs is discussed in Section 2.3. The final value for the study area is highlighted in red in Table 186.

Table 186: Basic human needs

Basic Human Need		
Census(2001) Adjusted	Dependence 18%	Estimate Mm ³ /a
13570	2443	0.022

1.1.220 Groundwater contribution to baseflow

The baseflow separation curves for the RU are shown in Figure 244.

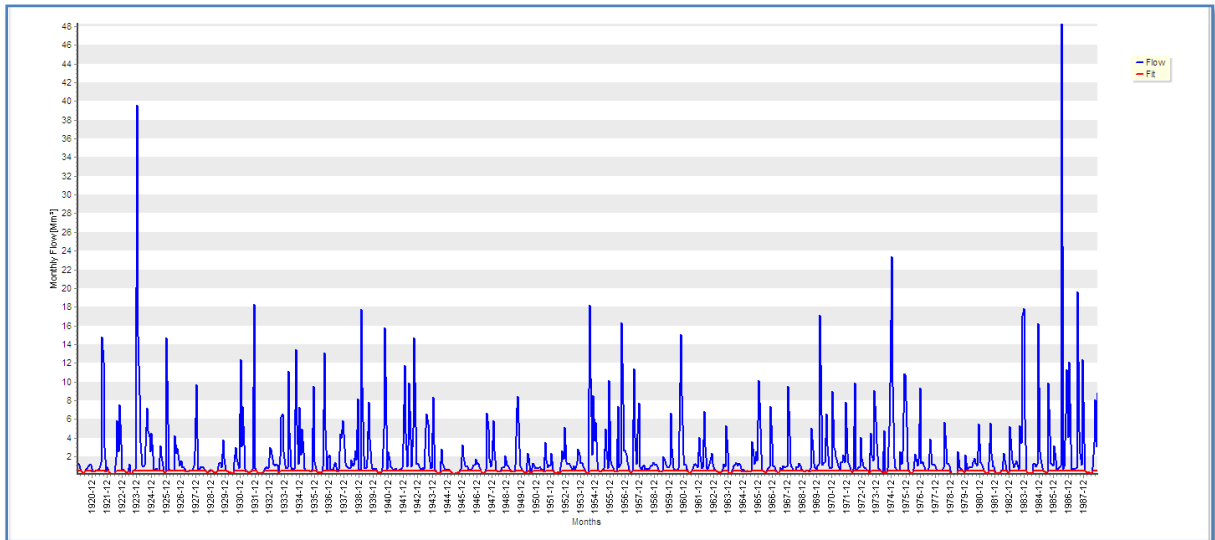


Figure 244: Baseflow separation for quaternary catchment V50D

The final groundwater contribution to baseflow values for the RU is highlighted in red in Table 187.

Table 187: Groundwater contribution to baseflow

Groundwater Contribution to Baseflow							
GRDM Mm ³ /a	Hughes Mm ³ /a	Shultz Mm ³ /a	Pitman Mm ³ /a	vTonder Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Herold Mm ³ /a
1.726	11.694	6.885	5.549	7.018	1.726	11.694	5.590

1.1.221 Groundwater use

The groundwater use for the RU is listed in Table 188.

Table 188: Groundwater use

Groundwater Use							
GRDM Mm ³ /a	WARMS Mm ³ /a	Hydrocensus Mm ³ /a	MIN Mm ³ /a	MAX Mm ³ /a	Forrest Mm ³ /a	Crops Mm ³ /a	TOTAL Mm ³ /a
0.120	0.000	0.018	0.000	0.120	2.945	0.000	2.923

1.1.222 Groundwater quality

The TDS values for the RU are shown in Figure 245. They are classified according to SABS standards. The overall quality of the resource unit is well within the drinking water guidelines. However very limited data are available.

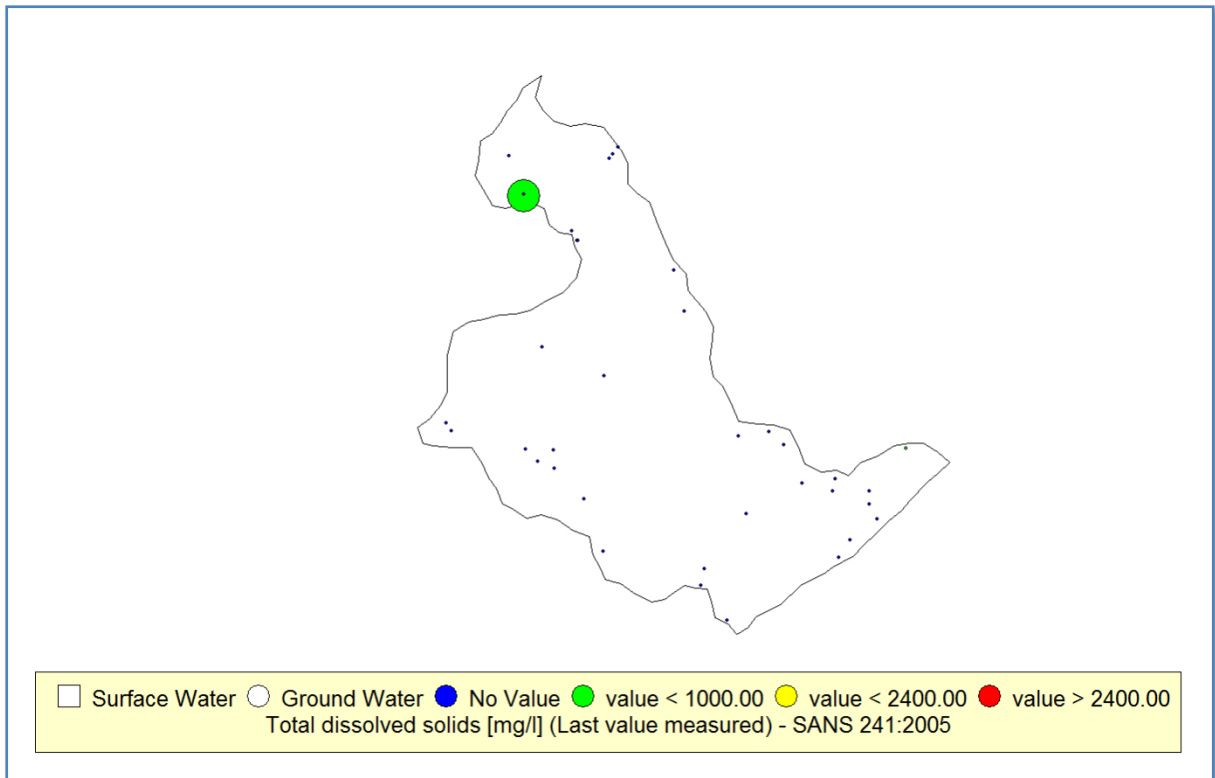


Figure 245: TDS values

1.1.223 Aquifer vulnerability

The aquifer vulnerability calculations are summarised in Table 189. The slope histogram is documented in Appendix B.

Table 189: Aquifer vulnerability

Aquifer Vulnerability						
Level mbgl	Recharge %	Slope %	Soil Texture	Aquifer Type	Vadose Zone	Vulnerability %
7.3	5.9%	0.9	SaCLm-SaCl, Sa	Weathered/Fractured	Karoo(southern)	59%

30.10 Classification

1.1.224 Groundwater usage

The stress index, defined as the ratio between total groundwater use and recharge, for the study area is calculated at 97%. Due to the uncertainty associated with the groundwater use component, the stress index was stochastically modelled through assigning a normal distribution curve with a standard deviation of 0.292 Mm³/a to the groundwater use estimate to account for the associated uncertainty. The stochastic results are shown in Figure 246. It is clear from the results that the stress index will vary between 89% and 100% with a certainty of 81.77%. Due to the small variability in the obtained range and high certainty, the uncertainty in the groundwater use component will not affect the calculated stress index significantly.

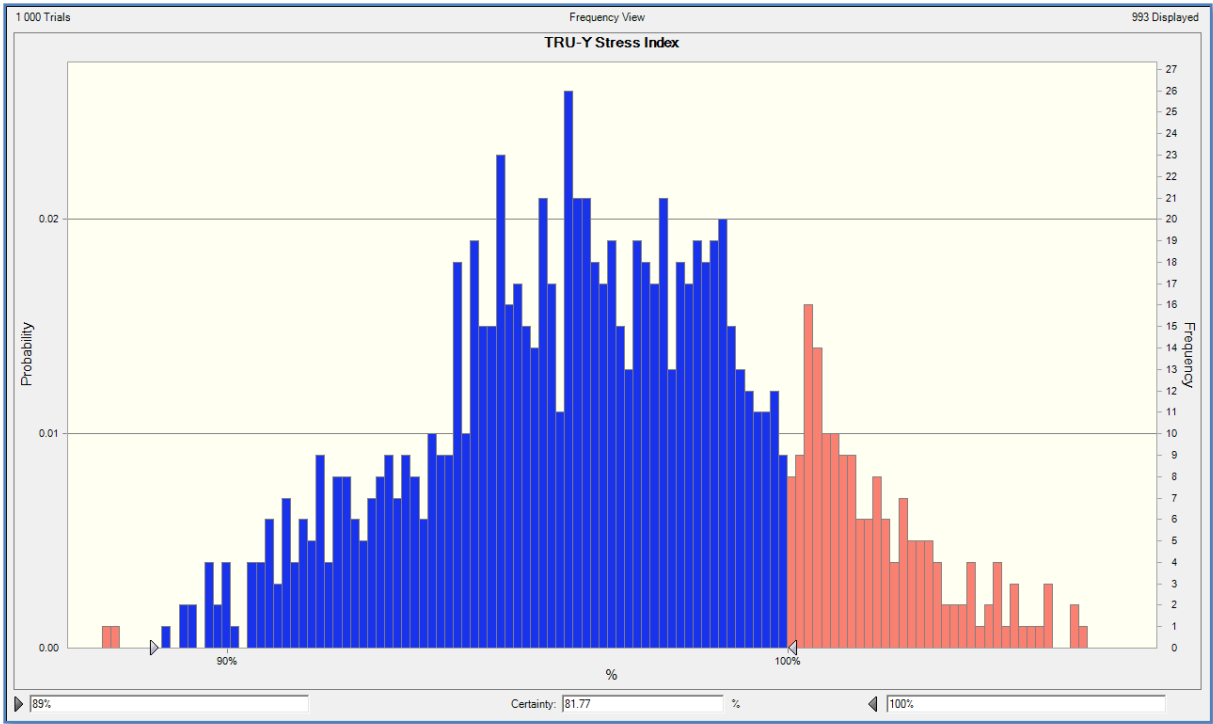


Figure 246: Stochastic results

1.1.225 Quality

The expanded Durov diagram with the groundwater quality is shown in Figure 247. An explanation of the classification process by means of the expanded Durov diagram is given in Section 2.3. There is not sufficient data to generate an expanded Durov diagram.

