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For:
Department of Water Affairs and Forestry

THE RIVIERSONDEREND:

SITUATION ASSESSMENT, WITH SPECIFIC REFERENCE TO THE EFFECTS OF THEEWATERSKLOOF DAM ON THE RIVERINE ECOSYSTEM

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EXECUTIVE SUMMARY

SCOPE OF THE STUDY

- This study was commissioned by the Department of Water Affairs and Forestry, as part of the Skuifraam Dam Feasibility Study. The optimal capacity of the proposed Skuifraam Dam, situated on the upper Berg River, will depend *inter alia* on whether Theewaterskloof Dam, situated on the Riviersonderend, is raised to increase its storage capacity, as a larger Theewaterskloof Dam could be used to store water from the Berg River.
- This study comprised an assessment of the current ecological condition of the Riviersonderend, downstream of Theewaterskloof Dam, with links being made where possible between the state of the river and the hydrological regime resulting from the presence of Theewaterskloof Dam. The study was aimed at providing a preliminary assessment of the possible impacts that may accompany further reduction or alteration in the hydrological regime of the river, which could result from the raising of Theewaterskloof Dam.
- The following terms of reference were suggested by Southern Waters, and accepted by the Department of Water Affairs and Forestry:

  1. to provide a brief review of existing relevant information on the Riviersonderend
  2. to review existing data on the hydrological regime of the river before and after construction of Theewaterskloof Dam, providing an assessment of potential ecologically-meaningful changes in flow patterns caused by the existing dam
  3. to provide an assessment of the present Conservation Status of the river (an assessment of habitat integrity was undertaken as a separate study)
  4. to determine the major geomorphological reaches of the river, as a desktop exercise
  5. to examine the major habitats (physical biotopes) available to the aquatic fauna downstream of the dam, and their distribution in the Riviersonderend
  6. to provide an assessment of past and present water quality, including information on aquatic algae presently in the river, as water quality indicators
  7. to provide an assessment of the present state of the riverine invertebrate fauna through rapid bioassessment techniques (SASS4), and the compilation of a reference list of invertebrate taxa collected from the Riviersonderend during field surveys, for use as baseline information
  8. to assess the crab, frog and otter populations along the river, based on existing records, with limited field collections of crab data

9. to comment on the presence and distribution of fish, both indigenous and alien, based on existing Cape Nature Conservation records
10. to describe and assess the riparian and instream flora along the course of the river
11. to provide a summary assessment of changes in the river that may be associated with the presence of the Theewaterskloof Dam
12. to provide a preliminary assessment of the possible impacts that may accompany further reduction or alteration in the hydrological regime of the river, with suggestions for possible future action.

- For the purposes of the study, six sites along the Riviersonderend, from downstream of the Theewaterskloof Dam to its confluence with the Breede River, were visited. These sites were selected after an initial geomorphological assessment of the river, to be appropriate also as sites for use in an Instream Flow Requirements workshop, should this be required. In addition, a brief examination of the water quality of the Breede River, up- and downstream of its confluence with the Riviersonderend, was undertaken, through collection of water chemistry data in the field, and through rapid bioassessment of the invertebrate fauna.
- Assessments of physical, chemical and biological components of the river were made, where possible in relation to the characteristics of flow in the reaches downstream of the dam. Field studies were conducted in late winter and again in summer, since the effects of the current hydrological regime on aspects of the ecosystem are likely to vary seasonally.
- Data on the river biota prior to the construction of the dam do not exist, and so it is not possible to describe the changes that have occurred in the river since impoundment of the upper reaches. This makes the task of relating the flow patterns in the river, resulting from the presence of the dam, to its present state a difficult one and it has been necessary to rely for the most part on general knowledge of the natural biotas of western Cape rivers.
- The study was conducted within the time constraints of a four month period, between late September 1995 and January 1996, and with financial constraints on the detail of the investigations undertaken.
- The study must therefore be considered as providing only a preliminary ecological assessment of the Riviersonderend.

MAJOR FINDINGS OF THE STUDY

- The Riviersonderend rises in the Groot Drakenstein Mountains, at an altitude of approximately 1590 m AMSL, and flows along the Riviersonderendkloof for some 15 km before it feeds into the Theewaterskloof impoundment at 300 m AMSL.
- Downstream of Theewaterskloof Dam, the Riviersonderend flows eastwards through the Donkerhoekberge, which are situated at the south-western limit of the Riviersonderend Mountains. These mountains extend in a broad east-west band and receive winter rainfall from the north-westerly frontal systems, as well as considerable, if unpredictable, summer rainfall from the south-easterly winds blowing on-shore along the south coast.
- The Riviersonderend drains the southern slopes of this mountain range, flowing over a distance of some 90 km, before the river curves in a north-easterly direction and cuts through the range at 'Die Poort". The river then flows eastwards for a further 15 km, to join the Breede River west of Swellendam.
- The source of the Riviersonderend is in Cape Fold Mountains where Table Mountain Group sandstones and quartzites of the Cape Supergroup are dominant. The Riviersonderend Mountains which run north of the river once it leaves Theewaterskloof Dam, are of a similar geology. Bokkeveld Group shales of the Cape Supergroup are found in patches along the course of the river as it flows from Theewaterskloof Dam to the Breede River.
- Upstream of the dam, the Riviersonderend is in good condition, except in limited stretches where forestry activities have degraded the riparian belt. The river downstream of Theewaterskloof Dam has been subjected to changes in water quality and flow regime as a result of both agriculture and the building of Theewaterskloof Dam.

Hydrological regime

- Hydrological data from two locations on the river, approximately 90 km apart, were used for the assessment, as follows:
  a) a site immediately downstream of the Theewaterskloof Dam (referred to as "the dam site")
  b) a point on the Riviersonderend upstream of the confluence with the Breede River, at the DWAF gauging weir H6H009 (referred to as "H6H009").
- Theewaterskloof Dam was completed and began operating in 1980, but only reached full supply capacity in the winter of 1993. Thus the 14 years of historical record since the dam was built do not reflect the actual effects of the dam in the way it will be operated in the future.
- The historical effect of the Theewaterskloof Dam, as seen in the post-dam flow records, is a substantial alteration in flow regime.

- Present-day mean annual runoff (MAR) just downstream of Theewaterskloof Dam, based on long-term simulated data, is estimated at 36% of virgin MAR (at 1996 irrigation demand levels). Flow records from 1993 to 1995, however, indicate that the annual runoff is a mere 18% of the virgin MAR. According to the simulated data, the raising of the dam wall will have a comparatively small effect on the MAR in the river downstream, decreasing the simulated present-day MAR by a further 2% of the virgin MAR.

- In its natural condition, the Riviersonderend is a perennial river, but shows strong seasonality in flow patterns. Winter rainfall is associated with a wet season, whilst summer flows are low (the dry season), and "transitional" wet-dry or dry-wet periods are discernible between these two seasons.

- During the period (1980-1989) when releases were made to keep the dam at 40% of full supply capacity and later (1990-1993) at 80% of full supply capacity (FSC), the trend was a delay in floods and a reduction in flood peaks. Since the dam has been operated at 100% FSC, as shown in the last two years of record, the seasonal distribution of flows indicates considerable departure from the natural seasonal flow regime of the Riviersonderend: the onset of higher flows associated with the wet season is delayed, the first winter floods are delayed by up to three months (now usually occurring in July and August, instead of in April/May as they were in the pre-dam period), and floods are reduced in both magnitude and frequency.

- Reduction in baseflows is severe in those months classified as "transitional" between wet and dry seasons, with the lowest flows of the year occurring in May and June. Between releases or dam spillages in the wet season, baseflows are also critically low with respect to providing the conditions necessary for survival of aquatic animals.

- Reduction in baseflows, together with the reduction in the onset and frequency of floods, has compressed the "winter" (transitional and high flow) period into far fewer months (July to October) than the period naturally encountered in perennial rivers in the western Cape (April/May to October).

- Components of the flow regime, such as seasonal cues heralding the end of summer and the onset of the wet season may be important for the biota and yet appear to have been removed from the system over the past two years.

- Releases of water for irrigation in summer have resulted in an increase in summer baseflows of the order of 100%.

- The flow regime is severely altered in the reaches immediately downstream of the dam (about 17km), after which runoff from the Riviersonderend Mountains, which follows a more natural pattern, ameliorate this effect to some extent.

- The effects of the dam are less obvious at DWAF Gauging weir H6H009 than just downstream of the dam, although increased summer flows in the post-dam period are noticeable, and the wet season is delayed. It is suggested that the effects of the dam become progressively dampened with distance downstream, as a result of the natural contributions of flow from the tributaries draining the Riviersonderend Mountains. No detailed hydrological study has been made of the flows and demands between Theewaterskloof Dam and Gauge H6H009 however, and the balance between runoff and abstractions along the course of the river is unknown.

- The effects of the alteration in flow regime on ecological and geomorphological aspects of the Riviersonderend, as a result of the Theewaterskloof Dam, are likely to be profound, particularly with regard to channel size and shape.
- As demand for water for irrigation grows, the changes in flow patterns are likely to become more extreme, with additional and more extreme consequences for the instream biota. Furthermore, more efficient regional management of water supply from the various dams within the western Cape means that, for the Riviersonderend downstream of the dam, there will probably be less late-winter spillage, (none at all in dry years), with wet-season flows in the river coming only from the Riviersonderend Mountains feeding into the river further downstream in the valley.

Physical characteristics of the river

- Biotope characteristics at each site were mapped and detailed data on substratum type (particle size), water depth and flow velocities were obtained by means of cross-sectional profiles.
- The Riviersonderend downstream of Theewaterskloof Dam comprises six geomorphologically distinct reaches. Each reach exhibits a distinctive channel morphology, substratum type and proportions of different biotopes. The six study sites were allocated one to each geomorphological reach.
- This geomorphological categorisation of reaches is reflected in the fact that there was no obvious progressive longitudinal (downstream) change in physical characteristics, for example, in width and depth.
- Reaches with a naturally well-defined, single channel (represented at Sites 1, 3 and 5) had received least physical interference, and these provided the greatest potential array of biotopes.
- Biotope diversity is dependent on flow regime and, as a result of Theewaterskloof Dam, the availability of different biotopes at Site 1 is reduced in summer and winter by unnaturally high and low flows respectively.
- Low winter flows have most affected biotope availability in the upstream reaches (Sites 1 and 2), and the effects of these flows are felt all along the river, although somewhat ameliorated downstream by runoff from the Riviersonderend Mountains.
- The absence of large, scouring floods in winter in the recent past has allowed the encroachment of palmiet into the main channel and secondary braids, the deposition of fines in shallow riffle and run areas, and the encroachment into the channel of bankside vegetation, especially of alien plants.

- Present-day releases for irrigation in summer have markedly reduced biotope diversity only at Site 1, just downstream of Theewaterskloof Dam, but the effects of these releases are less obvious further downstream by abstractions from the river, where fairly natural summer flow conditions exist, and which allow for a diversity of biotopes.

- The direct effects of Theewaterskloof Dam on the physical characteristics of the river (such as depths, velocities of flow, substratum composition, and overall availability of a range of biotopes) are most severe immediately downstream of the dam.

- The effects of the dam decrease with distance downstream, although in the lower reaches the effects become evident of encroachment of agricultural activities into the river channel. These include bulldozing of braids and canalisation of the river through infilling of the banks.

- The most severe indirect effect of the dam is that it has further encouraged the utilisation of areas of the macro-channel and flood channels, and the direct infilling of braids and secondary channels, as riparian owners have become aware of the reduced risk of flooding.

Water quality

- Historical water chemistry data were examined from three DWAF gauging weirs along the Riviersonderend, as follows:
  a) H6H008 - upstream of Theewaterskloof dam; data from 1977 to 1992 were used
  b) H6H012 - downstream of Theewaterskloof Dam; data from 1980 to 1995 were used
  c) H6H009 - in the Riviersonderend upstream of its confluence with the Breede River, and downstream of the town of Riviersonderend; data from 1977 to 1995 were used.

- In addition to the DWAF records, physical and chemical components of the water were recorded during field studies.

- The historical record does not reflect the natural (undisturbed) character of the water in the Riviersonderend, as collection of these data began only in the late 1970s at H6H009; and in the reach just downstream of the Theewaterskloof Dam, records exist only for the post-dam period since 1980.

- The water in the Riviersonderend is acidic, a natural characteristic of rivers of the Western Cape region, with waters of the upper reaches and mountain tributaries being more strongly acidic than those of the lower reaches. pH values were generally lower in winter than in summer, except immediately downstream of the data. This reflects water chemistry in the impoundment.

- Conductivities and concentrations of major ions increase with distance downstream from Theewaterskloof Dam. Some of the values for sodium and chloride in the lower reaches of the river indicate occasionally high salinities. This does not appear to be the result of the dam, but rather the consequence of agricultural activities, combined with the natural geological formations (Bokkeveld Group shales) in parts of the Riviersonderend Valley.

- Seasonal variation in the concentrations of ions below the dam was not apparent from the historical data recorded at DWAF gauges, but further downstream, concentrations were slightly higher in summer than in winter. This is probably the result of irrigation in summer and the dilution effects of rain, predominantly in winter.
- Conductivities in the Riviersonderend measured during the field surveys were all higher in September (winter) than in January (summer), which is the reverse of the pattern suggested by the DWAF data. This is probably linked to the very low discharges in the river in winter, and the increases in discharge at all the sites in summer. The floods in December, which preceded the January field visit, would have flushed accumulated salts from the catchment.
- No noticeable trends are discernible over time in salinisation of the river.
- Conductivities, and the concentrations of major ions, were lower in the Riviersonderend than in the Breede River and this indicates that the Riviersonderend contributes relatively purer water to the lower Breede River than that flowing in its reaches upstream of where the two rivers are joined.
- Nutrient concentrations in the Riviersonderend are generally low, with only a few outlying values suggesting mild nutrient enrichment at times.
- Aquatic algae were not abundant in the Riviersonderend, and at no places were dense mats of algal growth encountered.
- The extensive stands of palmiet in wider, braided sections of the river may be responsible for uptake of considerable quantities of nutrients.

Riparian vegetation

- There were four zones of vegetation found at the study sites. Zone A comprised the aquatic macrophyte zone, which is restricted to the areas with free water. Zone B comprised plants that are restricted to stream margins, where they are partially submerged but protrude from the water and do not have floating leaves. Depressions landward of zone B formed zone C; these depressions receive a heavier silt load because of slower flow rates than in Zones B or D. This area dries out fairly rapidly yet the soils are wet and gleyed. Because of human disturbance, it was difficult to distinguish the vegetation normally forming two or more zones behind and above Zone C. Consequently, for the purposes of this study, Zone D referred to all the remaining river-bank vegetation.
- Totally submerged aquatics were rarely encountered in the Riviersonderend. Three species of rooted aquatics with floating leaves were recorded along the length of the river, namely *Aponogeton distachyos, Nymphaea nouchali* and *Nymphoides indica.* A reduction in current speed will lead to an increase in their densities.

- *Eichhornia crassipes* was the only floating aquatic observed. It is anticipated that this aggressive alien plant will successfully invade the Riviersonderend through natural means (e.g. water birds) as nutrient enrichment occurs following increased abstraction of water.
- Under natural conditions, a band of *Prionium serratum* (palmiet) would probably line the edges of the river down its whole length. At present, palmiet forms wide beds along extensively braided parts of the river.
- *Isolepis prolifer* dominated zone C, and proved to be the most predictable indigenous species encountered along the whole course of the river. The species was observed to be extending its range into the shallower parts of the river during persistently low and would therefore be expected to take early advantage from lower flows coupled to increased abstraction.
- The invasive exotics, *Sesbania punicea* and *Salix babylonica* were abundant in zone C, along the length of the river. These species will probably increase as water levels drop more permanently to expose uncolonized sand below the *Prionium* zone.
- Very little remains of zone D to reconstruct the indigenous riparian vegetation which should occur. The river banks are clearly dominated over most of their extent by the Australian exotics *Acacia longifolia* and *A. mearnsii*. The reduction in the number and duration of floods, primarily through the construction of Theewaterskloof Dam, heavy water abstraction rates and ignorant riparian managers are probably contributing to this invasion.
- There is very little natural vegetation left along the course of the Riviersonderend except in Reach 7, at the Keeroms Poort below Theewaterskloof Dam. Further abstraction will reduce the rehabilitation potential of the highly invaded riparian vegetation along this river, below Reach 7.

Fish

- Two Red Data species, *Pseudobarbus burchelli* and *Barbus andrewi*, have been recorded in the Riviersonderend downstream of Theewaterskloof Dam as recently as 1991. Both these species are considered threatened due to reduction and destruction of their natural habitats, and predation by introduced alien fish.
- Three common indigenous species, *Sandelia capensis*, *Galaxias zebratus* and the common freshwater eel, *Anguilla mossambica*, are known to occur in the study area.
- Two species indigenous to southern Africa, *Oreochromis mossambicus* and *Tilapia sparrmanii*, have been translocated to the Riviersonderend from systems further north.
- A further five alien species have been introduced to the Riviersonderend. *Micropterus dolomieu* (smallmouth bass), *Micropterus salmoides* (largemouth bass), *Lepomis macrochirus* (bluegill sunfish) and *Tinca tinca* (tench) have been recorded in the river, while *Cyprinus carpio* (carp) has become established in Theewaterskloof and is likely to have moved downstream of the dam.

- Some of the fish introduced to the Riviersonderend, occur in slow-flowing quiet waters on sandy bottoms. These conditions prevail along much of the river length, and may thus these species might be favoured over those indigenous to the Riviersonderend.

Otters

- No fresh signs of otter were found along the Riviersonderend downstream of Theewaterskloof Dam, although they have been recorded in the past.
- During the current survey, otter spoor were found near Theewaterskloof, and scats, comprising crab remains, were found along the Breede River.
- Otters are affected by human disturbances around urban or developed areas, but may become accustomed to human activities. The effect of Theewaterskloof Dam on the distribution of otters is not clear, as some individuals use impoundments as hunting grounds, and may be more active below dams.
- Otters are limited by the availability of prey, and so numbers of otters may be reduced if the dam has had a detrimental effect on the abundance of prey.

Frogs

- Ten species of frog, none of which is considered endemic or threatened, have been recorded in the Riviersonderend, below Theewaterskloof Dam,.
- Four species of amphibian were found to be associated with riverine habitat in the Riviersonderend. These were *Xenopus laevis, Bufo rangeri, Rana fuscigula* and *Strongylopus grayii.*
- A further six species occur in quiet wetland areas associated with the river, and may occur away from the main river course. These species are *Cacosternum boettgeri*, *Cacosternum nanum*, *Strongylopus fasciatus*, *Tomopterna delalandii*, *Hyperolius horstockii* and *Semnodactylus wealii.*
- As most of the species prefer to live and breed in quiet standing waters or seasonal wetlands rather than in flowing waters within the river channel, alterations in the availability of these biotopes, by for example the infilling of channel braids, may reduce frog numbers and distributions.

Crabs

- All crab specimens collected from the Riviersonderend and Breede River were identified as the Cape river crab, *Potamonautes perlatus*, a species common to rivers in the western Cape.
- *Potamonautes perlatus* is a hardy species that occurs commonly in the western Cape, in rivers with variable discharge regimes, so this species is unlikely to be directly affected by regulation of flow as a result of Theewaterskloof Dam.

- The encroachment of vegetation into the river channel may, however, reduce the availability of cobble- and boulder-strewn biotopes, which the Cape river crab favours, but it will occur even on muddy bottoms of ponds.

Macroinvertebrates

- The macroinvertebrate faunas of the Riviersonderend downstream of Theewaterskloof Dam, and of the Breede River near its confluence with the Riviersonderend, were sampled in late winter (September 1995) and summer (January 1996) using SASS4, a rapid bioassessment technique.
- Total SASS4 scores for the sites on the Riviersonderend ranged from very low at Site 1, immediately downstream of Theewaterskloof Dam, to good scores further downstream, as far as the Riviersonderend gorge, near the town of Riviersonderend.
- It is likely that the low numbers of macroinvertebrate taxa recorded at Site 1 during both September and January, and at Site 2 in September, were caused by the altered flow regime as a result of the dam, rather than poor water quality, as suggested by the low SASS4 total scores but moderate ASPT values.
- SASS4 total scores were highest at Sites 3 and 5, where water quality was good. Further, all types of biotope were available to the biota at these sites. The Gobos River enters the main channel upstream of Site 3, contributing naturally-timed flows, pure water, and possibly invertebrate drift, which may play a large role in maintaining the fairly natural state of the river fauna, particularly during the wet season. Site 5 is situated close to the gorge near the town of Riviersonderend and is relatively undisturbed.
- The total scores at Sites 4 and 6 during summer conditions indicate a deterioration in water quality compared with winter, probably as a result of agricultural pollution. The ASPTs at these sites, however, changed little compared to other sites, indicating that other factors, such as infilling of the river channel in these reaches, which affect the biotic integrity of the river may be having a greater influence on the macroinvertebrates than water quality.
- A total of 58 taxa was recorded in the Riviersonderend and Breede Rivers during the September field study, and 59 in January. With the exception of Site 1 and, to some extent Site 6, most sites supported a fairly high diversity of both tolerant, cosmopolitan taxa, and some more sensitive species.
- The composition of the macroinvertebrate communities sampled in the Riviersonderend, in many cases, supports the observation that the biota are influenced more by alterations to the flow regime, than by changes in water quality. For example, the chironomid dipterans, which occur in large numbers where there is organic pollution, were not recorded in abundance in the Riviersonderend.
- Many of the taxa recorded in the Riviersonderend were present in both September and January, suggesting a lack of strong seasonality in invertebrate community structure. This apparent lack of

seasonality, particularly in the upper parts of the river closer to the dam, is undoubtedly influenced by the alteration in the flow regime of the river.

Conservation status

- Upstream of Theewaterskloof Dam, the Riviersonderend is in good condition, except in limited stretches where forestry activities have degraded the riparian belt, and the river was assigned a high conservation status.
- Downstream of the dam, in geomorphological reach 7 (Keeromspoort), the riparian zone on the river channel are relatively undisturbed. Theewaterskloof Dam has, however, had considerable impact on the flow regime.
- Downstream of Keeromspoort the river is subjected to considerable anthropogenic pressure. The effects of Theewaterskloof Dam are noticeable along the entire length of the Riviersonderend downstream of the dam. Contraction of the river channel (particularly the braided sections of the channel) and expansion of palmiet beds are evident, and probably result from the reduced frequency and size of flood events in the river since the construction of the dam.
- Because of the reduced risk of flooding resulting from the presence of Theewaterskloof Dam, farmers have extended their fields into the river channel, have bulldozed secondary channels and/or are utilising the in-channel islands for grazing or crop production. Furthermore, releases made from the dam for irrigation in the downstream farming areas have resulted in a shift in, and possibly even a reversal of, the natural hydrological regime in the river, which can have serious consequences for the river biota.
- Several other types of direct and indirect anthropogenic disturbance were identified. These included removal of indigenous riparian vegetation, invasion of the riparian strip by alien trees, infilling of the river channel to extend cultivated fields, run-of-river abstraction, closure of small braided channels, and dumping of litter and rubble.
- Consequently, the lower reaches of the Riviersonderend were assigned low conservation status values.
- Nowhere below Keeromspoort (Site 1) was the riparian vegetation in a reasonable state. It was all highly disturbed and invaded.
- Factors affecting the conservation importance of the Riviersonderend might include its size and length, since there are only a few other rivers in the south-western Cape of similar size. Its proximity to the towns of Genadendal, Greyton and Riviersonderend means that it should have both educational and recreational value for those towns. As such, the river might be accorded a high conservation importance.

Current and possible future impacts on the Riviersonderend of Theewaterskloof Dam

- Theewaterskloof Dam has had a major effect on the flow regime of the Riviersonderend, especially in the reaches closest to the dam. Several components of the natural flow regime have been altered or removed. The seasonality of flow has been changed, leading to flood-flows at inappropriate times of the year, and the magnitude and number of floods are now insufficient for the maintenance of the channel morphology and prevention the encroachment of marginal vegetation. Furthermore, baseflows are too low in winter and, in some cases, too high in summer, to sustain many of the animals that should be present in the river, and the transitional periods between the dry and wet season have been removed completely from the flow regime.
- As an inevitable consequence of lower flows and the lack of scouring floods, the width of the river has been reduced considerably relative to its undisturbed state. This has, in turn, allowed farmers to cultivate the river banks, which are now unlikely to flood with any regularity. In addition, the permanently-dry and often physically-altered banks of the river are ideal habitat for invasion by alien plants.
- The objective of future management of the water supply from the Riviersonderend includes increased irrigation releases into the Riviersonderend during summer, as well as more efficient regional management of water resources. This latter development will be aimed at minimising winter spillage from dams in the region, so that their annual yields are maximised.
- It is clear that such future management strategies do not include considerations of their effects on the ecological integrity of the river, whilst the effects of the current, altered flow regime in the Riviersonderend have been well demonstrated in this study.
- The continued ecological integrity or level of naturalness of the Riviersonderend is not guaranteed. At present, the river shows a some recovery downstream of the dam, if only in the middle reaches. An increase in irrigation demand and releases, however, coupled with increased use of Theewaterskloof Dam for municipal water supply would almost certainly extend the impacts of the dam further downstream.
- Should further development of the water resources of the tributaries draining the Riviersonderend Mountains occur, this would remove the single most important factor that allows the river to maintain its present state.

Possible future action for the management of the Riviersonderend

- The Department of Water Affairs and Forestry (DWAF) has stated that it is committed to the management of rivers as resources (DWAF White Paper, 1995), and this implies that the river should retain its basic natural character. An appropriate flow regime is central to this objective.
- Maintenance of the current state of the Riviersonderend should be the minimum objective of sound river management, but further degradation can be mitigated against by the provision of water to simulate the natural flow regime, with its wet, dry and transitional periods, and scouring

flows in winter. The determination of the instream flow requirements of the Riviersonderend may therefore be necessary action, whether or not the raising of Theewaterskloof Dam is investigated further.

- Irrigation demands need to be re-evaluated, along with an investigation of alternatives to spray irrigation.
- The removal of aliens would not only help to restore the natural vegetation of the riparian belt, but would considerably increase runoff in the river during summer, and this would mitigate against the effects of increases in run-of-river abstraction in the lower reaches of the river.
- If management to maintain the river as a functioning riverine ecosystem is undertaken, and appropriate releases made throughout the year for the river, it would probably undermine the feasibility of increasing the current storage capacity of Theewaterskloof Dam for increased water supply.

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1. SCOPE OF THE STUDY

1.1 BACKGROUND INFORMATION

The Western Cape System Analysis (WCSA) was undertaken by Ninham Shand Incorporated (NSI) Consulting Engineers for the Department of Water Affairs and Forestry (DWAF). A recommendation resulting from this analysis was that the proposed Skuifraam Dam on the upper Berg River near Franschhoek be investigated at engineering feasibility level, and this is currently underway. Water resource development of the upper Berg River and of the Riviersonderend forms part of a regionally linked water supply network: a tunnel link-up exists between the Berg River at the site of the proposed Skuifraam Dam and the existing Theewaterskloof Dam, situated on the Riviersonderend near Grabouw. The optimal capacity of Skuifraam Dam will depend *inter alia* on whether Theewaterskloof Dam is raised to increase its storage capacity, as a larger Theewaterskloof Dam could be used to store water from the Berg River.

1.2 STUDY OBJECTIVE

This study comprised an assessment of the current ecological condition of the Riviersonderend, downstream of Theewaterskloof Dam, with links being made where possible between the state of the river and the hydrological regime resulting from the presence of Theewaterskloof Dam. The study was aimed at providing a preliminary assessment of the possible impacts that may accompany further reduction or alteration in the hydrological regime of the river, which could result from the raising of Theewaterskloof Dam.

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5. to examine the major habitats (physical biotopes) available to the aquatic fauna downstream of the dam, and their distribution in the Riviersonderend

6. to provide an assessment of past and present water quality, including information on aquatic algae presently in the river, as water quality indicators
7. to provide an assessment of the present state of the riverine invertebrate fauna through rapid bioassessment techniques (SASS4), and the compilation of a reference list of invertebrate taxa collected from the Riviersonderend during field surveys, for use as baseline information
8. to assess the crab, frog and otter populations along the river, based on existing records, with possible, limited, field collecting
9. to comment on the presence and distribution of fish, both indigenous and alien, based on existing Cape Nature Conservation records
10. to describe and assess the riparian and instream flora along the course of the river
11. to provide a summary assessment of changes in the river that may be associated with the presence of the Theewaterskloof Dam
12. to provide a preliminary assessment of the possible impacts that may accompany further reduction or alteration in the hydrological regime of the river, with suggestions for possible future action.

For the purposes of the study, six sites along the Riviersonderend, from downstream of the Theewaterskloof Dam to its confluence with the Breede River, were visited. These sites were selected after an initial geomorphological assessment of the river, to be appropriate also as sites for use in an Instream Flow Requirements (IFR) workshop, should this be required. In addition, a brief examination of the water quality of the Breede River, up- and downstream of its confluence with the Riviersonderend, was undertaken, through collection of water chemistry data in the field, and through rapid bioassessment of the invertebrate fauna.

Assessments of physical, chemical and biological components of the river were made, where possible in relation to the characteristics of flow in the reaches downstream of the dam. Field studies were conducted in late winter and again in summer, since the effects of the current hydrological regime on aspects of the ecosystem are likely to vary seasonally.

1.4 RATIONALE FOR DETAILED EXPLANATIONS OF METHODS

This report aims to provide baseline ecological information of the Riviersonderend downstream of Theewaterskloof Dam. Where applicable, detailed explanation of methods of collection and analysis of samples are provided, since these are important both in assessing the reliability of the data and in the design of possible follow-up ecological investigations that may be required should the feasibility of raising the Theewaterskloof Dam be further investigated.

A detailed investigation into the feasibility of raising the Theewaterskloof Dam would require an Instream Flow Assessment to be performed for the river, which is a costlier exercise than the present study. Should this investigation proceed, the sites selected for this situation assessment, and the biological information gathered during fieldwork, would dovetail with the information required for the Instream Flow Assessment process.

1.5 LIMITATIONS OF THE STUDY

No ecological studies have been performed on the Riviersonderend in the reaches downstream of Theewaterskloof Dam, as far the authors are aware, with the exception of a small number of frog and insect collections from the Riviersonderend Mountains. Nor are data on the river biota prior to the construction of the dam available for comparison with the results of the present study, and so it is not possible to describe the changes that have occurred in the river since impoundment of the upper reaches. This makes the task of relating the flow patterns in the river, resulting from the presence of the dam, to its present state a difficult one and it has been necessary to rely for the most part on general knowledge of the natural biotas of western Cape rivers. The study must therefore be considered as providing only a preliminary assessment of the Riviersonderend.

The study was intended only as a preliminary survey of the river, with financial constraints on the detail of the investigations undertaken. Hydrological analyses, for example, were based only on existing recorded or simulated data, and additional simulations that would have improved the description of flow patterns in the lower parts of the river were not performed.

The study was also conducted within the time constraints of a four month period, between late September 1995 and January 1996. Thus, brief field trips were undertaken at the start and at the end of this period to provide the two best available (most different) "snapshot" views of the river ecosystem within this time, reflecting late winter/spring and mid-summer conditions respectively. These time constraints mean that collections of invertebrates and of riverine plants were limited, and may not reflect the full richness of these biotas, particularly with respect to those groups which are found only during autumn and winter. Also, time constraints mean that it was not possible to have the species indentities of many of the

1.6 DATES OF THE STUDY

The field studies were conducted from 23 - 26 September and from 11 - 14 January 1996. The deadline of 31 January 1996 for the final report was extended into February, because floods in December necessitated the postponement of the scheduled second field visit from December to January.

1.7 STUDY TEAM

The study was co-ordinated by G. Ractliffe, C. Snaddon and C. Brown of Southern Waters Ecological Research and Consulting CC, who compiled the information contained in this report, with the following exceptions:

- R. Wadeson, Geography Department, Rhodes University, undertook a geomorphological reach analysis for the full length of the Riviersonderend to its confluence with the Breede River, the results of which are reported in Section 2.
- Analyses of the hydrological data, performed by J. Larsen, Ninham Shand Consulting Engineers, provide the data for the section on assessment of flow patterns (Section 3).
- Dr C. Boucher, Botany Department, University of Stellenbosch undertook a field study of the riparian vegetation of the Riviersonderend, and compiled the section (Section 6) on riparian vegetation in this report.
- M. Somers, Zoology Department, University of Stellenbosch, compiled the report on otters (Section 8), based on existing data and on some further field surveys carried out under his own auspices.
- Dr B. Cook, South African Museum, identified specimens and compiled the report on crabs (Section 10).
- The reports on frogs and fish are based on data collected and collated by A. de Villiers and S. Thorne respectively, both of Cape Nature Conservation (CNC). Permission to use these data were kindly given by the Regional Director, CNC, Dr Kas Hamman.
- MAP Joska, Botany Department, University of Cape Town, identified freshwater algae collected in the field.

External review of this report was undertaken by Dr J.A. Day, Freshwater Research Unit, Zoology Department, University of Cape Town.

2. THE STUDY AREA

2.1 GENERAL DESCRIPTION OF THE STUDY AREA

2.1.1 The Riviersonderend catchment

Part of the greater Breede River system (Figure 2.1), the Riviersonderend rises in the Groot Drakenstein Mountains (3418 BB, 3419 AA; Grabouw 1:50 000 topographical maps, second edition 1979), at an altitude of approximately 1590 m AMSL, and flows eastwards for some 15 km along the Riviersonderend gorge within the Hottentots Holland Nature Reserve and State Forest, before it is dammed by the Theewaterskloof impoundment at 300 m AMSL. Theewaterskloof Dam was built in 1979, and is also fed by the Du Toits, Elands and Waterkloof Rivers, along with other smaller tributaries and seepage areas. The catchment area above the dam is 497 km^2, and the virgin Mean Annual Runoff (MAR), measured some 2 km downstream of the dam (DWAF gauging weir No. H6H012), was 291 x 10^6 m^3. The storage capacity of the Theewaterskloof Dam is 482 x 10^6 m^3. This impoundment acts as the source reservoir for the Riviersonderend-Berg-Eerste River Government Water Scheme, an inter-basin water transfer project that supplies water to Greater Cape Town, Stellenbosch and the upper Berg River catchment.

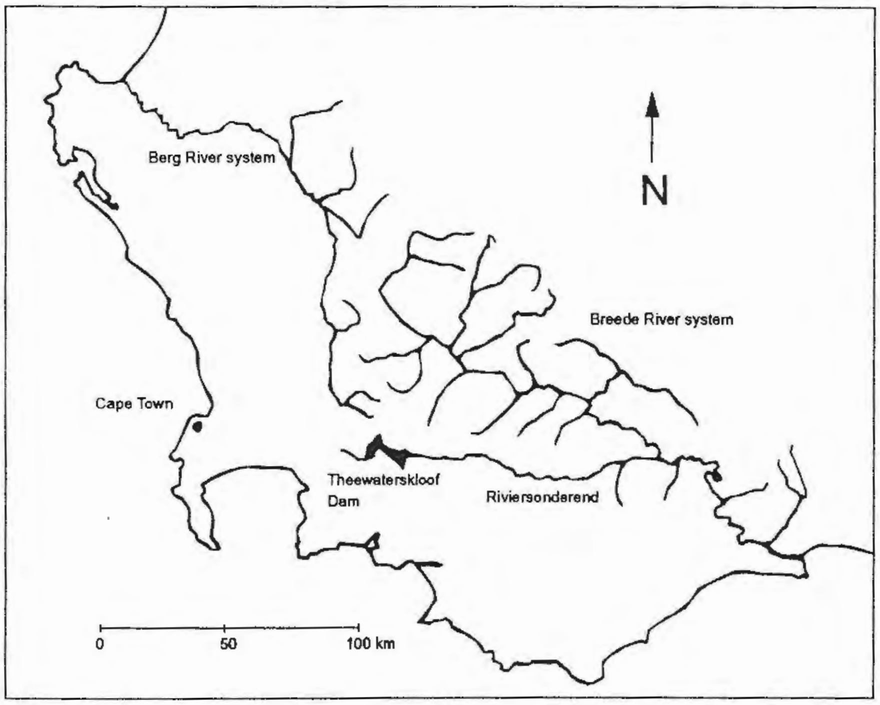

Figure 2.1 **Major river systems in the western Cape; the Berg and Breede River systems, showing the Riviersonderend and Theewaterskloof Dam.**

Downstream of Theewaterskloof Dam (Figures 2.2a - 2.2g), the Riviersonderend flows eastwards, entering Keeromspoort in the Donkerhoekberge after a short distance. The Donkerhoekberge are situated at the south-western limit of the Riviersonderend Mountains, which extend in a broad east-west band to the north of the Riviersonderend. These mountains receive winter rainfall from the north-westerly frontal systems, as well as considerable, if unpredictable, oreographic rainfall from the south-easterly winds blowing on-shore along the south coast in summer. The Riviersonderend drains the southern slopes of this mountain range, flowing over a distance of some 90 km, before the river curves in a north-easterly direction and cuts through the range at "Die Poort" near Rheenen (Figure 2.2g). The river then flows eastwards for a further 15 km, to join the Breede River west of Swellendam. The study area comprises the Riviersonderend from Theewaterskloof Dam to its confluence with the Breede River (3419 AB Caledon, 3419 Greyton, 3419 BB Riviersonderend, 3420 AA Stormsvlei and 3420 AB Swellendam 1:50 000 topographical maps, second edition 1979). This part of the subcatchment has an area of 2241 km^2.

2.1.2 Geology of the catchment

The sources of the Riviersonderend are in Cape Fold Mountains where sandstones and quartzites of the Table Mountain Group, part of the Cape Supergroup, are dominant. The Riviersonderend Mountains, which run north of the river once it leaves Theewaterskloof Dam, are of a similar geology. Bokkeveld Group shales of the Cape Supergroup are dominant along the course of the river as it flows from Theewaterskloof Dam to the Breede River (Lambrechts 1979).

The natural vegetation of the catchment is determined in part by the underlying geology. In the upper catchment areas, and in the areas north of the Riviersonderend close to the Riviersonderend Mountains, mesic and dry fynbos occur on the sandstones and quartzites. In the vicinity of Theewaterskloof Dam, and in the wide valley bottom downstream of the dam, some renosterveld grows on the Bokkeveld shales, but the land has been extensively cleared for agriculture and the river flows for the most part through farmlands with very little natural vegetation.

2.2 GEOMORPHOLOGICAL ANALYSIS OF RIVER REACHES

A geomorphological description of a river examines the major determinants of channel shape and substratum type, such as underlying and adjacent bedrock, slope, valley side slopes etc., and allows for a structured description of spatial variation in stream habitat (Wadeson 1996). Wadeson and Rowntree (1994) developed a classification procedure for dividing rivers into longitudinal "segments", or lengths of channel where the sediment:discharge ratio is constant. Each segment in turn may be divided into a number of "reaches", a geomorphological reach being defined as "a length of channel within which the constraints on channel form are uniform so that a characteristic assemblage of channel forms occurs" (Wadeson 1996).

A coarse-level macro-reach analysis of the Riviersonderend was performed by R. Wadeson, Geography Department, Rhodes University, and the resulting geomorphological reaches of the river are presented in Table 2.1. Although for this study the area of interest is downstream of the

Theewaterskloof Dam, the analysis included the full length of the Riviersonderend, from the source (Landroskop) to the confluence with the Breede River.

There are more, shorter reaches in those parts of the river upstream of Theewaterskloof Dam than downstream of the dam, because of the dynamic nature of the channel in the steeply graded sections. Here, the average gradient is 32 m km^{-1}. The substratum is cobble and boulder, with some bedrock, and the river comprises runs, riffles and pools. The characteristics of Reaches 1 to 5 are not discussed here, as they fall outside of the study area. An assessment of the conservation status of the river in Reach 4, however, was undertaken, and is reported in Section 12.

After the initial geomorphological reach analysis, the river was surveyed from helicopter, as part of the assessment of habitat integrity, a complementary study to this one. During the helicopter flight, channel shape, biotope diversity, and riparian vegetation were assessed, to provide general descriptions of the geomorphological reaches.

Table 2.1 **Geomorphological reaches of the Riviersonderend from Landroskop to its confluence with the Breede River.**

REACH NUMBER	CONTOUR	APPROXIMATE LENGTH (km)	DESCRIPTION	GEOLOGY
1	1000-620	2	steep section to Boegoeskloof confluence	quartzitic sandstone; thin bands of shale and conglomerate
2	620-540	1	steeper, more laterally confined section	as above
3	540-480	0.5	confluence of Victoria Peak stream	as above, but follows the fault line
4	480-320	5	wetland section up to where the influence of the dam on the river is observed	through shale, frequently micaceous, with thin bands of sandstone, tillite, grit and conglomerate
5	320-300		reservoir behind Theewaterskloof Dam	alluvium
6	300-260	1	below dam, before lateral confinement	alluvium
7	260-250	2	laterally confined through Donkerhoekberg	quartzitic sandstone; thin bands of shale and conglomerate
8	250-220	16	wide, poorly-defined channel through flat wetlands	alluvium; river terrace gravel passing on one hand into scree and on the other into alluvium
9	220-180	20	well-defined channel in wide valley bottom	across fault in quartzitic sandstone and shale
10	180-145	30	multiple channels	alluvium
11	145-130	6	laterally confined gorge behind Riviersonderend Town	probably controlled by a fault within quartzitic sandstone
12	130- 75	31	wide, poorly-defined channel through flat wetlands	along fault line, through alluvium and then quartzitic sandstone, shale and tillite

A short distance downstream of Theewaterskloof Dam the river becomes laterally confined between steep banks within the Keeromspoort (geomorphological reach no. 7, Figure 2.2a). The Riviersonderend State Forest (afforested with pines of the genus *Pinus*) is situated to the north of the river, but within the gorge the riparian vegetation, and that of the slopes, are comprised largely of indigenous vegetation, although some parts are infested with the black wattle, *Acacia mearnsii.*

As the valley floor opens, the channel becomes poorly defined (geomorphological reach no. 8, Figure 2.2a,b), flowing through flat wetlands, and surrounded by farmland, where wheat is the dominant crop and where some fields are cultivated in parts right up to the river's edge. For most of this reach, however, the channel is obscured under extensive stands of palmiet reed (*Prionium serratum*), with occasional open water occurring where the channel deepens. The river is fed by numerous tributaries draining the Riviersonderend Mountains, the largest being the Elandskloof and Klein Elandskloof Rivers.