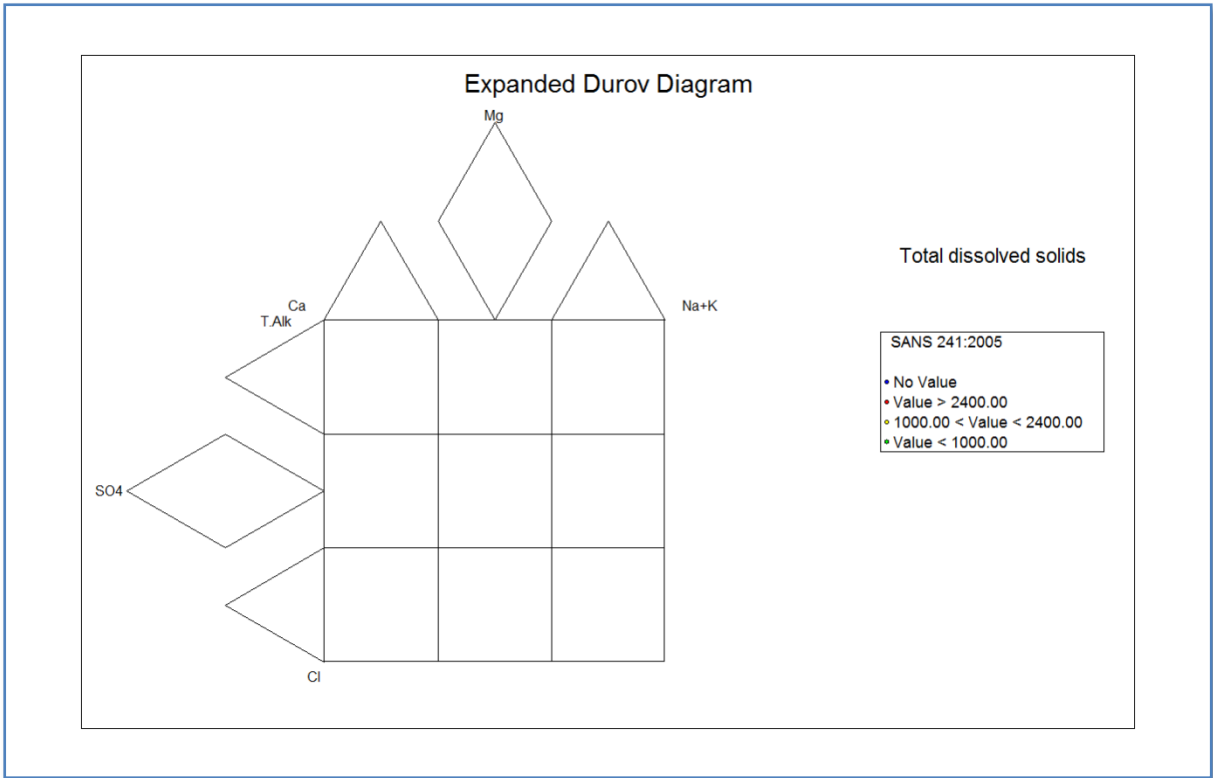


Figure 247: Expanded Durov diagram for RU

As documented the vulnerability is 59%. The impact of potential contamination according to Section 2.3 is low.

1.1.226 Final category

The final category for the RU is summarised in Table 190.

Table 190: Category for RU

Impact	Present status category	Water resource category
Groundwater usage	F	Poor
Groundwater contamination	-	-
Potential groundwater contamination (vulnerability and impact)	B	Good
FINAL	C	Fair

30.11 Quantification of the Reserve

The groundwater Reserve for the RU is summarised in Table 191.

Table 191: Reserve

Reserve			Allocation	
Baseflow Mm ³ /a	BHN Mm ³ /a	Reserve % Recharge	Allocation Mm ³ /a	Current Use Mm ³ /a
5.590	0.022	64%	0.288	2.923

31. Resource Quality Objectives

31.1 Preamble

The RQOs are addressed as a separate section due to the vast extent of the study area. The RQOs presented in this section should serve as a general guide for RQOs to be applied to local scale and to address hot spots. Local scale is referred to in the following sections as management areas and should not be confused with the bigger WMA (Water Management Area).

31.2 Defining RQOs for Water level Management

Water use should be managed in a sustainable way regardless of drought conditions. The only way to ensure a borehole is sustainable is to monitor water levels with time. It is however not possible to monitor all boreholes in an area due to time, budget and capacity constraints. Resource units of the size described in this report should be broken down into smaller management areas. Within these management areas monitoring boreholes should be identified which is representative of the specific aquifer. This is done by comparing trends in time series data. Once a network of monitoring boreholes is identified the following criteria should be applied:

- Allow water levels to drop during dry periods, but never allow boreholes to reach the main water strike as this might cripple the borehole. This places responsibility in water user's hands to properly manage the resource. In general over abstraction by an individual will lead to failure of his borehole, before permanent damage to neighbouring boreholes.
- If the water levels don't recover to previous levels after a wet period, abstraction rates should be lowered. As long as water levels recover after wet periods the system is considered sustainable. Figure 248 shows examples of boreholes in the vicinity of the study area that reflect sustainable behaviour.

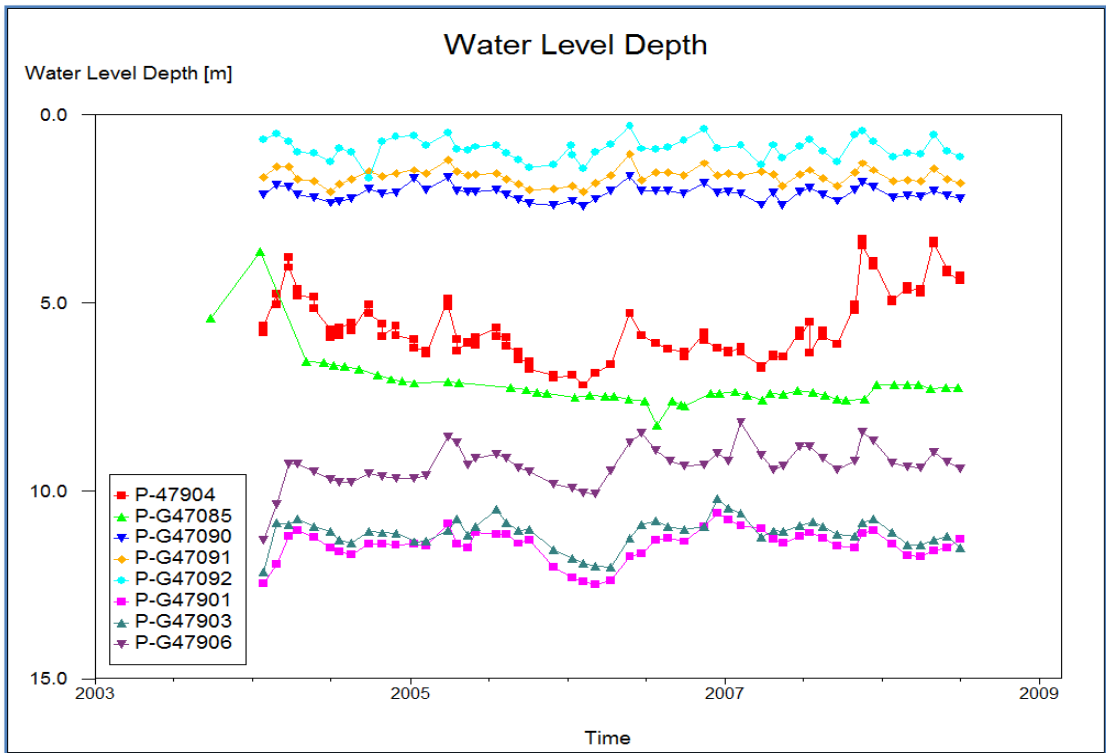
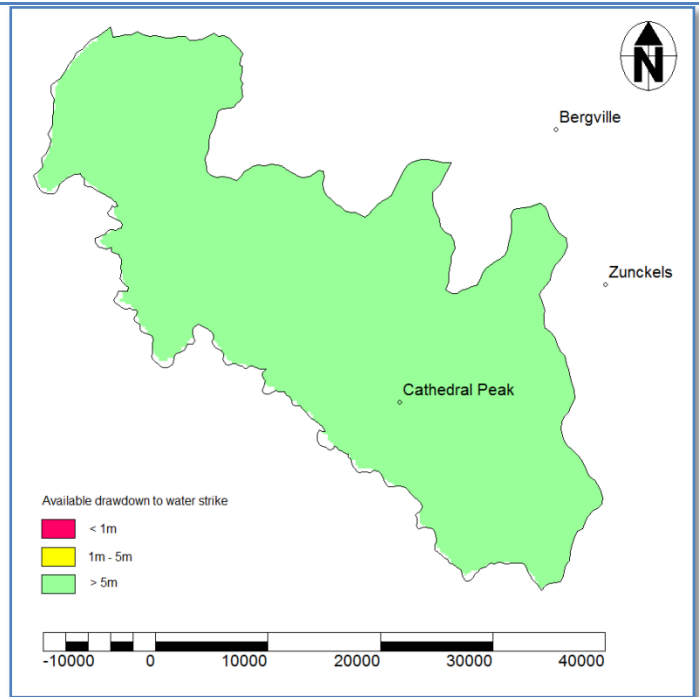


Figure 248: Time series water levels of boreholes within the WMA

For each of the RUs a map was produced based on water strike and water level information that shows the available drawdown to the borehole water strike. Note that the maps are not exact delineations due to scattered data and the interpolation technique used, but serves as a guide for hot spot identification. Within each of the stressed areas it is recommended that the individual boreholes be identified and managed accordingly.

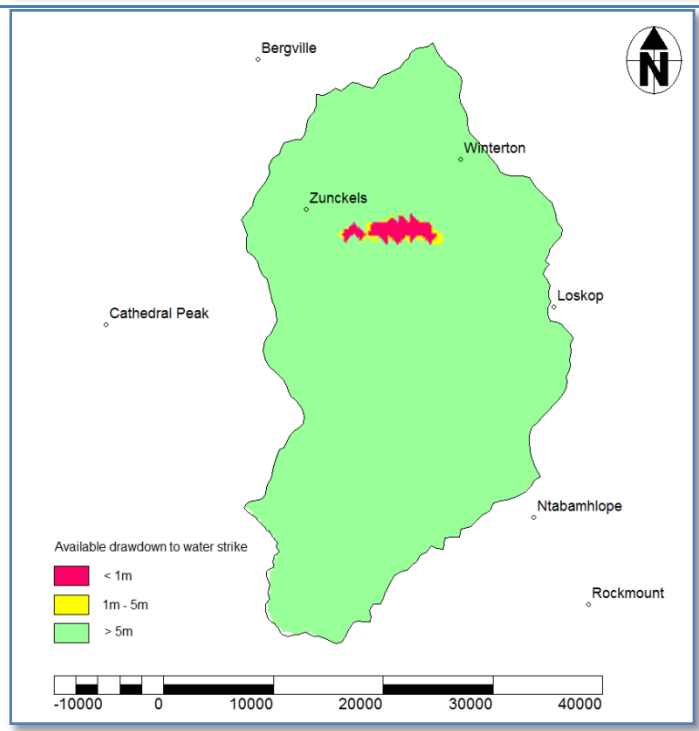
TRU-A

All available drawdown is at least 5m above the water strike for the whole RU.



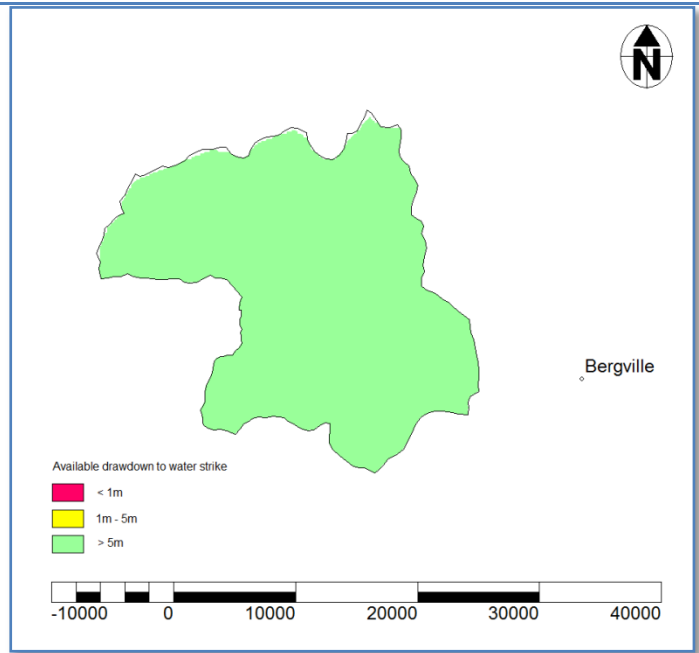
TRU-B

Most of the available drawdown is at least 5m above the water strike. A small area in the middle northern region of the RU shows the water level within at least a meter of the water strike. This area should be considered for active management of water levels.



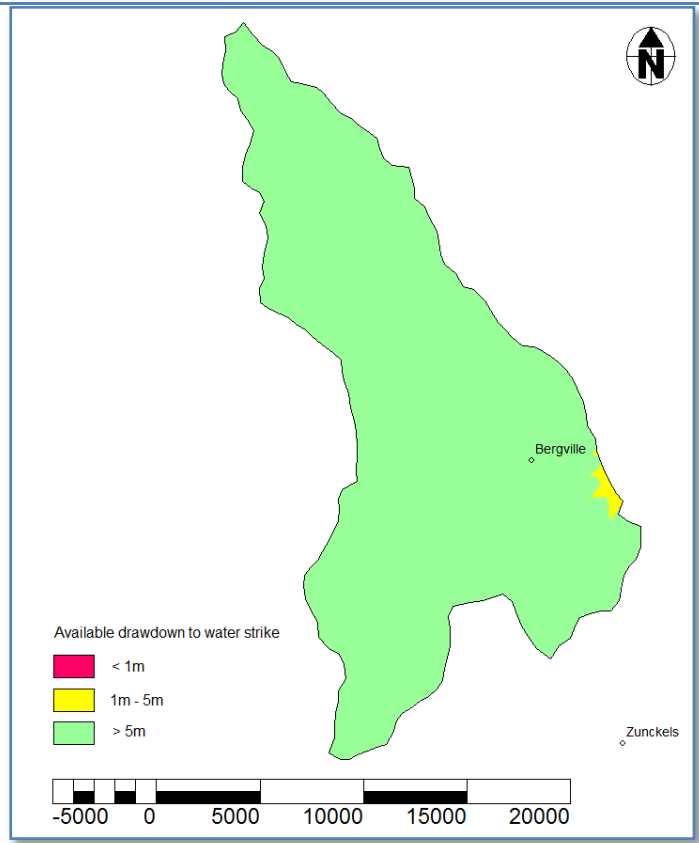
TRU-C

All available drawdown is at least 5m above the water strike for the whole RU.



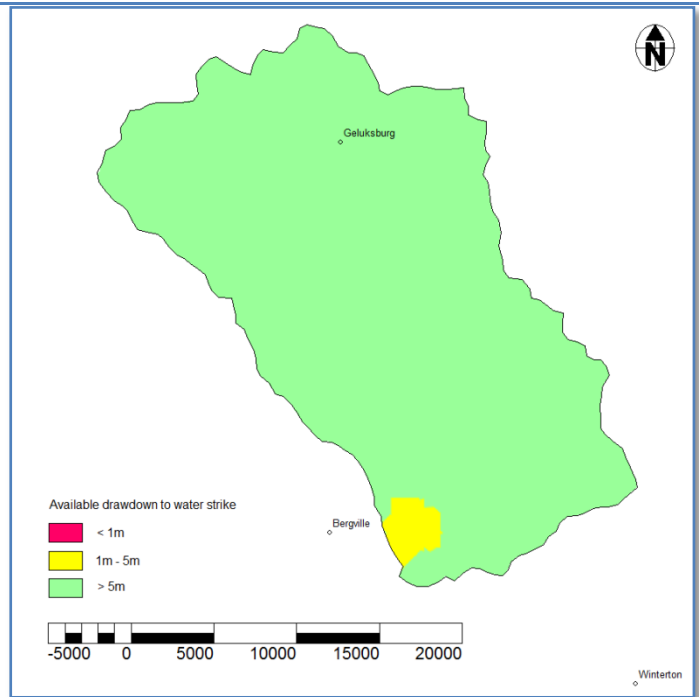
TRU-D

Most of the available drawdown is at least 5m above the water strike. A small area in the eastern side of the RU shows the water levels between 1-5m above the water strike.



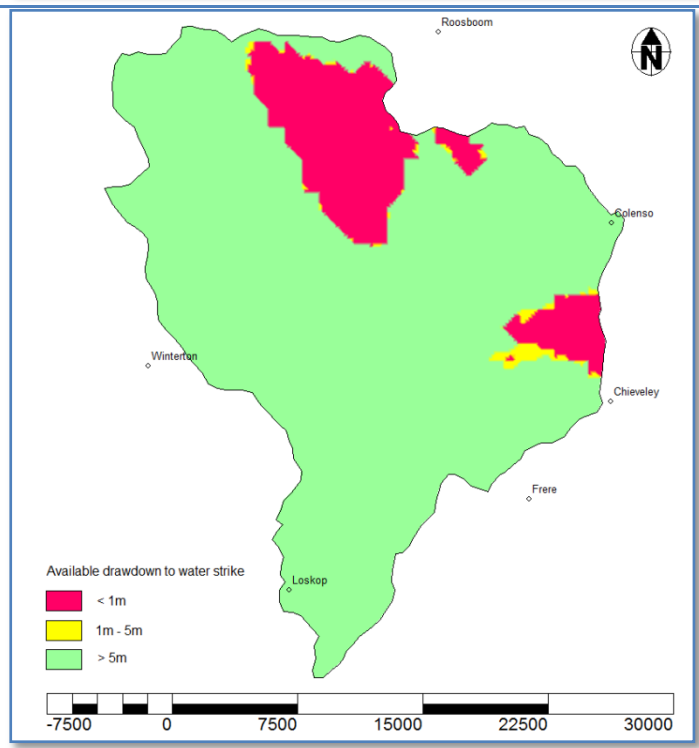
TRU-E

Most of the available drawdown is at least 5m above the water strike. A small area on the southern side of the RU shows the water levels between 1-5m above the water strike.



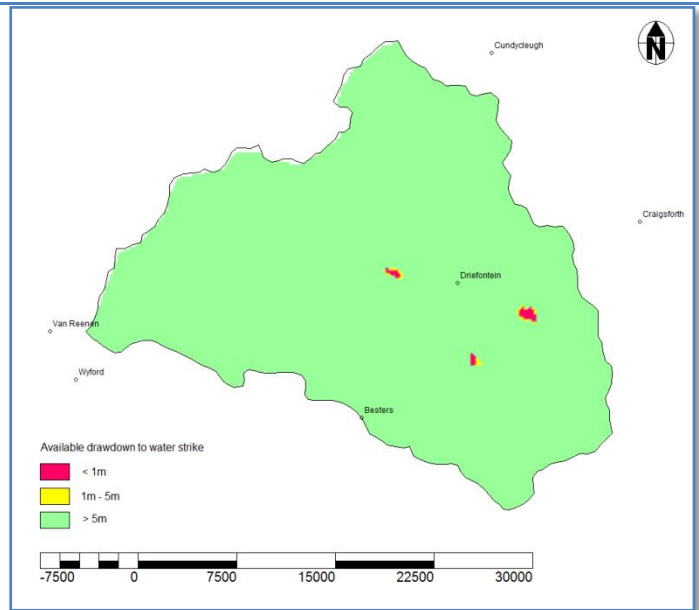
TRU-F

The water level across the RU is predominantly above 5m from the water strike, with major areas in the northern and eastern regions of the RU that are less than 1m from the water strike. These areas should be considered for active management of water levels.



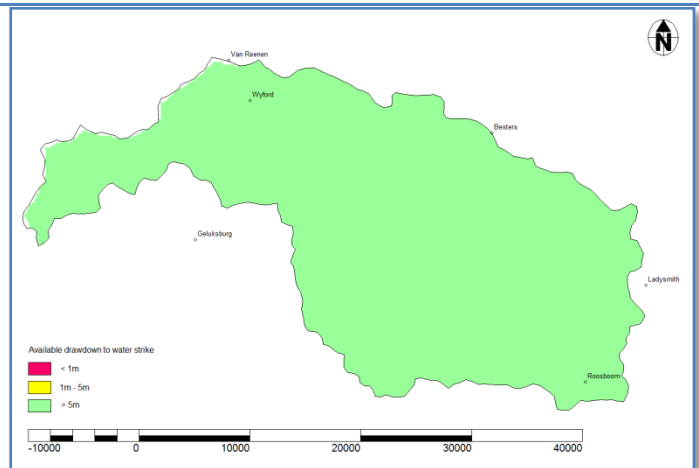
TRU-G

Most of the available drawdown is at least 5m above the water strike. Three areas in the central and south-eastern regions of the RU show water levels less than 1m from the water strike. The distribution of these stressed areas is highly localised and may be due to only a few boreholes with small available drawdown values. These areas should still be considered for active management of water levels.



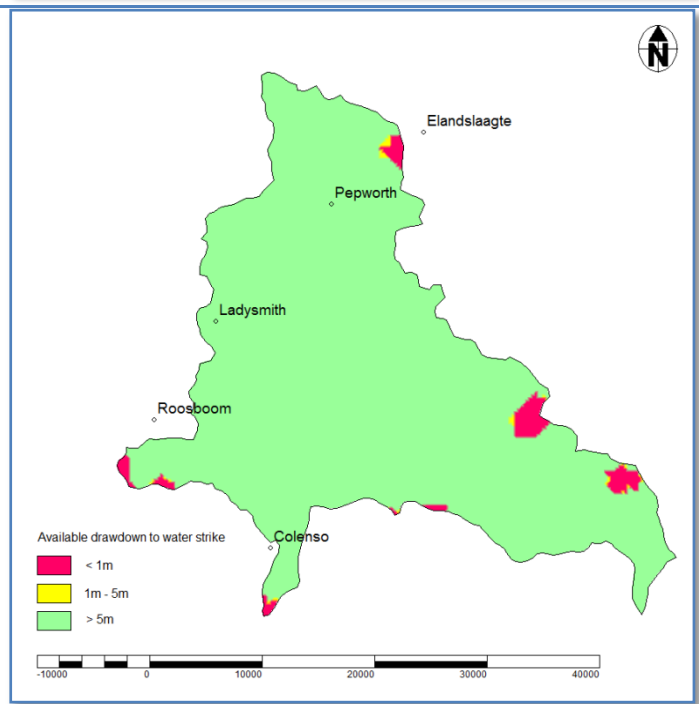
TRU-H

All available drawdown is at least 5m above the water strike for the whole RU.



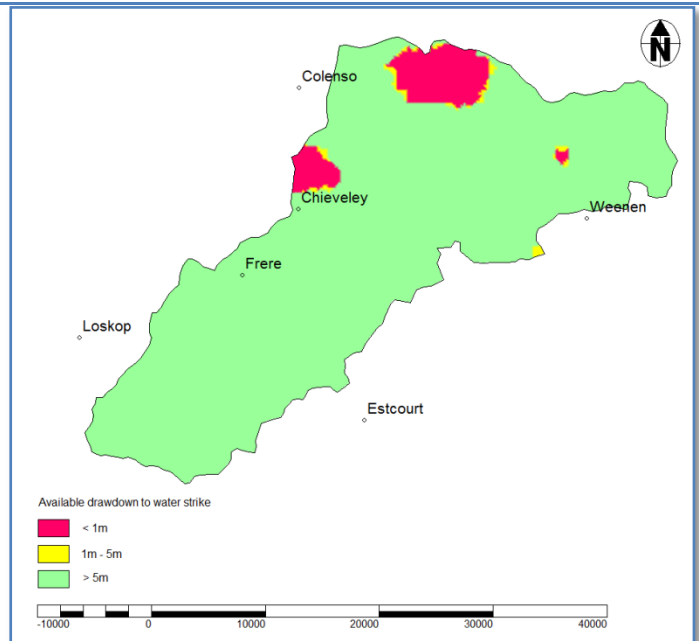
TRU-I

Most of the interior of the RU has water levels at least 5m above the water strike. Various areas on the RU perimeter show water levels less than 1m from the water strike. These areas should be considered for active management of water levels.