From Hopefield, the river flows within a better-defined channel (geomorphological reach no. 9), along a wide valley floor, past the towns of Genadendal and Greyton, which are situated some 10 km north of the river (Figure 2.2b,c). The Baviaans River, near Genadendal, and the Gobos River, which flows past Greyton, join the main river channel south of the towns. The palmiet, so prevalent in reach no. 8, is rapidly replaced by a riparian belt comprised largely of the invasive alien trees *Acacia mearnsii* (black wattle) and *A. saligna* (Port Jackson willow), palmiet generally being restricted to small clumps of instream vegetation. Within this reach, the channel is, or was, partly braided (for example at Soetkraal), and here the band of alien vegetation is considerably wider and more dense, and includes stands of eucalyptus and pines.

Just upstream of Het Ziekenhuis (geomorphological reach no. 10, Figure 2.1d,e), there is evidence of the well-defined multiple channels identified in the geomorphological analysis of the river, although in most parts of the reach these have been destroyed through expansion of agricultural activities into the river. The riparian belt over this 30 km reach widens and narrows, apparently tracking the old channel braids where they exist. The dominant vegetation comprises alien invasives, with palmiet restricted to instream islands and thin marginal strips.

Around the town of Riviersonderend, the Riviersonderend becomes laterally confined, flowing through the narrow gorge at the foot of the Tygerhoek Mountain and Oliphants Kloof (geomorphological reach no. 11, Figure 2.1e), and bankside development (i.e. farming) in this area is more restricted. As the river leaves the gorge (Figure 2.1e,f,g), and until it joins the Breede River, it becomes similar to geomorphological reach no. 8 - an ill-defined channel in a wide valley bottom. Whereas the river in reach 8 meandered through wide palmiet stands, in reach 12, dense infestation of the riparian vegetation by aliens, as well as extensive alteration of the valley lands for agriculture, has resulted in a simple channel with predominantly deep, slow-flowing water. Also, the channel is for the most part hidden under an expanse of alien trees, except for small cleared areas of cultivated lands or access roads (e.g. for maintenance of pumps).

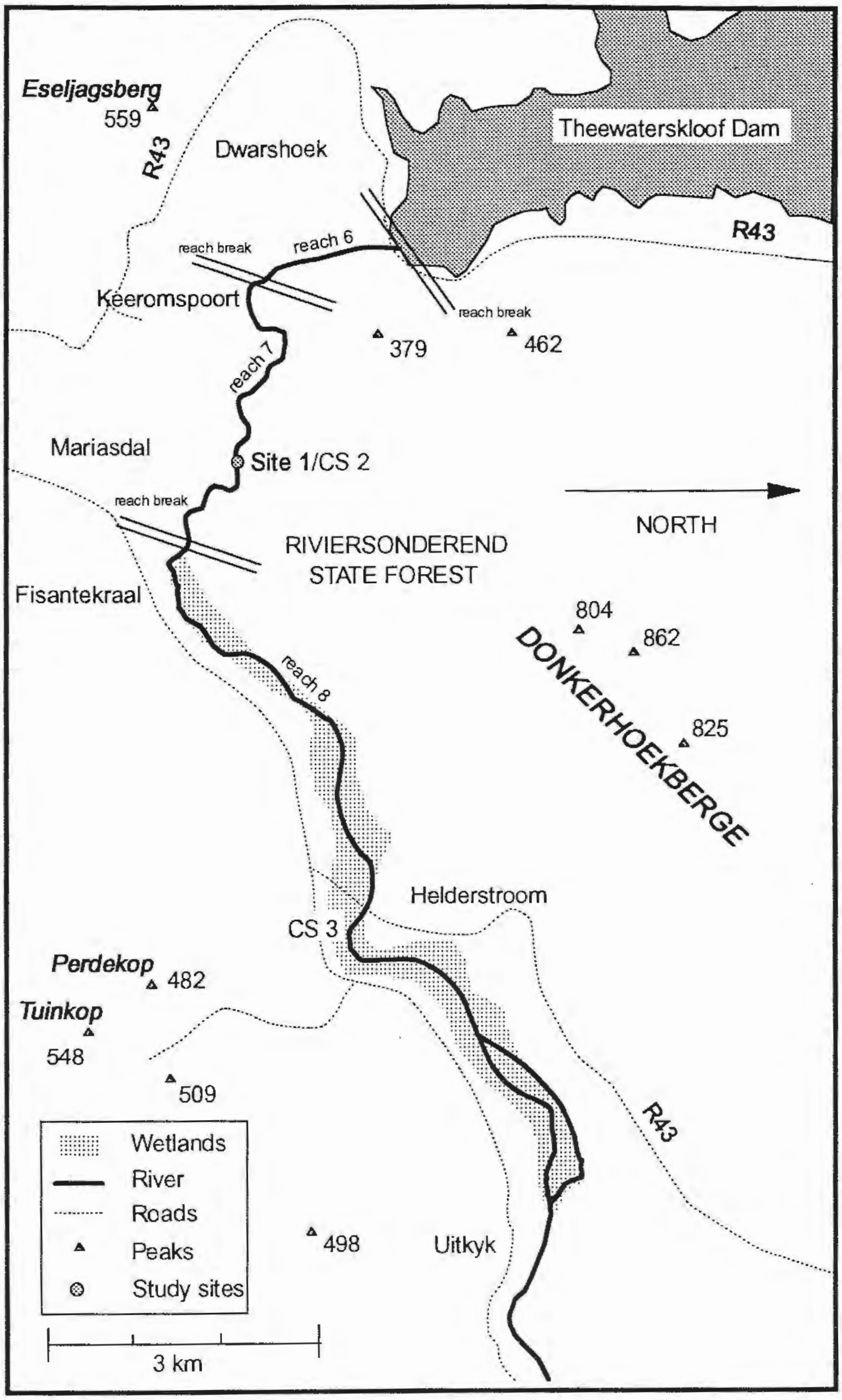

Figure 2.2a **Riviersonderend downstream of Theewaterskloof Dam, showing geomorphological river reaches 6, 7 and 8. Sampling Site 1, and the conservation assessment (CS) sites are also indicated.**

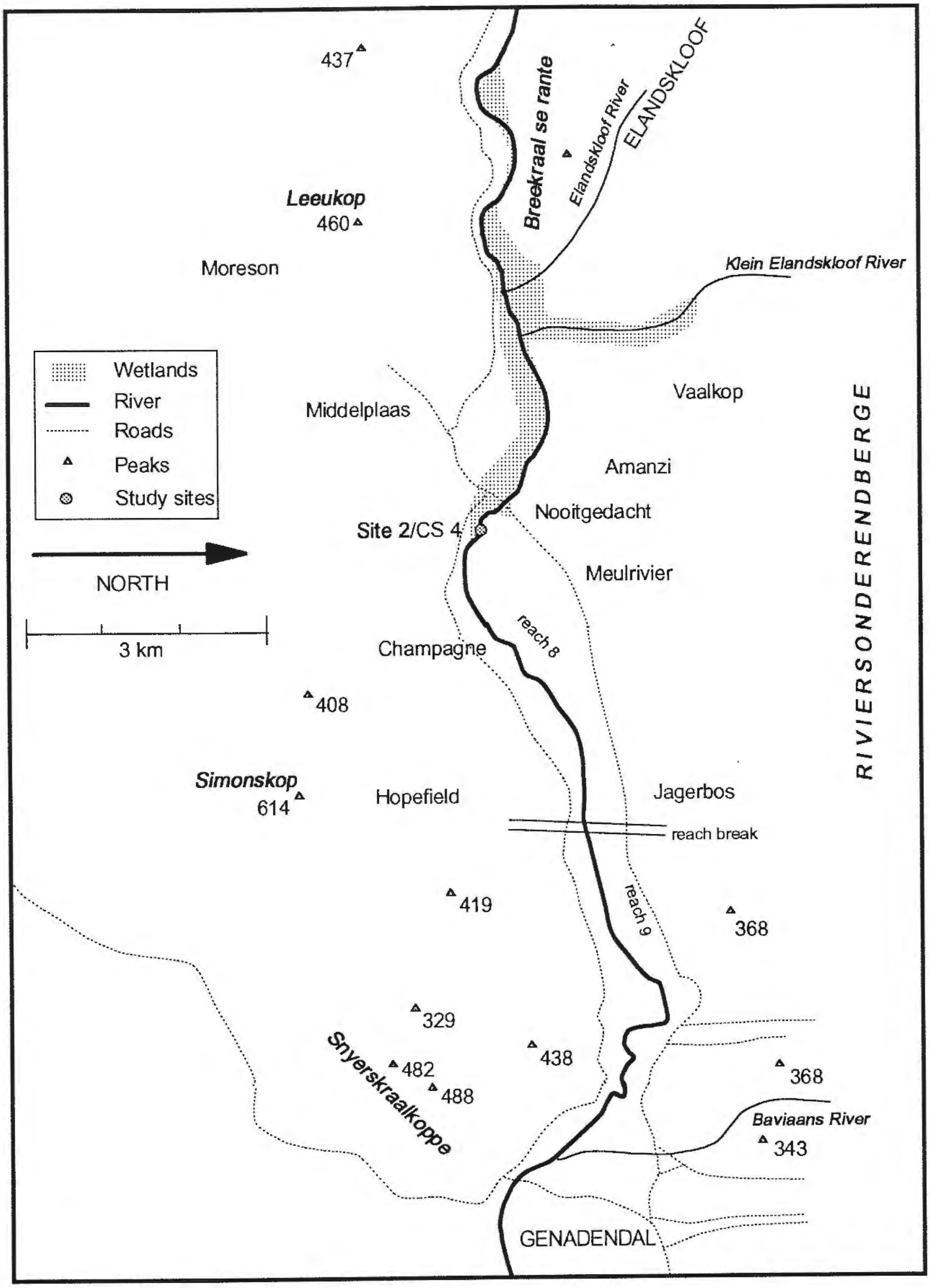

Figure 2.2b Riviersonderend downstream of Theewaterskloof Dam, showing geomorphological river reaches 8 and 9. Sampling Site 2, and the conservation assessment (CS) sites are also indicated.

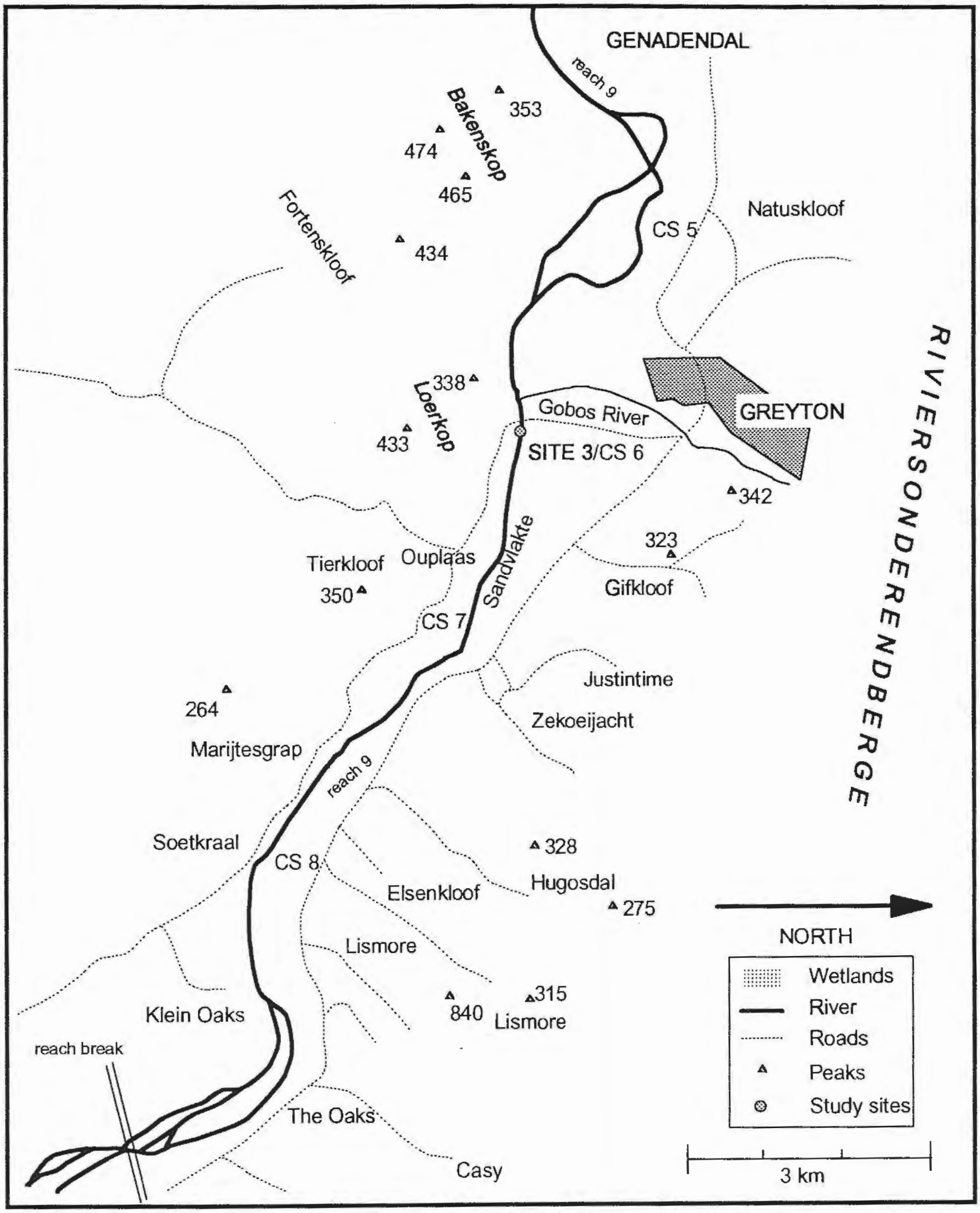

Figure 2.2c **Riviersonderend downstream of Theewaterskloof Dam, showing geomorphological river reach 9. Sampling Site 3, and the conservation assessment (CS) sites are also indicated.**

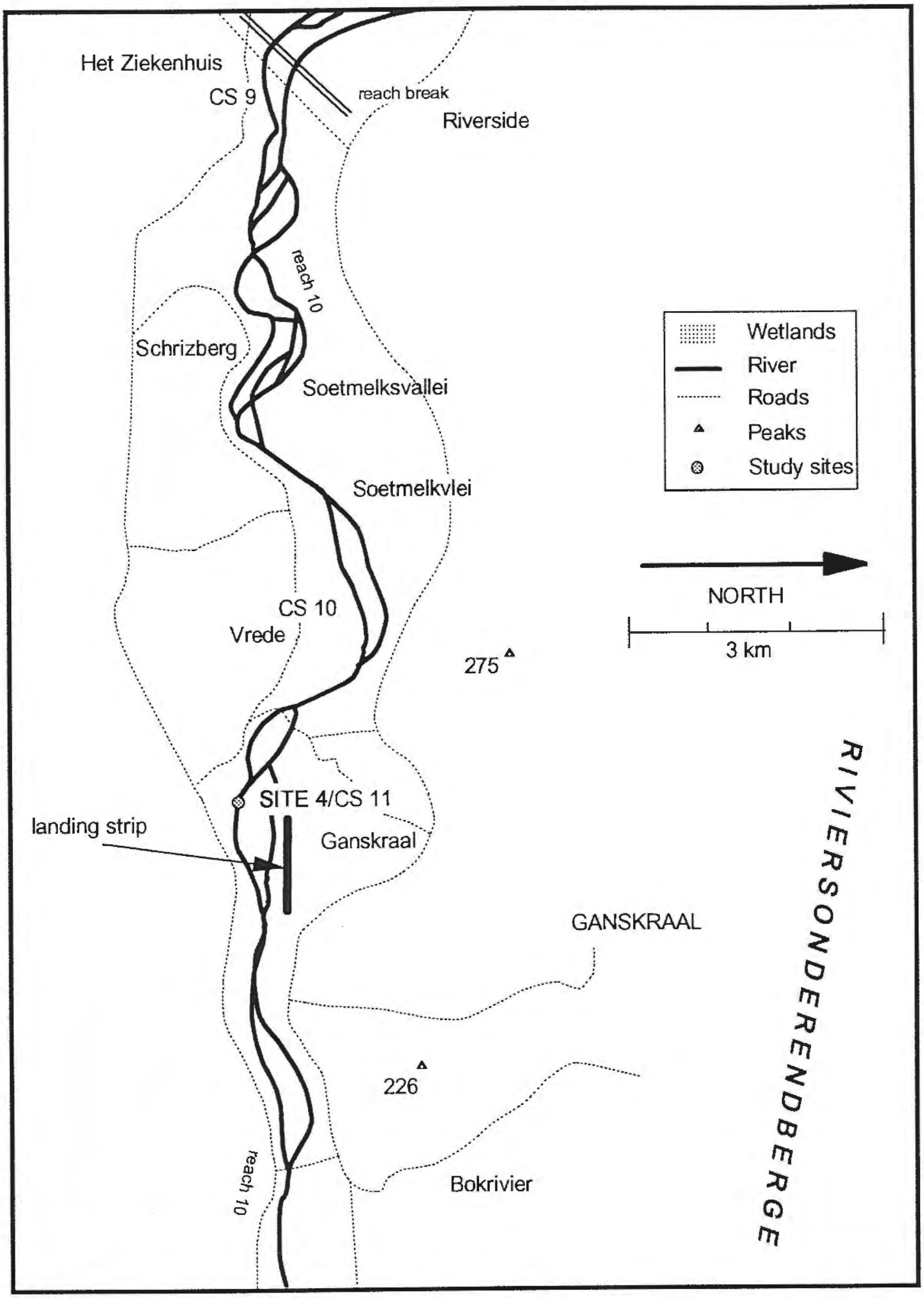

Figure 2.2d Riviersonderend downstream of Theewaterskloof Dam, showing geomorphological river reach 10. Sampling Site 4, and the conservation assessment (CS) sites are also indicated.

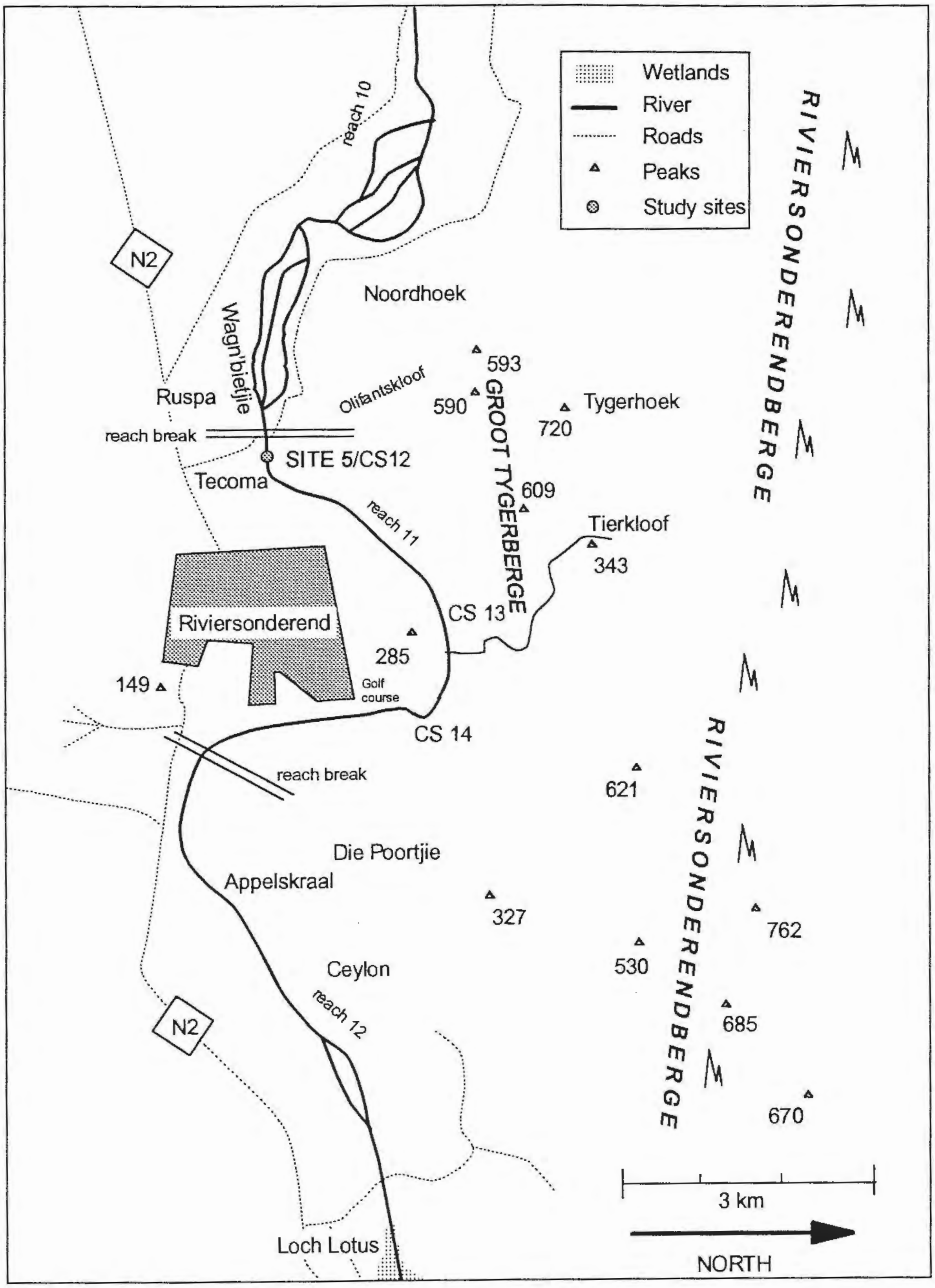

Figure 2.2e Riviersonderend downstream of Theewaterskloof Dam, showing geomorphological river reaches 11 and 12. Sampling Site 5, and the conservation assessment (CS) sites are also indicated.

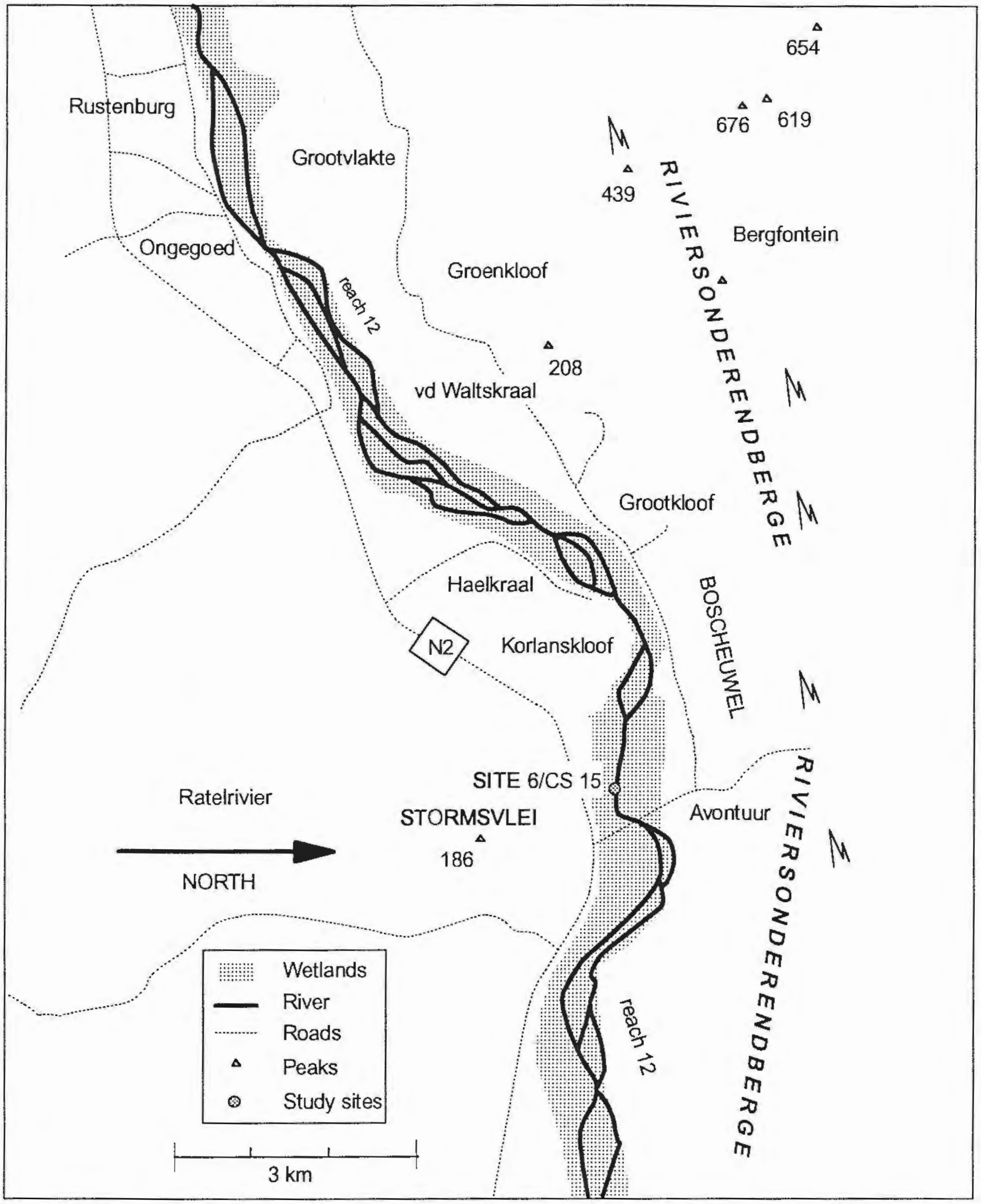

Figure 2.2f Riviersonderend downstream of Theewaterskloof Dam, showing part of geomorphological river reach 12. Sampling Site 6, and the conservation assessment (CS) sites are also indicated.

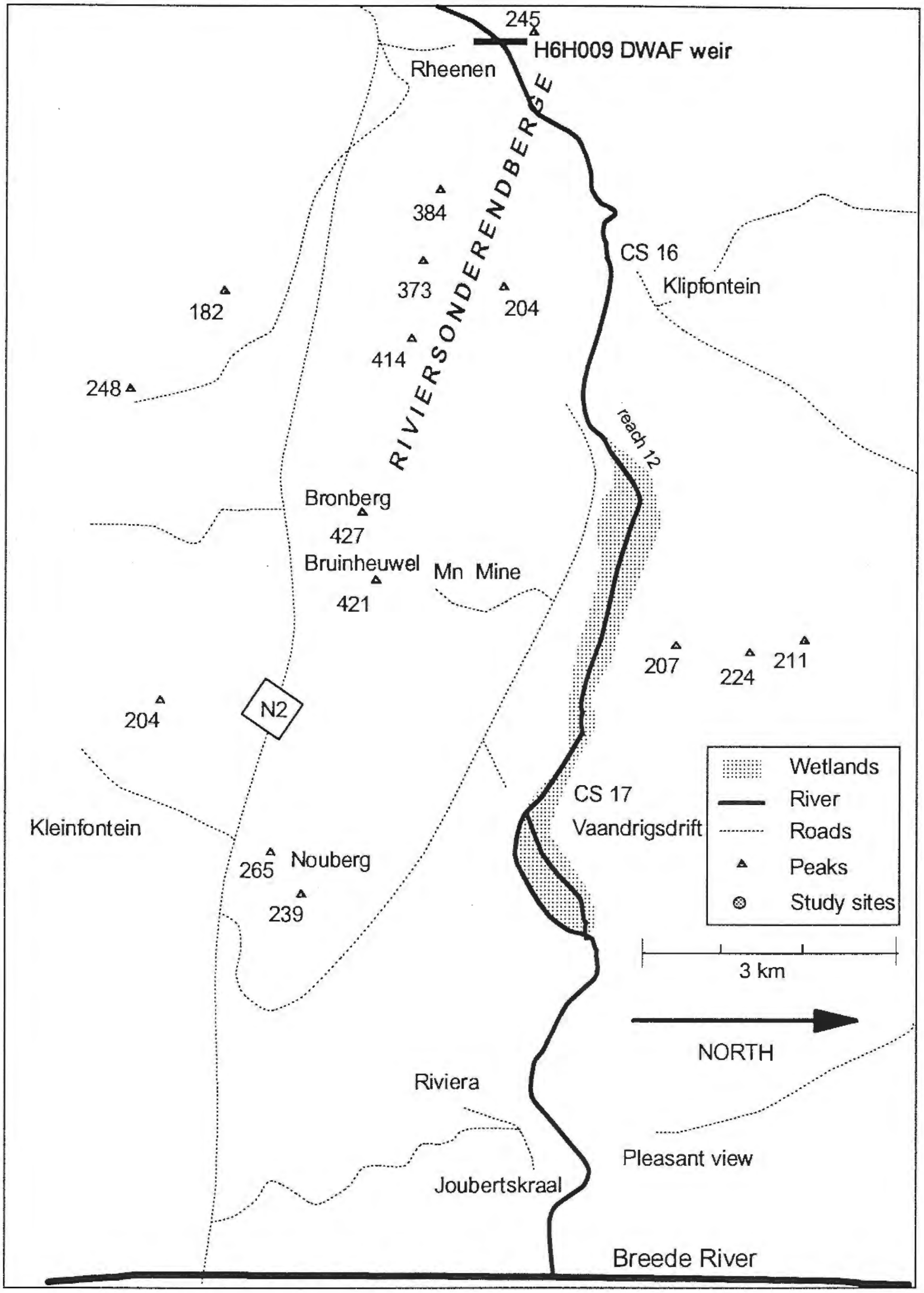

Figure 2.2g **Riviersonderend downstream of Theewaterskloof Dam, showing the remainder of geomorphological river reach 12. Sampling Site 6, and the conservation assessment (CS) sites are also indicated.**

2.3 SELECTION AND DESCRIPTION OF STUDY SITES

2.3.1 Methods for selection of the study sites

The study area comprises the Riviersonderend from Theewaterskloof Dam to its confluence with the Breede River, which represents geomorphological reaches 6 to 12, as numbered and described in Table 2.1.

Sampling sites had to be identified that would be acceptable also as sites used for the purposes of assessing the Instream Flow Requirements (IFR) of the river, should the scheme proceed further. Because of constraints on the extent and detail of the study, six sites were selected one in each of the geomorphological reaches 7 to 12. The 1 km section of the river immediately downstream of Theewaterskloof Dam was thus excluded from the assessment.

Some of the considerations when choosing an IFR site are that, besides being representative of the river or reach, the site should reflect the most natural conditions, and should include a range of physical biotopes, across which transects can be placed for hydraulic studies. Clearly these considerations are at times not mutually compatible and, furthermore, one of the overriding constraints on site selection is that the site has to be accessible.

For the purpose of assessing the feasibility of a further reduction or alteration of the hydrological regime of the Riviersonderend (in ecological terms), sites were selected that were most diverse in physical form (within the constraints of accessibility), in order to provide the "best case" assessment of the ecological state of the river, and to facilitate comparisons between sites.

After the initial geomorphological reach-analysis, the river was surveyed from helicopter, and potential sites within each reach identified on the basis of the above criteria. Video footage from the flight was examined in depth to confirm study sites. In the approximately 105 km of river downstream of the dam, there were only 25 areas of riffle biotope (typically 20 to 50 m in length) obvious from the air, with most of the river comprising slow runs and deep pools. Notwithstanding the relative rarity of this biotope, however, it formed one of the pre-requisites for selection of the sampling sites, because riffle biotopes fulfil the habitat requirements of a diverse array of invertebrates (Chutter 1968, 1972), with runs and pools, and in-stream and marginal vegetation supporting a smaller component of the total assemblage of fauna.

In addition to the six major sampling sites, one or two additional sites were briefly visited in each reach, for the purposes of determining the overall conservation status of each reach (refer to Section 9 for detail). Thus, conservation status was assessed at 17 points along the length of the river, and these are referred to as CS2, CS3 etc. (CS1, upstream of the dam, is not indicated in Figure 2.2).

2.3.2 Description of the study sites

a) Sampling sites on the Riviersonderend

Site 1

- ***Location***

  34°05.57' S, 19°18.89' E, between 240 and 260 m AMSL.

- ***Geomorphological reach***

  Reach #7; laterally confined; quartzitic sandstone; thin bands of shale and conglomerate

- ***General description***

  Site 1 is situated on the Riviersonderend some 3 km downstream of the Theewaterskloof Dam, within the narrow Keeromspoort gorge (Figure 2.1a). The riparian zone generally comprises natural terrain, with the exception of the pumphouse supplying the DWAF water works, which supplies the municipalities of Greyton, Genadendal and Riviersonderend.

- ***Channel form***

  The river is narrow, some 10 to 15 m in width, and the valley sides are steep. Long pools, grown over with palmiet, extend the width of the channel, and these alternate with areas where the channel is strewn with large boulders, creating runs, riffles and cascades.

- ***Substratum***

  The substratum is largely comprised of bedrock and boulders. Finer alluvium is scarce, limited to small patches of cobble and gravel in the hydraulic cover provided by larger boulders. In sheltered areas, orange-coloured silt deposits are visible.

- ***Canopy***

  The canopy is open, with the riparian vegetation forming a narrow fringe at the water's edge, except where the channel widens into long pools, where palmiet (*Prionium serratum*) extends in a broad (5 m) band into the river. Riparian species are mostly indigenous to fynbos, and include *Metrosideros angustifolia* (smalblaar) and *Brabejum stellatifolium* (wild almond) trees. Downstream of the site the channel starts to widen and here some encroachment of *Acacia mearnsii* has occurred. At this site, the south bank of the catchment is fairly heavily infested with *A. mearnsii* and *Pinus pinaster*. Some clearing of *P. pinaster* has occurred on the northern slopes.

- ***Marginal and instream vegetation***

  Isolated individuals of instream plants, such as *Aponogeton distachyos* and *Nymphoides indica* (both with floating leaves) are rooted in pools, while plants such as *Crassula expansa*, grow at the pool margins.

- ***Algae***

  In September only small quantities of algae were present, comprising:

  Oedogonium undulatum (Chlorophyta: Oedogoniaceae)
  Spirogyra subreticulata (Chlorophyta: Zygnemataceae)

  In January the following species were recorded:

  Spirogyra sp. (Chlorophyta)
  Oedogonium sp. x 1 (Chlorophyta)
  Oedogonium spp. x 2 (Chlorophyta)

Site 2

- ***Location***

  34°04.10' S, 19°28.32' E, between 220 and 240 m AMSL.

- ***Geomorphological reach***

  Reach #8; wide, poorly defined channel; alluvium and river terrace gravel passing on one hand into scree and on the other into alluvium

- ***General description***

  Site 2 is located downstream of the confluence of the Elandskloof and Klein Elandskloof Rivers with the Riviersonderend. A road-crossing immediately upstream of the site leads to the town of Genadendal. Much of the area adjacent to the river at this site appears to have been cultivated, and there is evidence of in-filling of parts of the channel to create agricultural or pastural fields.

- ***Channel form***

  Whilst the geomorphological reach in which Site 2 is situated has a characteristically ill-defined channel, Site 2 itself is located partly on a rocky outcrop, which has given rise to a well-defined simple channel, with shallow flows over bedrock and cobble, and slow-flowing pools. The site is thus not truly characteristic of the reach as a whole. The old macro-channel of the river, as indicated from areas where the banks and riparian vegetation are intact, was approximately 40 m in width, and far wider than the present-day channel (some 25 m in width). The apparently permanently dry parts have become overgrown with terrestrial grasses. The present, smaller channel is fringed with aquatic macrophytes, although alien plants have started to invade the marginal vegetation. At the downstream end of the site, the river widens and meanders through numerous, dense stands of palmiet.

- ***Substratum***

  Small to medium cobbles are deposited on the bedrock slabs that dominate at this site. Where the river widens, the cobble substratum has become slightly embedded with sand deposits.

- ***Canopy***

  The canopy is open, the riparian vegetation, where it has not been cleared, consisting of a mixture of indigenous understory plants and trees. The trees are mostly exotic species, such as the alien *A. mearnsii* (black wattle), *A. longifolia* and *A. cyclops*. Elements of the natural riparian vegetation, *Brabejum stellatifolium* (wild almond), *Salix mucronata* subsp. *capensis* (Cape willow) and *Metrosideros angustifolia* (smalblaar) are also present, but in very small numbers. The natural riparian zone has been invaded by other exotics such as *Sesbania punicea* and the bramble, *Rubus fruticosus*.

- ***Marginal and instream vegetation***

  Isolepis prolifera, a sedge, occurs on the margins and in shallow cobbled areas, whilst large stands of *Prionium serratum* (approximately 80% cover) are prevalent along the sides of the river in deeper sections. A low cover of the submerged aquatic *Ruppia* sp. and the floating-leaved *Aponogeton distachyos* comprise the instream vegetation.

- ***Algae***

  Algae were present on most stones in the shallow marginal areas in September, with the following species recorded:

  Oedogonium sp. (Chlorophyta: Oedogoniaceae)
  Oedogonium sp. (Chlorophyta: Oedogoniaceae)
  Spirogyra sp. (Chlorophyta: Zygnemataceae)
  Ulothrix sp. (Chlorophyta: Ulotricales)
  Chaetophora sp. (Chlorophyta: Chaetophorales)
  Batrachospermum sp. (Rhodophyta: Batrachospermaceae)

  In January the following species were recorded:

  Spirogyra sp. (Chlorophyta)
  Oedogonium sp. (Chlorophyta)
  Chaetophora cf. incrassata (Chlorophyta)
  Palmella sp. (Chlorophyta)
  Batrachospermum sp. (Rhodophyta)
  Tabellaria sp. x 2 (Bacillariophyceae)

Site 3

- ***Location***

  34°04.20' S, 19°36.80' E, between 180 and 200 m AMSL.

- ***Geomorphological reach***

  Reach #9; well-defined channel in wide valley bottom; across fault in quartzitic sandstone and shale.

- ***General description***

  Site 3 is adjacent to the Greyton Municipal Campsite, and just downstream of where the Gobos River joins the Riviersonderend. The Gobos River rises in Noupoort, and flows through the Greyton Nature Reserve and then to the east of the town before entering the Riviersonderend. The site appeared relatively undisturbed, apart from the road-bridge crossing, situated in the middle of the sampling site, and the presence of campers whose activities included fishing, boating and swimming.

- ***Channel form***

  Upstream of the bridge, the channel is deep and wide, and the river flows slowly through and around large islands of palmiet. Downstream of the bridge, shallow fast-flowing riffles predominate, before the river becomes divided by vegetated sand and gravel bars which channel the water into narrower, deeper riffles and fast runs. As was the case with Site 2, the wetted channel, although some 30 m wide, was narrower than the riparian zone, which is well-defined (albeit comprised of aliens) at this site. Wide marshy areas are prevalent on the wetted channel margins.

- ***Substratum***

  The substratum is composed primarily of cobble with underlying bedrock exposed in parts. Small and medium cobbles dominate in the riffle sections, with sand and mud being restricted to the instream islands and marginal areas.

- ***Canopy***:

  The canopy is open, with riparian trees situated some distance from the wetted channel. The bank vegetation is highly disturbed and dominated by alien invasives such as *A. mearnsii*, *A. saligna* and *A. longifolia* and the weeping willow, *Salix babylonica.* Some encroachment into the dry parts of the channel by younger plants of these species is evident.

- ***Marginal and instream vegetation***

  Typical marginal and instream vegetation species are present at this site, such as *Isolepis prolifera* (dominating along riffles and runs and on instream islands) and *Prionium serratum* (forming a wide belt on either side of the channel, as well as large instream islands. Also present in muddy shallows is the indigenous water buttercup (*Aponogeton distachyos*), and *Ruppia* sp. Floating stands of *Potamogeton* sp. are abundant in shallow riffle and run sections, forming a blanket over the substratum in places.

- ***Algae***

  Small amounts of algae were present, with the following species recorded in September:

  Spirogyra sp. (Chlorophyta: Zygnemataceae)

  In January algae were more abundant, and the following species were recorded:

  Oedogonium sp. (Chlorophyta)
  Stigeoclonium tenue (Chlorophyta)
  Chaetomorpha c.f. incrassata (Chlorophyta)
  Microspora sp. (Chlorophyta)
  Tabellaria sp. (Bacillariophyceae)

Site 4

- ***Location***

  34°07.09' S, 19°47.08' E, between 140 and 160 m AMSL.

- ***Geomorphological reach***

  Reach #10; multiple channels in wide valley bottom; alluvium.

- ***General description***

  Site 4 is located on the farm Leeuwkraal, in the heart of the wheat-farming belt along the Riviersonderend. The multiple channels, characteristic of the river in this geomorphological reach in its natural condition, are evident just upstream of this site, but are severely degraded through encroachment of farmlands. Not only does cultivation take place in the areas between channels, but some of the channels have been completely filled in to create fields. The result of these activities is that the river is largely restricted to one channel, as at Site 4. Other secondary channels, where they exist, are either dry or blind-ended, and are closed overhead by a dense stand of *A. mearnsii*.

- ***Channel form***

  The channel is narrow, compared with Sites 2 and 3, with deeper, faster flowing water. This is the result of there being only one remaining channel at this site. In-filling of the south bank has given rise to undercutting and erosion of this sandy slope. The river winds its way along a series of tight bends through stands of palmiet, and this creates some heterogeneity of biotopes, with a pool-run sequence bordered by backwaters and sand bars.

- ***Substratum***

  The substratum consists predominantly of gravel in the riffles and runs, with some small cobbles. Large sand deposits occur in pools and along the slower-flowing margins. The river banks are sandy.

- ***Canopy***

  Over the main channel the canopy is open, although comprised almost entirely of *A. mearnsii* on the north bank, with grasses such as *Cynodon dactylon*, and other exotic, herbaceous weeds, forming the main cover of the steep slopes on the south bank.

- ***Marginal and instream vegetation***

  Instream vegetation comprises *Aponogeton distachyos* and *Ruppia* sp. growing on the shallow sand bars. *P. serratum* (palmiet) dominates the marginal vegetation along the north bank, while erosion has removed most of the *P. serratum* from the south bank. The exotic tree *Sesbania punicea* provides a 15% cover on a sand spit between and behind the palmiet zone on the north bank. Very young saplings of *S. punicea* on the eroded and bare south bank during the September 1995 visit, had increased in number by the January 1996 visit, forming a dense thicket of young trees.