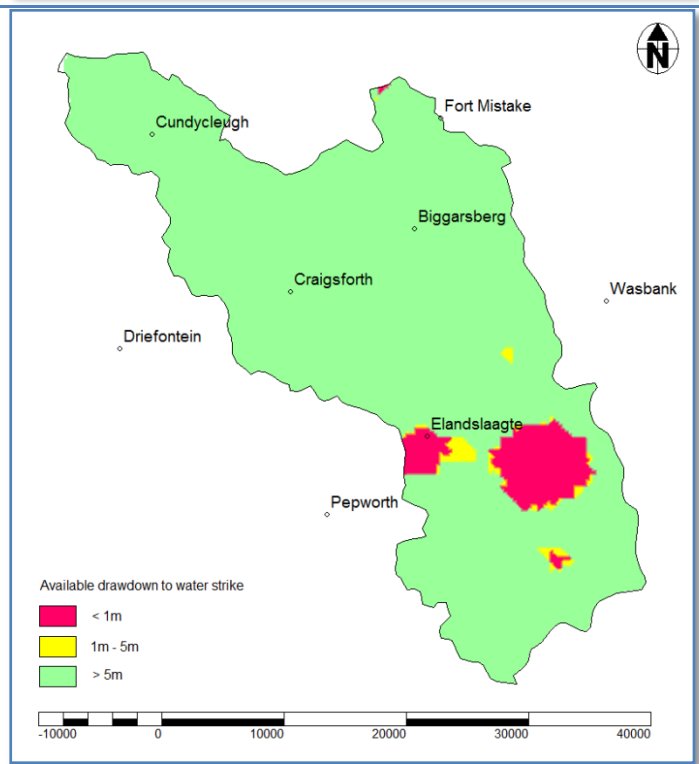
TRU-J

Most of the available drawdown is at least 5m above the water strike. Three areas in northern half of the RU show water levels less than 1m from the water strike. These areas should be considered for active management of water levels.



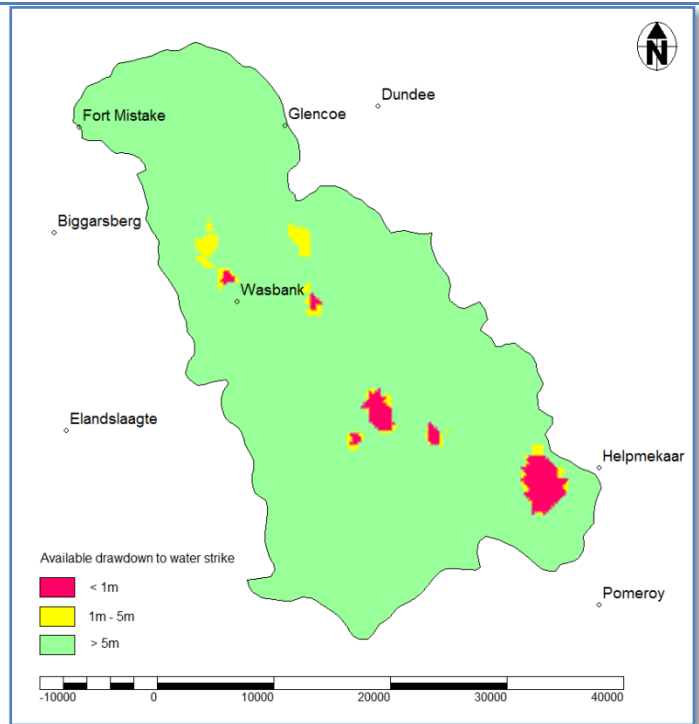
TRU-K

Most of the available drawdown is at least 5m above the water strike. Three areas in southern half of the RU show water levels less than 1m from the water strike. These areas should be considered for active management of water levels.



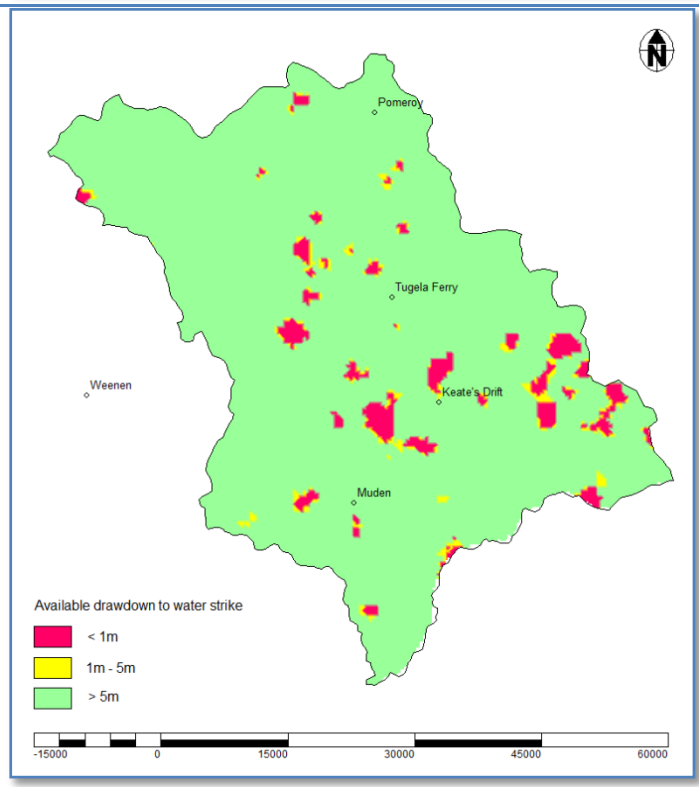
TRU-L

The RU primarily has water levels that are at least 5m above the water strike with scattered regions where the water level is less than 1m above the water strike. These areas should be considered for active management of water levels. Two areas are identified in the northern half which has water levels between 1-5m above the water strike. These areas can have a lower priority in terms of management compared to the aforementioned.



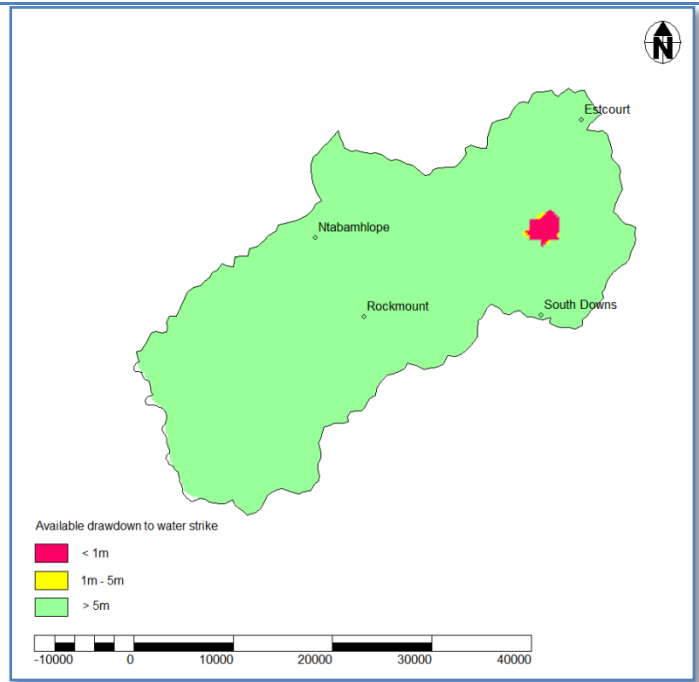
TRU-M

The RU has primarily water levels that are at least 5m above the water strike with scattered regions where the water level is less than 1m above the water strike. These areas should be considered for active management of water levels.



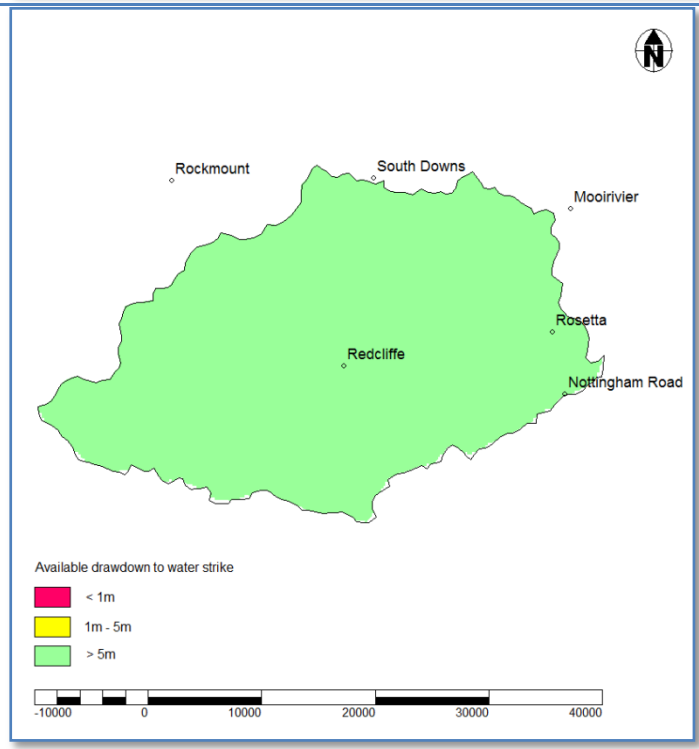
TRU-N

Most of the available drawdown is at least 5m above the water strike. A single area in north-eastern region of the RU show water levels less than 1m from the water strike. This area should be considered for active management of water levels.



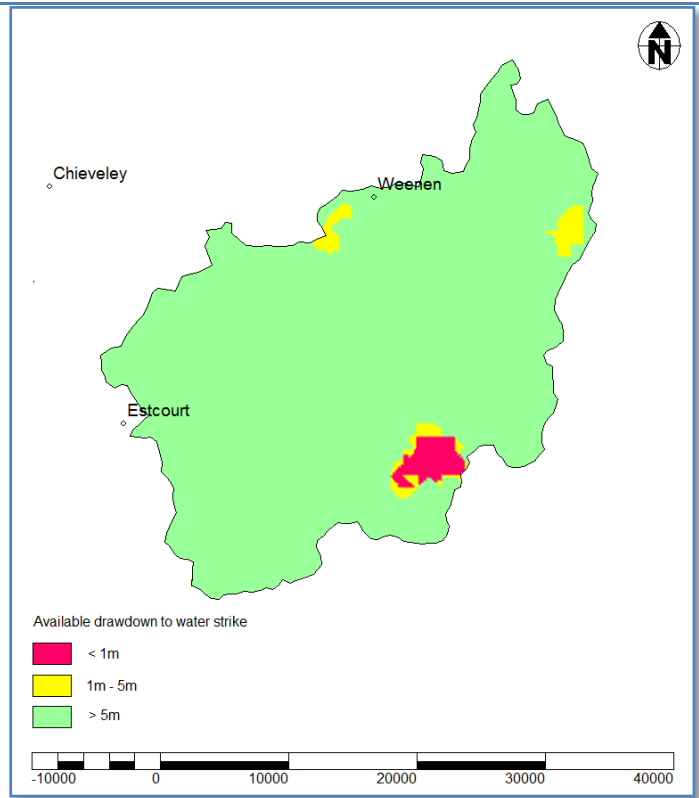
TRU-O

All available drawdown is at least 5m above the water strike for the whole RU.



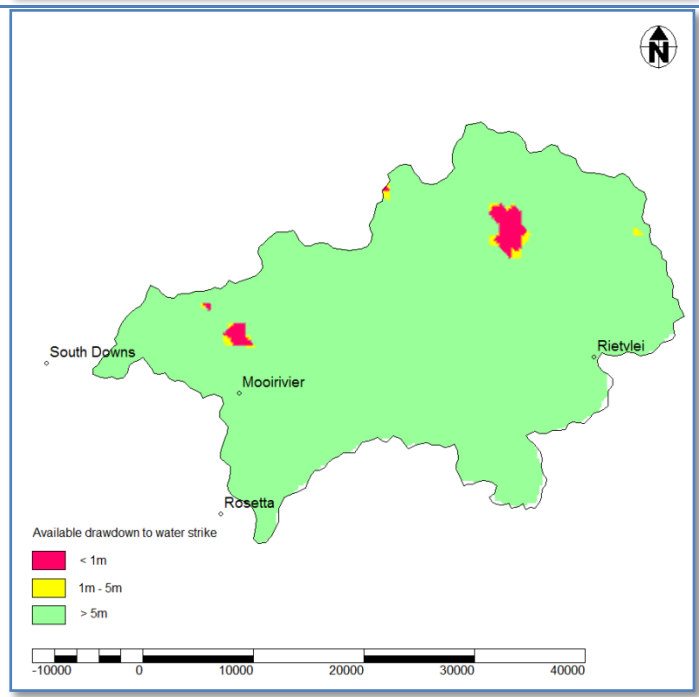
TRU-P

The RU primarily has water levels that are at least 5m above the water strike. One region in the southern half has water levels less than 1m above the water strike. This area should be considered for active management of water levels. Two areas in the northern half are identified as having water levels between 1-5m above the water strike. These areas can have a lower priority in terms of management compared to the aforementioned area.



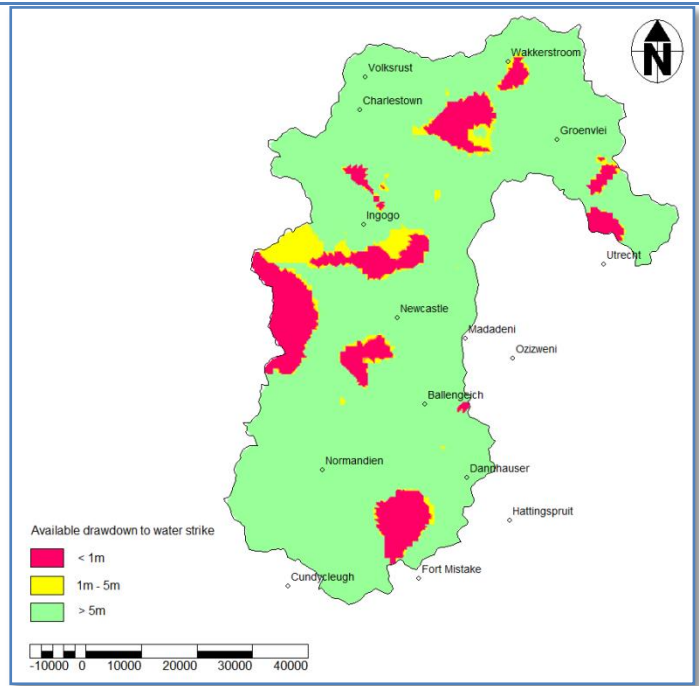
TRU-Q

The RU has largely water levels that are at least 5m above the water strike with scattered regions in the northern half of the RU where the water level is less than 1m above the water strike. These areas should be considered for active management of water levels.



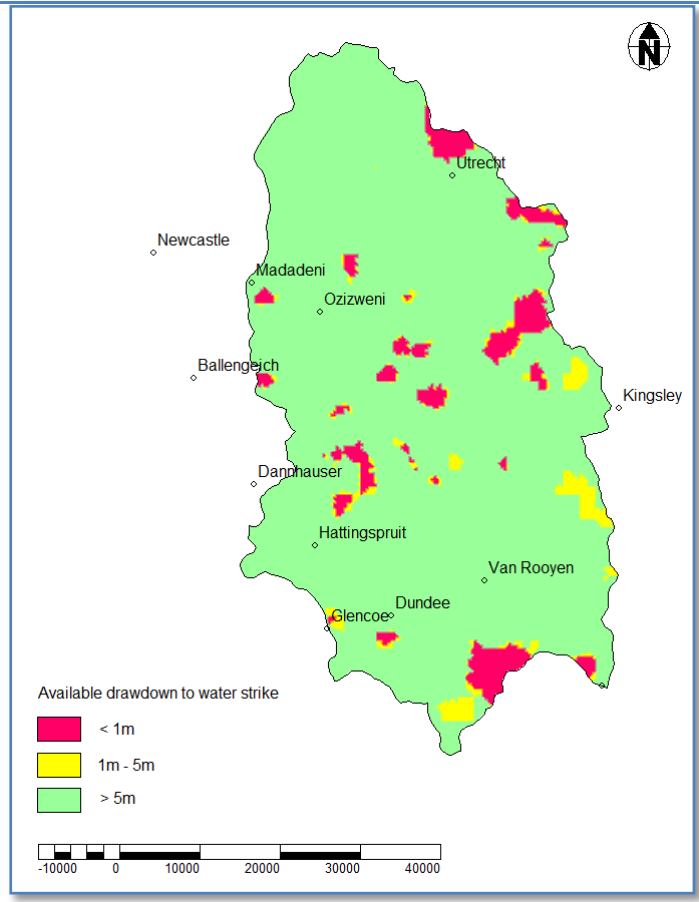
TRU-R

For the most part, the RU has water levels that are at least 5m above the water strike with scattered regions where the water level is less than 1m above the water strike. These areas should be considered for active management of water levels.



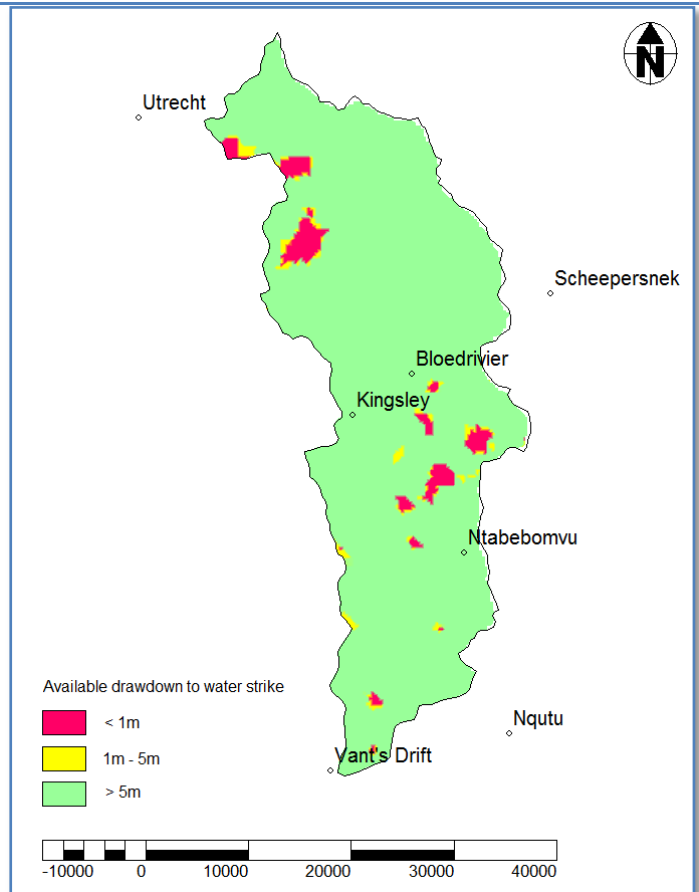
TRU-S

For the most part, the RU has water levels that are at least 5m above the water strike with scattered regions where the water level is less than 1m above the water strike. Various regions where the water level is between 1-5m above the water strike is also present in the southern half of the RU. These areas can have a lower priority in terms of management compared to the aforementioned.



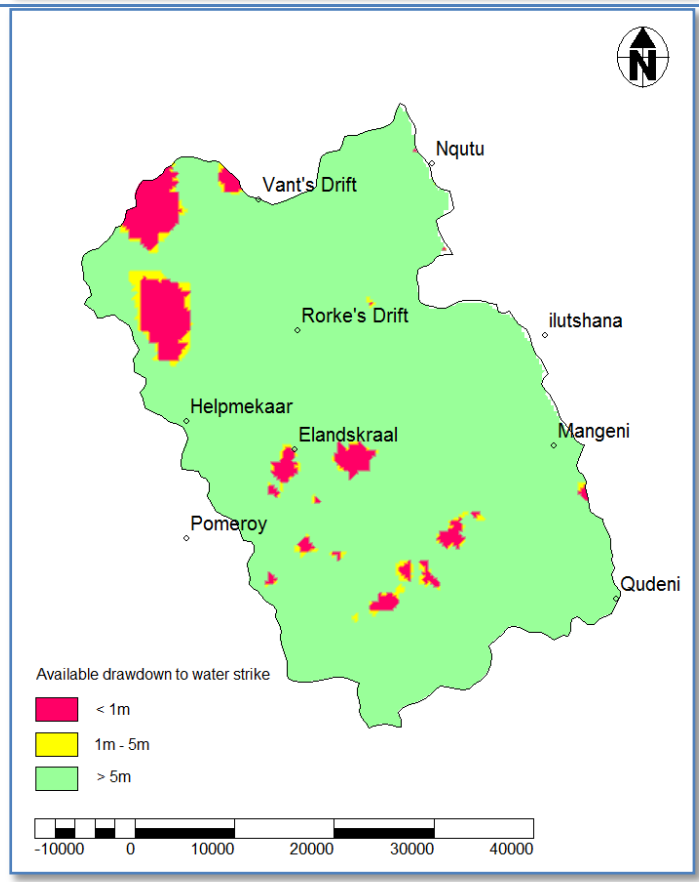
TRU-T

The RU has primarily water levels that are at least 5m above the water strike with scattered areas where the water level is less than 1m above the water strike. These areas should be considered for active management of water levels.



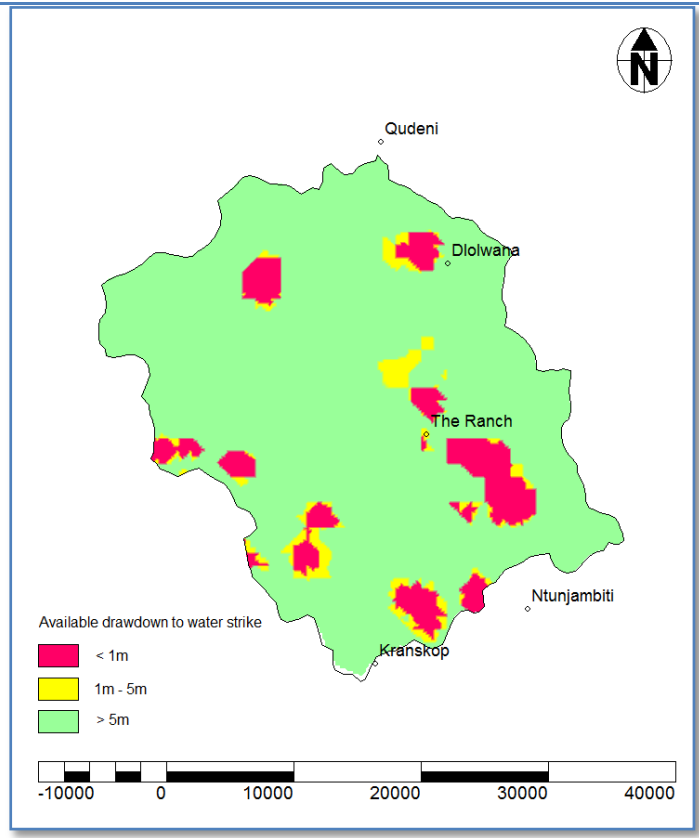
TRU-U

The RU has primarily water levels that are at least 5m above the water strike with scattered areas where the water level is less than 1m above the water strike. These areas should be considered for active management of water levels.