- ***Algae***

  Few algae were present in September, with only one species:

  Spirogyra sp. - possibly *S. subreticulata* - (Chlorophyta: Zygnemataceae)

  In January the following species were recorded:

  Spirogyra sp. (Chlorophyta)

  Sphaerotilus natans var. typica and *Beggiatoa alba* (both are species of freshwater bacteria, and comprised most of the sample)

Site 5

- ***Location***

  34°08.64' S, 19°42.46' E, between 140 and 160 m AMSL.

- ***Geomorphological reach***

  Reach #11; laterally confined; probably controlled by a fault within quartzitic sandstone

- ***General description***

  Site 5 is located on the Tygerhoek Experimental Farm (Department of Agriculture) on the Riviersonderend as it flows to the south of the Tygerhoek Mountain, just upstream of the narrow part of the gorge at Riviersonderend town. A road bridge crosses the river in the middle of the site. Farming activities are restricted largely to the lands south of the river, although there is an experimental protea plantation to the north of the river.

- ***Channel form***

  The channel is relatively straight, and wide, with gently sloping banks. There is no evidence of erosion. A large pool, extending the width of the river upstream of the bridge, gives way to shallow riffles and shallow to deep runs.

- ***Substratum***

  The substratum of the riffle and run areas is comprised mostly of small to medium cobbles, with cobbles and sand forming the banks. Large accumulations of sand and mud (30 cm deep) are present in the pools.

- ***Canopy***

  The river has an open canopy, mainly of alien vegetation dominated by *A. mearnsii* (60% cover), and *Populus canescens*, with other species including *A. longifolia* and *A. melanoxylon*, and *Eucalyptus* sp. also present. A few individuals remain, however, of the indigenous riparian species, such as *Brabejum stellatifolium*, *Ilex mitis*, *Diospyrus glabra*, *D. whyteana*, and *Kiggelaria africana*, with some indigenous understory species and creepers also growing here.

- ***Marginal and instream vegetation***

  A few small palmiet islands and clumps of marginal vegetation are present, and in addition, *Isolepis prolifera*, *Cyperus denudatus* and *C. textilis* are found on the shallow banks. Some *Ruppia* sp. occurs in the water along with a few algal species.

- ***Algae***

  Algae were present on most stones in the shallow areas in September, with the following species recorded:

  Oedogonium sp. (Chlorophyta: Oedogoniaceae)
  Spirogyra subreticulata (Chlorophyta: Zygnemataceae)
  Nitella sp. (Chlorophyta: Characeae)

  In January, not all the material collected was identifiable, but the following species was recorded:

  Spirogyra sp.

Site 6

- ***Location***

  34°04.88' S, 20°05.16' E, 100 m AMSL.

- ***Geomorphological reach***

  Reach #12; wide, poorly defined channel; along fault line, through alluvium and then quartzitic sandstone, shale and tillite.

- ***General description***

  Site 6 is located on the farm Avontuur, north of the town of Stormsvlei. Access to the river is difficult for much of the reach. The river is slow-flowing, and surrounded by dense stands of alien invasives. Riffles occur at this site only as a result of erosion of an old rocky access road to the river. A 1.75 m-high concrete weir blocks the main channel of the river, causing its diversion into a secondary channel over the old access road. This diversion probably occurred during a previous flood event, and ongoing erosion of the river bank is evident at the diversion.

- ***Channel form***

  The channel is generally simple and except for the U-bend formed by the diversion, is straight. The only shallow biotopes are those contributed by the partially washed-away access road, and the sand shallows at the edge of palmiet marginal vegetation. Here, constriction of the channel results in fast, turbulent riffles and runs, whilst up- and downstream of this, deep slow runs dominate.

- ***Substratum***

  Small and medium cobbles are present, mostly from material imported for building the road, but sand dominates in the deeper sections.

- ***Canopy***

  The canopy is open, and consists of *Acacia mearnsii* and *A. saligna*. The drier sections of the banks, which have been disturbed through cattle grazing, support a rich diversity of alien and indigenous plant species, many of them smaller understory shrubs and grasses.

- ***Marginal and instream vegetation***

  This is limited to extensive growth of *Prionium serratum* (palmiet) and *Phragmites australis* along the river margins. The wet areas in the remnant braided channels, behind the palmiet zone, supports species such as *Cyperus textilis* and *Isolepis prolifera.* No instream vegetation was observed.

- ***Algae***

  Dense tufts of algae, found on the rocks in the fast flowing areas in September, consisted of a single species:

  Stigeoclonium tenue (Chlorophyta: Chaetophorales)

  In January the following species were recorded:

  Sphaerotilus natans var. typica and *Beggiatoa alba*, both freshwater bacteria.

  Oscillatoria sp. (Cyanophyta)

b) Sampling sites on the Breede River

Site A

- ***Location***

  34°00' S, 12°50' E, 100 m AMSL.

- ***General description***

  Site A on the Breede River is located upstream of the confluence with the Riviersonderend, at "The Abbey", some 15 km south-west of the town of Bonnievale. The river flows southwards, through the surrounding mountainous Langeberge landscape, with limited agricultural activities to the west, although the eastern bank borders cultivated fields.

- ***Channel form***

  The channel is wide, with a number of well-vegetated sand bars, some which create backwater pools near the channel edges. A bedrock outcrop, as well as plentiful small- and medium-sized alluvium provide for riffle biotope, and this alternates with long slow runs.

- ***Substratum***

  Small- and medium-sized cobbles are present over much of the river bed, with some bedrock protruding. Sand deposits occur in the slower-flowing areas.

- ***Canopy***

  The canopy is open, and the riparian vegetation consists of a mix of indigenous and alien shrubs, including *Acacia saligna*, *Salix capensis* and *Sesbania punicea.* Very large specimens of *Eucalyptus* sp. form a band behind these smaller plants.

- ***Marginal and instream vegetation***

  The marginal vegetation is comprised largely of grasses such as *Cyperus textilis* and *Eragrostis sarmentosa*, but also includes *Phragmites australis*, some palmiet and the local native willow, *Salix mucronata* subsp. *capensis.* The bryophyte, *Fontinalis* sp., a freshwater sponge with symbiotic zoochlorellae, and the angiosperm, *Ceratophyllum demersum*, are present, and there is an abundance of *Potamogeton pectinatus* and a species of *Chara*.

- ***Algae***

  In September, the following species were recorded:

  Compsopogon coeruleus (Rhodophyta: Compsopogonales)
  Cladophora (Chlorophyta: Cladophorales)
  Cosmarium sp. (Chlorophyta: Desmidaceae)
  Anabaena sp. (Cyanophyta)

  In January the following species was recorded:

  Enteromorpha sp.

Site B

- ***Location***

  34°03.95' S, 20°24.25' E, 60 m AMSL.

- ***General description***

  Site B is located at the DWAF gauging weir No. H7H006, less than 10 km west of Swellendam. The river flows in a generally southward direction, but curves in a wide U-bend upstream of the site, so that the direction of flow here is northwards. The surrounding area is characterised by rolling hills of wheat fields, through which the river winds its way.

- ***Channel form***

  The river has a wide, straight channel, with gently sloped banks. The weir, situated at the upstream extreme of the site, is founded on a bedrock outcrop, and water is channelled narrowly through the weir and onto bedrock, where it flows in a turbulent rapid. Downstream of this are riffle and fast-run biotopes, which deepen into slow-flowing runs. Vegetated islands within the channel create shallow backwaters and small pools.

- ***Substratum***

  Small and medium cobbles are present, overlying the bedrock sections, with the occasional boulder. Sand deposits occur in the slow-flowing sections

- ***Canopy***

  The canopy is open, with a mix of indigenous and alien trees, the former including *Acacia karoo* and *Metrosideros angustifolium.*

- ***Marginal and instream vegetation***

  The marginal vegetation consists of sparse patches of palmiet, with *Cyperus textilis*, *Sesbania punicea* and *Salix mucronata* subsp. *capensis* being common. Instream vegetation includes *Apotomogeton* sp. (waterblommetjie), *Potamogeton pectinatus* and a species of *Chara,* although *Myriophyllum aquaticum* (parrot's feather) and *Eichhornia crassipes* (water hyacinth), both aggressive invasive aquatic Angiosperms, are also prevalent. The freshwater Bryophyte, *Fontinalis* sp. was also recorded.

- ***Algae***

  Considerable quantities of algae were present in September in the shallow and sheltered areas, and species recorded were:

  Compsopogon coeruleus (Rhodophyta: Compsopogonales)
  Cladophora fracta (Chlorophyta: Cladophorales)
  Chaetophora sp. (Chlorophyta: Chaetophorales)
  Spirogyra subreticulata (Chlorophyta: Zygnemataceae)
  Nitella furcata (Chlorophyta: Charophyceae)
  Melosira sp. (a filamentous diatom: Chrysophyceae)

  In January the following species were recorded:

  Compsopogon coeruleus (Rhodophyta)
  Cladophora fracta (Chlorophyta)
  Enteromorpha sp. (Chlorophyta)
  Spirogyra sp. (Chlorophyta)
  Melosira granulata (Bacillariophyceae)
  Fragilaria sp.

3. HYDROLOGICAL REGIME

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3.1 INTRODUCTION

Hydrological data from two locations on the river, approximately 90 km apart, were used for the assessment, as follows:

- a site immediately downstream of the Theewaterskloof Dam (referred to in this report as "the dam site")
- a point on the Riviersonderend upstream of the confluence with the Breede River (Figure 3.1), at the DWAF gauging weir H6H009 (referred to as "H6H009").

The parts of the hydrological assessment that have used daily discharge data are based on recorded (i.e. real) data only, for both sites and for pre- and post-dam periods - that is, no new hydrological simulations were undertaken for this study. The definition of the periods is given in the following section. Virgin mean annual runoff (MAR) and average monthly flow volumes are based on simulated data. Note that existing simulated hydrological information is provided for the dam at full operation and also for a possible future condition in which the dam is raised by a maximum of 0.7 m.

The following information is provided :

Section 3.4.1.	the virgin and present-day mean annual runoff (MAR)
Section 3.4.2.	the seasonal distribution of flow
Section 3.4.3.	average daily discharges for summer and winter baseflow conditions
Section 3.4.4.	the timing of floods and the shape of the flood hydrograph
Section 3.4.5.	annual and monthly flow duration curves based on daily flows.

In addition, instantaneous measurements of discharge at all the sites were made during the September 1995 and January 1996 field visits, for comparison with the DWAF data, and, more importantly, to examine the changes in discharge along the course of the river, albeit based on preliminary data.

3.2 METHODS OF ANALYSIS

3.2.1 Definition of pre-dam and post-dam periods

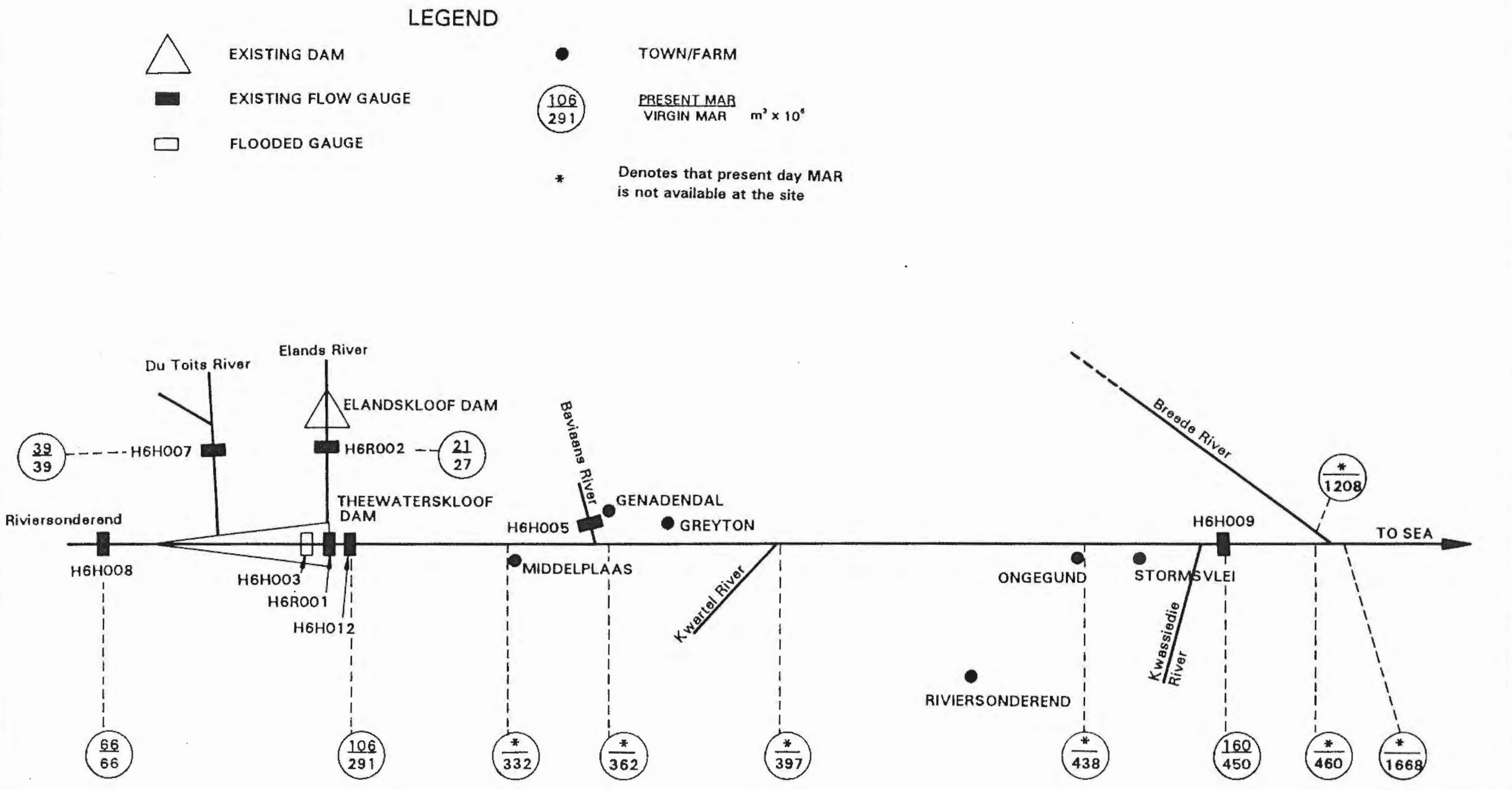
Operation of Theewaterskloof Dam commenced in 1980, but the dam was allowed to fill only gradually over the following ten years because of complications relating to the flooding of agricultural land in the dam basin. It was kept at 40% of full supply capacity (FSC) until 1990, then filled to approximately 80% of FSC between 1990 and 1993, and was finally filled to capacity in 1993. For the purposes of this study, the dam was assumed to be operational at the beginning of hydrological year 1980, (i.e. October 1980). The period prior to October 1980 is referred to in this report as "**pre-dam**", and the period after October 1980 as "**post-dam**".

Although the dam was operational from 1980, the release pattern between 1980 and 1993 included releases that were made in order to maintain the dam at 40% (pre-1990) or 80% (1990-1993) of FSC, as well as irrigation releases made each summer to supply farmers downstream. The period after July 1993 reflects flow patterns associated with the dam operating at 100% FSC, but even this period does not reflect conditions that are likely to prevail in the longer term. This is because the full draft of the dam has not yet been drawn i.e. the irrigation allocations, as well as urban supply to the greater Cape Town Municipality, have not as yet been fully utilised. This means that, even after 1993, the dam has been fuller and has spilled more often than it will once the demands increase to the full amount allocated. It also means that the irrigation releases made to supply farmers downstream of the dam have not been as high as they are anticipated to become, once the full allocation is released.

3.2.2 Data availability

Theewaterskloof Dam was included in the hydrological studies undertaken for the Western Cape System Analysis (WCSA) (DWAF 1994a), and detailed hydrological information is therefore available for the dam site. For example, data on long-term simulations of naturalised and present-day monthly instream-flow volumes and present-day offstream (user) demands are all available. Flow at the dam site itself has been monitored over the years by three separate gauges. Before the dam was built, the gauge H6H003 was situated slightly upstream of the dam wall. The quality of data from this gauge is poor, and was only considered usable from October 1967 (DWAF 1994a) until the start of dam construction in 1978. A second gauge, H6H012, was built in 1974 (before construction of Theewaterskloof Dam) just downstream of the present dam wall. This gauge is still in place and measures spills and releases from the dam. The dam itself now has the gauge number H6R001. The positions of the gauges are shown schematically in Figure 3.1. A composite of the available flow records at H6H003 and H6H012 was used to represent flows at the dam site from hydrological year 1967 to 1993. For this site, simulated hydrological modelling of the flow patterns under the current dam operation regimen is provided in this report.

No detailed hydrological studies have been undertaken for the river at H6H009, and therefore WR90 information (Midgely *et al.* 1994) has been used where possible. The WR90 publications provide naturalised flows on the basis of quaternary sub-catchments only, and do not include present-day MARs. A rough estimate of present-day MAR was made by DWAF (A. Roux, DWAF Western Cape Region, pers. comm.). Observed flow records at H6H009 are available from 1964 to date, but as a result of the variation in dam releases in the "post-dam" period (see Section 3.1.1), and because flow patterns associated with the dam operating at 100% FSC are represented by only two hydrological years of recorded flow data, the accuracy of the estimation of present-day MAR at H6H009 is



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SCHEMATIC DIAGRAM OF RIVIERSONDERENDE

SCALE / SKAAL : NOT TO SCALE

DRG No TKG Nr
FIGURE 3.1

uncertain. Although values for virgin MAR are provided for additional points on the Riviersonderend (Figure 3.1), no estimates of present-day MAR are available.

3.2.3 Wet-dry cycles

Annual rainfall measured at three rainfall stations in the catchment of Theewaterskloof Dam (Station Nos. 0006332, 0022504, 0022539) were used to ascertain the pattern of interannual wet and dry cycles during the periods under consideration. The average annual rainfall values of the three stations were used to calculate cumulative differences from the mean annual precipitation (MAP) (Figure 3.2).

The period of record of pre-dam flows at both sites (hydrological years 1967/8 to 1979/80 at the dam site and and 1964/5 to 1979/80 at H6H009) began near the end of a relatively dry period, which was at its greatest in 1972 (Figure 3.2). The remainder of the pre-dam period (1973-1979) was generally becoming wetter, with a marked increase from 1975 to 1976. The post-dam period (1980-1993) continued to become increasingly wetter than in the pre-dam period.

3.2.4 Data analysis

Virgin average monthly flow data were obtained from simulated long-term monthly flow sequences produced during previous studies, using the PITMAN monthly rainfall-runoff model. For the dam site these were obtained from data simulated in the WCSA. For H6H009, simulated virgin monthly flow volumes were obtained from simulated data reported in WR90. WR90 does not publish virgin average monthly flows for quaternary sub-catchments, so these values at H6H009 were estimated by factoring flows for the tertiary sub-catchment H600. The factor used (0.98) was based on the ratio of the MAR at Gauge H6H009 to that of the full tertiary catchment.

The flow data for the **pre-dam** period (1967-1979: dam site; 1964-1979: H6H009),the **post-dam** period with dam below FSC (1980-1992), and the period with the **dam at FSC** (1993-1995) were obtained from the observed flow record.

Present-day flow patterns with the dam operating at FSC, and with user demand set at projected 1996 levels, were modelled in the WCSA (DWAF 1994a), using the Water Resources Yield Model (WRYM) (DWAF 1994b). Those with the dam raised by 0.7 m are based on unpublished results of modelling performed by Ninham Shand Incorporated, Consulting Engineers (NSI), also using the WRYM. This raised-dam scenario modelling is available for the dam site only, and is restricted to data on monthly average flow volumes.

Values for baseflows were estimated by visual examination of the daily flow hydrograph, extracting commonly-occurring average daily discharges. A numeric baseflow separation technique was not used because we do not believe that the improved level of accuracy obtained from numeric methods is required for the preliminary level of this study. High flows with magnitudes of various recurrence intervals (in the pre- and post-dam periods) were calculated from an annual flood series, based on probability theory.

intervals (in the pre- and post-dam periods) were calculated from an annual flood series, based on probability theory.

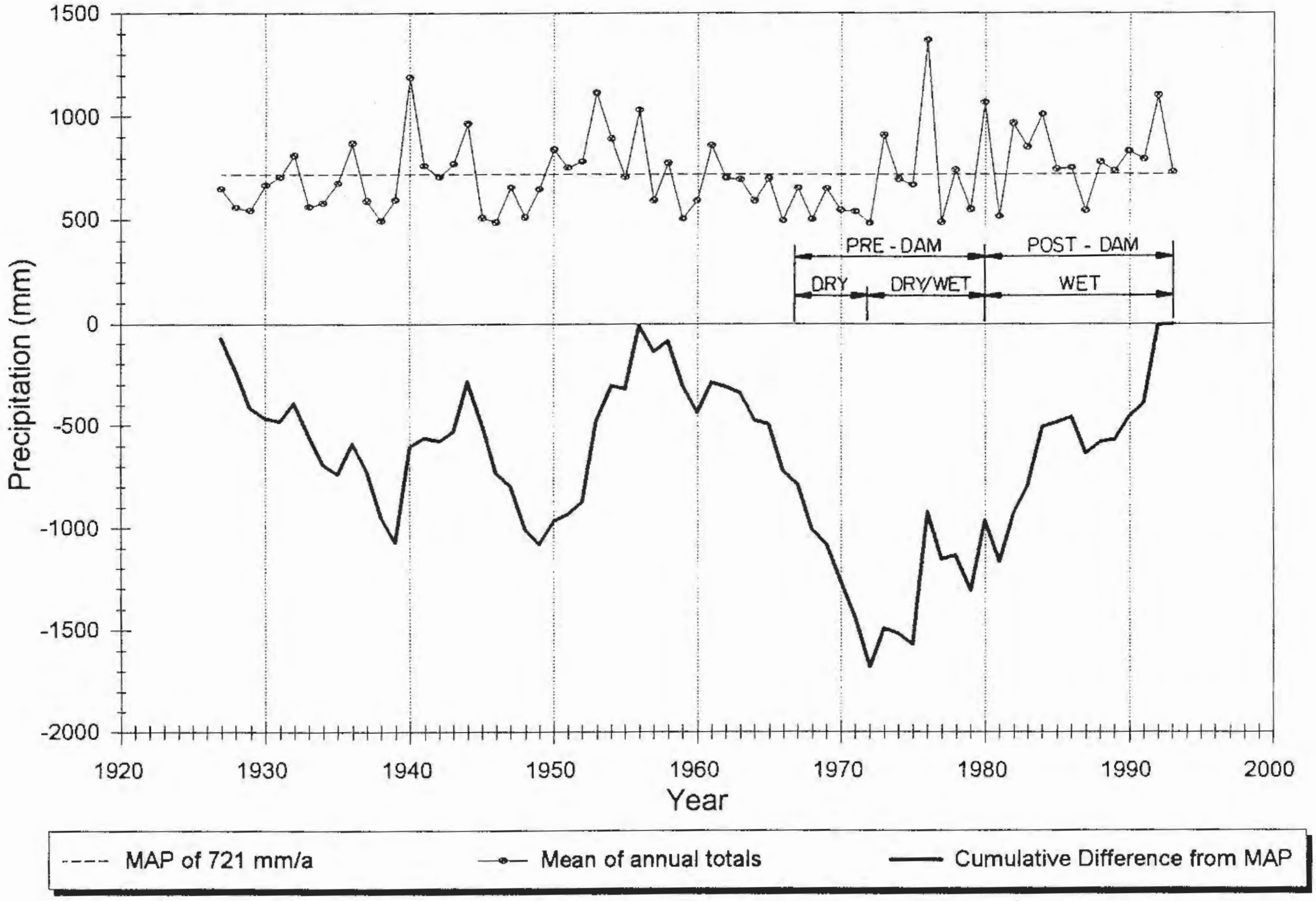

Figure 3.2 **Wet and dry cycles at Theewaterskloof Dam**

Annual and monthly flow-duration curves, based on daily average flows display the relationship between streamflow (as daily average discharge) and the percentage of time a particular discharge value is exceeded. The annual flow-duration curves were obtained by ranking, from highest to lowest, all average daily flow values for a given period (for example pre- or post-dam), and assigning them a plotting position. The highest flow was given the rank of 1. The monthly flow-duration curves were obtained in a similar way, except that each month's daily flow values were used independently.

3.2.5 Methods for the calculation of instantaneous discharge measurements at the sampling sites

Depth and velocity data collected at each cross-sectional point using a Price current meter fitted with a mini- or maxi-propellor (see Section 4.2.2 for details), were used to calculate instantaneous discharge, using equations calibrated for each propeller.

The method used to calculate the total discharges for the cross-sections is based on the partial section concept (Bovee & Milhous 1978). Each partial section (or "cell") across the cross-section comprises a vertical component representing the point measurement of depth and average velocity, and a horizontal or width component extending half the measured tape distance to both adjacent verticals. The discharge through each cell is then calculated using the following equation:

$$q_1 = a_1 \times v_1 = w_1 \times d_1 \times v_1$$

Where:

q_1 = the discharge through a cell
a_1 = the area of the cell
v_1 = mean column velocity, measured at the vertical
d_1 = mean depth of the cell, measured at the vertical
w_1 = width of the cell = the sum of half the distances to each of the two adjacent verticals

The total discharge through the cross-section (Q) is the sum of all the individual cell discharges:

$$Q = \Sigma q_1$$

Mean discharge at each site was calculated as the average of the cross-sectional discharges.

3.3 RELEASES FROM THEEWATERSKLOOF DAM INTO THE RIVIERSONDEREND

Releases from Theewaterskloof Dam into the Riviersonderend are made up of summer irrigation releases to supply farmers and municipalities downstream, and between 1980 and 1993 included releases made to keep the dam level down, during winter and summer.

The release of water for irrigation is made at the request of the Riviersonderend Irrigation Board. The volume of water released is measured at DWAF Gauge H6H012, and the farmers are charged for the water accordingly. The pattern of demand varies according to the time of year, the local temperature variations, variations in water levels and the frequency of summer rainfall in the Riviersonderend valley. Since the dam began operating at FSC (and therefore became fully operational) in November 1993, the releases have usually been made between November and March/April, starting at a daily average discharge of 0.50 m^3s^{-1} in November, increasing to 0.75 m^3s^{-1} in December, and reaching a peak of 1.2 m^3s^{-1} in January, after which releases drop to 0.5 m^3s^{-1} as a result of reduced demand. Thus, outside of times when the dam is spilling, there are no releases before November.

Irrigation demand is currently approximately 22 x 10^6 m^3 a^{-1} (provided in summer only), and is projected to grow annually by a factor of 0.053, thus reaching 33 x 10^6 m^3 a^{-1} in the year 2005. As this demand grows, more water will be released into the river during the summer months, and thus the current flow patterns will not remain as they are. Furthermore, more efficient regional management of water supplies for the greater Cape Town municipal demand will mean that supply from the various dams within the western Cape will be managed in an attempt to reduce spillage from one dam, where another is not at full capacity (K. de Smidt, NSI, pers. comm.). This means that, as user demand increases, the potential yield from dams is likely to be utilised to the full. For the Riviersonderend downstream of the dam, this will probably translate into less late-winter spillage, with the wet season flows in the river coming primarily from the Riviersonderend Mountains north of the Riviersonderend Valley.

Prior to November 1993, the release pattern was less regular than in the post-1993 period, and releases were more frequent because of the need to keep the level of Theewaterskloof Dam down. These releases, of discharges up to 100 m^3s^{-1}, were made at intervals throughout the year, usually linked to periods of high runoff, when the dam threatened to fill beyond the then-stipulated maximum level.

3.4 RESULTS OF THE HYDROLOGICAL ANALYSIS

3.4.1 Mean Annual Runoff (MAR)

The virgin and present-day MARs at both sites are summarised in Table 3.1, whilst the monthly flow data are contained in Appendix A. Four periods of different flow regimes can be identified:

- the virgin condition
- the period when the virgin condition was modified by run-of-river abstraction: for the period on record (hydrological years 1967/8 to 1979/80 at the dam site and and 1964/5 to 1979/80 at H6H009), the MAR was reduced to 81% of the virgin condition at the dam site and and 79% of the virgin condition at H6H009.
- the 13-year period when the dam was operated between 40 and 80% of FSC: the MAR was reduced to 68 and 74% of virgin MAR at the dam site and H6H009 respectively
- the present condition (since 1993) with the dam operating at FSC.

The value given in Table 3.1 for present-day MAR with the dam operating at FSC at the dam site (36% of virgin MAR) is based on long-term simulations performed with the dam operating at full draft, and on the basis of 1996 values for irrigation demand. Any simulated present-day MAR for any one year of record is not likely to reflect the actual total runoff, which is usually higher or lower than this mean. It is the values below the mean that are often most important with respect to river ecosystems, as they provide an indication of the "worst-case" scenario. Indeed, in the 1993/4 and 1994/5 hydrological years the actual total runoff at the dam site averaged only **18% of virgin MAR** at that site, whilst it averaged 39% of virgin MAR at H6H009.

Thus both the actual current, measured annual runoff, and the simulated present-day MAR, reflect a considerable reduction in MAR from the virgin condition. Whilst variation about a mean is natural, it does seem that, given that the period from 1993 is relatively wet (Figure 3.2), an annual total of 18% of virgin MAR indicates a substantial decrease in total runoff. Although the proposed raising of the dam wall will have a comparatively small incremental effect on the MAR in the river downstream, reducing the MAR by a further 2% from the simulated present value, even the present-day runoff is considerably reduced from what would occur under natural conditions.

Table 3.1 **Virgin, pre-dam, post-dam and present-day MARs for the dam site and for H6H009. The number of years of record for each period are also indicated. Simulated data are based on 60-year simulations.**

SITE	VIRGIN MAR [a]	PRE-DAM MAR [b]	POST-DAM MAR WITH DAM OPERATING AT 40-80% OF FSC [b]	PRESENT-DAY MAR WITH DAM AT FSC [a]	MAR WITH FUTURE PROPOSED DAM RAISED BY 0.7 m [a]
	m^3X10^6	m^3X10^6 (% of Virgin MAR)	m^3X10^6 (% of Virgin MAR)	m^3X10^6 (% of Virgin MAR)	m^3X10^6
Theewaterskloof Dam	291 [c]	235 (81%) (1967-79)*	197 (68%) (1980-93)*	84 (spill) + 22 (release) = 106 (36%) [c]	78 (spill) + 22 (release) = 100 (34%) [f]
Gauge H6H009	450 [d]	354 (79%) (1964-79)*	334 (74%) (1980-93)*	190 (42%) [e]	184 (41%) [g]

a	from long term simulations	e	Present-day MAR roughly estimated by DWAF, Western Cape (A Roux, pers. comm. 1995)
b	from historical flow data		
c	WCSA (DWAF 1994a)	f	NSI - unpublished modelling results (1995)
d	WR90 (Midgely *et al.* 1994)	g	Calculated from figures in this table
*	hydrological years		

3.4.2 Seasonal distribution of flow

a. Virgin and pre-dam state

The wet, dry and transitional months (or flow-volume categories) for the virgin, pre-dam and post-dam periods for both sites were identified by inspection of the monthly flow volumes, averaged over the period of simulated data (virgin flows) and over the historical record prior to and after dam construction (Appendix A). These are summarised in Table 3.2. The wet and dry months were first identified as months carrying similarly high or low proportions of annual flow, and the remaining months formed the two transitional periods.

The seasonal distribution of monthly flow volumes for the two locations (Figures 3.3 and 3.4) indicates an essentially perennial river, both prior to and after the construction of Theewaterskloof Dam. There are zero monthly totals in the record, but we believe that this is due to missing data, or, if flow actually reached zero, this was caused by abstractions of water from upstream, and not because the river was not perennial in its pre-dam condition. The zero flows in the record all occurred in the pre-dam period, during the dry season, and mostly at H6H009.

Table 3.2 **Seasonal distribution of monthly flow-volumes, showing wet, dry and transitional months. The average percentage of the MAR carried for each of the months in each flow-volume category is shown in parentheses. The number of years of record for each period are indicated in Table 3.1. Simulated data are based on 60-year simulations.**

SITE	PERIOD	WET-DRY TRANSITION	DRY	DRY-WET TRANSITION	WET
Theewaters-kloof Dam	Virgin [a]	September-November (7.6 %)	December - March (1.5 %)	April & May (6.6 %)	June - August (19.2 %)
	Pre-dam [b]	September-November (7.1 %)	December - March (0.8 %)	April & May (5.4 %)	June - August (21.3 %)
	Post-dam [b]	September & October (10.8 %)	November -April (2.4 %)	May & June (8.3 %)	July & August (23.5 %)
	Full dam [c]	October (10.0 %)	November - June (4.6 %)	none	July - September (17.7 %)
Gauge H6H009	Virgin [a]	October & November (7.3 %)	December - March (1.6 %)	April & May (6.7 %)	June - September (16.5 %)
	Pre-dam [b]	September-November (8.8 %)	December - April (1.4 %)	May (7.5 %)	June - August (19.8 %)
	Post-dam [b]	October & November (6.8 %)	December - March (2.4 %)	April - June (6.3 %)	July - September (19.4 %)
	Full dam [c]	September & October (9.1 %)	November - May (5.3 %)	June (7.4 %)	July & August (18.5 %)

a based on simulated data
b based on observed flow data
c based on observed data for 1993 and 1994 hydrological years

In the virgin condition, the river at the Theewaterskloof Dam site had a marked seasonality (Figure 3.3, Table 3.2), with low summer flows (December through to the lowest flow in March) and high winter flows (June - August). The autumn (dry-wet) transition period (April and May) was shorter than the spring (wet-dry) transition (September to November). This seasonal distribution of flow represents the characteristic flow pattern of any relatively natural perennial river in the western Cape. Strong seasonality in runoff patterns was also prevalent further downstream, as reflected at H6H009 (Figure 3.4, Table 3.2), but at this site the wet season in the natural condition extended into September, with flows gradually receding to a January low. The dry-wet transition period for this part of the river was also in April and May, with a shorter wet-dry period (October and November) than at the dam site.

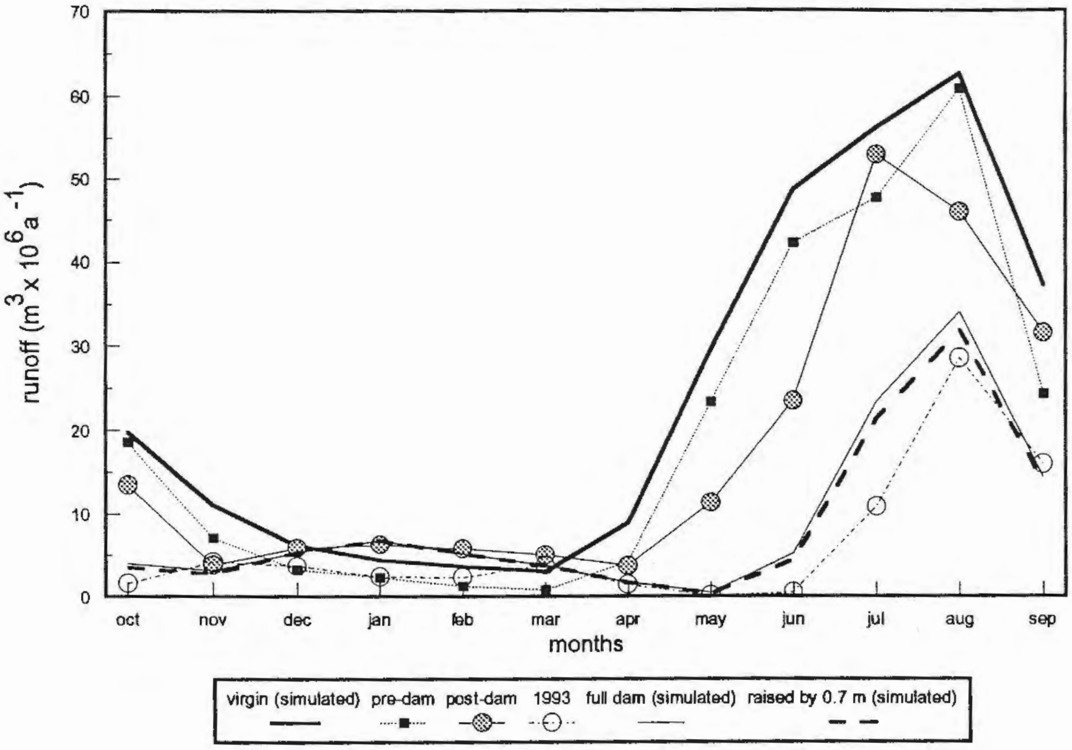

Figure 3.3 Seasonal distribution of monthly flow volumes at the Dam Site.

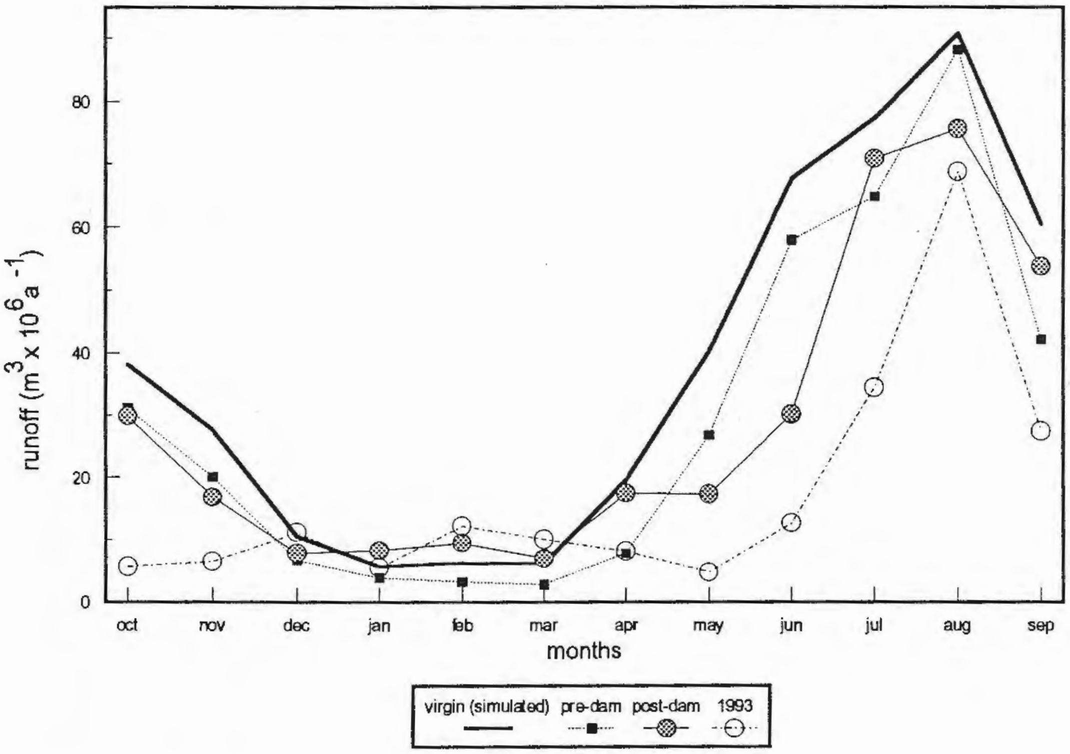

Figure 3.4 Seasonal distribution of monthly flow volumes at Gauge H6H009.

From prevailing south-easterly winds the Riviersonderend catchment, particularly the eastern part, receives summer rainfall, which falls against the southern slopes of the Riviersonderend Mountains. This is reflected in the hydrological record for both sites, which indicates that summer showers and associated periods of elevated flow were prevalent prior to the construction of the Theewaterskloof Dam, although summer spates were more numerous and larger in the river in the lower reaches of the river, as reflected at H6H009 (Appendix B). The summer rainfall does not, however, influence the seasonal distribution of runoff very strongly, being masked by the pronounced winter rainfall so characteristic of the western Cape climate.

In the pre-dam period of record (during which summer run-of-river water was abstracted for irrigation), this seasonality was maintained at both sites along the Riviersonderend. Pre-dam flows in summer were considerably lower than in the virgin condition (Figures 3.3 and 3.4), and carried on average a lower proportion of the annual runoff (Table 3.2), indicating that the run-of-river abstraction in this period (some 20% of MAR: see Table 3.1) occurred mostly in the summer months. This effect appears to have been more accentuated at the dam site, where pre-dam flows were about half of those in the virgin condition, whilst those at H6H009 were only slightly reduced from the virgin condition, suggesting that abstractions relative to runoff contributed by incoming tributaries were less in the downstream reaches. At the same time, pre-dam summer abstractions from these lower reaches appear to have extended to April (a dry-wet transitional month in virgin conditions), which carried only half of its natural proportion of flow in the pre-dam period, and was thus included in the "dry months" category. Thus at H6H009, the pre-dam dry period extended for a longer period than in the virgin condition, with a shorter dry-wet transitional period (Table 3.2).

b. Post-dam state, with dam below FSC

The most obvious change in the seasonal distribution of flows at the dam site from the pre- to post-dam period, prior to the dam operating at full supply capacity, was the increase in summer flows (Figures 3.3 and 3.4; Table 3.2), with the "dry months" carrying a far greater proportion of the annual flow (2.4% each month, as opposed to 0.8% in the pre-dam condition at the dam site). These flow volumes were released from the dam more or less constantly (see Section 3.3), reflecting requirements for irrigation.

The lowest flow volumes in the post-dam period at the dam site occurred in the month of April, corresponding to the decreasing irrigation releases from the dam in this month. This flow reduction at the end of summer represents **the reverse of natural patterns**. The wet-dry transition in the post-dam period was thus delayed by a month, and continued into June, with a shortened wet season (July and August only). In the post-dam (below FSC) period, releases were made specifically to maintain the dam below full capacity. This accounts for the increase in the proportion of MAR released into the river (relative to the virgin and pre-dam conditions) at the end of the natural winter season: compensation flows were not released into the river in autumn and early winter, when runoff would naturally be increasing, but were stored in the dam, and released only to maintain the stipulated maximum water level in the dam.