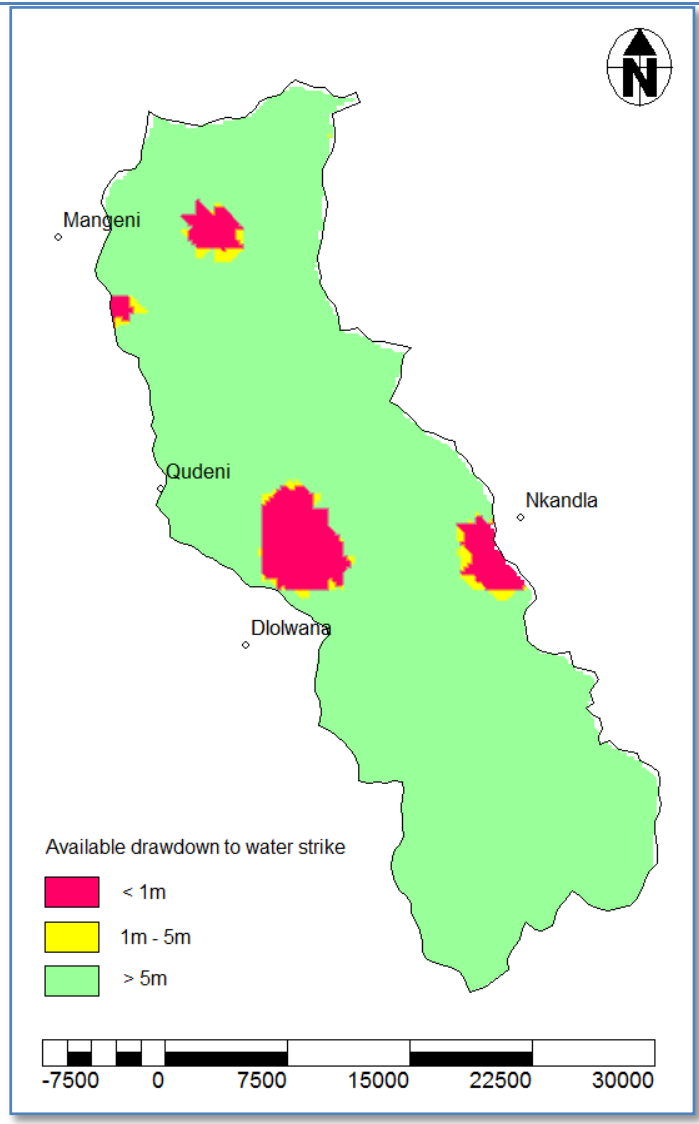
TRU-V

The RU has primarily water levels that are at least 5m above the water strike with scattered areas where the water level is less than 1m above the water strike. These areas should be considered for active management of water levels.



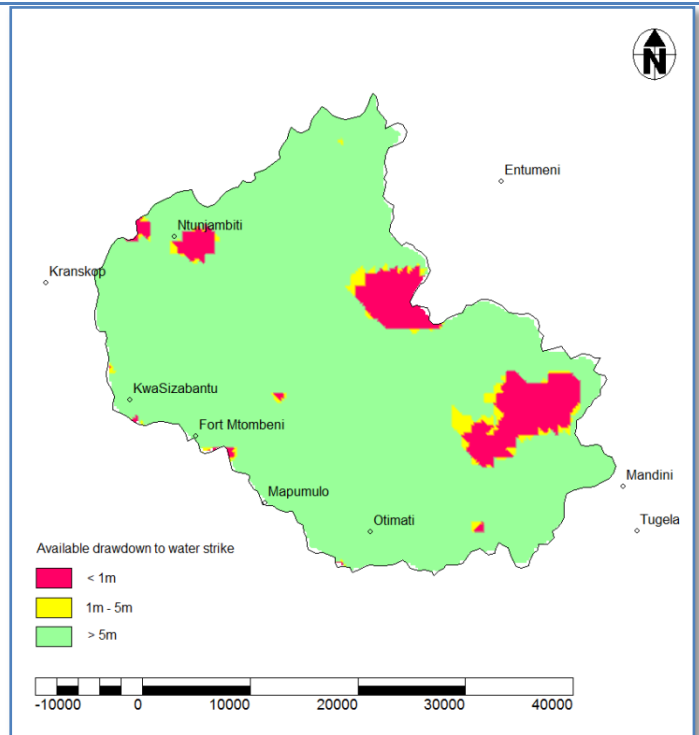
TRU-W

The area has mainly water levels that are at least 5m above the water strike. Two areas in the north and two in the central region are identified as having water levels 1m and below the water strike. These areas should be considered for active management of water levels.



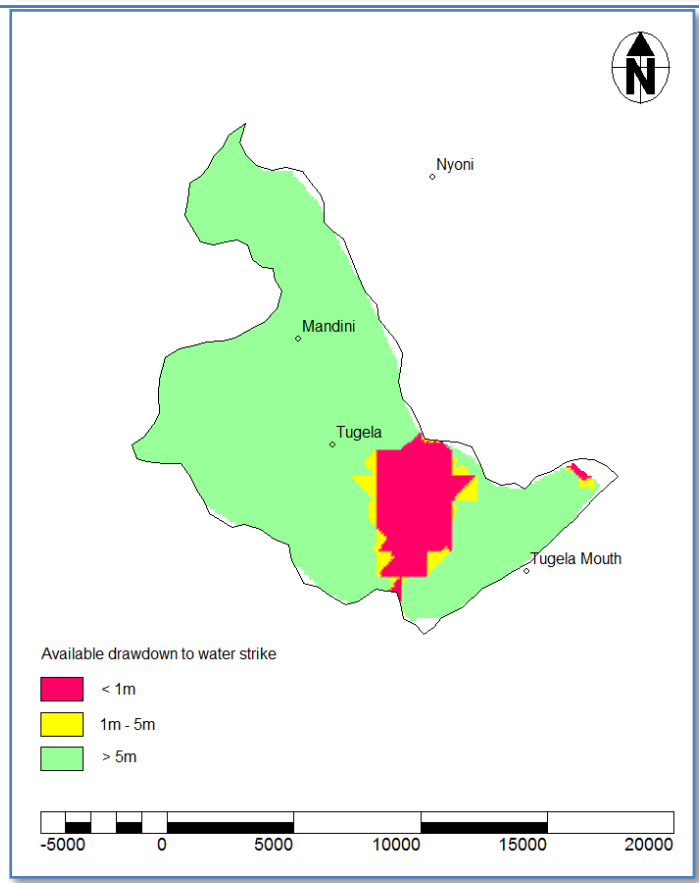
TRU-X

The RU has primarily water levels that are at least 5m above the water strike with scattered areas where the water level is less than 1m above the water strike. These areas should be considered for active management of water levels.



TRU-Y

Most of the area resembles water levels that are at least 5m above the water strike. A major area compared to the overall RU are identified in the southern-central region of the RU and a minor region on the eastern perimeter that has water levels less than 1m from the water strike. These areas should be considered for active management of water levels.



31.3 Defining RQOs for Rivers

Rivers can be groundwater fed and/or have riparian vegetation, which forms an ADE. Therefore both these issues are considered when setting the RQOs, as shown in Figure 249. Perennial rivers

and non-perennial rivers with pools are normally fed by groundwater and therefore need to be protected by means of RQOs. The amount of groundwater flowing into the river needs to be calculated (i.e. groundwater contribution to baseflow). Once this has been established, the RQO can be set as a groundwater level or gradient to be maintained for a certain distance from the river.

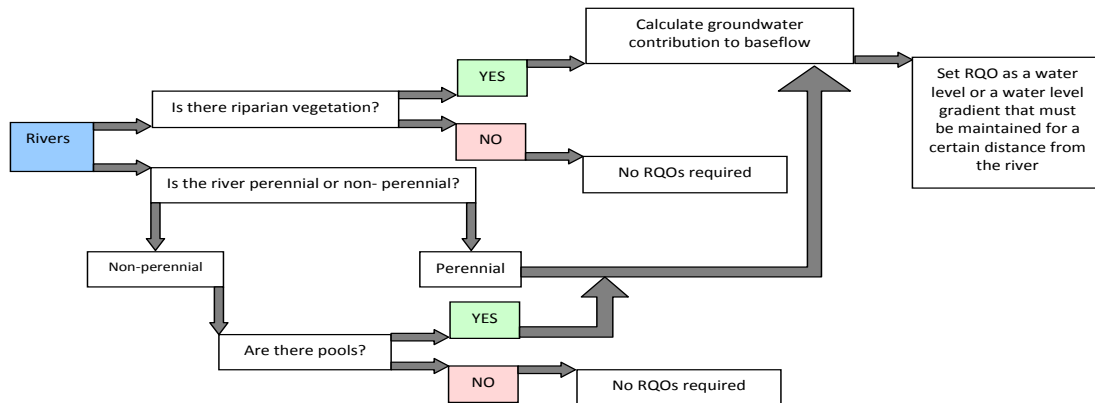


Figure 249: Setting RQOs for Rivers

31.4 Defining RQOs for Wetlands and Estuaries

RQOs for groundwater driven wetlands/estuaries must also be determined, as shown in Figure 250. The amount of groundwater flowing into these regions needs to be calculated. Once this has been calculated, the RQO can be set as a groundwater level or gradient to be maintained for a certain distance from the wetland/estuary.

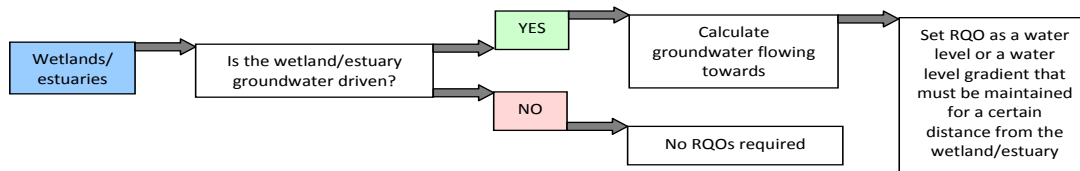


Figure 250: Setting RQOs for wetlands and estuaries

31.5 Defining RQOs for Springs

Springs are groundwater driven and therefore need to be protected, as shown in the Figure 251. However, the way in which they are protected differs between hot and cold springs. Hot or thermal springs, according to Kent (1949), are those for which the water temperature is above 30°C. Their groundwater source is usually very deep beneath the earth's surface. Boreholes must therefore not intercept these aquifers and deplete the source. The geothermal gradient for groundwater; that is, the rate of increase in temperature with depth, is about or 1°C per 30 m depth (Van Tonder, 2003), although there are exceptions to this rule. The capture area for a cold water spring can be determined by standard methods. A minimum distance for any potentially harmful activities (boreholes, possible pollution sources) must be allocated outside the minimum distance.

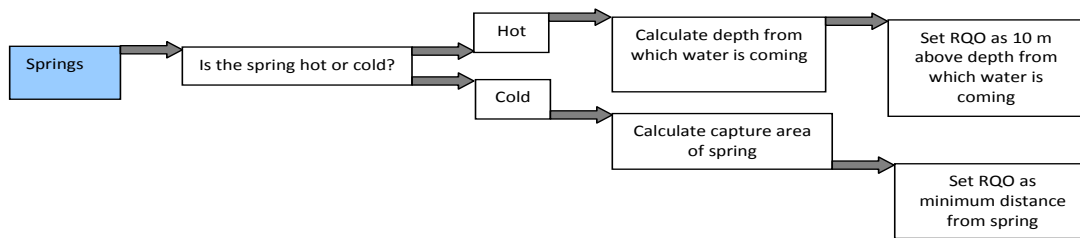
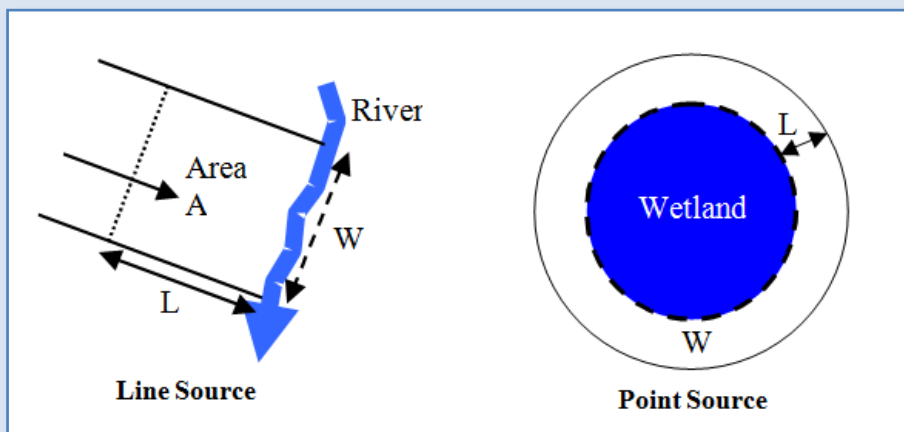


Figure 251: Setting RQOs for springs

A note on rivers, wetlands and springs . . .