As reflected by H6H009, a similar situation prevailed further down the river, although runoff from the Riviersonderend Mountains between the two locations allowed for slightly more natural April flows than at the dam site (Figure 3.4). The delay in the onset of the wet season, because of the presence of the dam, resulted in a three-month dry-wet transitional period.

c. *Observed record with dam at Full Supply Capacity*

The seasonal distribution of flows from October 1993 to September 1995 (Figures 3.3 and 3.4) indicates a considerable departure from the natural flow regime of the Riviersonderend. At the dam site, the onset of the wet season is delayed by three months, and there is no longer a transition period from dry to wet conditions (Table 3.2). The average monthly volumes in "wet" months (now July to September) are less than half of those in the natural condition (Figure 3.3), and considerably reduced from the situation in the post-dam period prior to 1993. A more drastic alteration of the flow regime is reflected in the fact that the lowest flows occurred in the previously dry-wet transitional months, with almost no flow in May or June. These two months, although included in the "dry" period, carry only 0.4 and 0.7% respectively of the annual total flow. Summer flows are elevated, reflecting the effect of irrigation releases.

A similar trend is evident at H6H009, although the effects of the dam are considerably ameliorated by catchment runoff in the area between the dam and this site. The contributions to autumn and winter flows (April to June) of the streams draining the Riviersonderend Mountains at least raises the flow volumes in these months above those experienced in the dry season, in a semblance of the natural seasonal pattern (Figure 3.4).

These data indicate that important components of the flow regime, such as the first high flows heralding the onset of the wet season, and gradually declining summer flows, have been removed from the system over the past two years.

d. *Potential future scenario with a full or raised dam, with dam operating at full draft (Theewaterskloof Dam site only)*

It is important to note that even the recently measured flows do not reflect the full extent of the effects of Theewaterskloof Dam being fully operational, as the full draft of the dam has not as yet been drawn. The seasonal distribution of the simulated flows for the situation with a fully operational dam based on projected 1996 demands is also shown in Figure 3.3 (such simulations are not available for H6H009). The flow distribution under these conditions is similar to the current observed patterns, although more flow is present from June through to September. These long-term simulations suggest that, on average, the seasonality of the river is better maintained than the 1993/4 and 1994/5 data indicate. In this simulated scenario, the MAR is 36% of the virgin MAR, whilst the annual totals recorded in 1993/4 and 1994/5 averaged 18% of virgin MAR, which may account for this discrepancy. The fact that 1993/4 and 1994/5 were relatively wet years (see Figure 3.2) means, however, that their total runoff should be close to the simulated MAR, and this presents an anomaly.

The simulated flow pattern is likely to change each year, as irrigation demand increases and the dam becomes more stressed to meet demand, so that spills during the wet months will be further reduced.

Figure 3.3 also shows the seasonal distribution that is likely to result from the proposed raising of Theewaterskloof by 0.7 m. The summer flows are unchanged from the full-dam simulation at 1996 demand levels, but flows during the winter and transitional months are slightly lower.

3.4.3 Baseflow estimations

Estimations of baseflows (average daily discharge) for the wet, dry and transitional months were made by visual inspection of the daily flow data (Appendices B(i) and B(ii)), and are summarised in Table 3.3. It should be emphasised that these are coarse estimations of the daily baseflows in the river.

a. *The dam site*

In the post-dam period at the dam site, the dry-season baseflows were higher than those of the pre-dam period, as a result of irrigation releases. The pre-dam dry-season discharges (Table 3.3) were probably lower than those which are likely to have occurred naturally (in virgin conditions), because of summer abstraction from the river in this period, but it is unlikely that virgin baseflows were as high as the irrigation release flows, given the low proportion of the MAR carried during the dry season in virgin conditions, some of which occurred as summer floods.

In the period when the dam was operating at 40 - 80% of FSC, releases were made periodically to keep the dam level down. These releases were usually linked to flood events, and were made in blocks of between 10 and 40 $m^3 s^{-1}$. (This is evident from examination of daily flow data for this period.)

Between these releases, baseflows during the wet season were extremely depressed compared with those prior to the existence of the dam, consisting only of runoff from the Donkerhoekberge just downstream of the dam (Table 3.3). Baseflows in the transitional months, particularly in those of the the dry-wet transition, were also dramatically altered by the presence of the dam, dropping to well below 0.1 $m^3 s^{-1}$ in June with only rare increases linked to rainfall events. This condition was exacerbated by the fact that releases from the dam did not occur as frequently during the dry-wet transition period as in the wet season, as the dam would usually be well below maximum levels at the end of the dry season.

Table 3.3 Summary of estimated baseflows for the Riviersonderend at the Theewaterskloof Dam site and at H6H009. Values in the table represent average daily baseflows in m^3 s^{-1}. The number of years of record for each period are also indicated. Simulated data are based on 60-year simulations.

SITE	PERIOD	WET-DRY TRANSITION	DRY	DRY-WET TRANSITION	WET
Theewaterskloof Dam site	Pre-dam	September - November	December - March	April & May	June - August
	(1967-79)	Starts high (2 - 3) and drops to between 0.5 and <0.1 by end Nov.	Could be as high as 1.5 (wet years) but more likely to be from 0.5 to <0.1	As for December-March period, but rises to between 0.5 and 1 in May.	Usually varies between 1.0 and 6.
	Post-dam	September & October	November - April	May & June	July & August
	(1980-93)	Between 0.1 and 0.2	Determined largely by irrigation releases - rises to average of 1.5	Could stay at April level of 1.5 but drops to <0.1 by end May.	<0.1 for periods, interspersed with frequent, high-magnitude block-releases of 30-40.
	Hydrological Years 1993/4+1994/5	October	November - June	—	July - September
		Depends on dam spillage, may be <0.1, or if spills, then between 0.4 and 1.9	Determined largely by irrigation releases (1.5), with some variation (0.5 to 1.9) but falls to 0.5 in April, and <<0.1 in May and June.	—	Mostly varies between <0.1 and 0.4, unless dam spills, when commonly from 2.7 to 10.
Gauge H6H009	Pre-dam	September - November	December - April	May	June - August
	(1964-79)	Starts as high as 4 - 8 and drops to between 0.8 and 2.0, sometimes <0.1.	Can be at <0.5 or even <0.1 for most of summer, but elevated by summer rain. Other common flows are 0.5-1, and can reach as high as 2 in a wet year.	Varies from 0.1 to 4. 2-3 is common.	Varies between 5 and 25, lower than 5 in dry years or early in season.
	Post-dam	October & November	December - March	April - June	July - September
	(1980-93)	Starts as above, and drops to between 0.5 and 3.	May be affected by unused irrigation releases from dam. Can be as high as 6 or as low as <0.1, but usually varies between 0.2 and 2.	Depends on timing of rains. Can start at <0.1, is usually around 0.5 - 1, but can be as high as 6.	Varies between 2 and 40 in some months, average around 5 - 10. If there is a dry start or end of season, can vary from 0.5 - 1.
	Hydrological Years (1993+1994)	September & October	November - May	June	July & August
		Starts high, 5 - 10, dropping, depending on spillage at dam, to 0.2 and 4.	Usually between 0.2 and 0.8; may be <0.1, and up to 2.1.	Between 1.6 and 4.5	Ranges from 2.4 to 20, commonly 3 - 10.

Thus not only was the wet season delayed in the post-dam period, but baseflows during the months preceding, and indeed, during the wet season, were among the lowest flows recorded in the river. This situation is the opposite of what might be expected in western Cape rivers under natural conditions, where baseflows typically increase during autumn and winter.

At the dam site, with the dam operating at FSC (i.e. 1993/4 and 1994/5), no releases were made after April or before November (A. Roux, DWAF Western Cape Region, pers. comm.). The "dry" season thus extended from after the dam had stopped spilling until it spilled again in the following year. On average over the past two years, this dry period has extended from November to June (Table 3.3), thus comprising eight months of the year. In addition, dry-season discharges started low, were raised by irrigation releases (1.5 $m^3 s^{-1}$) and ended at well below 0.1 $m^3 s^{-1}$ in May and June. During these latter two months, the natural river would have experienced high flows associated with winter rainfall. The (delayed) wet season baseflow, outside of periods when the dam was spilling or had recently spilled, was, at its highest, a mere 0.4 $m^3 s^{-1}$. Unlike the post-dam period with the dam below FSC, when frequent releases required in winter had the fortuitous effect of increasing winter flows in the river, the past two years have been characterised by no winter releases and only one or two spills each year at the end of the wet season.

b. H6H009

At H6H009, pre-dam baseflows in summer are likely also to have been reduced by abstractions from the river for irrigation, and in the post-dam period the baseflows recorded were somewhat higher than those of the pre-dam period. Much of the irrigation water released from Theewaterskloof Dam is intended for use upstream of this site but at times unutilised flows might contribute to maintaining comparatively high baseflows in the river.

As at the dam site, the dry-wet transitional period extended to the end of June in the post-dam period at H6H009, because of the harvesting of early winter floods and high flows by the dam, and the lack of releases from the dam after April. The pre- to post-dam reduction in baseflow in this dry-wet period, which was so extreme at the dam site (Table 3.3), however, was less severe at H6H009, and was maintained at around 1 $m^3 s^{-1}$ or higher. This stands to reason, given the contributions from the Riviersonderend Mountains to winter flows. At the same time, the post-dam period has been wetter than that (on record) prior to the existence of the dam, and in dry climatic cycles the effects of the dam may be more evident.

Theewaterkloof Dam appears to have severely altered the baseflows in the Riviersonderend just downstream of the dam, particularly by reducing baseflows in the dry-wet transitional and the wet seasons. This effect becomes gradually dampened with increasing distance downstream. The river downstream of the dam to Gauge H6H009 therefore alteration in the flow regime diminishes as a result of the natural contributions of runoff from the tributaries draining the Riviersonderend Mountains, although the effects of the dam remain evident throughout the length of the Riviersonderend.

3.4.4 Flood events

a. Timing of floods

The timing of the first and last floods in the wet season, and of summer floods, prior to and after the construction of Theewaterskloof Dam, have been ascertained from visual inspection of average daily discharges for the period of record (Appendix B), and are summarised in Table 3.4. The hydrological record indicates that small spates in summer (20-60 $m^3 s^{-1}$ maximum average daily discharge at the dam site; 20-100 $m^3 s^{-1}$ maximum average daily discharge at H6H009) were a common feature in the pre-dam period. In the post-dam period these were retained at H6H009, but closer to the dam, these high flows are captured by the dam, except in the first years after dam completion (i.e. until 1984, but particularly 1980) when summer releases were made to maintain low levels in the dam.

Table 3.4 Timing of the first and last floods of the wet season, and of dry-season floods.

SITE	PERIOD	TIMING OF FIRST AND LAST WET SEASON FLOODS		TIMING OF DRY SEASON FLOODS
		FIRST	LAST	
Theewaterskloof Dam	Pre-dam	April/May	September/October	November - January, March
	Post-dam	May to June prior to 1993, August in 1993 and only October in 1994	October/November	none after 1984
Gauge H6H009	Pre-dam	May	September/October	November - January, March
	Post-dam	May/June	October/November	November - March

The assessment of floods in the Riviersonderend is substantially affected by the fact that the pre-dam period was climatically drier than was the post-dam period. Also, the available record of the post-dam period, until 1993, reflects releases made specifically to maintain the dam at 40% or 80% of FSC. The consequence of this is that there appears to have been a relatively minor delay (1 month) in the onset and end of wet season floods (Table 3.4).

Examination of the hydrological record over the past two years, however, provides a different picture of the effects of the current operation of the dam. Here the onset of wet-season floods is delayed until late July/August at the dam site and until early July at H6H009.

b. Flood recurrence intervals and the shape of the hydrograph

The magnitude of floods of various recurrence intervals were calculated from an annual flood series, based on probability theory, and are summarised in Table 3.5, and the hydrographs of these flood events are provided in Figures 3.5 and 3.6.

It should be noted that direct comparison between pre- and post-dam periods is not strictly valid because they represent predominantly dry and wet climatic cycles respectively. Since the post-dam period is wetter, one would expect floods to be considerably higher and more frequent now than the pre-dam period without the dam in place. Comparison of the pre- and post-dam floods in this context will tend to under-represent the extent of the effects of the dam.

At the dam site, the magnitude of the 1:1 year-recurrence flood appears not to have been much affected by the presence of the dam. However, for most of the post-dam period, until 1993, the dam never reached full supply level, and flood releases were made to maintain the dam below FSC. Releases were made following the onset of floods coming into the dam. The duration of the releases depended on the levels in the dam, but discharges were relatively constant. Thus, although peak instantaneous discharge data are not available, it is reasonable to assume that the releases did not achieve the same instantaneous peak discharges as in the natural condition. Releases of large volumes of water, at intermediate discharges, suggest that annual floods in the post-dam period were somewhat smoothed, a feature which is also suggested by the shape of the hydrograph (Figure 3.5).

At the dam site in the post-dam period, floods with recurrence intervals of 1:2 years and more have peak flows of about half those recorded in the pre-dam period (Table 3.5, Figure 3.5), whilst the lower-recurrence-interval floods also appear to be affected with regard to the shape of the hydrograph (Figure 3.5), the time to peak, and duration of (the reduced) peak flows, being greater in the post-dam period, thus producing an atypical rectangular hydrograph.

Like at the Dam Site, the peaks of the lower-recurrence-interval floods (particularly 1:2 years) at H6H009 were also considerably lower in the post-dam period than in the pre-dam period, although the hydrograph shapes were not obviously different (Figure 3.6). This maintenance of the hydrograph shape is probably due to the tributaries of the Riviersonderend Mountains contributing natural floods to the main river, thus providing the "tops" of the hydrographs.

The two higher-recurrence-interval floods (1:10 and 1:20 years) in the post-dam period at H6H009 are higher than those for the pre-dam period. This would not be unusual if there was no dam, because the period post-dam was wetter. The fact that these flood events are higher, despite the existence of the dam, suggests that the tributaries draining the Riviersonderend Mountains contribute considerably to the larger floods, thus dampening the effect of the dam with distance downstream.

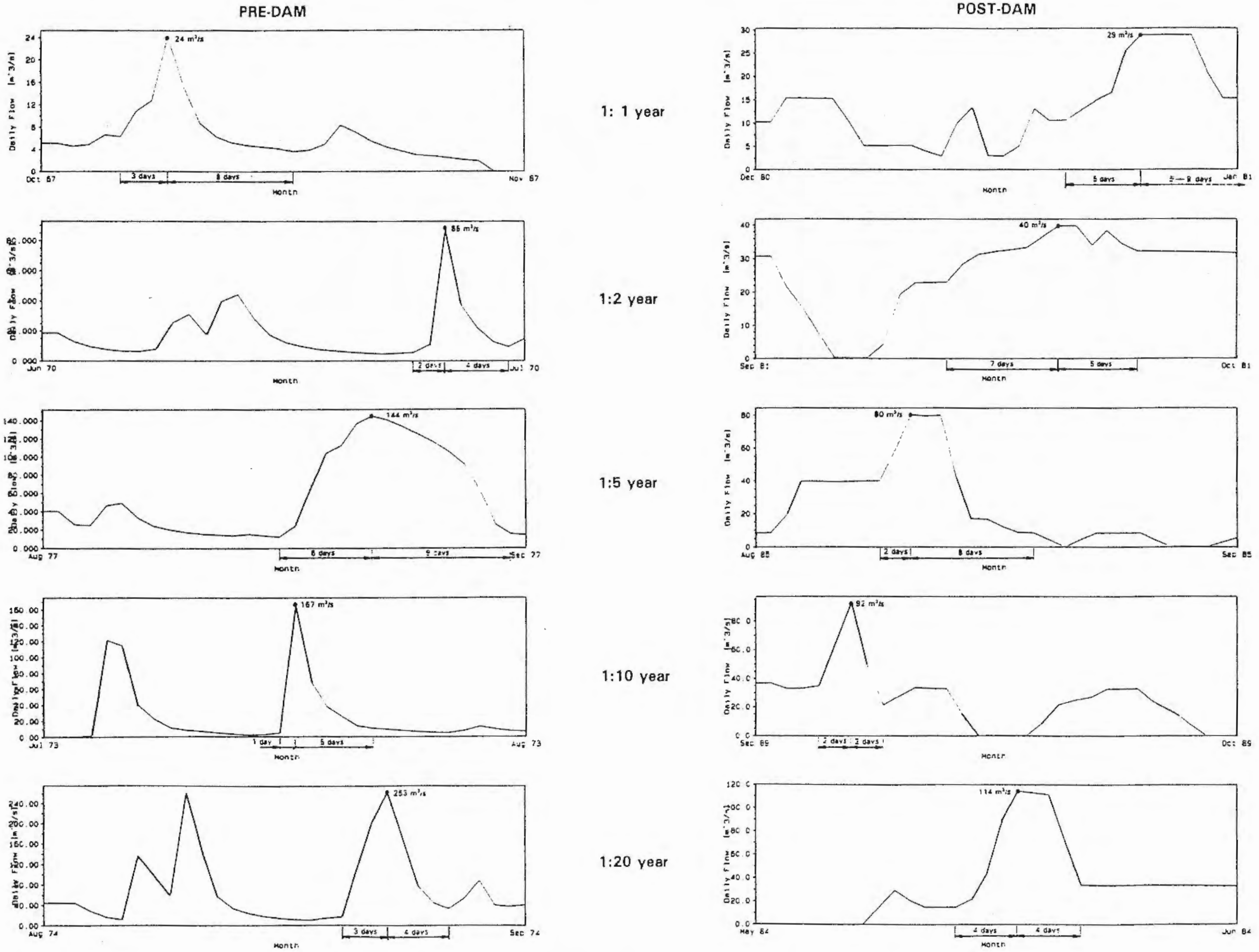

Figure 3.5 **Hydrographs of floods of various recurrence intervals at the Dam Site. Hydrographs are taken from real events that correspond to the magnitude of each recurrence-interval flood.**

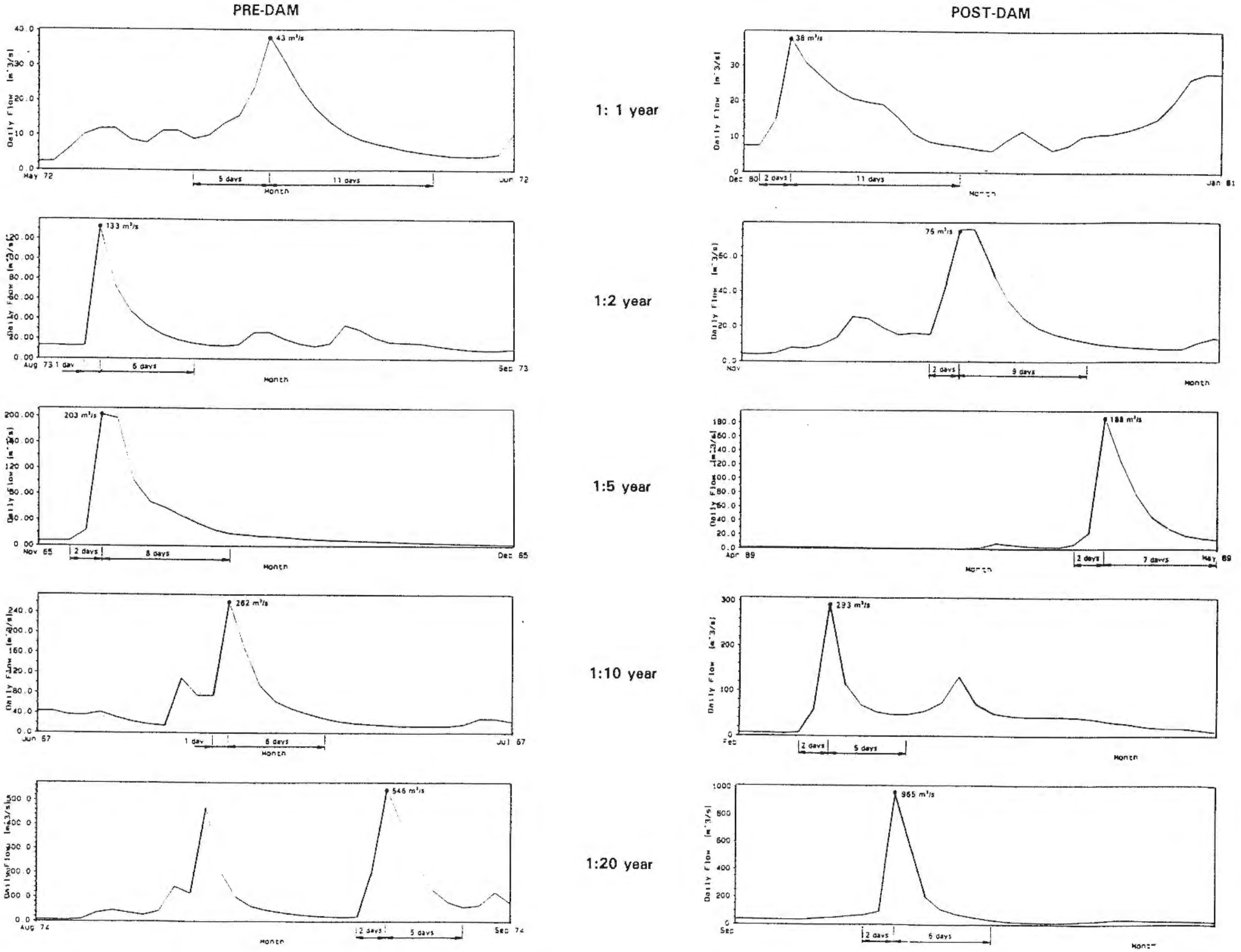

Figure 3.6 Hydrographs of floods of various recurrence intervals at H6H009. Hydrographs are taken from real events that correspond to the magnitude of the recurrence-interval flood.

Table 3.5 **Magnitude of floods of various recurrence intervals at the Dam Site and at H6H009. The floods represent real events that correspond to the magnitude of the recurrence-interval flood.**

LOCATION	PERIOD	DETAILS	RECURRENCE INTERVAL 1:1 YR	1:2 YR	1:5 YR	1:10 YR	1:20 YR
Theewaterskloof Dam	Pre-dam	Peak average daily flow ($m^3 s^{-1}$)	24	88	144	167	263
		Date	October 1967	June 1970	August 1977	July 1973	August 1974
	Post-dam	Peak average daily flow ($m^3 s^{-1}$)	29	40	80	92	114
		Date	December 1980	September 1981	August 1985	September 1989	May 1984
Gauge H6H009	Pre-dam	Peak average daily flow ($m^3 s^{-1}$)	43	133	203	262	547
		Date	May 1972	August 1973	November 1965	June 1967	August 1974
	Post-dam	Peak average daily flow ($m^3 s^{-1}$)	38	76	188	293	965
		Date	December 1980	November 1991	April 1989	February 1981	September 1986

The hydrological records from 1993/4, 1994/5 and 1995/6 at H6H012 and H6H009 (Figures 3.7 and 3.8) provide some insight into the effect on flood size and duration of the dam operating at FSC. In the 1993/4 hydrological year, the dam spilled for the first time in late July (1994), with a peak average daily flow of less than 20 $m^3 s^{-1}$, which is lower than a flood of a 1:1 year recurrence interval (Figure 3.7). A second smaller spill occurred in late September. In the following year, there were no spills until October 1995, which is at the start of the 1995 hydrological year, where again a "flood" peak of approximately 21 $m^3 s^{-1}$.was measured.

At H6H009 there is clear evidence that, with increasing distance downstream, the contributions of water from tributaries downstream of the dam ameliorate to some degree its effects on the hydrological regime of the Riviersonderend. A series of small floods (peak average daily discharge of 10 - 20 $m^3 s^{-1}$) were recorded between December 1993 and May 1994 (Figure 3.8), with two winter floods, one in July and one in August reaching flood peaks > 50 $m^3 s^{-1}$. Although this value is slightly higher than those of the 1:1 year recurrence floods in the pre-dam period, the fact that they occur in a relatively wetter cycle (compared to the pre-dam period) suggests that these floods may be lower than the natural annual event in a wet cycle. In the 1994/5 hydrological year, small floods (some 25 $m^3 s^{-1}$ peak flow) again occurred in April and May, and in June, but larger floods were absent, with December 1995 rainfall providing for the highest flows, but only in the 1995 hydrological year.

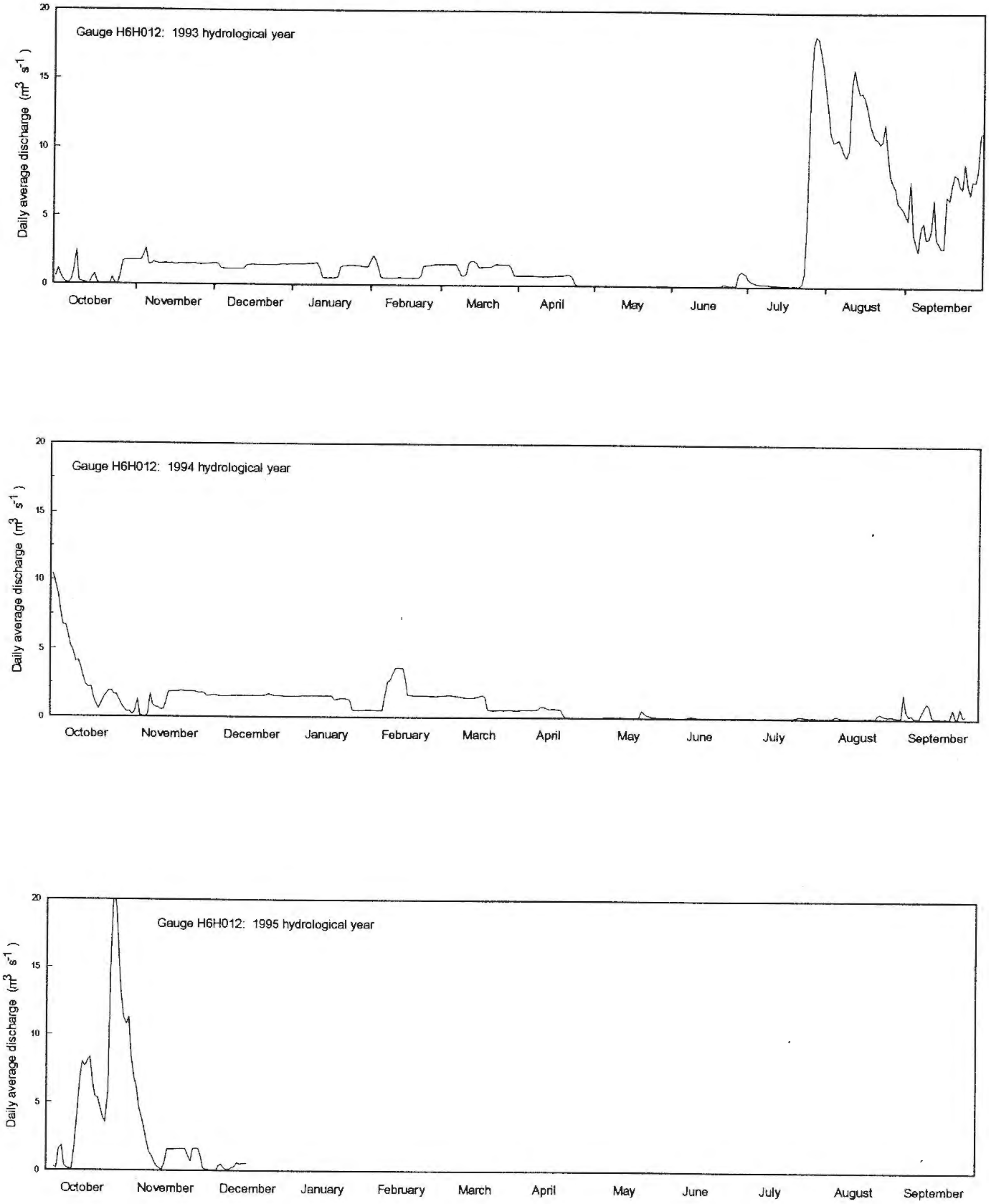

Figure 3.7 **Average daily flows at the Dam Site, for the 1993, 1994 and 1995 hydrological years.**

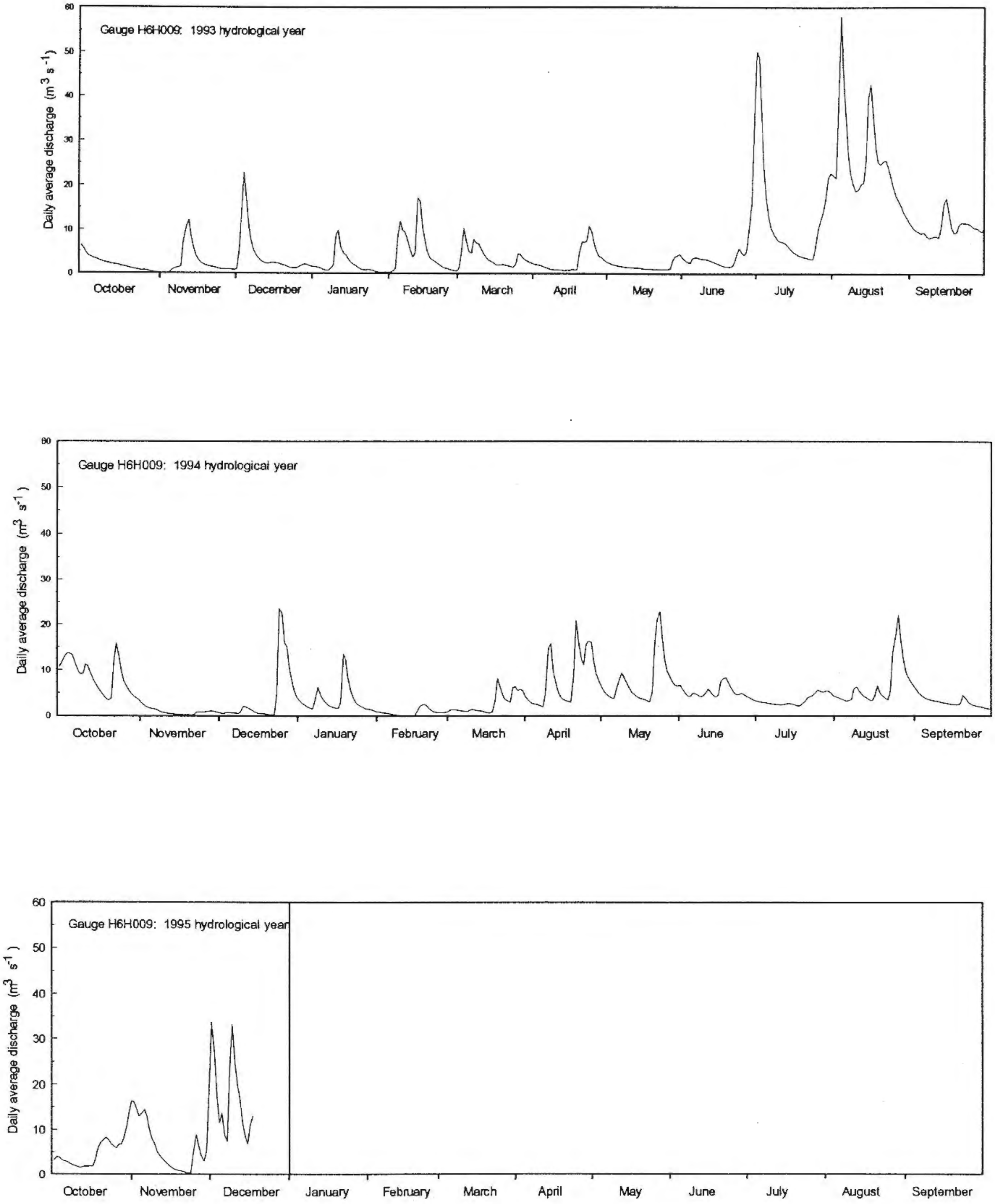

Figure 3.8 **Average daily flows at Gauge H6H009, for the 1993, 1994 and 1995 hydrological years.**

3.4.5 Flow-duration curves

Annual flow-duration curves, based on average daily flows and comparing pre- and post-dam conditions, are shown in Figures 3.9 and 3.10 for the two sites. It should be remembered that the pre- and post-dam periods are characteristic of predominantly dry and wet cycles respectively.

At the dam site the natural distribution of flows in the pre-dam period is altered to an obviously regulated one in the post-dam period (Figure 3.9). The annual curve representing the post-dam period primarily shows the effects of a release strategy aimed at maintaining the dam below FSC, not following natural flood patterns. The effect has been to remove the larger floods from the river, whilst increasing those floods of intermediate magnitude. This is still evident at H6H009 (Figure 3.10), but is less accentuated because of the influence of tributaries entering the lower river. With regard to low flows at the dam site, discharges of between 8 and 2 $m^3 s^{-1}$ occurred less often in the post-dam period, whilst extremely low flows occurred for a greater proportion of the time in the post-dam period (Figure 3.9).

Monthly flow-duration curves based on average daily discharge data for the two sites under pre- and post-dam conditions (Figures 3.11 and 3.12) facilitate examination of the effects of the dam on the flows of each month. Releases for irrigation in summer (December to April) in the post-dam period at the dam site are evident as an increase in the exceedence values for low flows. On the other hand, the pre-dam exceedence values for low flows reflect the effects of run-of-river abstractions, and are lower than would be expected under virgin conditions.

The increase in intermediate-discharge winter flows (from July to September in the post-dam period) is more evidence of the releases made to keep the dam level down (prior to 1993). The reductions in flow in May and June reflect the delay in the onset of the wet season in the post-dam period. This is linked to the harvesting of water in autumn and early winter, when the dam was at its annually lowest level, and to the absence of compensation releases in this period.

While these effects are particularly marked just below Theewaterskloof Dam, they become slightly dampened at the downstream site, and the shape of the flow-duration curves in the post-dam period resemble a generalised natural hydrograph more closely. The delay in the onset of winter high flows (until June) is still clearly evident. On the other hand, elevated flows in April in the post-dam period at H6H009 contrast with the low pre-dam flows, caused by run-of-river abstraction in that month, and reflect a combination of dry-season irrigation releases from the dam, and the fact that the post-dam period was wetter than the pre-dam period.

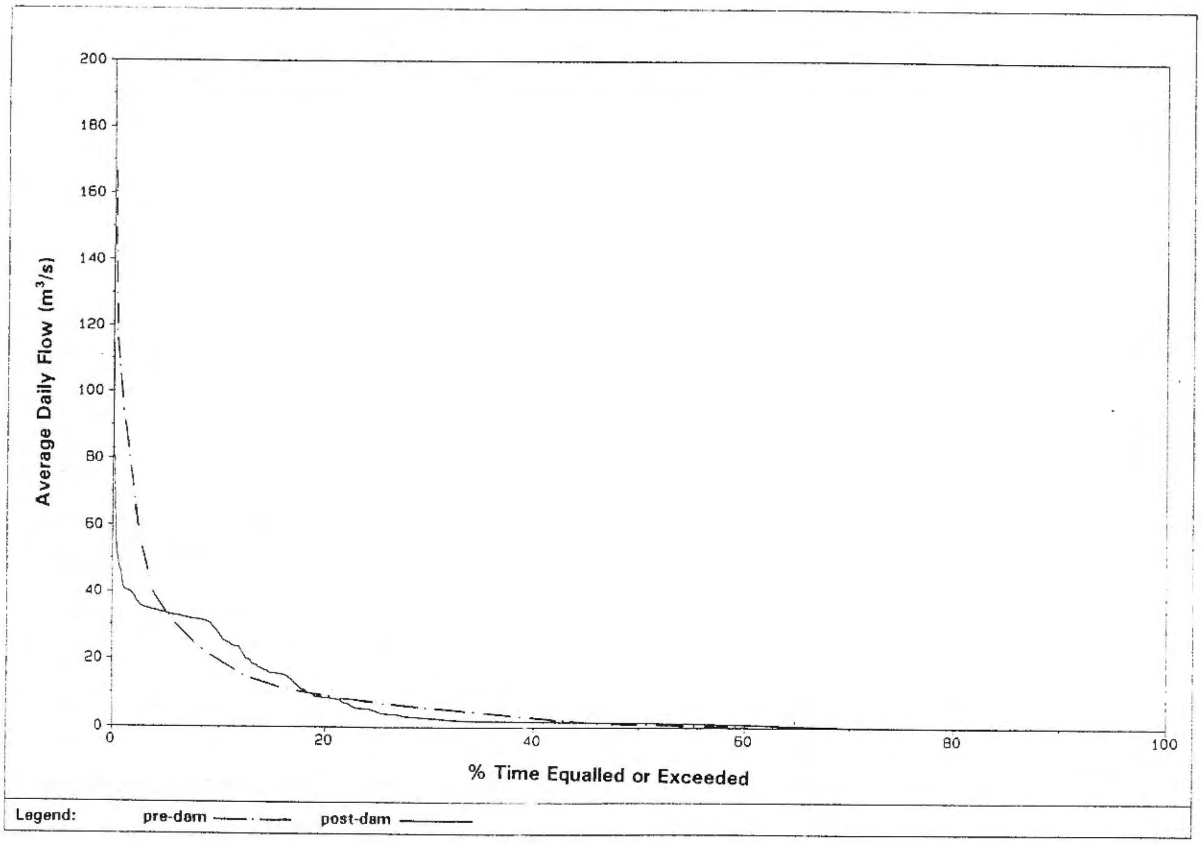

Figure 3.9 Annual flow duration curves for the Dam Site, showing the pre-dam (1967 to 1979) and post-dam (1980 to 1993) periods.

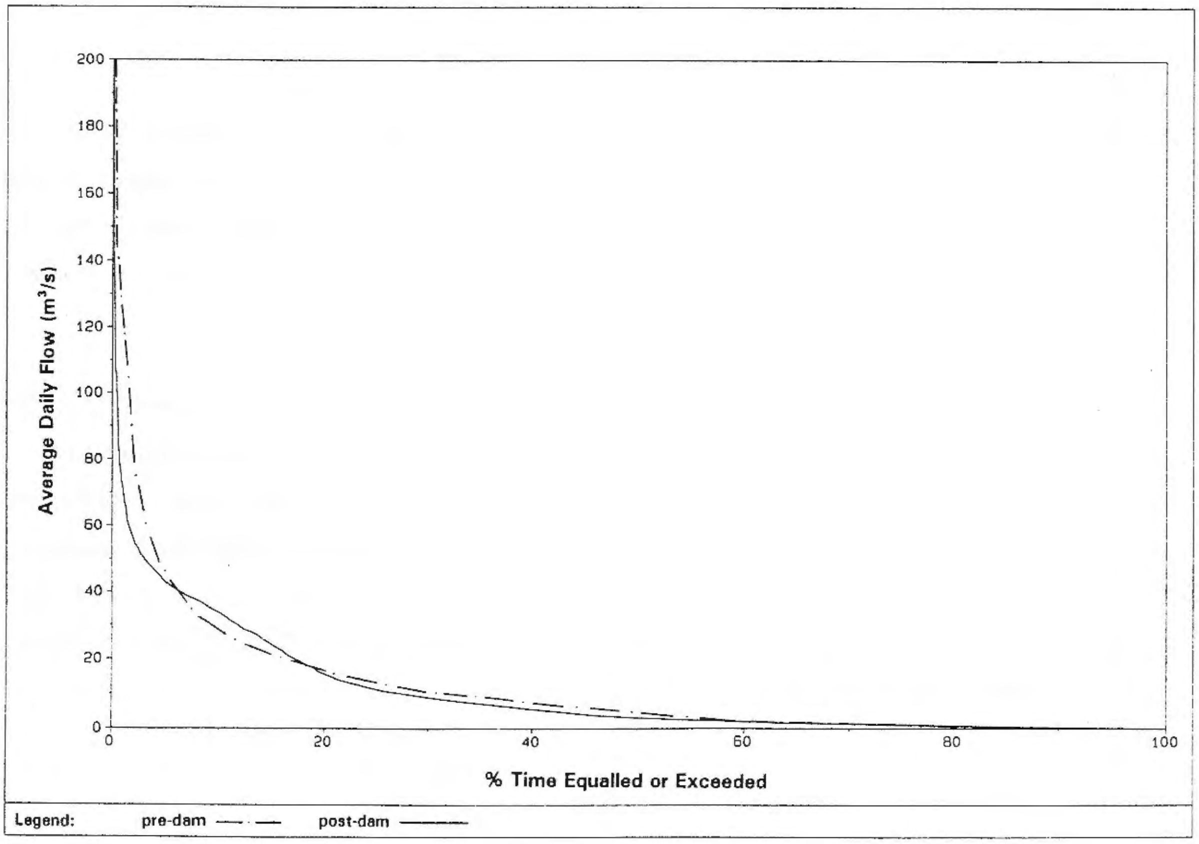

Figure 3.10 Annual flow duration curves for Gauge H6H009, showing the pre-dam (1967 to 1979) and post-dam (1980 to 1993) periods.

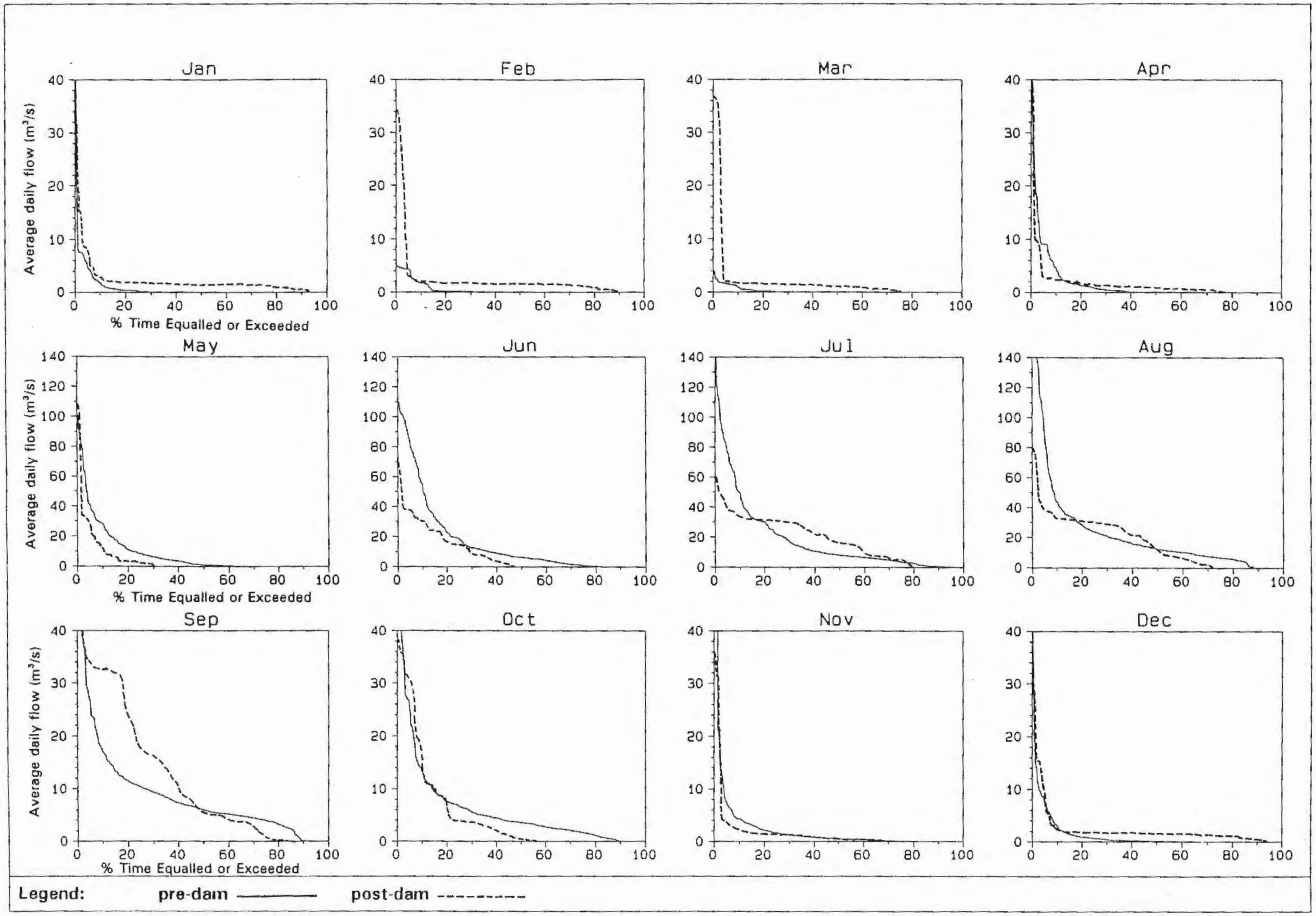

Figure 3.11 Monthly flow duration curves for the Dam Site, showing the pre-dam (1967 to 1979) and post-dam (1980 to 1993) periods. Note that there are different scales for individual months

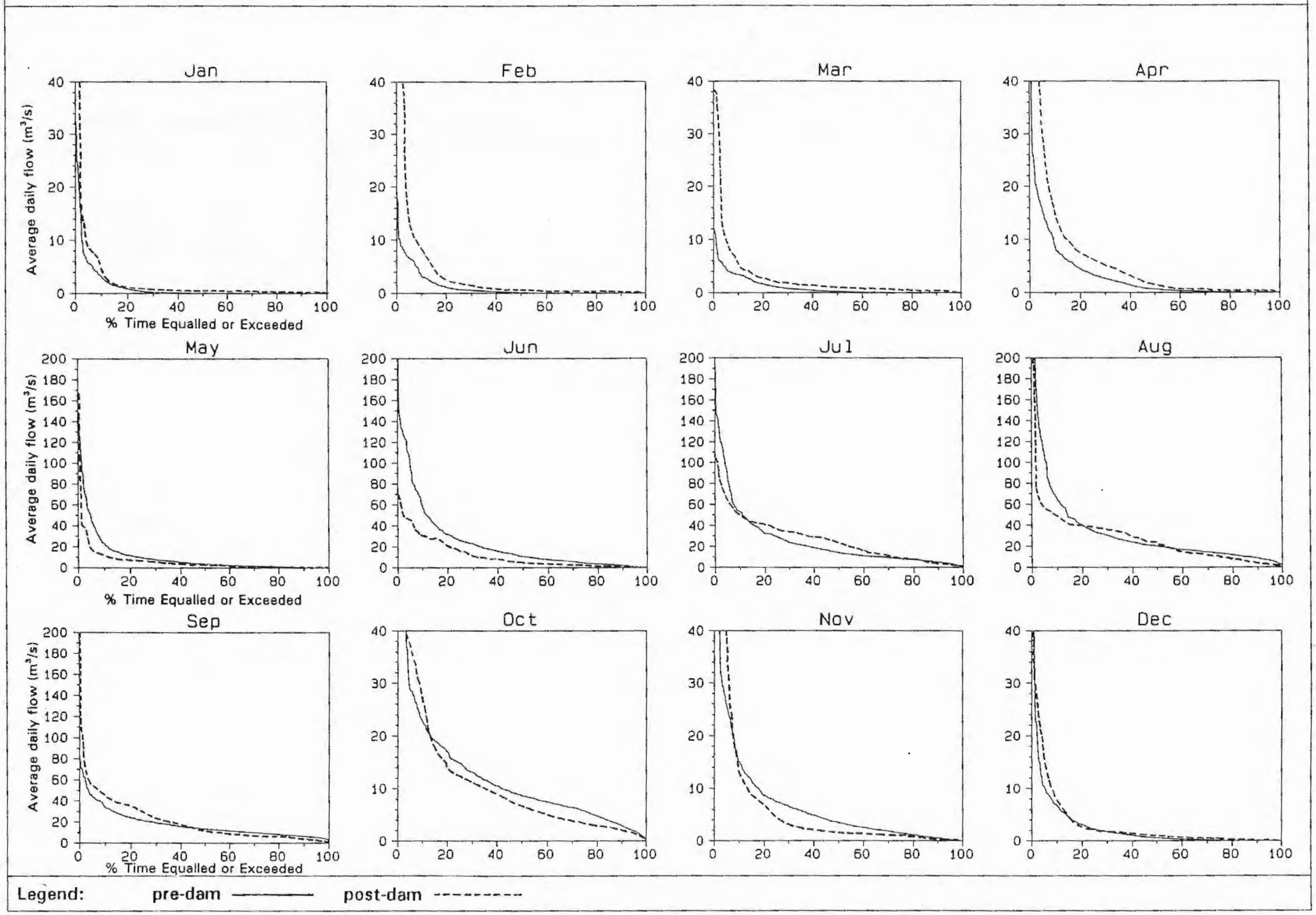

Figure 3.12 **Monthly flow duration curves for H6H009, showing the pre-dam (1967 to 1979) and post-dam (1980 to 1993) periods. Note that there are different scales for individual months**

3.4.6 Instantaneous measurements of discharge

The average instantaneous discharges, measured in September 1995 and January 1996 at Sites 1 to 6 on the Riviersonderend, are listed in Table 3.6. In September it was not possible to measure discharge at Site 1, because the dam began to spill during the field visit, and the water level rose so rapidly that the discharge measurement would have been meaningless. The average daily discharge for that day at DWAF weir H6H012 is provided in the table in parentheses.

In virgin conditions in the river, the wet-dry transitional period starts in September at the dam site, but is still part of the wet season at the lower end of the valley, as represented by H6H009 (see Table 3.2). Thus relatively high baseflows would be expected at both sites. From Table 3.3 these would be at least 1 $m^3 s^{-1}$ at the dam site and at least 2 $m^3 s^{-1}$ at H6H009.

At the start of the September field visit, the flow at Site 1 was very low, despite the fact that the dam had probably already started to spill (water was observed to be lapping at the spillway just prior to the visit to Site 1). The average daily discharge for that day (DWAF records) was 0.84 $m^3 s^{-1}$, and for the previous day it was 0.08 $m^3 s^{-1}$.

Table 3.6 **Average discharges (m^3s^{-1}) measured in September 1995 at Sites 2 to 6, and in January 1996 at Sites 1 to 6, in the Riviersonderend. The average daily discharge for Site 1 in September is provided from DWAF data for the day of, and previous to, the field visit. The estimated pre-dam baseflows at the Dam Site and at H6H009 for the two months is provided from Table 3.3.**

SITE	SEPTEMBER 1995	ESTIMATED SEPTEMBER BASEFLOW	JANUARY 1996	ESTIMATED JANUARY BASEFLOW
1	(0.08 - 0.84)	Dam Site: 1 - 3	1.90	Dam Site: 0.5 - <0.1
2	0.48		1.49	
3	1.00		1.02	
4	1.53		1.58	
5	1.48		1.72	
6	1.44	H6H009: 4 - 8, may be 2	2.29	H6H009: <0.5 - 1, may be 2

Downstream of this site, the contributions made to baseflow by incoming tributaries is evident in the clear longitudinal trend of increased discharge, from Site 2 to Site 6, although the flows were all lower than suggested by the gauged data in September. Discharge at Site 2 included runoff from the Elandskloof and Klein Elandskloof Rivers, although this appeared to provide inadequate compensation for the loss of flow caused by the dam. The larger Baviaans River and the Gobos River join the main channel upstream of Site 3, and contributed to the increased discharge at this site. The discharge at Site 4 was the highest recorded during the field visit. Slight decreases in discharge were recorded as the Riviersonderend approached its confluence with the Breede River, perhaps because of abstractions from the river by pumping from weirs situated on farms along the river's length.

In January, the reverse trend was apparent in the discharges measured at the six sites: high flows at Site 1, decreasing to Site 3, and increasing again to Site 6. At Site 1, pre-dam discharge in summer is likely to be <0.5 $m^3 s^{-1}$, rising to 1.5 $m^3 s^{-1}$ only in very wet years (Table 3.6). This discharge would naturally increase downstream, where common flows at H6H009 in the pre-dam period (Table 3.6) were 0.5 - 1 $m^3 s^{-1}$ (2 $m^3 s^{-1}$ in wet years). Releases for irrigation from the dam in January clearly elevate discharge to levels higher than those naturally encountered for extended periods at this time of year. Indeed, the water was deep right across the width of the channel at Site 1 in January, and had covered all but the large boulders, creating only fast turbulent runs, and making access difficult. Run-of-river abstraction during summer months are probably the cause of the reduction in flow in the reaches downstream of Site 1 in January, and the lower discharge measured at Site 2 was associated with a wider diversity of biotopes than at Site 1.

Summer rainfall, on the other hand, is a marked feature of the eastern part of the catchment, and the considerable rain in December 1995 and early January 1996 appears to have compensated for summer abstractions in the lower reaches of the Riviersonderend. For example, at Site 6 the discharge was higher than during average years in the pre-dam period, and reflected similar levels to estimations of baseflow during wet years (Table 3.6). In dry years, a different pattern might well be observed.

Thus the lower section of the river exhibits a more natural discharge regime than the reaches immediately below the dam, and this is due to the influence of streams draining the Riviersonderend Mountains, as well as summer rainfall in the eastern part of the catchment.

3.5 POTENTIAL GEOMORPHOLOGICAL AND ECOLOGICAL EFFECTS OF FLOW ALTERATIONS IN THE RIVIERSONDEREND

Changes in the seasonality of flows in the Riviersonderend as a result of the Theewaterskloof Dam are greatest immediately downstream of the dam, especially with regard to the complete absence of a natural dry-wet transitional period. For fish and invertebrates, the reduction in discharge in this transitional period will mean a loss of important ecological cues regarding spawning times, the end of summer emergence of adult insects, and the development of the winter invertebrate fauna. The two- or three-month delay in the onset of wet season floods and the critically low baseflows between flood events, so evident in the recent period (1993/4 and 1994/5 hydrological years), is likely to result in pronounced effects on the instream biota in the Riviersonderend, particularly in the reaches near the dam. It is uncertain as to whether such a harshly modified flow regime could support many of the naturally-occurring animals.

Floods of a 1:1.5 recurrence interval (based on an annual flood series of naturalised flows) are most important in sediment transport and channel maintenance (Dr K.M. Rowntree, Geography Department, Rhodes University, pers. comm.), causing the erosion that keep in check the plants that encroach on the river when discharges are low. One of the most severe consequences downstream of the Theewaterskloof Dam has been the reduction in the frequency of these scouring, or channel-maintenance flows: the floods of lower recurrence intervals (1:2 and 1:5 years) have been dramatically reduced in magnitude by the imposition of the dam and even the annual event is likely to have lower instantaneous peak flows and therefore less scouring potential. This means that the macro-channel of the river (i.e. the full natural channel), is unlikely to be maintained by the erosive action of floods. In turn, areas of the macro-channel become more available, and safer from the risk of flooding, for the encroachment of farming activities. Where the channel is anastomosing (i.e. has more-or-less permanent braids), some of these channels may disappear entirely as the river "shrinks" in adjustment to the lower range of high flows. The absence of scouring floods means that the channel may become increasingly choked by encroaching vegetation.

The elevation of summer baseflows in the Riviersonderend is likely to have the effect of increasing wetted areas, thus further encouraging the proliferation of aquatic macrophytes such as palmiet. Proliferation of macrophytes may be exacerbated by nutrient rich agricultural runoff.

Damage caused by very large floods, which cannot be harvested by upstream dams, is likely to be far greater in a river that has both been reduced in channel size and is choked by plants because of the absence of scouring flows.

Other likely consequences are that sediments will build up along the course of the river, reducing biotope diversity, particularly in stony-bed areas. High summer flows may transform areas of low velocity into areas of high velocity, particularly where the river has been reduced to a single channel, and this may interfere with fish spawning. These high flows could promote massive growth of opportunistic aquatic animals, such as blackfly, which prefer high-velocity areas. The increase in wetted area in the wider parts of the river at elevated flows may provide extensive slow-flowing shallows that would support the larvae of pests such as mosquitoes (Ward *et al.* 1984).

3.6 SUMMARY

- Theewaterskloof Dam was completed and began operating in 1980, but only reached full supply capacity in the winter of 1993. Thus the 14 years of historical record since the dam was built do not reflect the actual effects of the dam in the way it will be operated in the future.
- The historical effect of the Theewaterskloof Dam, as seen in the post-dam flow records, is a substantial alteration in flow regime.
- Present-day MAR just downstream of Theewaterskloof Dam, based on long-term simulated data, is estimated at 36% of virgin MAR (at 1996 irrigation demand levels). Flow records from 1993 to

1995, however, indicate that the annual runoff is a mere 18% of the virgin MAR. According to the simulated data, the raising of the dam wall will have a comparatively small effect on the MAR in the river downstream, decreasing the simulated present-day MAR by a further 2% of the virgin MAR.

- In its natural condition, the Riviersonderend is a perennial river, but shows strong seasonality in flow patterns. Winter rainfall is associated with a wet season, whilst summer flows are low (the dry season), and "transitional" wet-dry or dry-wet periods are discernible between these two seasons.
- During the period (1980-1989) when releases were made to keep the dam at 40% of full supply capacity and later (1990-1993) at 80% of FSC, the trend was a delay in floods and a reduction in flood peaks. Since the dam has been operated at 100% FSC, as shown in the last two years of record, the seasonal distribution of flows indicates considerable departure from the natural seasonal flow regime of the Riviersonderend: the onset of higher flows associated with the wet season is delayed, the first winter floods are delayed by up to three months (now usually occurring in July and August, instead of in April/May as they were in the pre-dam period), and floods are reduced in both magnitude and frequency.
- Reduction in baseflows is severe in those months classified as "transitional" between wet and dry seasons, with the lowest flows of the year occurring in May and June. Between releases or dam spillages in the wet season, baseflows are also critically low with respect to providing the conditions necessary for survival of aquatic animals.
- Reduction in baseflows, together with the reduction in the onset and frequency of floods, has compressed the "winter" (transitional and high flow) period into far fewer months (July to October) than the period naturally encountered in perennial rivers in the western Cape (April/May to October).
- Components of the flow regime, such as seasonal cues heralding the end of summer and the onset of the wet season may be important for the biota and yet appear to have been removed from the system over the past two years.
- Releases of water for irrigation in summer have resulted in an increase in summer baseflows of the order of 100%.
- The flow regime is severely altered in the reaches downstream of the dam, at least to Site 3, after which runoff from the Riviersonderend Mountains, which follows a more natural pattern, ameliorate this effect to some extent.
- The effects of the dam are less obvious at H6H009 than just downstream of the dam, although increased summer flows in the post-dam period are noticeable, and the wet season is delayed. It is suggested that the effects of the dam become progressively dampened with distance downstream, as a result of the natural contributions of flow from the tributaries draining the Riviersonderend Mountains. No detailed hydrological study has been made of the flows and

demands between Theewaterskloof Dam and Gauge H6H009 however, and the balance between runoff and abstractions along the course of the river is unknown.

- The effects of the alteration in flow regime on ecological and geomorphological aspects of the Riviersonderend, as a result of the Theewaterskloof Dam, are likely to be profound, particularly with regard to channel size and shape.
- As demand for water for irrigation grows, the changes in flow patterns are likely to become more extreme, with additional and more extreme consequences for the instream biota. Furthermore, more efficient regional management of water supply from the various dams within the western Cape means that, for the Riviersonderend downstream of the dam, there will probably be less late-winter spillage, (none at all in dry years), with wet-season flows in the river coming only from the Riviersonderend Mountains feeding into the river further downstream in the valley.

4. PHYSICAL CHARACTERISTICS OF THE REACHES

4.1 INTRODUCTION

An analysis of the physical characteristics of the Riviersonderend was undertaken because the biological communities characteristic of a river ecosystem are determined by interactions between, *inter alia*, flow velocity, the physical and chemical composition of water, and the nature of the substratum and the riparian vegetation (Hawkes 1982). Different zones are identifiable within a river system (e.g. Davies and Day 1986); these range from the steeply-graded, fast-flowing upper reaches, where cobbles and boulders dominate the substratum, to the typically wider, slower-flowing reaches lower down the system, where sand and finer sediments dominate the river bed. Coarse organic matter (leaves and wood) forms the main food sources for animals in the headwaters (Cummins 1974). In the middle and lower reaches, however, increased penetration of sunlight leads to the establishment of instream algae and macrophyte plants, which form the base of the food chain.

As a result of the interplay of channel complexity (bends, braids, areas of scour and deposition), substratum characteristics (boulder, cobble and sand) and flow rates, which vary considerably across the width of a river, the middle reaches of most Western Cape rivers (including the Riviersonderend below Theewaterskloof Dam) typically exhibit diverse hydraulic environments. Areas of the stream bed with different substratum and flow conditions (i.e. different biotopes) support different plant and animal assemblages (Davies *et al.* 1993), thereby contributing to the overall composition of the biological communities in different reaches of the river.

Impoundment of a river changes the magnitude and frequency of discharge and the overall flow velocities in the system, thus changing the availability or extent of the different biotopes, or reducing the overall availability of benthic (i.e. on the river bottom) habitat (O' Keeffe *et al.* 1992), which will subsequently influence the biological components (Howard-Williams *et al.* 1984). For example, in the Riviersonderend, a reduction in the frequency of flushing flows released from Theewaterskloof Dam has led to the encroachment by palmiet, *Prionium serratum*, into the main channel, which often also chokes secondary channel braids and reduces the range of biotopes available to only one or two types: slow-flowing runs and emergent vegetation. In other places along the river, the decreased risk of large floods has encouraged encroachment of agricultural activities into the river channel, thus reducing available habitat for instream biota.

4.2 METHODS FOR MAPPING OF BIOTOPES AND THE COLLECTION OF DATA ON CHANNEL CROSS-SECTIONS

Biotope characteristics were mapped at the six selected sampling sites on the Riviersonderend on two occasions, in late winter (September 1995) and in summer (January 1996), and more detailed data on substratum type, water depth and flow velocities were obtained by means of cross-sectional profiles.

4.2.1 Methods for mapping of biotopes

Sections of the river that were considered to be representative of each site were selected and drawn freehand in order to map the locations, numbers and dimensions of the various geomorphological channel features and biotopes present, and the locations of the transects. Photographs were taken upstream and downstream of each study site and survey tapes were used to measure the dimensions of the different biotopes. The main biotopes that were identified are outlined below, using the descriptions of King and Tharme (1994).

Riffles	High-velocity areas with turbulent flow, indicated by broken water surfaces and typically shallow water depth relative to bed-particle sizes. The substratum is predominantly cobbles and boulders, with limited deposits of fine particulate matter. Changes in slope from head to foot of riffles are generally perceptible. Riffles are spatially and temporally variable in that they can "migrate" upstream or downstream with changes in flow, and can become runs at high flows.
Pools	Features that are deep relative to river size and which have low to zero flow velocity. The substratum ranges through all types from bedrock to sand or mud. Flow is smooth, except in small areas of turbulence at the heads of some pools. The combination of deep water and low flow velocity often promotes deposition of fine particulate matter, such as sand, silt and organic detritus, on the pool bottoms. Pools form bodies of standing water when river flow is very low or is zero, and can become runs at very high flows. In the Riviersonderend, "pools" often occurred as very slow runs (i.e. no visible water movement) covering the full width of the river channel. For the purposes of this report, such areas were characterised as pools, whilst runs were distinguished as areas where the flow was visible, although laminar.
Runs	Features that represent areas of transition between pools and riffles/cascades. Depths varying from fairly shallow to deep. The velocities are generally moderate, but can be low or high depending on flow conditions. Substratum types are variable. Runs are characterised by smooth flow with no broken surface water, no obvious change in river bed gradient and a higher ratio of depth to river bed roughness elements than for riffles.
Backwaters	Areas that are hydraulically "detached" from the channel, where there is no through-flow of water, but where water tends to enter and leave using the same route. Depth is variable, and velocities are low, or often zero. The substratum is variable, but usually

constitutes depositions of sand, silt and organic detritus. Backwaters tend to be situated along the margins of the main channel, often resulting from the isolation of side flood-channels, when flow decreases. Increased flows turn some backwaters into runs, and accumulated fines are flushed during these periods.

Cascades Features characterised by water free-falling over bedrock and boulders in step-like arrangements. Water depth and velocity are not distinguishing features. The features form a series of low "waterfalls" with downstream pools. The average gradient is steep, and the elevation of the substratum is a distinguishing criterion with step height a maximum of 3 m.

4.2.2 Methods for the collection of cross-sectional data

Biotope characteristics and hydraulic information were collected along cross-sectional transects at each site. Cross-sections were not recorded at Site 1 in September because water releases from Theewaterskloof Dam led to such a rapid increase in water level during sampling, that the transect had to be abandoned. In January, data were recorded across only one transect at Site 1, due to the high flows and deep water at this site which made the river inaccessible in parts.

At each cross-section, a survey tape was stretched taut across the channel above the water surface and attached to either bank. Hydraulic and biotope data were collected along the tape at a number of points (between 6 and 33), which were determined by noticeable changes in physical biotope features (e.g. change from bedrock to gravel) and hydraulics (e.g. changes in flow velocity) across the channel. The following information was recorded at each cross-section:

- distance along the survey tape at each point along a cross-section
- location of right- and left-bank water's edge (looking in a downstream direction)
- water depth (to the nearest cm), measured using a top-setting wading rod
- average velocity (velocity at 0.6 of the water depth from the surface), measured using a Price current meter, fitted with a mini- or maxi-propellor, depending on the depth of the water
- at each point along the tape, particle sizes of the bed material were visually estimated, using a modified version of the Wentworth Scale (refer to King and Tharme 1994)
- location of instream cobble and vegetated bars
- boulders/bedrock submerged or out of water
- bankside and instream vegetation cover
- presence of algae on the bed at each point along the transect.

4.3 RESULTS OF BIOTOPE MAPPING AND PHYSICAL BIOTOPE CHARACTERISTICS

4.3.1 Biotope mapping

Freehand sketches of representative reaches at the six sites in September 1995 and January 1996 are provided in Figures 4.1 to 4.6. Where the wetted edge of the channel was different in September 1995 and January 1996, this is indicated on an overlay to each figure.

In the gorge downstream of the Theewaterskloof Dam, at Site 1, there was a marked change in the availability of different biotopes between field visits (see Plates 2a and 2b), and this was linked to the difference in discharge. In September, which represented late winter conditions, discharge was very low at the start of the field visit, but increased as the dam began to spill, which occurred during the visit. Thus the flows observed during the September visit were not representative of the average winter baseflows, and the diversity of biotopes present (Figure 4.1), was probably a temporary result of dam spillage. Despite this availability of different biotopes, the scarcity of small particles of alluvium meant that there were no areas of shallow riffle, and most of the "broken water" was caused by the boulder bed creating narrow chutes and eddies. In January (Figure 4.1 overlay), irrigation releases of some 1.9 $m^3 s^{-1}$ (field measurement, see Section 3.4.6), resulted in the only available biotope being fast, deep runs, with torrential flow, with an occasional backwater on the channel margins behind large boulders. This is to be expected when high flows are released into a naturally laterally-confined gorge.

At Site 2, a low winter baseflow was evident in September (the dam spillage appeared not to affect this site, perhaps because of upstream abstractions), and this low flow was associated with large areas of the potential riffle being dry (Figure 4.3; see Plate 4a). Releases for irrigation in summer (January 1996) resulted in a discharge of 1.5 $m^3 s^{-1}$ (field measurement) which had the comparatively beneficial effect of increasing the availability and diversity of biotopes (Figure 4.2 overlay; Plate 4b). For example, areas at the edges of the slow runs became inundated at a higher discharge, creating shallow pools.

At Site 3, the contributions from the Gobos River, and other tributaries draining the Riviersonderend Mountains, augmented winter baseflows, and the complexity of the hydraulic environment appeared to be maintained at this site in September 1995 (Figure 4.3; Plates 5a and 5b), unlike the case at Site 2. Interestingly, field measurements indicated that summer discharge (January 1996) was the same as that in September (both 1.0 $m^3 s^{-1}$), and the biotope characteristics remained unchanged.

A similar situation prevailed at Site 4, where discharges of 1.5 and 1.6 $m^3 s^{-1}$ were measured in September and January respectively, and the channel characteristics were similar on both occasions (Figure 4.4; Plates 9a to 9c). Here, the infilling of the multiple channels (see Section 2.2) resulted in the river in this area flowing through only a single, narrow channel, and consequently in a reduction in the diversity of hydraulic conditions, relative to that expected under natural conditions. For

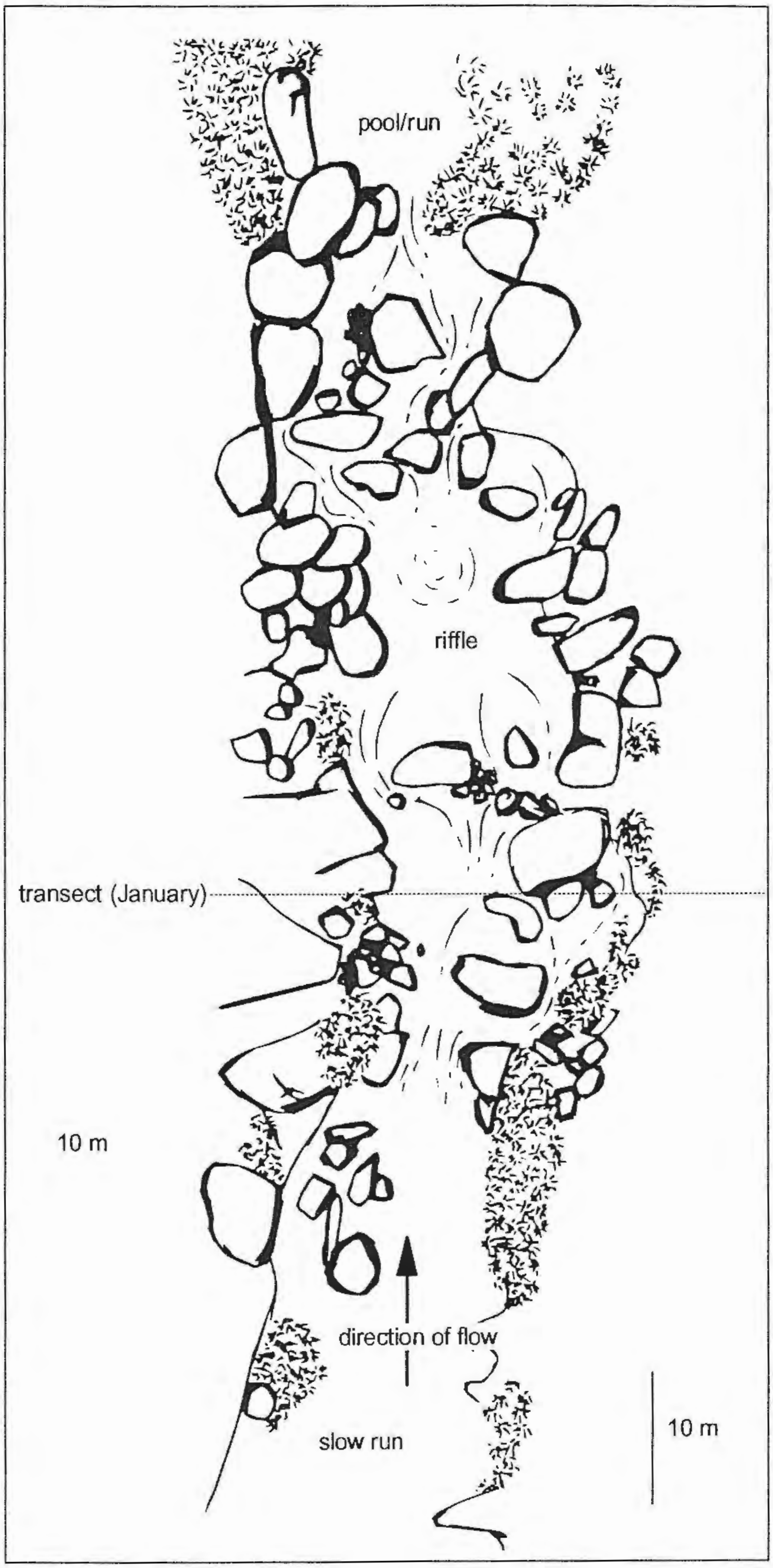

Figure 4.1 **Freehand sketch of Site 1, showing channel shape and biotope characteristics in September 1995. The overlay represents the wetted edge of the channel in January 1996.**

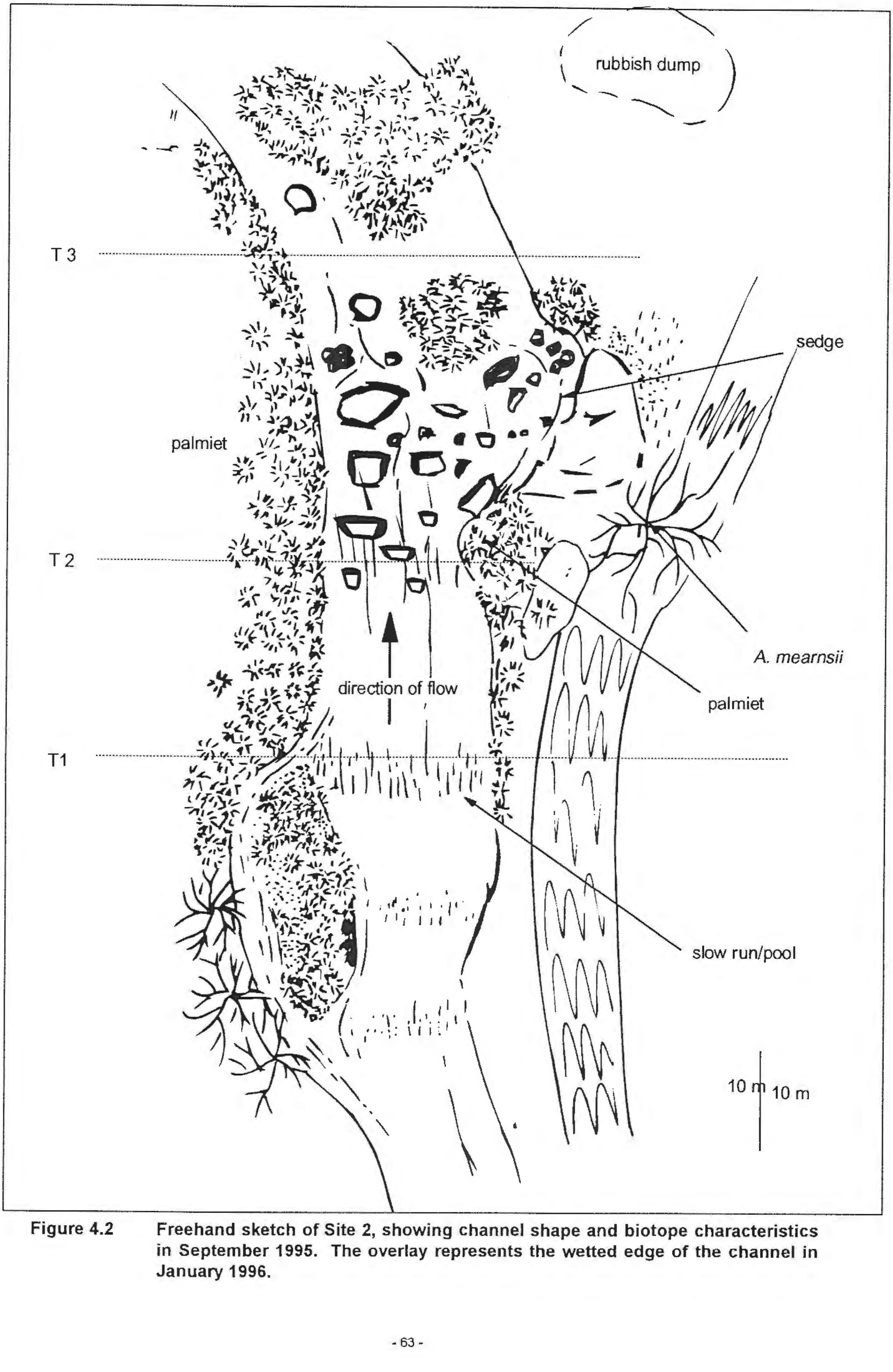

Figure 4.2 Freehand sketch of Site 2, showing channel shape and biotope characteristics in September 1995. The overlay represents the wetted edge of the channel in January 1996.

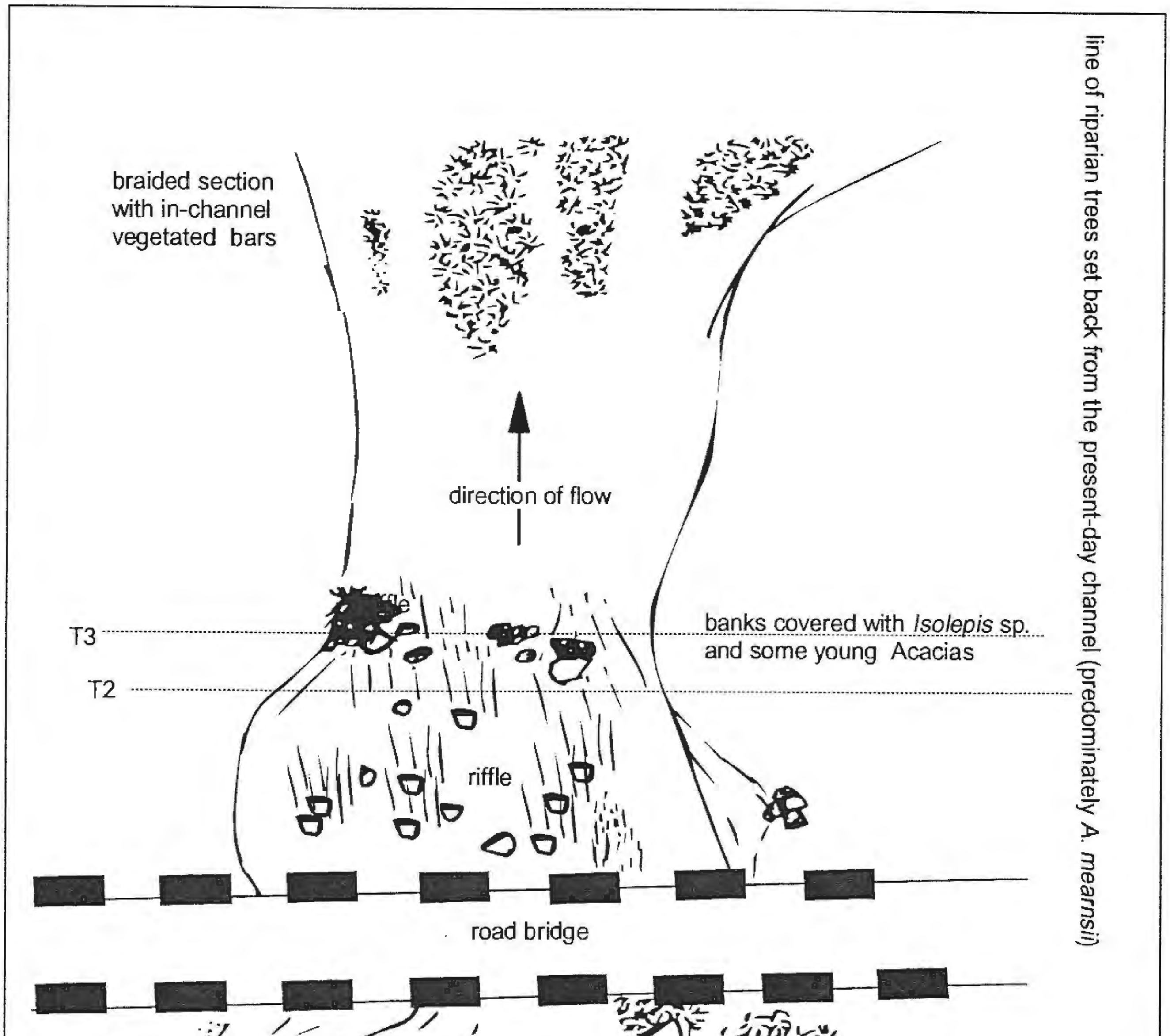

Figure 4.3 **Freehand sketch of Site 3, showing channel shape and biotope characteristics in September 1995 and in January 1996.**

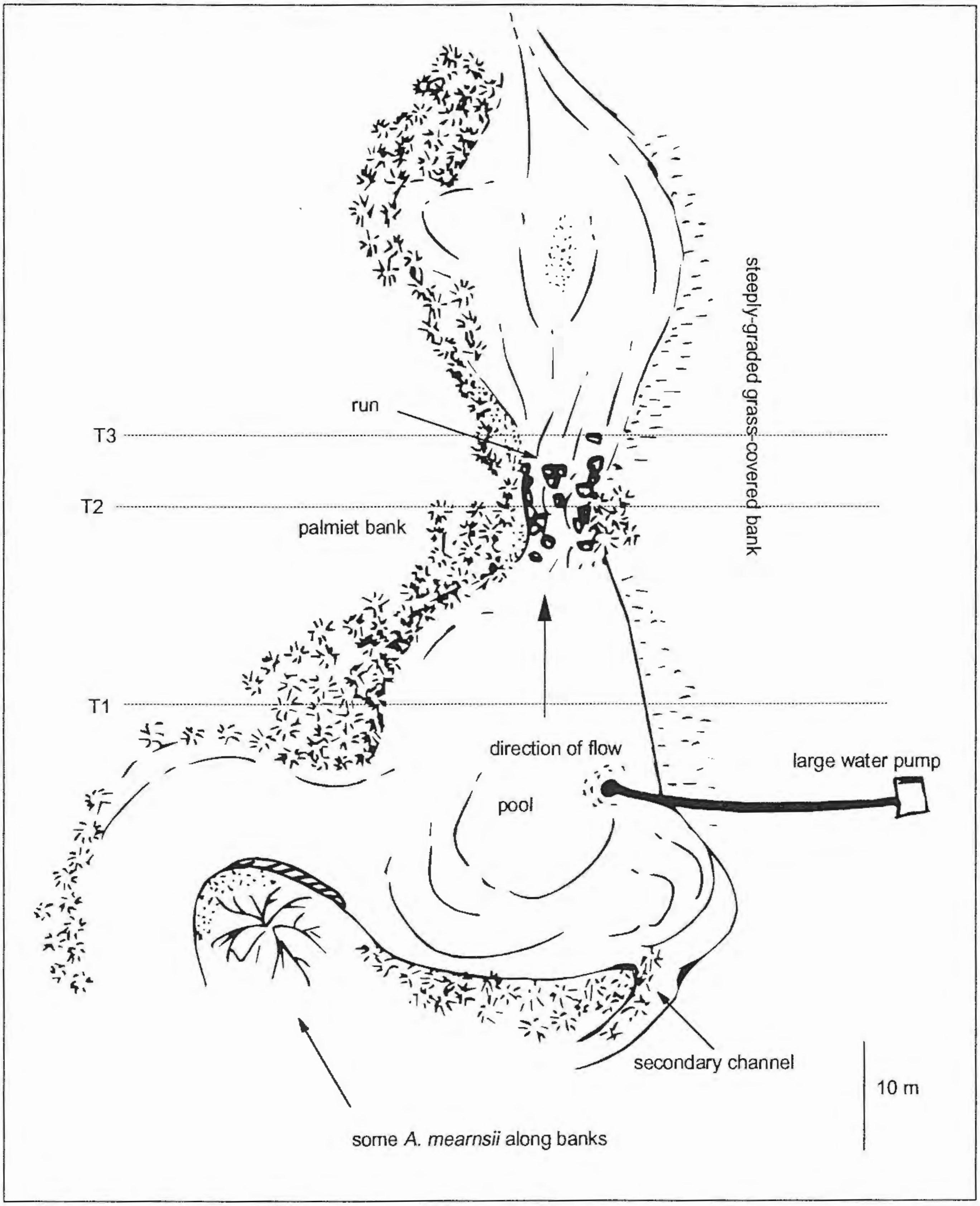

Figure 4.4 **Freehand sketch of Site 4, showing channel shape and biotope characteristics in September 1995 and in January 1996.**

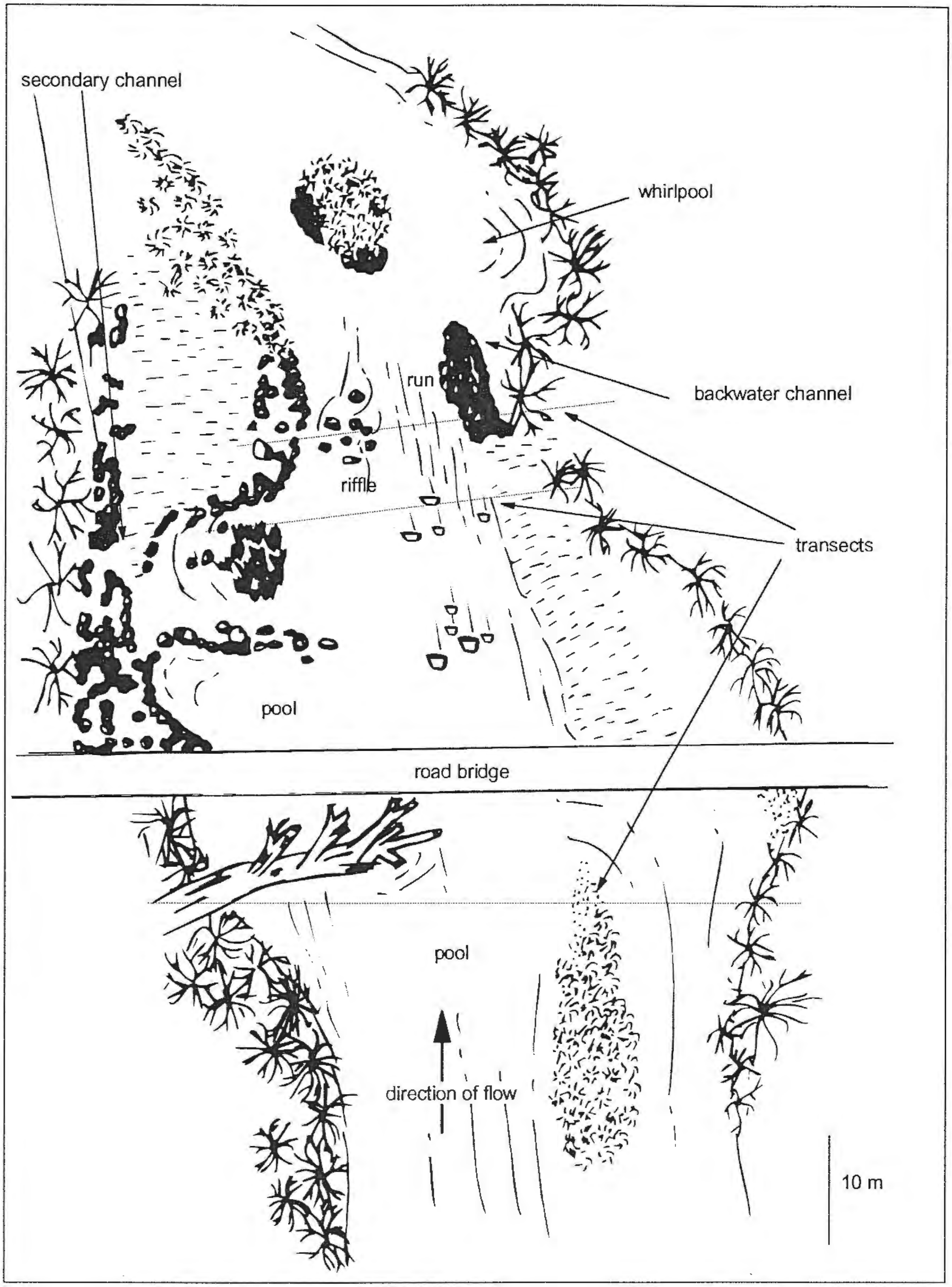

Figure 4.5 Freehand sketch of Site 5, showing channel shape and biotope characteristics in September 1995 and in January 1996.