The protection distances to rivers, wetlands and springs are based on the concept of preserving the flux to the entity in question. The flux in each case is determined on local scale e.g. the groundwater contribution to baseflow. By dividing the flux (L^3/T) through the recharge (L/T) associated with the region the area (L^2) to be protected is obtained. Once the area is known the associated protection distance (L) is calculated as shown in the Figure below.



On local level river stretches, wetlands and springs affected by current and future borehole development need to be identified and the associated protection distances calculated and enforced.

31.6 Defining RQOs for BHNs, Strategic use and International obligations

Groundwater use for basic human needs, strategic use, and international obligations must also be protected, as seen in Figure 253. The rates in the boreholes or flow across international boundaries must be calculated and protection zones delineated. Once this has been calculated, the RQO can be set as a groundwater level or gradient to be maintained for a certain distance, or as assurance of supply (sustainability) of the groundwater resource.

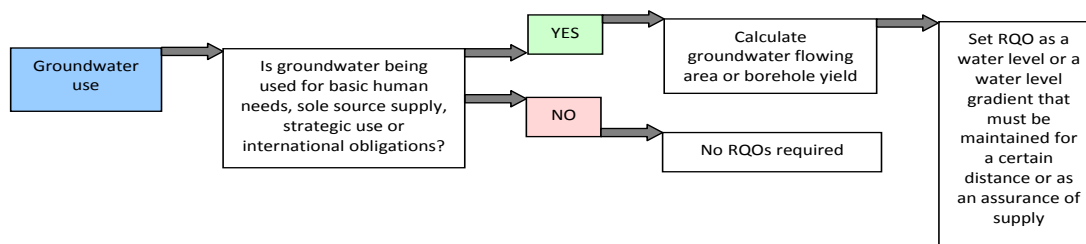


Figure 253: RQOs for BHNs, strategic use and international obligations

A note on boreholes . . .

The radius of influence for boreholes can be used as a conservative guide for development of new boreholes. The radius of influence is determined by setting the drawdown to zero in the Cooper-Jacob equation. Due to the nature of the drawdown curve represented by the Cooper-Jacob equation it is not always a practical radius due to the fact that the drawdown curve tends to zero over a long distance. A more practical approach would be to set the drawdown to something like 10cm and calculate the radius of influence accordingly. The Table shows the practical implication of this if the following constant parameters are assumed:

- Abstraction = 1 m³/d
- Transmissivity = 5 m²/d
- Storativity = 0.001
- Time = 360 days

Allowed Drawdown (cm)	Radius of Influence (m)
0	2012
1	1469
5	418
10	87

Note that not setting the drawdown to zero makes the radius of influence dependent on both the abstraction and the time that abstraction takes place.

If a new borehole cannot be placed according the specified radius of influence due to physical constraints e.g. geophysical results or property boundaries the borehole may be placed on the optimal position taking into account all factors as long as proper water level management takes place as described earlier in Section 31.2.

31.7 Defining RQOs for Protected Areas

RQOs also need to be assigned to protected areas such as national parks and world heritage sites, as seen in the Figure below. The amount of groundwater flowing into these regions needs to be calculated. Once this has been done, the RQO can be set as a groundwater level or gradient to be maintained for a certain distance from the protected area.

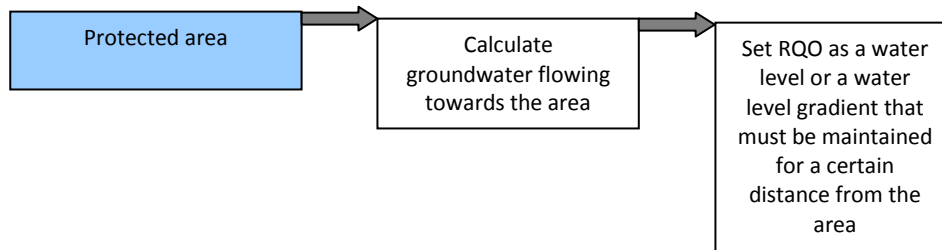


Figure 254: RQOs for protected areas

31.8 Defining RQOs for Contaminated Sites

31.8.1 General

To be able to calculate protection zones aquifer parameters are required. Due to the vast extent of the study area ranges of parameters exist, hence when a calculation is made the local aquifer parameters are required. Table 192 shows typical ranges of aquifer parameters across the study area.

Table 192: Groundwater parameters

Parameter	Range
Hydraulic conductivity [m/d]	0.001 – 0.0001
Hydraulic gradient	0.04 – 0.0001
Porosity	0.005 – 0.2

31.8.2 Mines, industry etc.

Most of the mines in the area are associated with coal mining. Coal mines are known for high sulphate values that occur at the source ~ 2000 mg/l. Pyrite (FeS₂) an iron disulphide, are one of the most important sulphides found in the waste rock of mines. When exposed to water and oxygen, it can react to form sulphuric acid. This process is known as acid mine drainage where low pH values result in heavy metals going into solution. Using the parameters shown in Table 192, the attenuation of the SO₄ concentration is within the drinking water guidelines at a distance of 500m when considering a constant source input.

A conservative approach is taken and a protection distance in the direction of the hydraulic gradient of a 1000m is recommended for mines and industrial areas. In practice preferred pathways exist in the form of fractures which can transport the pollutants orders of magnitude further than what is predicted in the porous media. From a multitude of industrial and mining monitoring sites it is

evident that pollutants moving through fractures are subject to a high degree of dilution resulting in less of a threat compared to the primary porosity movement.

All mining and industrial areas are to be treated as hotspots and monitoring boreholes close to the recommended protection distance of a 1000m in the direction of the groundwater gradient should form part of the monitoring network in the area. Sampling of these monitoring points should be done at least once a year with full chemical analysis to ensure safe drinking water outside the hot spot area.

31.8.3 Sanitation

All new sanitation developments and new water supply projects should adhere to the DWAF guidelines on sanitation. Existing installations not complying with the DWAF standard should form part of the monitoring network of the management area. Nitrate pollution in drinking water can be fatal especially to infants. Sampling of these monitoring points should be done at least once a year with microbial analysis to ensure safe drinking water.

32. Conclusions

The Thukela River is a principal river of the KwaZulu-Natal province in South Africa, and is ranked as the second largest river in the country by volume. It rises as a stream on the 3050 m high Mont-aux-Sources plateau near the merger point of the Lesotho – Free State Province borders. Its upper course lies within the Royal Natal National Park in the Northern Drakensberg. The river hurtles down a series of waterfalls as it drops a total of 948 m. The river cuts through the Thukela Gorge at the foot of the escarpment (approximately 1500 mamsl), passes through the Ladysmith Basin and becomes narrow and deep below Colenso. At Jameson's Drift, it enters the wide open Thukela Trough and then the coastal plain. The 405 km Thukela River mouth lies midway between Durban and Richards Bay, 10 km to the east of the national road bridge, 14 km to the south-east of the town Mandini and 104 km from Durban. The Thukela Water Management Area (WMA) consists of the entire catchment of the Thukela River, also referred to as the 'V' Hydrological Drainage Region (Midgeley et al., 1994). The WMA contains 88 quaternary catchments.

The catchment experiences a wide range of climatic conditions, ranging from generally wet and cold in the Drakensberg Mountains to dry and hot in the Thukela Valley from Colenso towards the coast, and hot and humid at the coast. Summers are generally hot with temperatures often exceeding 35°C. Winters are cold, particularly in the west and north, where temperatures fall below freezing and frost occurs regularly. Along the coast, conditions are generally more temperate. Rainfall varies significantly throughout the catchment and exhibits a strong correlation with relief. Rainfall is strongly seasonal, with in excess of 80% occurring as thunderstorms during the period from October to March. The peak rainfall months are December to February in the inland areas and November to March at the coast. Mean annual precipitation ranges from in excess of 1500 mm in the west to 750 mm, to over 1000 mm at the coast.

The Thukela River and some of its main tributaries rise in the west of the catchment in the high lying Drakensberg Mountain Range. These mountains attain elevations in excess of 2500 m. The river then winds its way through gently rolling hills before entering the steep sided gorges below Colenso. This rugged topography continues down to the river mouth, broken only occasionally by flatter, more densely populated floodplains (e.g. Tugela Estates and Tugela Ferry).

The natural vegetation types of the Thukela River Catchment follow a similar pattern to the geology. Montane grasslands covers the higher lying areas, giving way to Southern Tall Grassveld interspersed with invading *Acacia sieberiana* savanna and tilled agriculture in the lower parts of the Upper Thukela Sub-Catchment, between Bergville and Colenso. Moving downstream past Colenso, vegetation slowly changes to Valley Bushveld. Coastal grasslands and sugarcane farming characterise the lower part of the catchment. The Mooi River system is mainly modified by pastoral farming practices, with areas of indigenous subtropical forests along the steeper parts of this sub-catchment. Cattle farming bushveld dominates the Buffalo River Sub-Catchment, with the exception of montane grasslands in the upper part of this sub-catchment. The largest listed land use in this WMA is for nature reserves. A large portion of the Thukela Catchment is used for agriculture, comprising mainly subsistence farming, temporary commercial dryland agriculture, temporary commercial irrigated

agriculture, and commercial forestry. Approximately 1% of the catchment is urban, comprising mostly residential, industrial and commercial development, as well as mines and quarries. This is mainly associated with the towns of Estcourt, Ladysmith, Dundee and Newcastle, situated in the upper catchment.

There are many important wetlands in the Thukela Basin. They are concentrated in three areas: the upper Buffalo Catchment, the upper Mooi/Bushmans Catchment and the upper Myamvubu Catchment upstream of Craigie Burn Dam. In the upper Buffalo Catchment, the Wakkerstroom Vlei, Groenvlei and the Blood River Vlei are important in themselves, but are also renowned for their bird life. There are several smaller vleis in the upper catchment of the Slang River. Boschoffsvlei is near Utrecht. Well-known vleis in the upper Mooi River Catchment are the Hlatikulu, Stillerust Vlei and the Highmoor Vlei.

The soil is a complex mixture of eroded rock, mineral nutrients, decaying organic matter, water, air and billions of organisms, most of which are microscopic decomposers. The following soil types occur in the Thukela WMA:

- Drakensberg Escarpment (western boundary): moderate to deep clays on steep slopes
- Drakensberg Escarpment (northern boundary): moderate to deep sandy loams on undulating terrain
- Central area: moderate to deep clays on undulating terrain and moderate to deep clayey loams on steep slopes and undulating terrain
- Coastal belt: moderate to deep clayey loams and sandy loams on undulating terrain

The study area is mostly underlain by the Karoo Supergroup and is either sub-horizontal or has a very gentle inland dip to the west, and a minor eastern coastal and coastal hinterland portion, wherein the structure comprises numerous south-easterly or seaward tilted fault blocks. These fault blocks play an important role in groundwater flow. In the low-standing east central portion of the basin, extending east to within about 20 km of the coast - 'Basement' rocks are exposed, comprising granite-gneiss, schists and amphibolites. Younger unconsolidated sands are limited to the coastal area and river beds.