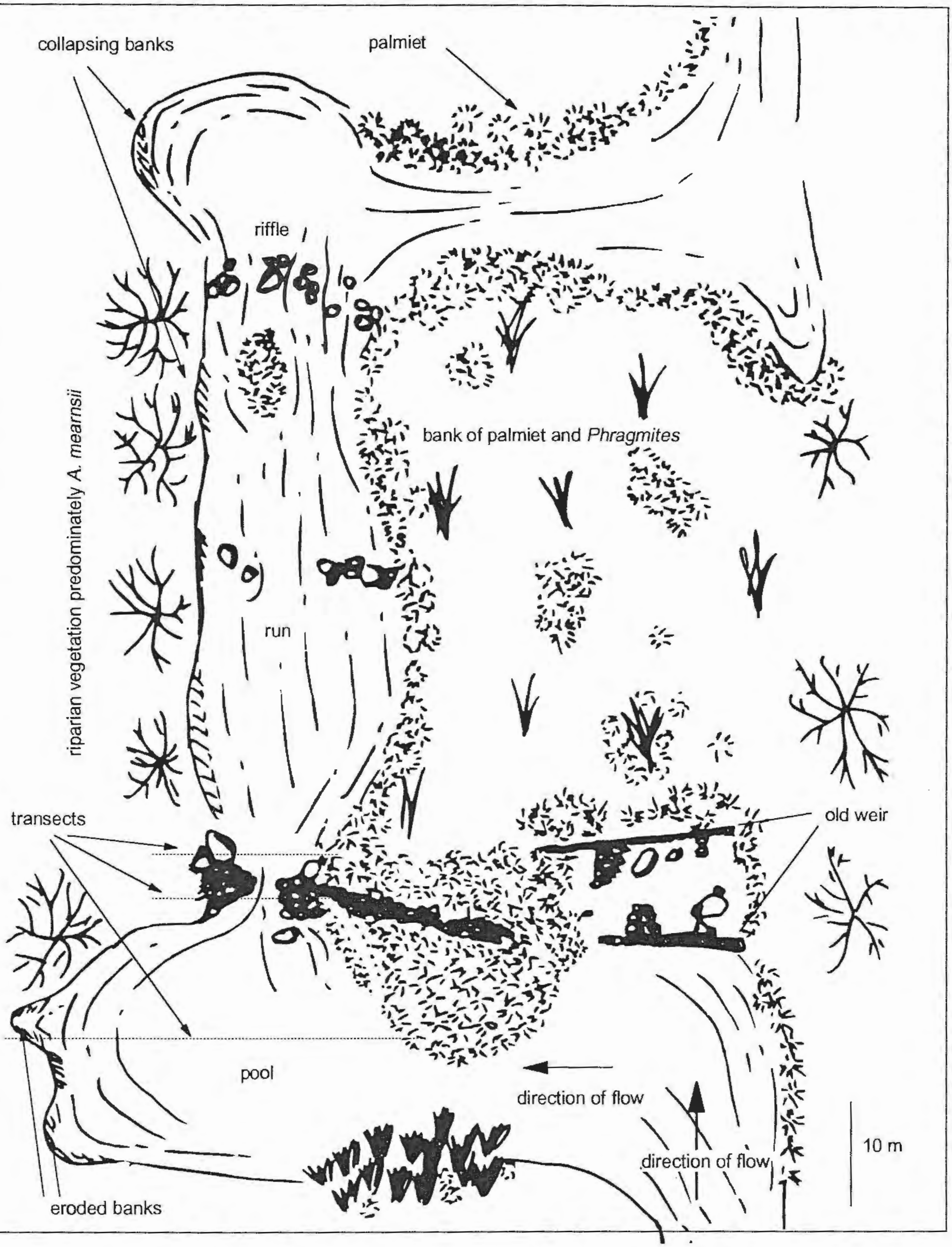

Figure 4.6 Freehand sketch of Site 6, showing channel shape and biotope characteristics in September 1995. The overlay represents the wetted edge of the channel in January 1996.

example riffle areas, which are usually associated with high invertebrate diversity, were literally " drowned".

At Site 5 (Figure 4.5; Plates 10a and b), a small increase in discharge from September (1.5 $m^3 s^{-1}$) to January (1.7 $m^3 s^{-1}$) accompanied minor changes in biotope characteristics and proportions, although some previously-dry side channels were wet at the time of the later visit. The effects of the recent summer floods (in December) were evident in the erosion of some small alien trees at the river margins. The overall heterogeneity of hydraulic conditions at the site was similar to that at Site 3.

The simple channel, characteristic of the reach in which Site 6 is situated, has been altered at this site by a U-bend formed by a concrete weir that caused erosion of an old access road, and contributed to the only shallow biotopes at the site (Figure 4.6; Plates 12a and b). Here, constriction of the channel resulted in fast, turbulent riffles and runs, whilst up- and downstream of this, deep slow runs dominated. The January discharge was greater than that measured in September (1.4 $m^3 s^{-1}$ in September; 2.3 $m^3 s^{-1}$ in January), and this resulted in the riffle biotope becoming deeper and more turbulent.

4.3.2 Channel cross-sections

4.3.2.1 Channel width

Channel widths across each of the three transects at each site are presented in Table 4.1, as measured in the September 1995 (late winter) and January 1996 (summer) field visits. To facilitate comparison at all sites, the position of the transects remained the same for both field visits.

Changes in channel width were largely restricted to those sites most affected by changes in discharge between the field visits - Sites 1, 2 (as a result of releases for irrigation) and 6 (as a result of summer floods).

Although it is not evident from the table (because width was not recorded in September), increased discharge at Site 1 translated into an increase in wetted channel of no more than 4 m, probably because of the lateral confinement of flow by the boulder slopes of the gorge. At Site 2, however, there were marked increases in widths, resulting in the increased availability of habitat (Table 4.1).

Summer rainfall occurs along the Riviersonderend Mountains, although predominantly on the eastern part of the range. Thus, despite abstraction of water from the river, the effects of persistent summer rains in late 1995 were evident at Site 6 in January, when a higher discharge than in September resulted in an increase in width, albeit only across the pool.

Table 4.1 **Channel widths (in metres) at sampling sites on the Riviersonderend in September 1995 and in January 1996.**

SITE 1	SEPTEMBER 1995	JANUARY 1996
Run	not measured	13.5
SITE 2	**SEPTEMBER 1995**	**JANUARY 1996**
Pool	15.5	26.6
Riffle	16.6	24.8
Run	14.4	27.1
SITE 3	**SEPTEMBER 1995**	**JANUARY 1996**
Pool	42.1	42.1
Riffle	27.6	28.7
Run /marsh	32.3	31.9
SITE 4	**SEPTEMBER 1995**	**JANUARY 1996**
Pool	14.6	16.4
Run	5.3	5.2
Run	6.8	7.0
SITE 5	**SEPTEMBER 1995**	**JANUARY 1996**
Pool	32.7	32.4
Riffle	15.3	15.0
Run /pool	14.0	14.4
SITE 6	**SEPTEMBER 1995**	**JANUARY 1996**
Pool	11.7	15.7
Riffle	5.2	6.0
Run	7.7	7.3

4.3.2.2 Water depth and velocity

The averages and ranges of depths and velocities, recorded in September 1995 and January 1996, are presented in Table 4.2. These data have been categorised according to the main biotopes present at each site.

The only biotope consistently present at all sites was run biotope, although these runs were of variable depths and velocities. Sites 1, 4 and 6 exhibited deepest, and fastest-flowing runs. At Site 1 the river is naturally confined, while at Sites 4 and 6 it is channelled by infilling. This narrowing of the river results greater depths and velocities, and a loss of shallow biotopes. Indeed, riffles have in this way become displaced at Site 4, whilst at Site 6, the run was steeply graded, and may also be classified as a cascade.

At Site 2, slower and shallower conditions prevailed, whilst Sites 3 and 5 exhibited a diverse array of biotopes, with deep, slow-flowing pools, faster-flowing runs, and shallow riffles.

Pools were variable in size and depth along the length of the river, and at Site 2 they were either shallow (January) or absent (September).

Table 4.2 **Average water depths and velocities in the main biotopes at Sites 1-5 on the Riviersonderend in September 1995 (no transects at Site 1), and at Sites 1-6 in January 1996. The ranges in depth and velocity are given in parentheses in each column.**

	DEPTH (m)		VELOCITY (m s^{-1})	
SITE 1	**SEPTEMBER 1995**	**JANUARY 1996**	**SEPTEMBER 1995**	**JANUARY 1996**
Pool	-	-	-	-
Backwater	-	-	-	-
Riffle	-	-	-	-
Run	-	0.44 (0.08 - 0.91)	-	0.36 (0.01 - 0.89)
SITE 2	**SEPTEMBER 1995**	**JANUARY 1996**	**SEPTEMBER 1995**	**JANUARY 1996**
Pool	-	0.13 (0.08 - 0.18)	-	0.00 (0.00)
Backwater	-	0.17 (0.04 - 0.33)	-	0.00 (0.00)
Riffle	0.14 (0.03 - 0.33)	0.17 (0.05 - 0.54)	0.24 (0.02 - 0.54)	0.35 (0.00 - 0.92)
Run	0.21 (0.03 - 0.42)	0.29 (0.04 - 0.60)	0.14 (0.01 - 0.34)	0.24 (0.00 - 0.64)
SITE 3	**SEPTEMBER 1995**	**JANUARY 1996**	**SEPTEMBER 1995**	**JANUARY 1996**
Pool	- (0.29 - > 1.7)	0.99 (0.31 - 1.48)	not measured	0.03 (0.00 - 0.05)
Backwater	-	-	-	-
Riffle	0.10 (0.04 - 0.19)	0.10 (0.04 - 0.22)	0.30 (0.01 - 0.82)	0.29 (0.05 - 0.65)
Run	0.16 (0.04 - 0.32)	0.22 (0.07 - 0.40)	0.30 (0.01 - 0.96)	0.37 (0.01 - 1.16)
SITE 4	**SEPTEMBER 1995**	**JANUARY 1996**	**SEPTEMBER 1995**	**JANUARY 1996**
Pool	0.68 (0.32 - 0.92)	0.70 (0.26 - 0.96)	0.20 (0.05 - 0.34)	0.14 (0.00 - 0.34)
Backwater	-	-	-	-
Riffle	-	-	-	-
Run	0.41 (0.12 - 0.76)	0.34 (0.10 - 0.72)	0.71 (0.05 - 1.25)	0.76 (0.05 - 2.55)
SITE 5	**SEPTEMBER 1995**	**JANUARY 1996**	**SEPTEMBER 1995**	**JANUARY 1996**
Pool	0.39 (0.08 - 0.52)	0.40 (0.09 - 0.60)	0.11 (0.01 - 0.23)	0.19 (0.01 - 0.59)
Backwater	-	-	-	-
Riffle	0.13 (0.01 - 0.28)	0.06 (0.02 - 0.11)	0.57 (0.12 - 1.22)	0.31 (0.01 - 0.56)
Run	0.27 (0.06 - 0.47)	0.24 (0.05 - 0.44)	0.57 (0.16 - 1.16)	0.48 (0.05 - 1.23)
SITE 6	**SEPTEMBER 1995**	**JANUARY 1996**	**SEPTEMBER 1995**	**JANUARY 1996**
Pool	1.43 (1.02 - 1.84)	1.56 (0.72 - 2.04)	0.09 (0.07 - 0.14)	0.09 (0.04 - 0.16)
Backwater	-	-	-	-
Riffle	0.17 (0.08 - 0.20)	0.22 (0.08 - 0.38)	1.07 (0.36 - 1.58)	0.94 (0.16 - 1.38)
Run	0.29 (0.06 - 0.56)	0.38 (0.07 - 0.72)	0.71 (0.07 - 1.91)	0.73 (0.12 - 2.62)

4.3.2.3 Substratum characteristics

At each point on the river bed along the cross-sectional transects, particle size was classified according to size categories (using the modified Wentworth scale; see Section 4.2.2), and the biotope at that point was noted. The percentages of these size categories occurring in each biotope were calculated from these data, and are presented in Table 4.3.

The substratum at Site 1 was dominated by boulders with very little material of small size present. It is probable that high discharges in the narrow gorge wash the smaller alluvial matter downstream. At

Table 4.3 Percentages of substratum size categories in each biotope at each sampling site.

SUBSTRATUM SIZE CATEGORIES		bedrock		boulder (512<x≤4096 mm)		large/medium cobbles (128<x≤512 mm)		small cobbles/coarse gravel (8<x≤128 mm)		medium gravel/fine gravel/sand (0.0625<x≤8 mm)		mud (<0.0625 mm)	
SITES AND BIOTOPES		Sept	Jan	Sept	Jan	Sept	Jan	Sept	Jan	Sept	Jan	Sept	Jan
Site 1	Run		4		83		2		9		2		
Site 2	Riffle	79	73		2		2		11	14	10	7	2
	Run	31	67			26		19	10	10	6	14	17
	Pool				44		7		3		21		15
	Backwater		7				21		39		11		22
Site 3	Riffle					8	3	92	61		36		
	Run							68	11	11	79	21	11
	Pool								38		62		
Site 4	Run						3	29	71	71	19		7
	Pool							44	30	56	63		7
Site 5	Riffle					20		80	82		18		
	Run					25	39	75	59		2	2	
	Pool					10	8	64	70	24	18	2	5
Site 6	Riffle					67	96	33	4				
	Run			14		86	26		47		27		
	Pool					25				42	89	33	11

the same time the dam represents a barrier to the movement of new material from upstream into the lower reaches. The net effect is the gradual reduction in the availability of cobbles and of even finer material so important in creating the riffles necessary for many kinds of invertebrates. Boulders were largely absent from the course of the river downstream of Theewaterskloof Dam, except in slow-flowing areas at Site 2. Here the substratum was mainly bedrock, with small amounts of coarse alluvium. The substratum at Site 2 had the widest range of particle size. Large to medium cobbles, and a single boulder, comprised the channel bed at Site 6, with a range of other substratum sizes represented. Most of the cobbles at Site 6 were, however, provided by the erosion of material from the access road at this site while, both upstream and downstream, sand dominated the bed in the pools and runs naturally occurring in this reach.

Small cobbles and some coarse gravel were plentiful at Sites 3 and 5, which had similar substratum characteristics, although Site 5 had the wider range of particle sizes. At Site 5, cobbles of various sizes were arranged in layers on the bed, providing heterogeneous riffles and runs. At Site 4, the substratum was mostly limited to gravels and finer particles, with very few cobbles present.

4.4 SUMMARY

- The Riviersonderend downstream of Theewaterskloof Dam comprises six geomorphologically distinct reaches, with in considerable differences in channel morphology, substratum and proportions of different biotopes from site to site.
- This geomorphological categorisation of reaches is reflected in the fact that there was no obvious progressive longitudinal (downstream) change in physical characteristics, for example, in width and depth.
- The reaches with a naturally well-defined, single channel (represented at Sites 1, 3 and 5) had received least physical interference, and these provided the greatest potential array of biotopes.
- Biotope diversity is dependent on flow regime and, as a result of Theewaterskloof Dam, the availability of different biotopes at Site 1 is reduced in summer and winter by unnaturally high and low flows respectively.
- Low winter flows have most affected biotope availability in the upstream reaches (Sites 1 and 2), and the effects of these flows are felt all along the river, although somewhat ameliorated downstream by runoff from the Riviersonderend Mountains.
- The absence of large, scouring floods in winter in the recent past has allowed the encroachment of palmiet into the main channel and secondary braids, the deposition of fines in shallow riffle and run areas, and the encroachment into the channel of bankside vegetation, especially of alien plants.
- Present-day releases for irrigation in summer have markedly reduced biotope diversity only at Site 1, just downstream of Theewaterskloof Dam, but the effects of these releases are less

obvious further downstream by abstractions from the river, where fairly natural summer flow conditions exist, and which allow for a diversity of biotopes.

- The direct effects of Theewaterskloof Dam on the physical characteristics of the river (such as depths, velocities of flow, substratum composition, and overall availability of a range of biotopes) are most severe immediately downstream of the dam.
- The effects of the dam decrease with distance downstream, although in the lower reaches the effects become evident of encroachment of agricultural activities into the river channel. These include bulldozing of braids and canalisation of the river through infilling of the banks.
- The most severe indirect effect of the dam is that it has further encouraged the utilisation of areas of the macro-channel and flood channels, and the direct infilling of braids and secondary channels, as riparian owners have become aware of the reduced risk of flooding.

5. WATER QUALITY

5.1 INTRODUCTION

The term "water quality" is a composite term describing the physical and chemical properties of water relative to its usefulness (Dallas and Day 1993). Frequently, assessments of water quality include the categorisation of the water in a river or river reach as being of "good" (denoting pure or dilute water) or "poor" (suggesting high concentrations of suspended and/or dissolved substances) quality. Natural variations in the physical and chemical properties of water even within one river system, however, are common, depending on the local climate, geology and vegetation, and these variations should underly any assessment of the extent to which a river's water has been altered from its natural condition by anthropogenic activities. Data on various physical and chemical properties of water have been collected by the Department of Water Affairs and Forestry (DWAF) from many rivers in South Africa. These data largely concern the concentrations of the major cations and anions, and of nitrates, nitrites, ammonium and phosphates - the forms in which nitrogen and phosphorus are used by plants (Davies and Day 1986).

Geologically, the Riviersonderend catchment is dominated by sandstones and quartzites of the Table Mountain Group in the upper, mountainous reaches of the river near its source and in the tributaries draining the Riviersonderend Mountains (see Section 2.1.2), while Bokkeveld Group shales are found along parts of the course of the river as it flows through the valley from Theewaterskloof Dam to the Breede River (Lambrechts 1979). The geological character and the vegetation of the area influence chemistry of the water along the length of the Riviersonderend. Waters draining the sandstones and quartzites of the Table Mountain Series are typically oligotrophic (King *et al* 1979; Allanson *et al.* 1990), and low in pH, as a result of the well-leached soils associated with such formations, and the organic acids released from the surrounding fynbos. The water in the mountain stream zones of the Groot Drakenstein and Riviersonderend Mountains, where there has been little disturbance, is very dilute, and acid (Kate Snaddon, Freshwater Research Unit, University of Cape Town, unpublished data).

Soils overlying the Bokkeveld Group shales, which occur in parts of the Riviersonderend valley, are richer in nutrients, and have larger quantities of leachable ions than do those of the Table Mountain Group. These all determine the chemical composition of waters draining from these soils (Lambrechts 1979). Most of the shale-derived soils of the southern and south-western Cape coastal forelands, and their natural vegetation, have been transformed by cultivation of agricultural crops (Cowling and Olivier 1992), in part as a result of the relative richness of these soils in nutrients and minerals. Runoff from agricultural lands, both surface and subsurface, usually introduces higher-than-natural loads of nutrients and minerals into rivers draining such lands (Dallas and Day 1993). It is likely that such activities have also left their mark in the Riviersonderend valley.

Changes to the natural environment associated with impoundments, such as the Theewaterskloof Dam in the upper reaches of the Riviersonderend, are usually profound, the most critical being the alteration in flow patterns (see Section 3). Less obviously, impoundments change other physical, chemical and biological properties of the regulated system (Ward and Stanford 1983). Alterations to chemical composition and thermal characteristics associated with this shift from running to standing waterbodies have been well documented (e.g. Ridley and Steel 1975; Davies *et al.* 1993). Consequences of river impoundment for the water chemistry in the downstream river include changes in water temperature, pH, sediment load and oxygen saturation (Byren and Davies 1989), and nutrients and alkalinity (Palmer 1991). The effects of changes in water quality on riverine biotas are reviewed in Dallas and Day (1993).

The Riviersonderend downstream of Theewaterskloof Dam has been subject to changes in the composition of its water, as a result of both cultivation of the natural catchment lands, and the building of Theewaterskloof Dam. Agricultural activities in the middle and lower reaches of the Riviersonderend were established well before the Department of Water Affairs and Forestry (DWAF) began measuring water quality constituents in the river (Sonja Human, riparian owner, "Vrede", Riviersonderend, pers. comm.). The recording of water quality data was initiated in the uppermost reaches of the river in 1967, and in the middle and lower parts of the river in the mid 1970s.

Historical water quality data are available from three DWAF gauging weirs along the Riviersonderend:

- H6H008 - upstream of Theewaterskloof dam; data from 1977 to 1992 were used in the present analyses
- H6H012 - downstream of Theewaterskloof Dam; data from 1980 to 1995 were used in the present analyses
- H6H009 - in the Riviersonderend upstream of its confluence with the Breede River, and downstream of the town of Riviersonderend; data from 1977 to 1995 were used in the present analyses.

Records for the Baviaans River (DWAF Gauge H6H005; records from 1978 to 1995) were also examined. The Baviaans River is a tributary of the Riviersonderend, which flows from the Riviersonderend Mountains near Genadendal.

In addition to the DWAF records, water quality data were collected during field studies in September 1995 and in January 1996. These reflect only a single instantaneous measure of conditions in the river at those times, and are insufficient on their own to provide information on seasonal trends. Nonetheless they are useful for comparison with the DWAF data.

5.2 METHODS OF DATA COLLECTION AND WATER ANALYSIS

5.2.1 Analysis of historical water quality records

For the purpose of this study, the prefix "H6" was omitted from the reference name of each of the gauges from which water quality records were analysed, for ease of graphic representation of the data. Data for the following variables (expressed in mg ℓ^{-1}) were extracted from all available records recorded at DWAF gauging weirs Nos. H008, H012, and H009 on the Riviersonderend, and H005 on the Baviaans River:

- pH
- Total alkalinity (TAL) as $CaCO_3$ (mg ℓ^{-1})
- Electrical conductivity (mS m^{-1})

Major ions:

- Ca^{2+} (mg ℓ^{-1})
- Mg^{2+}(mg ℓ^{-1})
- Cl^- (mg ℓ^{-1})
- Na^+ (mg ℓ^{-1})
- K^+ (mg ℓ^{-1})
- SO_4^{2-} (mg ℓ^{-1})

Nutrients:

- PO_4^{3-} - P (mg ℓ^{-1})
- NO_2^- - N + NO_3^- - N (mg ℓ^{-1})
- NH_4^+ - N (mg ℓ^{-1})

The records from each of the DWAF weirs were grouped by season and summarised in notched box-and-whisker plots (Statgraphics Statistical Package version 6). The months of December, January and February were considered to represent summer conditions in the river, and June, July and August, winter conditions.

5.2.2 Collection of field data

Three replicate field measurements of instantaneous temperature, pH, and conductivity were made at each site. Temperature was measured using a digital thermometer, accurate to 0.1 °C. pH was recorded with a Crison Portable 506 field pH meter, accurate to 0.01 pH units, and conductivity was measured with a Crison Portable 523 field Conductimeter, accurate to 0.01 mS m^{-1}, with built-in temperature compensation to 25°C.

Water for laboratory analyses of the major anions and cations, nutrients and the total concentration of suspended solids, was filtered through 0.45 μm pore size Whatman GF/F glass microfibre filter papers at each site. A measured volume of water, approximately 1000 mℓ, was filtered through a pre-combusted and pre-weighed filter paper, and the filter paper stored on ice for later analysis of Total Suspended Solids (TSS). All filtered water, except that for analysis of cations and ammonium, was bottled in polythene vials that had been pre-cleaned in 5% Extran solution (phosphate-free), and rinsed first in deionised and then in double-distilled water. Samples for analysis of cations and ammonium were acidified with sulphuric acid and stored in HCl-washed glass vials. All water samples were stored on ice immediately on collection and transferred to a freezer within eight hours. Concentrations are expressed in units of mg ℓ^{-1}, to allow comparison with DWAF data.

5.2.3 Laboratory analyses

Total Suspended Solids (TSS) and the organic fraction

Each GF/F filter of known pre-filtration dry mass was dried at 60°C for 48 h and then reweighed using a Mettler AE 100 laboratory balance (readability and reproducibility of 0.1 mg). The difference in dry mass pre- and post-filtration in relation to the volume of water filtered constituted a measure of TSS in mg ℓ^{-1}. The filter paper was then heated to 400°C for 4 hours, and re-weighed to ascertain the organic fraction.

Nutrients

Concentrations of nitrate (as NO_3^- - N), nitrite (as NO_2^- - N), phosphate (as PO_4^{3-} - P) and silicate ions were determined using a TECHNICON AutoAnalyser (AA11) Segmented Flow System. The principles of the methods employed are outlined in Mostert (1983) and Windt (1993). Results were converted to ppm (mg ℓ^{-1}) from μmolℓ^{-1}, and levels were detectable from:

Nutrients:	
• PO_4^{3-} - P	0.1 μmol ℓ^{-1}
• NO_2^- - N	0.1 μg ℓ^{-1} 0.1 μmol ℓ^{-1},
• NO_3^- - N	0.5 μmol ℓ^{-1}
• Si^+	2 μmol ℓ^{-1}

Major Anions and Cations

Concentrations of sulphate and chloride ions were measured using an HPIC-AS4A anion exchange separator column, with a carbonate/bicarbonate buffer eluent. Results are expressed in mg ℓ^{-1}, and are accurate for levels above 0.5 mg ℓ^{-1}.

Concentrations of magnesium, potassium, calcium and sodium ions were measured using an HPIC-AS4A cation exchange separator column, with an appropriate eluent. Results are expressed in mg ℓ^{-1}, and are accurate for levels above 0.5 mg ℓ^{-1}

Total Alkalinity

Total Alkalinity was measured by titrating the sample with 0.005 M HCl (methyl orange indicator) according to the method prescribed by Golterman *et al.* (1978). Results were obtained as mg ℓ^{-1} $CaCO_3$ and expressed as meq ℓ^{-1}.

5.3 RESULTS

5.3.1 Seasonal and longitudinal changes in water quality, from DWAF records

The historical record does not reflect the natural character (i.e. its character prior to agricultural activities) of the water in the Riviersonderend, as collection of these data began only in the late 1970s at H6H009. In the reach just downstream of the Theewaterskloof Dam, records exist only for the post-dam period since 1980.

In Figures 5.1 and 5.2, the box encloses the middle 50% of data values (i.e. the second and third quartiles), and the "waist" in each box represents the median value. The "whiskers" above and below each box extend to 1.5 times the range of values between the first and third quartiles (i.e. the length of the box, which is the "interquartile range") on either side. Outliers are indicated as black squares. Crossed outliers are greater than three interquartile ranges away from the first or third quartile. In some cases, crossed outliers from the full data set have been omitted from the analysis, as they obscure comparison of the median and interquartile ranges of the data from different gauges and seasons.

Since many DWAF water samples collected before 1983 were not preserved, the values presented for nutrients may be inaccurate and should be interpreted with care. Similarly, the DWAF records are not based on field measurement of pH, and thus true pH values are probably lower than those indicated by the records (Brown 1991), while alkalinity measurements of dilute, acid waters are notoriously inaccurate unless performed within a few hours of collection.

5.3.1.1 pH, conductivity and the major ions

The waters of the Riviersonderend, for all of its length to its confluence with the Breede River, are acidic (Figure 5.1). The mountain-stream tributaries of the Riviersonderend upstream of Theewaterskloof Dam (H6H008), and the Baviaans River (H6H005), are strongly acidic (median pH of <5), whilst toward the eastern part of the catchment the median pH increases to around 6.6. Acidity has important consequences for the faunal communities that inhabit these reaches. Harrison and Agnew (1962) have described the Cape endemic fauna as being limited to the acid streams and rivers of the western and southern Cape. The pH values at most of the gauges considered here indicate lower median values in winter months, consistent with greater leaching of acidic polyphenols from the surrounding fynbos vegetation (Midgeley and Schafer 1992). Downstream of Theewaterskloof Dam, however, the seasonal pattern is reversed, with markedly higher pH values in winter. This probably reflects altered features of water chemistry in the dam itself: the same phenomenon is observed in the Berg River immediately downstream of the Theewaterskloof inter-basin transfer releases (Kate Snaddon, Freshwater Research Unit, Zoology Department, University of Cape Town, unpublished data).

The majority of ions in natural waters derive from the weathering of the rocks over which they drain. In South Africa the waters of the coastal regions tend to be dominated by sodium and chloride ions (Day and King 1995). Conductivity provides an indication of the total quantity of dissolved ionic substances in water, and is a major descriptor of water quality, as defined in Section 5.1. In the period covered by the DWAF records, the conductivities and the concentrations of individual ions in the Riviersonderend were very low in the mountain reaches - in the Riviersonderend upstream of the Theewaterskloof Dam (H008 in Figures 5.1 and 5.2) and in the Baviaans River (H005 in Figures 5.1 and 5.2), both of which flow off TMS formations. This is consistent with values expected of natural systems with similar lithology (i.e. chemical composition of rocks), where an upper limit in conductivity of approximately 6 mS m^{-1} is commonplace (Dallas and Day 1993).

Downstream of the dam the water is less dilute, a feature that may be explained in part by differences in lithology down the length of the Riviersonderend valley (see Section 5.1). Conductivity of the water increases down the river, from the dam site (H012) to the gauge upstream of the confluence of the Riviersonderend and the Breede River (H009), where median values range between 20 and 25 mS m^{-1}, but may be as high as 120 mS m^{-1} (this value is an outlier, and is not indicated in Figure 5.1). Sodium and chloride salts are the major contributors to the total quantity of dissolved ionic substances (Figure 5.2), whilst the other commonly occurring ions contribute only small amounts.

Salinisation is the process whereby the concentration of ions in water is increased (Rabie and Day 1992). Irrigation of cultivated lands is a major cause of salinisation (Williams *et al.* 1984), which is regarded by some as the most serious water quality problem in South Africa (O'Keeffe *et al.* 1992). The medians and ranges for conductivity and major ions recorded at H012 and H009 indicate medium levels of salinity in the lower reaches of the Riviersonderend (Figures 5.1 and 5.2). The values for sodium and chloride, indicate occasional high salinities in the lower reaches. The values are similar to those for some other western Cape rivers with a similar lithology, and where extensive farming occurs within the catchment (e.g. Dwars River, Ceres: Ractliffe and Brown 1995).

Concentrations of all the major ions at H009 are somewhat higher in summer than in winter, reflecting on the one hand, summer irrigation in the Riviersonderend valley (and consequently increased ionic loads in the subsurface drainage), and on the other hand, the dilution effects brought about by predominantly winter rainfall (Van Wyk 1988). At H012, just downstream of the Theewaterskloof Dam, there is very little seasonal variation in concentrations of ionic substances, reflecting the fact that almost all the water at this gauge comes directly from the dam.

5.3.1.2 Nutrients

Nitrates and phosphates, the nutrients most responsible for eutrophication of water bodies (Dallas and Day 1993), occur naturally in unpolluted rivers in the western Cape at concentrations >0.01 mg ℓ^{-1} (PO_4^{3-} - P) and >0.2 mg ℓ^{-1} (NO_3^- - N), (Dallas and Day 1993). The DWAF records (Figure 5.1) at all the gauges suggest that, aside from some outlying values, the nitrite/nitrate levels generally remain below this level. Outlying values are important, however, as they reflect the more extreme conditions in the river. The highest nitrate values recorded both upstream and downstream of the dam were about 0.4 mg ℓ^{-1} , whilst at H009 they were ≤1.0 mg ℓ^{-1}. These reflect occasional nutrient enrichment of the river. Interestingly, nitrate plus nitrite concentrations appear to be generally higher in winter in the reaches downstream of the dam (H012 and H009, Figure 5.1). This is often the case in natural systems, and is related to runoff, but may also reflect the farming practise of autumn harvest and winter fertilisation of fields, which would mean that winter rainfall has the effect of increasing concentrations of these nutrients in runoff entering the river.

Phosphate concentrations throughout the river are slightly elevated over natural conditions, even upstream of Theewaterskloof Dam (Figure 5.1), suggesting very mild enrichment at times. Although algal blooms, associated with high phosphate concentrations, are recorded in the dam (Harding 1992), the record for H012 does not suggest that releases from the dam contain particularly high phosphate levels. For much of the winter period however, the flow in the gorge downstream of the dam is contributed only from the Donkerhoek Mountains, and this could have the effect of reducing the range and median phosphate values at the gauge.

High ammonium concentrations are often associated with sewage or industrial effluents, but median values in the Riviersonderend were all below a naturally-occurring upper level for natural systems in the western Cape of 0.15 mg ℓ^{-1} (Dallas and Day 1993).

5.3.2 Time-series analysis of DWAF water quality records

Time-series analyses of conductivity levels (Figures 5.3 to 5.5) were undertaken at three sites on the Riviersonderend, up- and downstream of the dam, to determine whether the medium to high salinities in the lower reaches of the river are the result of a process of salinisation. There are no data from prior to agricultural development in the catchment, and only limited data from the pre-dam period. For the H6H012 gauge, the data reflect conditions only in the post dam period. This analysis was therefore intended as only a cursory examination of the change in conductivity over the time period on record. At H008, upstream of the dam (Figure 5.3), each June and December record, starting in June 1977, was used in the analysis. At the gauges downstream of the dam, monthly records were available for most of the period on record, and these were used in the analyses (Figures 5.4 and 5.5). Gaps in the data record at H012 are indicated by blank spaces on the graph.

Although median concentrations of ions and of conductivities were higher in summer than in winter (Figure 5.1), the time series analyses do not show any clear seasonal difference in conductivity. For

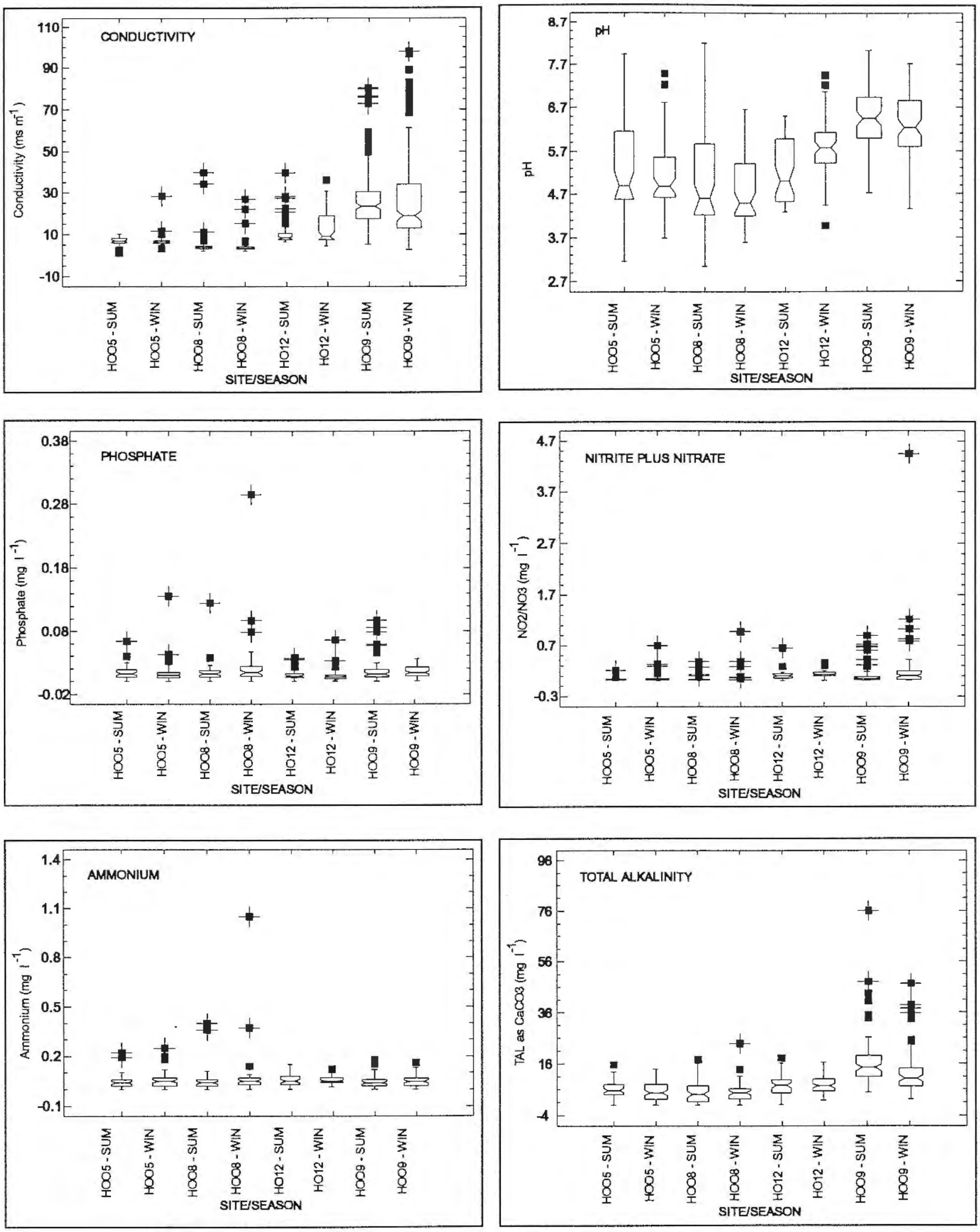

Figure 5.1 Seasonal values for conductivity, pH, alkalinity and nutrients in the Riviersonderend, and one of its tributaries, the Baviaans River. Values for each variable are grouped by station and season. H005 = Baviaans River, HOO8 = upstream of Theewaterskloof Dam, H012 = gorge immediately downstream of Theewaterskloof, H009 = near Stormsvlei. The suffix - SUM refers to summer and - WIN refers to winter. (See Section 5.3.1 for explanation)

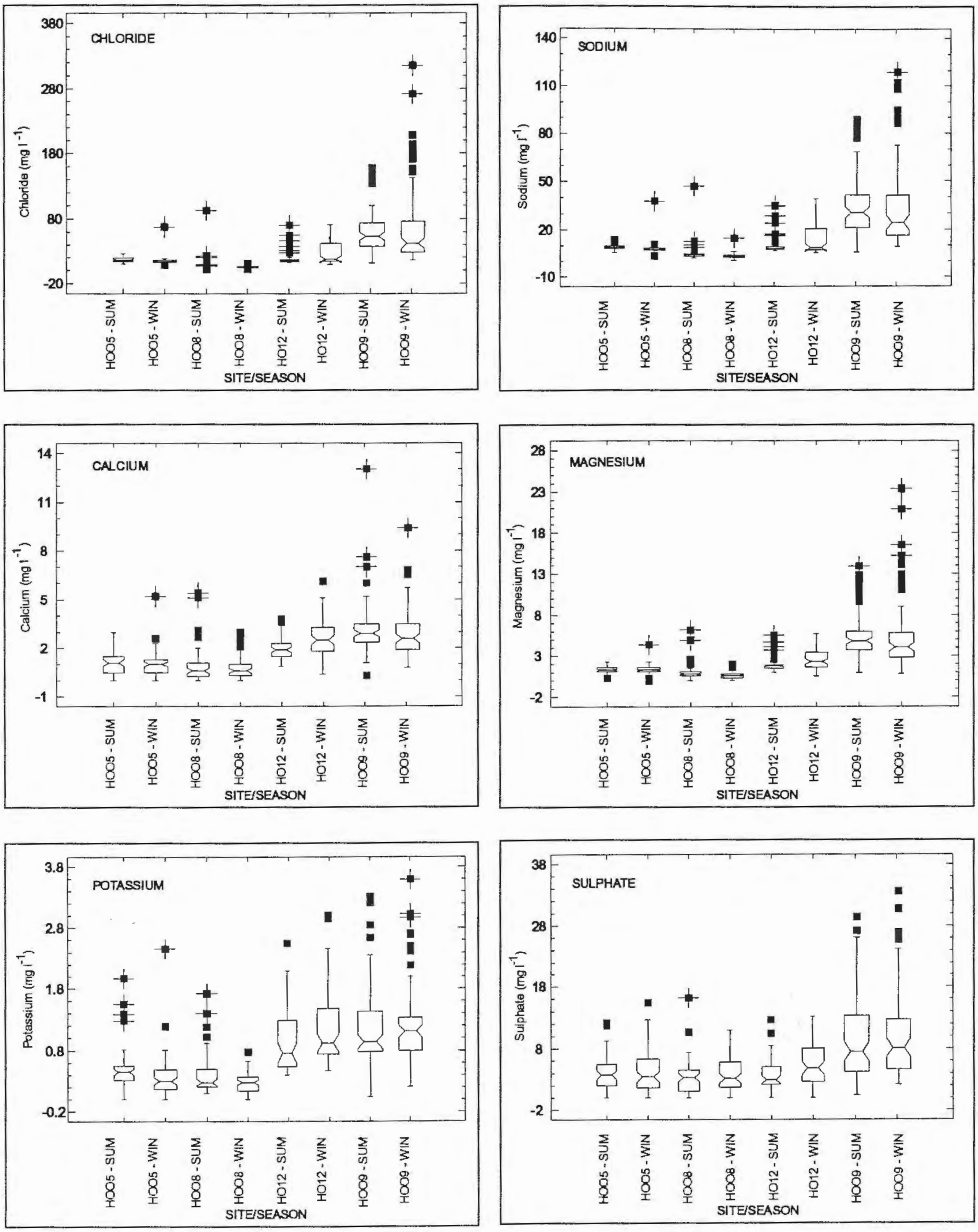

Figure 5.2 Seasonal values for major ion concentrations in the Riviersonderend, and one of its tributaries, the Baviaans River. Values for each variable are grouped by station and season. H005 = Baviaans River, HOO8 = upstream of Theewaterskloof Dam, H012 = gorge immediately downstream of Theewaterskloof, H009 = near Stormsvlei. The suffix - SUM refers to summer and - WIN refers to winter. (See Section 5.3.1 for explanation)

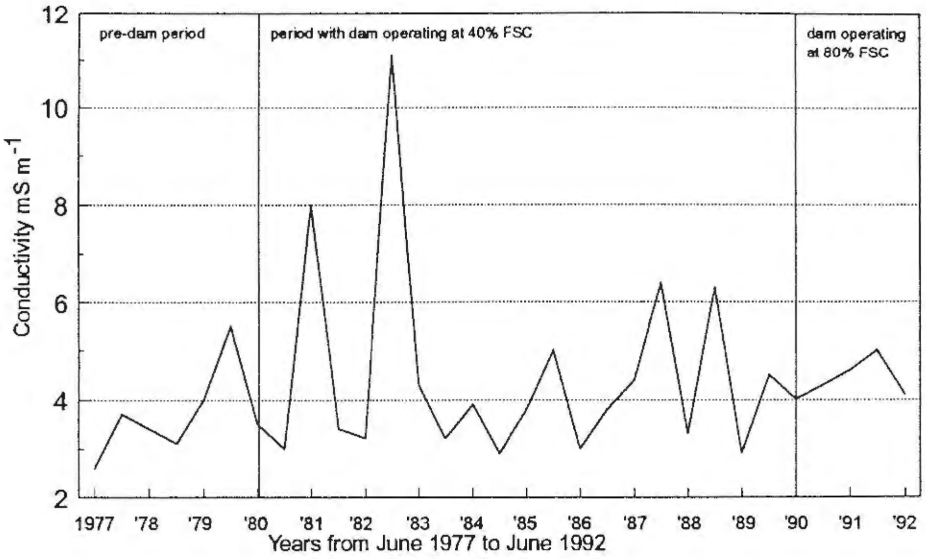

Figure 5.3 **Conductivity: time-series analysis using June and December records from DWAF gauging weir No. H6H008, upstream of Theewaterskloof Dam.**

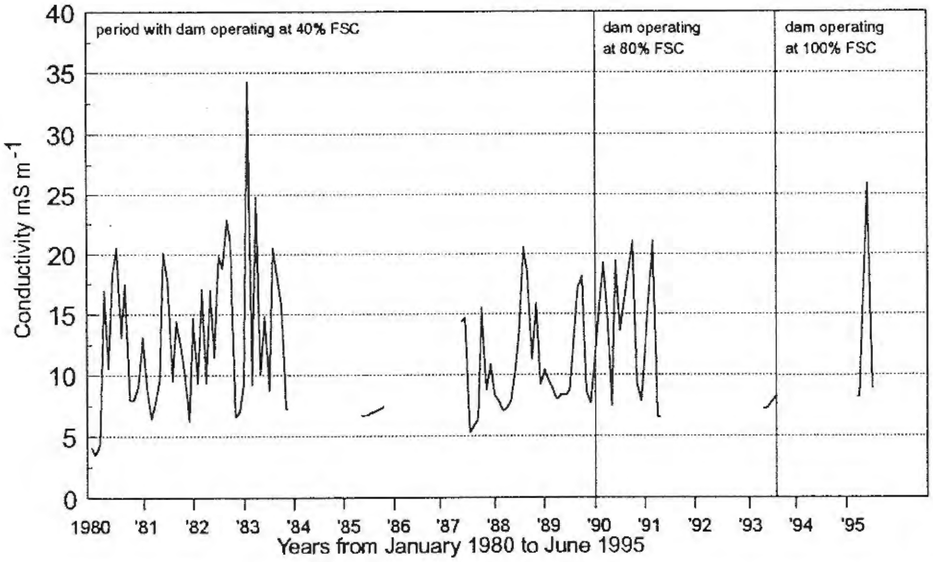

Figure 5.4 **Conductivity: time-series analysis using all monthly records from DWAF gauging weir No. H6H012, downstream of Theewaterskloof Dam.**

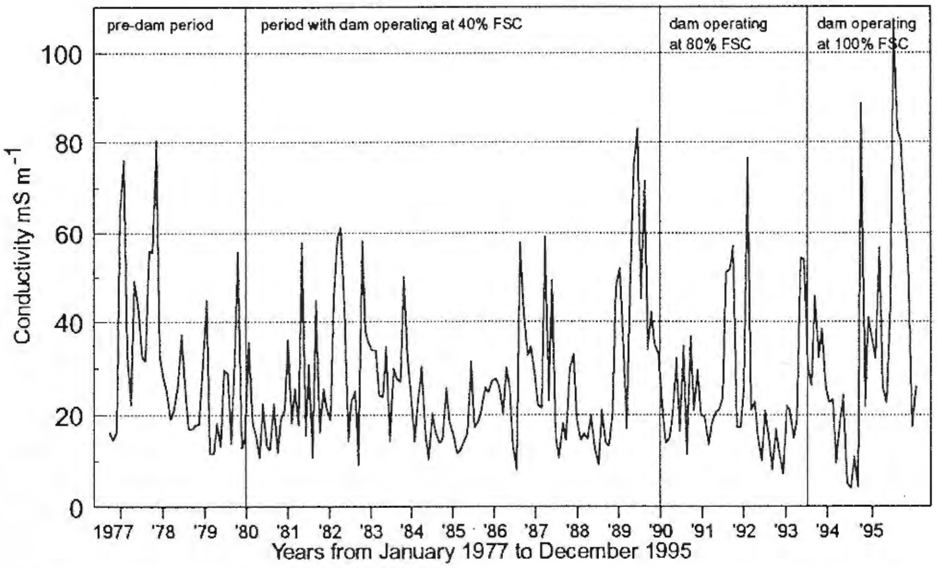

Figure 5.5 **Conductivity: time-series analysis using all monthly records from DWAF gauging weir No. H6H009, in the lower part of the river.**

example, at H008 high conductivities are recorded variously in winter (June) and summer (December), and this feature is prevalent also at the sites downstream of the dam.

All three analyses reflect that, although substantial increases in conductivity are evident along the course of the river, there are no noticeable trends in salinisation discernible at any of the three sites. Notwithstanding, there are more occasions in the recent period at H009 where high conductivities are recorded (Figure 5.5).

5.3.3 Results of the baseline survey

Physical and chemical variables sampled during the field visits are presented in Tables 5.1 and 5.2. Sampling was extended to two sites on the Breede River, up- and downstream of its confluence with the Riviersonderend, to find out whether the Riviersonderend was contributing relatively pure or relatively polluted water to the Breede River.

5.3.3.1 pH, conductivity and major ions

The field measurements confirm that the Riviersonderend is an acid river (Tables 5.1 and 5.2), whilst conditions in the Breede River upstream of their confluence were alkaline in January (pH was not measured in September). The high pH values measured along the Breede River are not within its natural pH range, and may be the result of nutrient enrichment and increased salinity (Chutter 1995; Dallas and Day 1993).

Within the Riviersonderend, conductivities, and the concentrations of major ions all increased considerably along the length of the river, from Site 1 to Site 6, reflecting higher concentrations of dissolved ions in the river from Site 4 downstream. This may be partly a natural phenomenon, given the presence of Bokkeveld Shales along the valley, and because rivers naturally tend to become more saline down their length, but it may also be linked to anthropogenic activities. Interestingly, conductivities were all higher in the Riviersonderend in September than in January, which is the reverse of the pattern suggested by the DWAF data. This is probably linked to the very low discharges in the river in winter, and the increases in discharge at all the sites in summer. The floods in December 1995 (see Section 3.4.4b), which preceded the January visit, would have flushed accumulated salts from the catchment.

Conductivities, and the concentrations of major ions, were lower in the Riviersonderend than in the Breede River and this indicates that the Riviersonderend contributes relatively purer water to the lower Breede River than that flowing in its reaches upstream of where the two rivers are joined.

Although the concentrations of Total Suspended Solids (TSS) reflect only spot measurements in the river, it is clear from the data that TSS were higher during January, where the river at all sites but Site 1 was fairly turbid. The spot TSS measurements were all less than 10 mg ℓ^{-1}, which is not a particularly high value for that part of a river transitional between foothills and the lower river.

Table 5.1 **Summary of physical and chemical constituents of water at Sites 1-6 on the Riviersonderend, and Sites A and B on the Breede River in September 1995.**

	RIVIERSONDEREND						BREEDE	
	Site 1	**Site 2**	**Site 3**	**Site 4**	**Site 5**	**Site 6**	**Site A**	**Site B**
Temperature (°C)	15.5	15.6	17.6	17.4	17.4	18.3	21.3	20.0
Conductivity (mS m^{-1})	21.5	51.9	47.4	88.4	76.8	71.5	141.6	111.7
pH	6.54	6.24	6.23	6.48	6.67	6.45	-	7.32
TSS (mg ℓ^{-1})	2.3	3.8	2.2	3.0	3.1	3.4	7.1	1.9
Organic fraction of TSS (mg ℓ^{-1}	1.6	3.8	2.2	2.4	2.1	2.9	5.0	1.6
NO_2^- -N (mg ℓ^{-1})	0.002	0.002	0.001	0.004	0.003	0.003	0.005	0.003
NO_3^- -N (mg ℓ^{-1})	0.100	0.053	0.046	0.178	0.162	0.111	0.147	0.149
PO_4^{3-} -P (mg ℓ^{-1})	0.021	0.028	0.013	0.015	0.018	0.016	0.005	0.013
Si^+ (mg ℓ^{-1})	0.42	0.31	0.72	1.51	0.82	1.01	0.71	1.18
TAL (meq ℓ^{-1})	0.14	0.26	0.30	0.47	0.42	0.39	1.58	1.02
SO_4^{2-} (mg ℓ^{-1})	4.49	8.11	13.56	15.97	15.81	14.29	73.36	30.44
Cl^- (mg ℓ^{-1})	28.91	52.96	84.37	108.76	112.83	106.41	112.35	112.24
Na^+ (mg ℓ^{-1})	16.67	34.96	44.65	62.95	78.90	82.66	125.81	105.04
Ca^{2+} (mg ℓ^{-1})	2.28	3.42	4.99	5.24	6.30	5.08	23.61	13.14
Mg^{2+} (mg ℓ^{-1})	3.73	5.58	4.39	5.88	7.43	1.74	18.03	11.99
K^+ (mg ℓ^{-1})	0.88	0.55	1.02	1.17	1.34	1.31	2.96	2.10

Table 5.2 **Summary of physical and chemical constituents of water at Sites 1-6 on the Riviersonderend, and Sites A and B on the Breede River in January 1996.**

	RIVIERSONDEREND						BREEDE	
	SITE 1	SITE 2	SITE 3	SITE 4	SITE 5	SITE 6	SITE A	SITE B
Temperature (°C)	22.7	22.0	24.0	22.4	21.9	22.3	25.8	24.5
Conductivity (mS m^{-1})	11.1	28.2	22.1	43.8	48.0	47.4	165.5	79.6
pH	6.35	6.16	6.31	6.44	6.47	6.47	8.28	6.78
TSS (mg ℓ^{-1})	0.2	6.1	4.9	8.1	6.0	7.0	>9.1	8.6
Organic fraction of TSS (mg ℓ^{-1})	0.0	3.5	2.3	2.4	2.9	2.6	9.1	2.4
NO_2^- -N (mg ℓ^{-1})	0.001	0.002	0.003	0.005	0.006	0.005	0.002	0.004
NO_3^- -N (mg ℓ^{-1})	0.095	0.086	0.061	0.171	0.202	0.131	0.006	0.028
PO_4^{3-} -P (mg ℓ^{-1})	0.005	0.007	0.007	0.013	0.010	0.022	0.015	0.105
Si^+ (mg ℓ^{-1})	0.26	0.12	0.35	1.81	2.16	1.33	1.32	0.98
TAL (meq ℓ^{-1})	0.13	0.49	0.23	0.35	0.52	0.42	2.52	0.96
SO_4^{2-} (mg ℓ^{-1})	3.09	2.83	2.56	7.78	8.31	7.50	57.26	14.93
Cl^- (mg ℓ^{-1})	19.69	87.92	48.04	102.53	104.11	92.86	181.16	123.29
Na^+ (mg ℓ^{-1})	11.26	30.24	21.40	49.67	53.85	46.81	89.77	62.71
Ca^{2+} (mg ℓ^{-1})	9.77	5.39	2.79	5.68	5.62	4.50	27.05	9.85
Mg^{2+} (mg ℓ^{-1})	7.78	3.84	2.18	4.86	5.32	4.86	26.31	6.49
K^+ (mg ℓ^{-1})	0.85	1.36	0.60	1.78	1.28	1.15	3.46	1.62

5.3.3.2 Nutrients

The concentrations of nutrients measured during the field visits were all well within the limits of concentrations commonly found in natural rivers of the western Cape (Dallas and Day 1993). The relatively unenriched water of the Riviersonderend is somewhat unexpected, given that it is a large river flowing through agricultural lands. However, the extensive beds of instream and marginal macrophytes, especially of palmiet, may be take up much of the nutrient load, and thus contribute to maintenance of fairly natural conditions. The vast stands of palmiet in the reaches of the river just below the dam, where aliens have not been able to shade out this macrophyte, must be responsible for considerable nutrient uptake. Nutrient levels measured during the two field visits were similar, but were lowest in the upper parts of the Riviersonderend (from Site 1 to Site 3), increasing slightly from Site 4. This confirms the results of analysis of DWAF records, and provides some evidence that the dam is not implicated in an increase in nutrient concentrations in the reaches downstream, despite its devastating effect on the flow regime.

5.4 AQUATIC ALGAE

Algal species occurring at each site are presented in the descriptions of study sites in Section 2.3.2.

Aquatic algae were not abundant in the Riviersonderend, and at no places were dense growths of algae encountered. Algae occurred mostly as a thin film on the surfaces of bedrock, cobbles and gravel in shallow areas, although at Sites 2 and 3 their presence was more visible. It may be that competition for nutrients from macrophytes, both floating and emergent, may inhibit prolific algal growth. However, the species present along the river provide insights into aspects of water chemistry in each reach.

The genus *Spirogyra* has a very large number of species, some of which may indicate different types of organic pollution. *Spirogyra* has a notably mucilaginous outer cell wall and is often found in areas of fast flow. Similarly, the genus *Oedogonium* has a large number of species. It is suspected that the presence of some species indicate polluted water conditions. Both of these genera were found at all sites, except at Site 6, in either or both September and January. They were the only genera found at Site 1, but the presence there of more than one species of each genus indicates relatively natural water. A similar situation prevailed at Site 5.

The algae found at Site 2 represented the most diverse assemblages, in both September and January, and suggest reasonably natural water. In particular, the *Oedogonium* sp., *Palmelloid* sp. and *Batrachospermum* sp. seldom grow in polluted water.

Water samples containing relatively few genera of algae which form large growths usually indicate polluted water, which often has above-neutral pH values, increased conductivity and raised temperatures. Some genera (and often individual species) of algae, such as *Compsopogon, Enteromorpha, Stigeoclonium* and *Cladophora*, are known to be indicators of such conditions.

In January, algae were most abundant at Site 3. Here some algae (*Stigeoclonium* sp. and *Microspora* sp.) indicated a mild degree of organic pollution.

The presence of "sewage fungus"(heterotrophic slimes, which are comprised of a mixture of bacteria, fungi and small diatoms) at Sites 4 and 6 in January indicates pollution of the river. In very low densities sewage fungus is thought to be an important source of food for invertebrates, but its presence as a large biomass over a period of time can cause deoxygenation and thus the death of invertebrates in the water. The growth of sewage fungus is stimulated by the availability of decomposing organic matter. *Sphaerotilus natans var. typica* and *Beggiatoa alba*, both species of bacteria, dominated the samples at Sites 4 and 6 and are typical constituents of "sewage fungus", indicating high levels of organic pollution. The extensive physical destruction of the natural channel and associated bulldozing of organically-enriched soils, trees and scrub into the river, which is prevalent in these reaches, may be the cause of this organic pollution.

Most of the algae found in the Breede River at both Sites A and B in September, and at Site B in January, viz. *Compsopogon coeruleus, Cladophora fracta*, *Enteromorpha* sp. and *Melosira granulata*, typify sites that are mildly polluted and have high conductivities, sometimes being noticeably saline. Very often in polluted areas these algae are found as almost complete dominants. The presence of *Enteromorpha* sp. on its own at Site A on the Breede River indicates relatively saline conditions.

5.5 SUMMARY

- The water in the Riviersonderend is acidic, a natural characteristic of rivers of the Western Cape region, with waters of the upper reaches and mountain tributaries being more strongly acidic than those of the lower reaches. pH values were generally lower in winter than in summer, except immediately downstream of the data. This reflects water chemistry in the impoundment.

- Conductivities and concentrations of major ions increase with distance downstream from Theewaterskloof Dam. Some of the values for sodium and chloride in the lower reaches of the river indicate occasionally high salinities. This does not appear to be the result of the dam, but rather the consequence of agricultural activities, combined with the natural geological formations (Bokkeveld Group shales) in parts of the Riviersonderend Valley.

- Seasonal variation in the concentrations of ions below the dam was not apparent from the historical data recorded at DWAF gauges, but further downstream, concentrations were slightly higher in summer than in winter. This is probably the result of irrigation in summer and the dilution effects of rain, predominantly in winter.

- Conductivities in the Riviersonderend measured during the field surveys were all higher in September (winter) than in January (summer), which is the reverse of the pattern suggested by the DWAF data. This is probably linked to the very low discharges in the river in winter, and the increases in discharge at all the sites in summer. The floods in December, which preceded the January field visit, would have flushed accumulated salts from the catchment.

- No noticeable trends are discernible over time in salinisation of the river.
- Conductivities, and the concentrations of major ions, were lower in the Riviersonderend than in the Breede River and this indicates that the Riviersonderend contributes relatively purer water to the lower Breede River than that flowing in its reaches upstream of where the two rivers are joined.
- Nutrient concentrations in the Riviersonderend are generally low, with only a few outlying values suggesting mild nutrient enrichment at times.
- Aquatic algae were not abundant in the Riviersonderend, and at no places were dense mats of algal growth encountered.
- The extensive stands of palmiet in wider, braided sections of the river may be responsible for uptake of considerable quantities of nutrients.

6. RIPARIAN VEGETATION

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6.1 INTRODUCTION

Riparian vegetation is a fundamentally important component influencing water chemistry and the health of a river.

The invasion of rivers in the western Cape by exotic species has reached alarming proportions. Macdonald *et al.* (1986) suggest that riverine ecosystems are more densely invaded than adjacent upland systems. The extent of invasion has not been ascertained in any detail along the course of a single river in the region.

*Acacia mearnsii** (exotic species are indicated by means of an asterisk in the text) forms dense impenetrable uniform stands that suppress indigenous species, thereby reducing the species diversity of the systems they invade. Fallen mature trees regularly block river channels and cause flooding in winter. Mature individuals of *Eucalyptus* sp.* tend to dry out the superficial layers of the soil, reducing cover, which leads to subsequent soil and bank erosion. Dense stands of both species are visually monotonous, reducing the aesthetic appeal of the rivers, in contrast to the natural varied mix of indigenous species.

Vegetation provides food for detritus feeders in the river. King (1982) provides convincing results indicating the disadvantages of the mass release in autumn of leaves of exotic deciduous species (e.g. *Populus canescens** (poplar) and *Quercus robur** (oak)) versus the continuous, year-round, slow release of materials into the rivers by indigenous evergreen riparian species.

The density of exotic species in a system is a barometer of the degree of disturbance to which it has been exposed. The greater the history of disturbance, the greater the diversity and density of exotic species.

The purpose of this section is:

(a) to describe a general, reconstructed natural vegetation pattern along the Riviersonderend River below the Theewaterskloof Dam;

(b) to attempt to describe the extent to which the natural vegetation has been altered;

(c) to assess the probable effect of the present dam on the river and

(d) to comment on the potential influence of less water in the river because of a raised dam wall.

6.2 METHODS OF ANALYSIS

The extremely disturbed, highly invaded, residual nature of the riparian vegetation makes it extremely difficult to reconstruct the natural zonation patterns, let alone to sample them in a formal manner. The information presented here is based on visual assessment of species contributions to the conspicuous zones observed (no plots were demarcated). The names of plants used here are generally based on the identification of representative specimens by the staff of the Government Herbarium at Stellenbosch, where collected specimens are housed. No specimens were collected of some common and widespread species if there was no doubt about their identity.

The sampling sites, Sites 1 to 6 on the Riviersonderend, were those selected from the study of the video for further general evaluation, and the data were collected during the September 1995 field visit. For each reach (reaches 7 to 12, corresponding with the geomorphological reaches described in Section 2), scores were allocated based on the Braun-Blanquet cover-abundance scale given in Table 6.1. These were averaged for the reach from assessments at a number of sites to give an overall impression of the contribution by each species to the vegetation of the relevant reach. Table 6.2 comprises a list of the species recorded along the river during fieldwork.

Table 6.1 Braun-Blanquet cover-abundance scale (Werger 1974).

R	Very rare and with negligible cover
+	Present but not abundant and with a low cover value
1	Numerous but covering less than 1% of the area, or not very abundant but covering between 1 and 5% of the area
2	Very numerous but covering less than 5% of the area, or covering 5-25% of the area, irrespective of abundance
3	Covering 25-50% of the area, independent of abundance
4	Covering 50-75% of the area
5	Covering 75-100% of the area

The zones generally found at the various sites visited are:

Zone A	Aquatic macrophyte zone. This zone is restricted to the areas with free water. The plants in it may be completely submerged (e.g. *Ruppia*), or rooted with floating leaves (e.g. *Nymphaea nouchali*).
Zone B	Water margin. The plants in this zone are restricted to stream margins, where they are partially submerged but protrude from the water and do not have floating leaves. They can survive out of water if they are rooted where the water table is high and their bases are frequently inundated by short-term rises in water level. (Examples are *Prionium serratum* and *Isolepis prolifer*.)

Zone C	Depressions landward of zone B. These receive a heavier silt load because of slower flow rates than in Zones B or D. This area dries out fairly rapidly yet the soils are wet and gleyed.
Zone D	Because of human disturbances, it was difficult to distinguish the vegetation normally forming two or more zones behind and above Zone C. Consequently, for the purposes of this study, Zone D refers to all the remaining river-bank vegetation.

Table 6.2 **Preliminary list of plants recorded during the survey of the Riviersonderend.**
* = Naturalised (ie. exotic or introduced)

TAXON	REACH NUMBER					
	7	8	9	10	11	12
DENNSTAEDTIACEAE						
Pteridium aquilinum (L.) Kuhn		+				
ADIANTACEAE						
Adiantum aethiopicum L.					R	
PODOCARPACEAE						
Podocarpus elongatus (Aiton) L'Hér. ex Pers. (yellowwood)				R	R	
PINACEAE						
* *Pinus pinaster* Aiton					R	
TYPHACEAE						
Typha capensis (Rohrb.) N.E.Br. (bulrush)		1		R		
POTAMOGETONACEAE						
Potamogeton pectinatus L.				R	R	
RUPPIACEAE						
Ruppia sp. (5964)		R	2			
APONOGETONACEAE						
Aponogeton distachyos L.f.	R	1	1	R	+	+
JUNCAGINACEAE						
Triglochin striata Ruiz & Pav.				R		
POACEAE						
Hemarthria altissima (Poir.) Stapf & C.E.Hubb.	1	2		2	1	+
* *Pennisetum clandestinum* Chiov.				2	+	1
Pennisetum macrourum Trin.		+	1	1	R	2
Ehrharta erecta Lam. var. *erecta*					+	
Phragmites australis (Cav.) Steud.		2				2
Agrostis lachnantha Nees var. *lachnantha*			2			
Aristida junciformis Trin. & Rupr. subsp. *junciformis*	2					
Sporobolus virginicus (L.) Kunth		R		+	+	
Eragrostis curvula (Schrad.) Nees		R			R	R
Eragrostis sarmentosa (Thunb.) Trin.			+	1		
Cynodon dactylon (L.) Pers.		+	+	2		+
CYPERACEAE						
Cyperus denudatus L.f.			+	+	+	
Cyperus textilis Thunb.				R	1	1
Mariscus thunbergii (Vahl) Schrad.	+	1	+		+	
Fuirena hirsuta (P.J.Bergius) P.L.Forbes			2			
Isolepis prolifer R.Br.		3	3	3	1	+
Eleocharis limosa (Schrad.) Schult.			R	2		+
ARACEAE						
Zantedeschia aethiopica (L.) Spreng.		+	R	R	R	+
RESTIONACEAE						
Ischyrolepis subverticillata Steud.	1	+				+
Elegia caespitosa Esterh.	2					
JUNCACEAE						
Prionium serratum (L.f.) Drège ex E.Mey. (palmiet)	5	5	3	4	2	3
Juncus acutus L.		2		+		+
Juncus effusus L.		1	1			
Juncus lomatophyllus Spreng.		1	2		+	
Juncus oxycarpus E.Mey. ex Kunth					+	
ASPARAGACEAE						
Myrsiphyllum declinatum (L.) Oberm.		+				

Table 6.2 **Preliminary list of plants recorded during the survey of the Riviersonderend (continued).** * = Naturalised (ie. exotic or introduced)

TAXON	REACH NUMBER					
	7	8	9	10	11	12
HAEMODORACEAE						
Wachendorfia paniculata Burm.		R				
HYPOXIDACEAE						
Spiloxene aquatica (L.f.) Fourc.			+	+		R
Spiloxene capensis (L.) Garside						R
IRIDACEAE						
Dietes iridioides (L.) Sweet ex Klatt					+	
SALICACEAE						
* *Populus x canescens* (Aiton) Sm.		3			3	R
* *Salix babylonica* L.			R			
Salix mucronata Thunb. subsp. *capensis* (Thunb.) Immelman		R	1	+	1	R
BETULACEAE						
* *Alnus* cf. *viridis* DC. (green alder)		R				
FAGACEAE						
* *Quercus robur* L. (oak)		+		+		
MORACEAE						
* *Ficus* sp. (fig)					R	
PROTEACEAE						
Brabejum stellatifolium L. (wild almond)	1	2	+		+	
POLYGONACEAE						
Rumex acetosella L. subsp. *angiocarpus* (Murb.) Murb.				+		+
Persicaria serrulata (Lag.) Webb & Moq.		1	1	1	+	+
Persicaria sp. (5968)		1				
NYMPHAEACEAE						
Nymphaea nouchali Burm.f. var. *caerulea* (Savigny) Verdc.			+	1	R	+
PITTOSPORACEAE						
* *Pittosporum undulatum* Vent.					2	
BRUNIACEAE						
Berzelia lanuginosa (L.) Brongn.	2					
ROSACEAE						
Rubus fruticosus L.		R		2	+	1
Cliffortia strobilifera Murray		1	1	1		2
FABACEAE						
* *Acacia cyclops* A.Cunn. ex G.Don (rooikrantz)		R				
Acacia karroo Hayne						R
* *Acacia longifolia* (Andrews) Willd.		1	2	+	2	
* *Acacia mearnsii* De Wild. (black wattle)		1	3	4	5	1
* *Acacia melanoxylon* R.Br.		R	2	+	2	
* *Acacia pycnantha* Benth.					R	
* *Acacia saligna* (Labill.) H.L.Wendl.		+	3	+		+
Virgilia oroboides (P.J.Bergius) Salter subsp. *oroboides* (keurboom)					R	
* *Sesbania punicea* (Cav.) Benth.		+	1	1		
MELIACEAE						
* *Melia azedarach* L.					R	
EUPHORBIACEAE						
* *Ricinus communis* L.		1				+
ANACARDIACEAE						
Rhus angustifolia L.		2	+	1		+
Rhus crenata Thunb.						R
Rhus laevigata L. var. *laevigata* forma *laevigata*		+				2
Rhus rehmanniana Engl. var. *rehmanniana*					+	
Rhus tomentosa L.	R		+			
AQUIFOLIACEAE					+	
Ilex mitis (L.) Radlk. var. *mitis* (wild holly)					+	
CELASTRACEAE						
Maytenus heterophylla (Eckl. & Zeyh.) N.Robson						R
CELASTRACEAE						
Putterlickia pyracantha (L.) Szyszyl.						1
RHAMNACEAE						
Noltea africana (L.) Rchb.f.		R				
FLACOURTIACEAE						
Kiggelaria africana L. (wild peach)					+	
PASSIFLORACEAE						
* *Passiflora edulis* Sims					R	

Table 6.2 **Preliminary list of plants recorded during the survey of the Riviersonderend (continued).** * = Naturalised (ie. exotic or introduced)

TAXON	REACH NUMBER 7	8	9	10	11	12
PENAEACEAE						
Penaea cneorum Meerb. subsp. *cneorum*	+					
THYMELAEACEAE						
Passerina vulgaris Thoday		1	+			
MYRTACEAE						
Metrosideros angustifolia (L.) Sm.	2	R	2		R	
* *Eucalyptus camaldulensis* Dehnh.					+	4
APIACEAE						
Centella cf. *glabrata* L.			+			+
ERICACEAE						
Erica lycopodiastrum Lam.	R					
MYRSINACEAE						
Rapanea melanophloeos (L.) Mez				R	1	
EBENACEAE						
Diospyros glabra (L.) De Winter	2	+		+	+	
OLEACEAE						
Olea europaea L. subsp. *africana* (Mill.) P.S.Green (wild olive)						R
* *Ligustrum ovalifolium* Hassk. (5983)					R	
MENYANTHACEAE						
Nymphoides indica (L.) Kuntze subsp. *occidentalis* A.Raynal	R	+	2		+	
ASCLEPIADACEAE						
Secamone alpini Schult.					R	
VERBENACEAE						
* *Verbena bonariensis* L.					+	
LAMIACEAE						
Leonotis leonurus (L.) R.Br.						+
Mentha aquatica L.			R			
SOLANACEAE						
* *Solanum pseudocapsicum* L.					R	+
SCROPHULARIACEAE						
Halleria elliptica Thunb.		+			+	
LOBELIACEAE						
Lobelia erinus L.		+	+			
ASTERACEAE						
* *Conyza bonariensis* (L.) Cronquist				1		
Helichrysum cymosum (L.) D.Don subsp. cymosum						+
Helichrysum foetidum (L.) Moench					+	R
Stoebe vulgaris Levyns		2				
Elytropappus rhinocerotis (L.f.) Less. (renosterbos)		R				
Cotula coronopifolia L.		+	+			
Senecio halimifolius L.			+			
Senecio repandus Thunb.						+
Oldenburgia paradoxa Less.	R					
* *Hypochoeris radicata* L.					R	R
* *Sonchus oleraceus* L.					R	R

6.3 RESULTS

6.3.1 Vegetation patterns

The actual vegetation observed at each site is described here. Some comment is also made about each site's representativeness of the reach as a whole.

6.3.1.1 Site 1

Zonation

A. Some pools between rocks contain isolated plants of the aquatics *Aponogeton distachyos* and *Nymphoides indica*. These species have tubers imbedded in the silt. The narrow pool margins support *Crassula expansa*, *Hemarthria altissima* and *Pennisetum macrourum*.

B. The instream and marginal vegetation consists of a dense 5 m-wide monospecific band of 1.5 m-tall individuals of *Prionium serratum*.

C. Depressions behind zone B on a silt substratum support grasses (*Hemarthria altissima* and *Aristida junciformis*), a restio (*Elegia caespitosa*) and a sedge (*Mariscus* sp.).

D. The bank vegetation behind zones B and C consists of two bands of vegetation typical of fast-flowing streams over sandstone substrata. The lower zone is dominated by *Diospyros glabra, Metrosideros angustifolius* and *Ischyrolepis subverticillata.* The upper zone includes a low cover of *Brabejum stellatifolia* up to 2 m tall, *Berzelia lanuginosa* and a few individuals of *Rhus tomentosa.* Where the rocky sandstone substratum is exposed, *Penaea cneorum* subsp. *cneorum*, *Oldenburgia paradoxa* and *Erica lycopodiastrum* occur. These three species are important floristically. The first represents a disjunct and, along with a population along the Palmiet River, the most western distribution record, while the last two are listed rare-and-endangered plants.

Assessment

The vegetation at this site was in good condition with little evidence that altered flow regimes have had any effect. This is not the case just below the Theewaterskloof Dam in Reach 6, where dam construction and farming disturbance have altered the vegetation significantly and dense infestations of exotics, particularly of *Pinus pinaster** and *Acacia mearnsii**, occur. Less disturbance occurs in the Keerom Gorge itself because it is steep-sided and reasonably inaccessible.

I expected to find *Scirpus fluitans* growing on shallowly-submerged bedrock in the river along Reach 7 but did not observe it. It is possible that abnormally large unseasonal releases of water and heavy silt loads during construction of the dam have eliminated this useful indicator of natural summer water levels in mountain streams.

Clearing of exotic species, particularly of *P. pinaster**, has been undertaken on the eastern bank and slopes that support *Protea laurifolia* Fynbos vegetation. The western bank above the sampling site is still fairly heavily infested with *A. mearnsii** and *P. pinaster**.

The river immediately downstream of Site 1 changes into one with wide and deep pools. The marginal flora remains *Prionium serratum* while the banks are heavily infested with *Acacia mearnsii**. An old excavated area has developed an ox-bow type of situation in which *Phragmites communis* is dominant, together with *Fuirena hirsuta*. *Nymphoides indica* and *Scirpus lomatophyllus* are located in the marsh area while the banks contain *Cliffortia strobilifera, Diospyros glabra* and *Alnus viridis**. The last is a garden escape occasionally found in the riparian zone.

6.3.1.2 Site 2

Zonation

A. The instream vegetation consists of a sparse cover of the submerged aquatic *Ruppia* sp. and of *Aponogeton distachyos*, which has floating leaves.

B. The band of marginal vegetation, 5 - 8 m wide, is dominated by *Prionium serratum* (80% cover). *Cliffortia strobilifera* is a conspicuous 2 m-tall emergent providing about 10% of the canopy cover. The following species are also present in this zone but cover is sparse: *Rubus* sp.*, *Sesbania punicea**, *Typha capensis* and *Wachendorfia thyrsiflora*.

C. The depressions and wet areas behind and between zone B are principally vegetated by *Isolepis prolifer* (30% cover) together with sparse cover of the following species: *Acacia cyclops**, *A. longifolia**, *Cotula coronopifolia, Eragrostis curvula, Hemarthria altissima, Juncus lomatophyllus, Lobelia erinus, Mariscus* sp., *Nymphoides indica, Pennisetum macrourum, Persicaria* sp.*, *Salix mucronata, Scirpus maritimus, Sesbania punicea** and *Sporobolus virginicus*.

D. The vegetation of the western bank in the vicinity of the rubbish tip is dominated by *Populus canescens** and also contains *Acacia longifolia**, *Cynodon dactylon, Elytropappus rhinocerotis, Quercus robur** and *Ricinus communis.*

Assessment

A dense stand of vegetation approximately 40 m wide along the right bank (looking downstream), immediately upstream of the site, gives an indication of the indigenous bank vegetation (Zone D) of the area. *Brabejum stellatifolium, Cliffortia strobilifera, Rhus angustifolia* and *Stoebe vulgaris* are dominant, with the following species also present: *Diospyros glabra, Halleria elliptica, Ischyrolepis subverticillatus, Metrosideros angustifolius, Noltea africana, Passerina vulgaris, Pteridium aquilinum* and *Zantedeschia aethiopica*. Some exotic species, such as *Acacia longifolia**, *A. mearnsii**, *A. melanoxylon**, *A. saligna** and *Rubus* sp.*, are also fairly abundant here. This remnant vegetation probably owes its existence to its locality on a small island where the river has a braided channel and the banks are thus not suitable for agriculture.

The vegetation at this site is reasonably representative of the reach as a whole, with lateral encroachment by agriculture into the riparian flood zone being a regular practice. In some instances fringing fields are left fallow for extended periods and are then colonized by exotics, particularly *Acacia mearnsii** and *A. longifolia**, which form dense fringing stands.

6.3.1.3 Site 3

Zonation

A. *Ruppia* sp. is fairly abundant (with a relative cover of about 15%) while *Aponogeton distachyos* is relatively rare.

B. The naturally dense band of *Prionium serratum* along the river margin has been disturbed immediately downstream of the road-bridge and zone C vegetation is presently dominant here. The presence of young palmiet plants indicate that the banks might be in the process of recovery. Instream islands of *Prionium serratum* occur upstream of the road-bridge. *Isolepis prolifer* dominates the marginal vegetation of the run and riffle probably because of disturbance in the *Prionium serratum* zone.

C. This zone is widespread. It is dominated by *Isolepis prolifer, Juncus lomatophyllus, Nymphoides indica* and *Persicaria* sp. The following species have low cover values: *Agrostis lacnantha, Cliffortia strobilifera, Cotula coronopifolia, Cyperus denudatus, Fuirena hirsuta, Juncus oxycarpus, Mentha aquatica, Salix mucronata* subsp. *capensis* and *Sesbania punicea**.

D. The bank vegetation is highly disturbed. Selective wood-cutting of exotics for firewood has also taken place. Dense stands of *Acacia saligna** particularly are regenerating following the disturbance. The following exotic species are dominant: *Acacia longifolia**, *A. mearnsii** and *A. saligna**. Other exotics recorded include *A. melanoxylon** and *Salix babylonica**. Two indigenous species noted on the banks are *Passerina vulgaris* and *Rhus tomentosa.*

Assessment

Rehabilitation of the riparian vegetation in and opposite the campsite would increase the appeal of this facility.

This site is not entirely representative of the whole reach as some clearing of exotic vegetation has been attempted and has allowed the recovery of some indigenous species. The extent of riffle is atypical of the reach as a whole, where deep pools lined by *Prionium serratum* and fringed by dense stands of *Acacia mearnsii** are the norm.

Considerable water extraction by farmers compounds the effect of Theewaterskloof Dam along this reach. The increased abstraction and poor farming practices have led to increased siltation and so to the expansion of *Scirpus prolifer* in this reach. Further reduction in flow will compound this effect and the extent of the pools will be reduced. Heavy floods simulating the natural condition should help to alleviate this problem.

6.3.1.4 Site 4

Zonation

A. The following two aquatics were observed: *Aponogeton distachyos* and *Ruppia* sp.

B. The dense band of *Prionium serratum* is approximately 4 m wide on the left bank (facing downstream). Erosion along the right bank has removed most of the *Prionium serratum*.

C. Between and behind the palmiet on the left bank there is a spit of sand and mud deposits which support about a 15% cover of *Sesbania punicea**. Indigenous species present, with low cover values, are *Cyperus denudatus, Eragrostis sarmentosa, Isolepis prolifer* and *Polygonum salicifolium*, all of which are also present on the right bank. A thorny tangle of *Rubus fruticosa* with taller *Cliffortia strobilifera* and *Salix mucronata* also occurs along the left bank.

D. The left bank supports a very dense stand of 10-15 m-tall individuals of *Acacia mearnsii**. Along the highly disturbed and eroded right bank, *Cynodon dactylon, Pennisetum clandestinum* and *Verbena bonariensis*, and other herbaceous, exotic, weedy species, are abundant.

Assessment:

Individuals of *Acacia mearnsii** have fallen or been felled into the river. They will mat to form an effective wall should the river receive large volumes of water. Flood damage to the channel and surrounding land will be exacerbated.

Prionium serratum is the conspicuous natural dominant plant along this reach, where the channel has many braids. This plant serves to slow water movement in the braids and particularly to cover the banks and so reduce erosion during floods. During periods of reduced flow *Prionium* individuals bend over channels, effectively covering the narrower ones. Establishment of young individuals does not take place under this dense mat. The edges of the marshes tend to dry out more rapidly with extended excessive abstraction and therefore lead to the narrowing of the band of *Prionium*. The exposed areas are then invaded by exotic species, which produce many viable seeds.

It is anticipated that increased abstraction will lead to a reduction in the width of the *Prionium* beds in this reach.

6.3.1.5 Site 5

Zonation

A. A low cover of species of *Ruppia* occurred in the water, along with a number of algae species.

B. *Prionium serratum* stands are poorly developed along the stream margin here. This zone also supports a mixture of the following indigenous species which are usually associated with zone C: *Cyperus denudatus, C. textilis, Helichrysum foetidum, Isolepis prolifer, Juncus lomatophyllus, Nymphoides indica, Polygonum salicifolium* and *Sporobolus virginicus.*

C. This zone supports the following indigenous species: *Eragrostis curvula, Hemarthria altissima, Juncus oxycarpus, Metrosideros angustifolius, Pennisetum macrourum, Rubus fruticosus* and *Salix mucronata* subsp. *capensis.*

D. The left bank in particular is densely covered by a riparian forest, primarily of exotic trees such as *Acacia mearnsii** (about 60% cover), *A. longifolia**, *A. melanoxylon**, *A. pycnantha**, *Eucalyptus* spp.*, *Melia azedarach**, *Pinus pinaster**, *Pittosporum undulatum** and *Populus canescens** (20% cover) but includes a few individuals of a number of naturally occurring, indigenous species such as *Brabejum stellatifolium, Diospyros glabra, D. whyteana, Ilex mitis, Kiggelaria africana, Podocarpus elongatus, Rapanea melanophloeos, Rhus rehmanniana* and *Virgilia oroboides.* Climbing plants include *Passiflora edulis** and *Secamone alpinii.* Herbaceous plants in the understorey include *Adiantum aethiopicum, Dietes iridioides, Ehrharta erecta* and *Zantedeschia aethiopica.*

Assessment

The reason for the rich mix of exotic and indigenous tree species found here might be explained historically. The site is located on a State-owned Agricultural Experimental Farm, where utilizable indigenous species are evaluated, in conjunction with research into economically important exotic species. For instance, a *Protea* plantation adjoins an old plantation located in zone D, which contains a variety of different species of exotic *Eucalyptus.** The plantation is an important source of seed contributing to the change in dominance from *Acacia mearnsii** to *Eucalyptus* sp.* downstream of the site.