Aquifers within the study area include:

- Weathered and fractured hard rock aquifer systems.
- Primary aquifers that are confined to a narrow strip along the coast and the middle reaches of the Thukela, Sundays and Buffalo Rivers. The primary aquifer in the immediate vicinity of the estuary provides a source of moderate quality water to the estuary during periods of low flow.

As already mentioned, there are 88 quaternary catchments within the Thukela WMA, making delineation a complex process. In addition, as the surface water Reserve has already been completed for the WMA, the groundwater Reserve must take these results into account and the surface water RUs must therefore also be taken into account together with groundwater. The first step in the delineation process was to divide the study area into four sub-catchments, namely the

Upper Thukela, Buffalo, Mooi/Sundays and Lower Thukela catchments. Each area is then divided into smaller and in most cases quaternary catchments. Other aspects taken into consideration are:

- Geology
- Topography
- Recharge
- Groundwater use (and stress)

The results of the classification and the Reserve are summarised in Table 193.

Table 193: Results of Study

Resource Unit	Classification		Recharge			Reserve			Allocation	
	Present Status Category	Resource Category	Total Area km ²	Effective Area km ²	Recharge Mm ³ /a	Baseflow Mm ³ /a	BHN Mm ³ /a	Reserve % Recharge	Allocation Mm ³ /a	Current Use Mm ³ /a
TRU-A	B/C	Good/Fair	1098.5	715.2	109.275	58.880	0.108	54%	43.762	6.525
TRU-B	C	Fair	1064.5	827.9	69.597	19.210	0.122	28%	20.656	29.609
TRU-C	C	Good/Fair	518.3	505.3	44.273	15.890	0.130	36%	15.145	13.107
TRU-D	B/C	Good/Fair	304.7	304.7	15.498	4.070	0.031	26%	1.873	9.524
TRU-E	B/C	Good/Fair	558.5	520.7	25.694	5.960	0.030	23%	4.431	15.272
TRU-F	B/C	Good/Fair	659.1	659.1	24.195	5.030	0.017	21%	2.259	16.889
TRU-G	C	Fair	755.2	755.2	41.220	12.140	0.125	30%	19.950	9.005
TRU-H	B/C	Good/Fair	892.8	892.8	39.041	11.040	0.007	28%	6.864	21.130
TRU-I	C	Fair	962.6	962.6	47.506	8.420	0.279	18%	25.136	13.672
TRU-J	B/C	Good/Fair	827.0	794.0	50.633	12.274	0.034	24%	24.635	13.689
TRU-K	B/C	Good/Fair	1019.1	1019.1	41.252	13.360	0.072	33%	10.860	16.960
TRU-L	B/C	Good/Fair	1055.1	1055.1	36.900	11.100	0.170	31%	10.854	14.776
TRU-M	C	Fair	2553.6	2553.6	62.028	21.430	0.227	35%	40.191	0.180
TRU-N	B/C	Good/Fair	1046.6	597.1	80.922	29.340	0.262	37%	36.940	14.380
TRU-O	B/C	Good/Fair	944.5	763.2	69.793	26.450	0.005	38%	12.875	30.464
TRU-P	B/C	Good/Fair	869.0	852.6	28.148	5.870	0.034	21%	20.082	2.162
TRU-Q	C	Fair	1006.2	994.4	51.900	12.530	0.031	24%	18.338	21.000
TRU-R	C/D	Fair	4142.0	4062.8	295.926	47.170	0.595	16%	164.523	83.638
TRU-S	D	Fair	2761.4	2761.4	97.261	21.530	0.525	23%	3.096	72.110
TRU-T	C	Fair	1061.7	1041.4	41.378	8.040	0.084	20%	12.616	20.637
TRU-U	B/C	Good/Fair	1836.8	1825.1	67.968	14.860	0.173	22%	52.748	0.187
TRU-V	B/C	Good/Fair	965.4	928.5	52.764	11.490	0.051	22%	40.914	0.309
TRU-W	B/C	Good/Fair	788.2	755.8	26.065	10.380	0.038	40%	15.138	0.509
TRU-X	B/C	Good/Fair	1201.8	1198.3	87.847	31.700	0.144	36%	51.589	4.414
TRU-Y	C	Fair	146.8	144.2	8.822	5.590	0.022	64%	0.288	2.923

Guidelines for Resource Quality Objectives were provided for the following:

1. Borehole management
2. Wetlands and estuaries
3. Springs
4. Basic human needs, strategic use and international obligations
5. Protected areas
6. Contaminated sites

33. References

- Bredenkamp, DB, Botha, LJ, Van Tonder, GJ, Van Rensburg, HJ (1995) Manual on Quantitative Estimation of Groundwater Recharge and Aquifer Storativity. WRC Report TT73/95, Pretoria.
- BKS (2003) Thukela Water Management Area: Overview of Water Resources Availability and Utilisation. Report No P WMA 07/000/00/0203. Department of Water Affairs and Forestry, Pretoria.
- Colvin, C, Xu, Y, van Tonder, GJ, Hughes, S, le Maitre, D, Zhang, J, Mafanya, T and Braune, E (2003) Towards the Resource Directed Measures: Groundwater component; WRC Report No. 1090-2/1/03, Water Research Commission, Pretoria.
- Department of Minerals and Energy (2007) Operating and developing coal mines in the Republic of South Africa 2006, 234 Visagie Street, Pretoria
- Department of Minerals and Energy (2007) Producers of non-ferrous metal commodities in South Africa 2007, 234 Visagie Street, Pretoria
- Department of Minerals and Energy (2008) Producers of industrial minerals commodities in South Africa 2008, 234 Visagie Street, Pretoria
- Department of Minerals and Energy (2008) Operating mines and quarries and mineral processing plants in the Republic of South Africa 2008, 234 Visagie Street, Pretoria
- Department of Water Affairs and Forestry (1995) Characterisation and Mapping of the Groundwater Resources, KwaZulu-Natal Province. Reports and Maps, Mapping Units 1,6,8,9 and 11.
- Department of Water Affairs and Forestry (1997) The Impacts of Timber Plantations on runoff in South Africa: A Handy Reference Manual. Compiled by the CSIR.
- Department of Water Affairs and Forestry (2002a) Thukela Water Project Feasibility Study: Main Report. Report No. V000/00/9600, Pretoria.
- Department of Water Affairs and Forestry (2002b) Thukela WMA – Water Resources Situation Assessment. Report No: P WMA 7/000/00/0301, Pretoria.
- Department of Water Affairs and Forestry (2003a) Thukela Water Management Area: Overview of Water Resources and Utilisation. Report No. P WMA 5/000/00/0203.
- Department of Water Affairs and Forestry (2008) KwaZulu-Natal Groundwater Plan, Pretoria.
- Department Economic Development and Planning (2008) Emnambithi/Lady Smith Municipality: Integrated Development Plan 2007/2008, Lady Smith.
- De Swart G (2007) Personal communication, Geotail, PO Box 38457, Faerie Glen, Pretoria.
- E. Martinelli and Associates (1995) Characterization and mapping of the groundwater resources KwaZulu-Natal Province – Mapping Unit 5; Department of Water Affairs and Forestry, Pretoria.
- Hobbs PJ (1993) Characterization and mapping of the groundwater resources KwaZulu-Natal Province – Reconnaissance phase; Department of Water Affairs and Forestry, Pretoria.
- Hughes, DA (1999) SARES. Institute for Water Research, Rhodes University, Grahamstown, South Africa.

- IWR Source-to-sea (2003) Thukela Water Project Decision Support Phase: Reserve determination module main report. Report No: PBV00-00-1034. Directorate National Water Resource Planning. Department of Water Affairs and Forestry, Pretoria.
- IWR Source-to-sea (2003) Thukela Water Project Decision Support Phase: Reserve determination study – groundwater scoping report. Report No: PBV00-00-10315. Directorate National Water Resource Planning. Department of Water Affairs and Forestry, Pretoria.
- King, GM (2003) An explanation of the 1:500000 General Hydrogeological Map Vryheid 2730, Department of Water Affairs and Forestry, Pretoria.
- King, G (1997) The development potential of KwaZulu-Natal aquifers for rural water supply. Unpublished MSc thesis, Rhodes University, Grahamstown
- Knight Piesold Consulting (2003) Thukela Water Management Area: Water Resources Situation Assessment Report No P 07000/00/0101. Directorate Water Resource Planning. Department of Water Affairs and Forestry, Pretoria.
- Low AB and Rebelo AG (1996) Vegetation of South Africa, Lesotho and Swaziland. Department of Environment and Tourism, Pretoria
- Maseko Hlongwa and Associates cc (2004) Uthukela District Integrated Development Plan (2003/2004 Review).
- Midgley, DC, Pitman, WV and Middleton, BJ (1994) Surface Water Resources of South Africa 1990. Volume IV Appendices. WRC Report No 298/4/1/94
- National Water Act (1998) Government Gazette, 19182. Act 36, 26 August 1998. Pretoria, South Africa.
- Okhahlamba Local Municipality (2007) IDP Review 2007/2008, Bergville.
- Pienaar HH (2005) Towards a classification system of significant water resources with a case study of the Thukela River. Unpublished MSc thesis, University of the Western Cape, Cape Town.
- Parsons, R and Conrad, JE (1998) Explanatory notes for the aquifer classification map of South Africa. WRC Report No. 116/98. Water Research Commission, Pretoria.
- Parsons, R and Wentzel, J (2005) Groundwater Resource Directed Measures Manual. WRC Project K5/1427. Water Research Commission, Pretoria.
- Rowntree, KM and Wadeson, RA (1999) A hierarchical framework for categorising the geomorphology of river systems, Water Research Commission Report. Report No. 497/1/99. WRC, Pretoria.
- Quality of Domestic Water Supplies, Volume 1: Assessment Guide (2001) Report no TT 101/98, Water Research Commission, Pretoria.
- Quinn N and Whitefield A (1999) Thukela Estuarine flow requirements: An initial assessment. Department of Water Affairs and Forestry, Pretoria.
- Seymour, A (1995) Explanation for the harvest potential map of South Africa. Department of Water Affairs and Forestry, Pretoria
 Tlou & Matji (Pty) Ltd (2004) Thukela Water Management Area: Internal Strategic Perspective Report No: P WMA 07/000/00/0304. Directorate National Water Resource Planning. Department of Water Affairs and Forestry, Pretoria.

- Schulze RE (1997) South African Atlas of Geohydrology and Climatology. Report TT 82/96 Water Research Commission, Pretoria.
- SAEON (accessed 2008) <http://www.saeon.ac.za/eNewsletter/Online/2007/november/saeon-steps-in-to-safeguard-80-years-of-long-term-observation-records>
- Sustainable Development Projects (2006) Preliminary ecological assessment of the proposed fish barrier on the Mooi River above Inchbrakie Falls at "Coldstream", Ballito.
- Van Tonder, GJ (2003) Base flow estimates per quaternary catchment. Personal communication. Institute for Groundwater Studies, University of the Free State, Bloemfontein.
- Vegter, JR (1995) An Explanation of a Set of National Groundwater Maps, WRC report TT 74/95, Water Research Commission, Pretoria.
- Veltman, S (2004) Personal communication. Department of Water Affairs, Pretoria.
- Wentzel J and Smart M (2002) Revision of the General Authorisations no 1191 as set out Government Gazette no 20526, 8 October 1999 – Groundwater Component, Department of Water Affairs and Forestry, Pretoria.
- Woodford AC and Chevallier L (2002) Hydrogeology of the Main Karoo Basin: Current Knowledge and Future Research Needs. WRC Report No. TT 179/02. Water Research Commission, Private Bag X03, Gezina.