The adjacent Tierberg, which is part of the Riviersonderend Mountain Catchment area, has measures in place for controlling exotic vegetation. The slopes of Tierberg are a source of indigenous riparian seed, which serves to improve the quality of the riparian vegetation along this short reach, although this is counteracted to a degree by the increased use of the river and its water by the inhabitants of Riviersonderend Town.

6.3.1.6 Site 6

Zonation

A. No aquatics were observed in the fast-flowing channel.

B. Dense marginal stands of 2.5 m-tall *Prionium serratum*, *Phragmites australis* and *Cliffortia strobilifera* block the central portion of the river.

C. The zone behind the palmiet and in the wet areas of the remnant braided channels support *Cyperus textilis, Isolepis prolifer, Mariscus thunbergii* and *Spiloxene aquatica.*

D. The drier parts of the broad bank support a rich flora resulting from disturbance through cattle grazing. The following species were recorded: *Acacia mearnsii**, *A. saligna** (with fungal galls), *Centella eriantha, Cynodon dactylon, Eragrostis curvula, Eucalyptus cf. camaldulensis**, *Helichrysum cymosum, H. foetidum, Hemarthria altissima, Hypochoeris radicata, Ischyrolepis subverticillatus, Leonotis leonurus, Pennisetum clandestinum, P. macrourum, Polygonum salicifolium, Putterlickia pyracantha, Rhus angustifolius, R. laevigata*, *Ricinus communis, Rubus fruticosum, Rumex acetosella, Senecio repandus, Solanum pseudocapsicum**, *Sonchus oleraceus**, *Spiloxene capensis* and *Zantedeschia aethiopicum*.

Assessment

Reach 12 is typified, *inter alia*, by the numerous braided channels upstream of DWAF weir H6H009. Extensive *Prionium* beds occur between the braids. The effects of increased abstraction will be similar to those described for Reach 10, namely closing of channels by palmiet and a reduction in width of the palmiet beds with increased encroachment by exotic vegetation. Floods will tend to cause erosion here because of blocking of the channels.

Below the DWAF weir the river has fewer braids. Extensive water abstraction has already reduced flooding considerably and the river is mainly lined by a *Eucalyptus** forest with very little undergrowth. The riparian vegetation in this area is in a particularly poor condition with few indigenous species remaining. River banks unsuitable for crop cultivation are used for pasture purposes.

6.3.2 Assessment of trends

6.3.2.1 Zone A - Aquatic macrophyte vegetation

Totally submerged aquatics such as *Chara, Potamogeton* and *Ruppia* were rarely encountered in the Riviersonderend River. This group of aquatics is in riffles and runs.

Three species of rooted aquatics with floating leaves were recorded along the length of the river, namely *Aponogeton distachyos, Nymphaea nouchali* and *Nymphoides indica*. These species root in pools less than one meter in depth with slow currents and silty bottoms. A reduction in current speed through increased abstraction will lead to an increase in their densities.

*Eichhornia crassipes** was the only floating aquatic observed. It was recorded in the Breede River below the junction with the Riviersonderend, where floods keep this invasive species under control. It is anticipated that this plant will successfully invade the Riviersonderend by natural means (e.g. through water birds) as nutrient enrichment occurs following increased abstraction of water.

6.3.2.2 Zone B - Marginal vegetation

Under natural conditions, a band of *Prionium serratum* (palmiet) would probably line this river down its whole length. *Prionium* is an effective bank stabilizer, slowing the current in its immediate vicinity and bending easily during high flows. A similarly supple species, *Salix mucronata* subsp. *capensis*, often protrudes through palmiet clumps.

Prionium serratum persists away from the primary channels along the edges of old courses and pools and eventually completely colonizes them. Along extensively braided parts of the river it forms wide beds (e.g. at CS15). *Cliffortia strobilifera* generally occurs as an emergent among older stands of palmiet. Its branches continue lengthening as sand accumulates, so that it gives the appearance, under advanced conditions of deposition, of growing on dry sand banks.

Where palmiet is absent, through natural or artificial disturbance, one would expect to find species from Zone C to be early colonizers.

6.3.2.3 Zone C - Vegetation of wet depressions or disturbed margins

Isolepis prolifer, a dominant in this zone, proved to be the most commonly-occurring indigenous species encountered along the whole course of the river. It is able to colonize wet and shallowly-inundated areas even with moderate summer flows along the edges of riffles. Some further herbaceous species with lower cover values found amongst the stands of the latter species are *Cotula coronopifolia, Hemarthria altissima, Juncus lomatophyllus, Pennisetum macrourum, Spiloxene aquatica, Sporobolus virginicus* and an admixture of other sedges. *Salix mucronata* subsp. *capensis* is a regular emergent shrub in this zone.

Rocky areas or those with cobbles commonly support *Metrosideros angustifolius* in this zone. Under locally suitable conditions, e.g. in slight backwaters, small localized stands of *Phragmites australis* (or the exotic *Arundo donax**) or *Typha capensis* may occur.

The invasive exotics, *Sesbania punicea** and *Salix babylonica**, serve as replacement species for *Salix mucronata* along this river.

6.3.2.4 Zone D - Bank vegetation

Very little remains of this zone to reconstruct the indigenous riparian vegetation which should occur here. The highly utilizable tree, *Podocarpus elongatus*, for instance, was only found as rare seedlings, while *Brabejum stellatifolium*, which might have been abundant throughout, was only found sporadically. Other indigenous trees occasionally encountered included *Ilex mitis, Kiggelaria africana* and *Rapanea melanoxylon*.

Olea europaea subsp. *africana* was encountered only at CS17. The species was recorded again at Site Abbey on the Breede River.

Indigenous riparian shrubs, which were found slightly more often than the trees, included *Halleria elliptica, Leonotis leonurus, Noltea africana, Passerina vulgaris, Rhus angustifolia, R. crenata, R. rehmanniana* and *R. tomentosa*. On the sandier substrates associated with the Breede River, there was a conspicuous increase in species such as *Acacia karoo, Maytenus heterophylla, Putterlickia pyracantha* and *Rhus laevigata*, characteristic of drier scrub.

Ischyrolepis subverticillatus, the restio commonly expected along rivers of the Fynbos Biome, was encountered only on a few occasions.

The river banks are clearly dominated over most of their extent by the Australian exotics *Acacia longifolia** and *A. mearnsii**. It is conspicuous that *Eucalyptus cf. camaldulensis** only becomes dominant below Riviersonderend town. This probably relates to the history of its introduction into the area.

6.4 CONCLUSIONS

There is very little natural vegetation left along the course of the Riviersonderend River except in Reach 7, at Keeroms Poort below Theewaterskloof Dam. Scattered individuals of most of the species anticipated for the river below Reach 7 are present but in very low numbers. This shows that disseminules are still present and that it is not too late to start a rehabilitation programme. The critical questions pertain (a) to the observable effects of the present Theewaterskloof Dam and (b) to the anticipated effect of increased abstraction from this dam.

*Eichhornia crassipes** is a potentially dangerous invasive species which will benefit from a reduction in spates. It is present in the Breede River at the mouth of the Riviersonderend. It has the potential to invade the Riviersonderend, if it has not already done so, particularly where nutrient enrichment takes place. It will completely cover the open water and requires annual floods to clear it from the channels. A continued reduction incurrent speed over a longer period than is presently the case, will result in an annual increase in density of this invasive species, which will contribute to blockages during the first winter floods.

Isolepis prolifer, the principal indigenous colonizer of Zone C, was observed to be extending its range into the shallower parts of the river during persistently low flows. Individuals of this species are more robust on the edges of the open water and were observed to be going into a second flowering phase in September, in contrast to those individuals located in the drier areas further from the waters edge. This species would therefore be expected to take early advantage from lower flows coupled to increased abstraction.

Stands of *Sesbania punicea** and *Salix babylonica** will probably increase as water levels drop more permanently to expose uncolonized sand below the *Prionium* zone.

The river banks are dominated over most of their extent by *Acacia mearnsii**. The reduction in the number and duration of floods, primarily through the construction of Theewaterskloof Dam, heavy water abstraction rates and ignorant riparian managers are probably contributing to this invasion. Fallen individuals of *Acacia mearnsii** often lie across the channels in the lower Riviersonderend thereby limiting recreational use of the river, and a heavy rainy season will see exceptional flooding as a result of blockages caused by fallen trees. Dense infestations of *Acacia mearnsii** result in an accumulation of inflammable material (the indigenous riparian vegetation is less flammable), which leads to an increased fire hazard. Furthermore, exotic tree species are known to utilize more water than indigenous riparian plants. This loss of water aggravates the losses from the river of water through abstraction.

Further abstraction will reduce the rehabilitation potential of the highly invaded riparian vegetation present along this river below Reach 7.

6.5 SUMMARY

- There were four zones of vegetation found at the study sites. Zone A comprised the aquatic macrophyte zone, which is restricted to the areas with free water. Zone B comprised plants that are restricted to stream margins, where they are partially submerged but protrude from the water and do not have floating leaves. Depressions landward of zone B formed zone C; these depressions receive a heavier silt load because of slower flow rates than in Zones B or D. This area dries out fairly rapidly yet the soils are wet and gleyed. Because of human disturbance, it was difficult to distinguish the vegetation normally forming two or more zones behind and above Zone C. Consequently, for the purposes of this study, Zone D referred to all the remaining river-bank vegetation.
- Totally submerged aquatics were rarely encountered in the Riviersonderend. Three species of rooted aquatics with floating leaves were recorded along the length of the river, namely *Aponogeton distachyos, Nymphaea nouchali* and *Nymphoides indica*. A reduction in current speed will lead to an increase in their densities.

- *Eichhornia crassipes** was the only floating aquatic observed. It is anticipated that this plant will successfully invade the Riviersonderend through natural means (e.g. water birds) as nutrient enrichment occurs following increased abstraction of water.
- Under natural conditions, a band of *Prionium serratum* (palmiet) would probably line the edges of the down its whole length.. At present, palmiet forms wide beds along extensively braided parts of the river.
- *Isolepis prolifer* dominated zone C, and proved to be the most predictable indigenous species encountered along the whole course of the river. The species was observed to be extending its range into the shallower parts of the river during persistently low and would therefore be expected to take early advantage from lower flows coupled to increased abstraction.
- The invasive exotics, *Sesbania punicea** and *Salix babylonica** were abundanct in zone C, along the length of the river. These species will probably increase as water levels drop more permanently to expose uncolonized sand below the *Prionium* zone.
- Very little remains of zone D to reconstruct the indigenous riparian vegetation which should occur. The river banks are clearly dominated over most of their extent by the Australian exotics *Acacia longifolia** and *A. mearnsii**. The reduction in the number and duration of floods, primarily through the construction of Theewaterskloof Dam, heavy water abstraction rates and ignorant riparian managers are probably contributing to this invasion.
- There is very little natural vegetation left along the course of the Riviersonderend except in Reach 7, at the Keeroms Poort below Theewaterskloof Dam. Further abstraction will reduce the rehabilitation potential of the highly invaded riparian vegetation along this river, below Reach 7.

7. FISH

7.1 METHODS FOR COLLECTION OF FISH DATA

Field surveys conducted by Cape Nature Conservation (CNC) generate records of the species of fish occurring in rivers in the Western Cape. These records were consulted to provide a species list of fish occurring in the Riviersonderend below Theewaterskloof Dam, and the current conservation status of each species (data supplied by S. Thorne, CNC Jonkershoek). Further information on distribution and species characteristics was derived from the South African Red Data Book on fishes (Skelton, 1987) and Skelton (1993).

7.2 RESULTS

A summary of the species of fish recorded in the Riviersonderend downstream of Theewaterskloof Dam is provided in Table 7.1. It should be noted that these data do not necessarily reflect current conditions in the river, as the most recent field surveys were conducted in 1991.

Table 7.1 The species of fish occurring in the Riviersonderend, downstream of Theewaterskloof Dam, and their present status as listed in the Red Data Book on fishes (Skelton 1987).

SPECIES	STATUS
Indigenous	
Pseudobarbus burchelli (Burchell's redfin)	rare
Barbus andrewi (Breede witvis)	vulnerable
Sandelia capensis (Cape kurper)	common
Galaxias zebratus (Cape galaxias)	common
Anguilla mossambica (Longfin eel)	common
Alien	
Oreochromis mossambicus (Mozambique tilapia)	common, introduced from Orange River
Tilapia sparrmanii (Banded tilapia)	common, introduced from Zambezi River system
Micropterus dolomieu (Smallmouth bass)	common, introduced from USA
Micropterus salmoides (Largemouth bass)	common, introduced from USA
Lepomis macrochirus (Bluegill sunfish)	common, introduced from USA
Tinca tinca (Tench)	common, introduced from Europe
Found in Theewaterskloof, but may have moved downstream:	
Cyprinus carpio (Carp)	common, introduced from Europe

7.2.1 Species indigenous to the Riviersonderend

Burchell's redfin, *Pseudobarbus burchelli* (Family Cyprinidae), is listed in the Red Data Book on fishes (Skelton 1987). Its conservation status is "rare", due to reduction and destruction of its natural habitat through human development and to predation by alien fish. Increased regulation of rivers in the area will further threaten this species. Its distribution is recorded in Skelton (1993) as the Breede River and adjacent river systems of the western Cape. *P. burchelli* inhabits clear, rocky pools and deeper flowing reaches of larger tributary streams and mainstreams. The species often occurs with *Galaxias zebratus* and *Sandelia* capensis (Skelton 1987). It feeds mostly on benthic detritus and small organisms, and breeds in summer.

The witvis, *Barbus andrewi* (Family Cyprinidae), is an indigenous fish included in the list of Red Data species in 1987 (Skelton 1987). It is considered to be vulnerable, and possibly endangered, due to the decline in numbers of this species in its natural habitat. Major threats and causes for its decreasing abundance include agricultural pollution, water abstraction for agriculture and municipal supply, weirs, and the introduction of alien, predatory fish such as bass and trout (Skelton 1987). The witvis favours deep, rocky pools and flowing sections of the larger tributaries of the Berg and Breede River systems. Witvis feed on algae and benthic invertebrates. The species breeds in summer; breeding adults congregate at the base of rapids, and eggs are laid in gravel in flowing water.

Sandelia capensis (Family Anabantidae), the Cape kurper, is a common indigenous species which occurs in coastal rivers, from the Koega (Algoa Bay) to the Cape Flats, and north to Verlorenvlei (Skelton 1993). It is considered a hardy species that utilises a wide variety of biotopes, but that favours quiet or slow-flowing water, and plant cover. It feeds on invertebrates and small fish. Males are territorial during the breeding season, which occurs in summer. Despite the common status of this species, many populations have declined and are threatened by habitat destruction and predation by bass.

The Cape galaxias, *Galaxias zebratus* (Family Galaxiidae), is another species common in coastal rivers and streams in the western Cape. It has a wide distribution from the Keurbooms River on the south coast to the Olifants River on the west coast (Skelton 1993). *Galaxias zebratus* is a small but hardy species, occurring in both flowing and standing waters, but preferring the slow-flowing areas near the shelter of banks, usually at the heads of pools. It is tolerant of a wide range environmental conditions, and forages on small drifting invertebrates. Breeding tends to occur either in spring or in summer, depending on local conditions (Skelton 1993).

The longfin eel, *Anguilla mossambica* (Family Anguillidae), is a common species of freshwater eel found in coastal rivers from Kenya south to Cape Agulhas. The adult eels breed at sea, but the immature "glass" eels migrate upstream, often over long distances, where they develop to sexual maturity before returning to the sea in floods or strong river flows (Skelton 1993). The eels feed on aquatic invertebrates when immature, and on crabs and small vertebrates such as frogs when mature.

7.2.2 Species indigenous to southern Africa but introduced in the Riviersonderend

Oreochromis mossambicus, the Moçambique tilapia (Family Cichlidae), occurs naturally in east coast rivers from the lower Zambezi system south to the Bushmans River in the eastern Cape, but has been introduced to a wide variety of aquatic ecosystems in the southern and western Cape, and Namibia (Skelton 1993). The species is tolerant of a range of salinities and water temperatures. These fish feed largely on algae and detritus, but may prey on invertebrates. Males build nests on sandy bottoms during the breeding season, which is summer, and females mouthbrood the eggs, larvae and small fry (Skelton 1993).

The banded tilapia, *Tilapia sparrmanii* (Family Cichlidae), is found in the Orange River and from Natal coastal rivers, northwards to Lake Malawi and Zaire (Skelton 1993). The species has been extensively translocated south of the Orange River. It prefers slow-flowing or standing waters with submerged or emergent vegetation, but is tolerant of a wide range of conditions. *Tilapia sparrmanii* feeds on algae, soft plants, small invertebrates and fish (Skelton 1993). As with the Moçambique tilapia, males build nests, but the banded tilapia does not mouthbrood.

Both of the abovementioned tilapias were introduced into the Breede River system as 'fodder fish" for bass.

7.2.3 Alien species introduced to the Riviersonderend

The smallmouth bass, *Micropterus dolomieu* (Family Centrarchidae), is a problematic alien pest species introduced to southern African rivers from North America. The species prefers loose, rocky substrata and flowing water. The immature fish feed on insects, crabs and small fish, while the adults are primarily piscivorous. Breeding occurs in spring and early summer (Skelton 1993). This species, introduced as a sport fish, has been very successful in the western Cape, where it has had a devastating effect on indigenous fish species. The largemouth bass, *Micropterus salmoides*, also occurs naturally in North America, but is now widespread in rivers throughout southern Africa. This species prefers standing or slow-flowing clear waters with submerged and floating vegetation (Skelton 1993), and is very successful in farm dams. Adult fish are largely piscivorous, but will feed on virtually any animal food. The largemouth bass is tolerant of a wide range of temperatures, and the species breeds in spring.

The bluegill sunfish, *Lepomis macrochirus* (Family Centrarchidae), has its natural distribution in eastern and central North America, but is now established and is considered a pest species in rivers and streams in many parts of South Africa where it preys on smaller indigenous fish and their eggs. The species was introduced as a 'fodder fish" for bass. It favours quiet, well-vegetated waters in rivers and dams and breeds in summer (Skelton 1993).

The tench, *Tinca tinca* (Family Cyprinidae), is an alien species that was initially introduced from England as an angling species, but was later used as a 'fodder fish" for bass. The tench has established in the Breede River system, and in several isolated farm dams in the Western Cape and KwaZulu/Natal. It inhabits deep, well-vegetated water, such as swamps and vleis, and lays its eggs in shallow water, in dense vegetation (Skelton 1993). It is omnivorous, feeding on a wide variety of benthic macroinvertebrates.

Cyprinus carpio (Family Cyprinidae), the common carp, is considered a pest species due to its destructive foraging habits, which lead to the suspension of sediments and uprooting of plants (Skelton 1993). The species has its natural distribution in Central Asia and in some rivers in Europe, but it now occurs in rivers throughout southern Africa, except for mountain streams. Carp are hardy, but generally prefer slow-flowing or standing water and soft bottom sediments. The species is omnivorous and does especially well in dams and larger rivers (Skelton 1993).

During the field visits, *Lepomis macrochirus* was observed at Site 5, whilst anglers at Site 3 confirmed that bass were the fish most often caught.

7.3 SUMMARY

- Two Red Data species, *Pseudobarbus burchelli* and *Barbus andrewi*, occurred in the Riviersonderend downstream of Theewaterskloof Dam, at least as recently as 1991. Both these species are considered threatened due to reduction and destruction of their natural habitats, and predation by introduced alien fish.
- Three common indigenous species, *Sandelia capensis*, *Galaxias zebratus* and the common freshwater eel, *Anguilla mossambica*, are known to occur in the study area.
- Two species indigenous to southern Africa, *Oreochromis mossambicus* and *Tilapia sparrmanii*, have been translocated to the Riviersonderend from systems further north.
- A further five species not indigenous to southern Africa have been introduced to the Riviersonderend. *Micropterus dolomieu*, *Micropterus salmoides*, *Lepomis macrochirus* and *Tinca tinca* have been recorded in the river, while *Cyprinus carpio* has established in Theewaterskloof and is likely to have moved downstream of the dam.
- Some of the fish introduced to the Riviersonderend, occur in slow-flowing quiet waters on sandy bottoms. These conditions prevail along much of the river length, and may thus favour these species over those indigenous to the river.

8. CAPE CLAWLESS OTTERS ASSOCIATED WITH THE RIVIERSONDEREND AND BREEDE RIVERS

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8.1 INTRODUCTION

This report provides a brief introduction to the Cape clawless otter *Aonyx capensis* inhabiting the Riviersonderend and Breede Rivers and environs and discusses possible effects of an impoundment on these animals.

Many of the 13 species of otter occurring worldwide are rapidly disappearing, along with the natural freshwater ecosystems (rivers and wetlands) they inhabit (Foster-Turley 1990). Populations of otters (*A. capensis* and the spotted-necked otter *Lutra maculicollis*) may also be declining in South Africa, but little is known about their present distribution and status. Chemical pollution by pesticides (polychlorinated biphenyls and mercury) is usually blamed for their disappearance but the scientific evidence is only circumstantial and many other factors could also be playing a role (Kruuk 1995). This author, however, considers habitat destruction probably to be the main factor influencing South African populations.

Aonyx capensis is dependent on freshwater aquatic habitats, including rivers, streams, lakes, or ponds, and seldom ventures far from water. In terms of diet, they are particularly well-adapted for the capture and consumption of crabs. Rowe-Rowe (1977a, b, c) provided initial information on *A. capensis* in KwaZulu/Natal but base-line information is only now being collected in the rest of the country (Somers & Nel In press).

Adult *A. capensis* weigh between 10 and 18 kg. They are most active at dusk (Rowe-Rowe 1977b, 1978), and may occur in groups of up to eight, but are more often solitary. In shallow, stony-bottomed streams, *A. capensis* walks in the water, submerging the head occasionally, and feeling with the forefeet under and between stones for prey (Rowe-Rowe 1977b). In deeper water, the otter dives to the bottom to forage (Rowe-Rowe 1977b, Purves *et al.* 1994).

Aonyx capensis is widely distributed south of the Sahara in suitable aquatic habitats. It occurs throughout southern Africa except in the arid western parts but are nowhere common (Skinner & Smithers 1990).

At present, the only accurate method for estimating otter densities is the use of radio-tracking and radionuclide recovery, as described by Kruuk *et al.* (1993). This is expensive and time consuming. A new method, using DNA recovered from scats, to determine numbers and distributions of individual Eurasian otters, *Lutra lutra*, is presently being developed (H. Kruuk, Institute of Terrestrial Ecology, Banchory, Scotland, pers. comm.). Current estimates of *A. capensis* densities, based only on observational records, are one per 2 km of coast (Van der Zee 1982; Arden-Clarke 1986) and one per 3-4 km of river (Rowe-Rowe & Somers pers. obs.).

8.2 METHODS

As suggested by Rowe-Rowe (1992), surveys of 1 km of bank were carried out to investigate the presence or absence of *A. capensis*. As dense stands of *Prionium serratum* in some reaches of both the Riviersonderend and Breede Rivers made surveys difficult, surveys were not always conducted along continuous stretches. Five sites on the Riviersonderend, including one site alongside the Theewaterskloof Dam, and four sites on the Breede River were surveyed (Table 8.1). (The sites were not the same as those used for the field visits reported in other sections of this document, and are thus labelled A to E.) In addition, a short survey of *ca* 40 m was undertaken next to the bridge (34°05'00"S; 19°21'30"E) near Helderstroom Prison. The diet of the otters was determined as in Erlinge (1968) and Rowe-Rowe (1978). All the surveys formed part of a separate study on the Cape clawless otter, but some conclusions from the results are reported here.

Table 8.1. Dates and localities of 1 km surveys for sign of *Aonyx capensis* along the Riviersonderend (RSE) and Breede Rivers, with results of the survey.

SITE	DATE OF SURVEY	LOCALITY	CO-ORDINATES	SIGN FOUND
RSE A	17-10-1995	Theewaterskloof Dam	34°01'25"S -19°03'30"E	Foot prints
RSE B	17-10-1995	Uitkyk	34°03'55"S -19°24'40"E	None
RSE C	17-10-1995	Elandskloof	34°03'50"S - 19°26'00"E	None *
RSE D	18-10-1995	Amanzi	34°03'30"S - 19°27'05"E	None*
RSE E	18-10-1995	Stormsvlei	34°05'00"S - 19°26'15"E	None
Breede 1	18-10-1995	Bonnievale	33°50'40"S - 20°06'45"E	6 scats (1 latrine)
Breede 2	19-10-1995	Drew	34°00'30"S - 20°13'25"E	3 scats (1 latrine)
Breede 3	19-10-1995	Malgas	34°18'00"S - 20°35'30"E	13 scats (3 latrines)
Breede 4	19-10-1995	Witsand	34°23'50"S - 20°50'25"E	None

* Sign of *A. capensis* were found during a survey done on 26-01-1993 (J.A.J. Nel, pers. comm.).

8.3 RESULTS AND DISCUSSION

8.3.1 Otter presence and densities

As rainfall can have a significant influence on scat frequency, the best time to survey for carnivores using scats is at the end of the dry season (Cavallini 1994). This was not possible for this report and the results may therefore not be entirely representative of otter populations in the area. Even if dry season sampling were possible, scat density at a given time of year is a tenuous measure of utilization of an area by otters (Kruuk 1995).

Although there were no fresh signs of otters along the Riviersonderend downstream of Theewaterskloof Dam, past surveys at two of the Riviersonderend sites, in January 1993, demonstrated their presence. In addition, old scats were collected during the recent survey from the river banks near Helderstroom

Prison. Otters do occur around the Theewaterskloof Dam, and were also found along the Breede River, from Bonnievale downstream at least as far as Malgas. Twenty-two fresh scats were collected along the Breede River (Table 8.1). No sign of otters was found at the mouth of the Breede River. Otters need fresh water to wash salt off their fur, so the lack of fresh water at this locality may explain their absence.

Owing to the limitations of current methods of estimating otter densities, no estimates could be made for the Riviersonderend or Breede River.

8.3.2 Diet of *Aonyx capensis*

From analysis of the scats on the Breede River, their percentage composition in terms of prey categories was estimated and is presented in Table 8.2. Table 8.3 gives the diets of otters in the Kingna River just upstream of its confluence with the Breede River (from Ligthart *et al.* 1994). At least three old scats were found along the Riviersonderend at the bridge near Helderstroom, but were not collected as they had disintegrated. They all consisted chiefly of crab remains.

Table 8.2. Diet of *Aonyx capensis* in the Breede River, as determined from 22 scats.

PREY CATEGORY	% OCCURRENCE
Crab	40
Plant	25
Fish	12
Mammal	12
Insect	8
Bird	4

Table 8.3. Diet of *Aonyx capensis* in part of the Breede River system, as determined from 105 scats (Ligthart *et al.* 1994).

PREY CATEGORY	% OCCURRENCE
Crab	49
Insect	17
Mammal	16
Fish	10
Mollusc	4
Frog	3
Bird	1

Although the results are preliminary, they show *A. capensis* to be predominantly crab eaters, as has been shown in studies in freshwater systems elsewhere (Turnbull-Kemp 1960; Rowe-Rowe 1977a; Kruuk & Goudswaard 1990; Ligthart *et al.* 1994; Purves *et al.* 1994; Somers & Purves In press). Rowe-Rowe & Somers (pers. obs.) suggest the importance of prey other then crabs is related to local prey-availability.

8.3.3 Disturbance of otters

It appears from radio-tracking that along the Eerste River, Western Cape, *A. capensis* are affected by disturbance from urban environments (Somers & Nel In press). In another area surveyed (Bushmans River, Eastern Cape) however, *A. capensis* and *L. maculicollis* coexist along a stretch of river disturbed by a road, a railway and urbanization within meters of the river (Somers & Nel In press). Otters are shy and human activities will certainly have an effect on the movement of the individuals using the area. They may, however, become habituated to such activities, as they have in the Bushmans River area.

As *A. capensis* use numerous dens (in rock, soil or thick vegetation) and have home ranges covering up to 45 km of river (Somers In prep.), the destruction of short stretches of available habitat may not be too detrimental to them.

Otters are active just below impoundments and leave more scats in these areas than in other parts of river systems (Somers In prep.). The reason for this is at present unclear. Some individuals also use impoundments extensively as hunting areas, even where there is human disturbance (Somers In prep.). Impoundments once constructed, therefore, do not appear to have a detrimental effect on the otters' behaviour. As otter numbers are limited by prey populations (Kruuk *et al.* 1993), impoundments that have a detrimental effect on the prey of *A. capensis* (Tables 8.2 & 8.3) may, however, negatively affect otter numbers.

8.4 SUMMARY

- No fresh signs of otter were found along the Riviersonderend downstream of Theewaterskloof Dam, although they have been recorded in the past.
- During the current survey, otter spoor were found near Theewaterskloof, and scats, comprising crab remains, were found along the Breede River.
- Otters are affected by human disturbances around urban or developed areas, but may become accustomed to human activities. The effect of Theewaterskloof Dam on the distribution of otters is not clear, as some individuals use impoundments as hunting grounds, and may be more active below dams.
- Otters are limited by the availability of prey, and so numbers of otters may be reduced if the dam has had a detrimental effect on the abundance of prey.

9. AMPHIBIANS

9.1 METHODS FOR COLLECTION OF AMPHIBIAN DATA

The Scientific Services Branch of the Cape Nature Conservation (CNC) collects data on the species of amphibians that occur in the Western Cape, and their distribution patterns. These data are based on specimen, sight and auditory records, as well as on records from the literature (A. de Villiers, CNC, Stellenbosch). Using this source of information, a checklist has been established of amphibian species occurring in the Riviersonderend between Theewaterskloof Dam and its confluence with the Breede River. Further information on breeding and habitat preferences was gained from Cape Nature Conservation and from Dr Mike Picker, Zoology Department, University of Cape Town.

9.2 RESULTS

Table 9.1 gives a list of the amphibians occurring in the Riviersonderend downstream of Theewaterskloof Dam. Species normally associated with habitats such as fynbos seepages and seasonal wetlands, which are not connected to the main channel, have not been included, although some of the listed species prefer quiet waters, and might therefore occur away from the main river channel.

Table 9.1 The species of amphibians occurring in the Riviersonderend downstream of Theewaterskloof Dam.

RIVERINE SPECIES:	WETLAND SPECIES:
Xenopus laevis (common platanna)	*Cacosternum boettgeri* (common caco)
Bufo rangeri (raucous toad)	*Cacosternum nanum* (bronze caco)
Rana fuscigula (Cape river frog)	*Strongylopus fasciatus* (striped grass frog)
Strongylopus grayii (spotted grass frog)	*Tomopterna delalandii* (Cape sand frog)
	Hyperolius horstockii (arum lily frog)
	Semnodactylus wealii (rattling kassina)

None of the species in Table 9.1 are endemic, nor are they regarded as threatened.

The common platanna, *Xenopus laevis*, is usually found in permanent standing waters, such as pools and backwaters in river channels, but also occurs and can breed in permanent and seasonal vleis. This species is rarely found in running waters. *Xenopus laevis* breeds from July through to October, and preys on other species of frog.

Bufo rangeri, the raucous toad, inhabits seasonal wetlands as preferred habitats, but may occur in permanent standing waters, while the Cape river frog, *Rana fuscigula*, is found in river channels, in standing and flowing water. Both of these species are dependent on permanent waters for breeding.

Both the spotted grass frog, *Strongylopus grayii*, and the striped grass frog, *S. fasciatus*, breed in winter and are commonly found in seasonal wetlands associated with rivers, while *S. grayii* also occurs in permanent standing or flowing water. *Cacosternum boettgeri* (the common caco) and *C. nanum* (the bronze caco) are winter-breeders that prefer seasonal wetlands. *Cacosternum nanum* and *Strongylopus fasciatus* occur in the eastern half of the study area. The Cape sand frog, *Tomopterna delalandii*, and the rattling kassina, *Semnodactylus wealii*, are associated with seasonal wetlands, while the arum lily frog (*Hyperolius horstockii*) requires more permanent standing waters. This species breeds from October to December, while the Cape sand frog and the rattling kassina are winter breeders.

Many of these species occur and breed in permanent, semi-permanent to seasonal standing water bodies. One of the indirect consequences of the presence of Theewaterskloof Dam (discussed in section 4.3) is the potential for increased conversion of wetlands and secondary channels into cultivated lands, and the effective canalisation of the river in places. This may reduce the availability of seasonal wetlands associated with the river, preferred by many of the species, and force them to use the more permanent waters of the main river where the aggressive predator, *Xenopus laevis*, which prefers river pools and backwaters, might place increased predator pressure on these other species of amphibian.

Most of the species described here are winter-breeders. Low winter baseflows may reduce the area of wetted channel, especially pools and secondary channels, available for breeding,.

9.3 SUMMARY

- Ten species of frog, none of which is considered endemic or threatened, have been recorded in the Riviersonderend, below Theewaterskloof Dam,.
- Four species of amphibian were found to be associated with riverine habitat in the Riviersonderend. These were *Xenopus laevis, Bufo rangeri, Rana fuscigula* and *Strongylopus grayii.*
- A further six species occur in quiet wetland areas associated with the river, and may occur away from the main river course. These species are *Cacosternum boettgeri*, *Cacosternum nanum*, *Strongylopus fasciatus*, *Tomopterna delalandii*, *Hyperolius horstockii* and *Semnodactylus wealii.*
- As most of the species prefer to live and breed in quiet standing waters or seasonal wetlands rather than flowing waters within the river channel, alterations in the availability of these biotopes by, for example, the infilling of channel braids, may reduce frog numbers and distributions.

10. CRABS

Dr Barbara Cook, South African Museum, Cape Town

10.1 METHODS FOR COLLECTION AND IDENTIFICATION OF CRABS

Crabs were collected during the first field visit to the Riviersonderend, in September 1995, from each of the six sites along the Riviersonderend (see Figure 2.1). In addition, crabs were collected from a site on the Riviersonderend upstream of the Theewaterskloof Dam (called Site 0), to allow for an assessment of whether the dam is affecting distribution of crab species.

Ox-heart, tied with string, was used as bait in rocky areas at approximately seven locations at each site. Crabs feeding on the meat were captured with a hand net and kept in a bucket until return to the overnight station, where they were frozen and then stored in 70% alcohol.

10.2 RESULTS

More than 20 crabs were collected from the Riviersonderend. All of the specimens could be identified as the Cape river crab, *Potamonautes perlatus* (H. Milne Edwards, 1837). This species is common in river systems of the Western Cape, particularly in the lower reaches, and can be recognised by its smooth to moderately granulose carapace lacking teeth or heavy serrations along the anterolateral margins (Figure 10.1). Although two species of potamonautid crabs occur in the Berg, Eerste and Olifants River systems, only *P. perlatus* has thus far been collected from the Breede River System. The upper reaches of the other major Western Cape river systems have revealed the existence of an undescribed potamonautid species, recognisable by the existence of small epibranchial teeth. This species has yet to be found in the Breede River system.

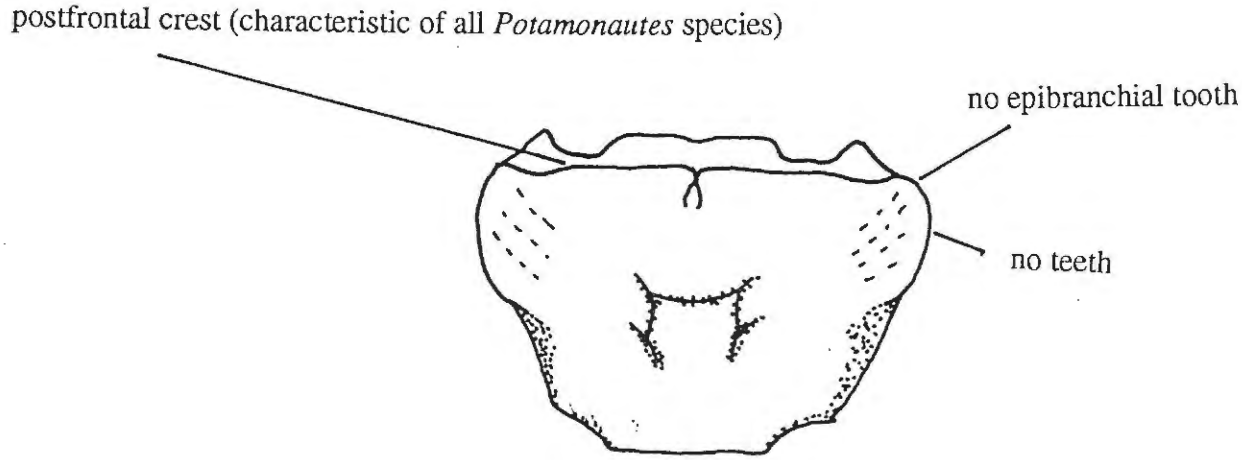

Figure 10.1. Carapace outline of specimen of *Potamonautes perlatus*.

All of the specimens were in good conditon, and no abnormalities were detected.

In order to assess whether the *P. perlatus* specimens collected from the Riviersonderend could be distinguished morphometrically from specimens of this species collected from other rivers of the Breede River system, a discriminant functions analysis, based on seven carapace measurements, was performed. In this analysis, crabs collected from the Riviersonderend were compared with with crabs from the Elands River, which flows into Theewaterskloof, as well as those from the Tradouw and Buffeljags Rivers, both tributaries of the Breede River near Swellendam.

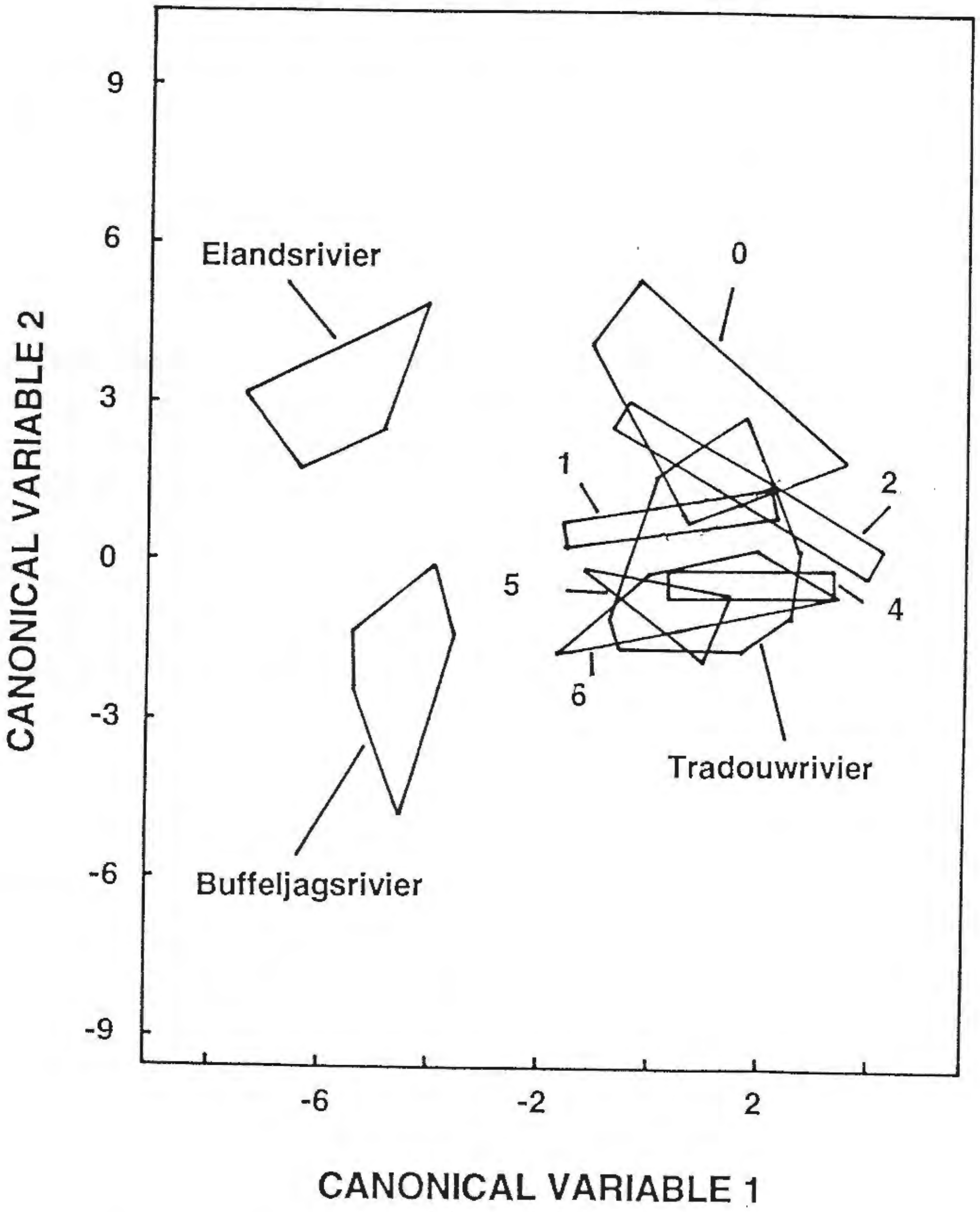

Figure 10.2. Polygons encompassing individual scores for the first two canonical variables for crabs from Sites 0 (upstream of Theewaterskloof Dam) and Sites 1 to 6 on the Riviersonderend, and from sites on the Elands, Tradouw and Buffeljags Rivers.

The results showed that the Riviersonderend specimens were similar in shape to those collected from the Tradouw River (Figure 10.2). However, they were clearly distinguished from specimens collected from the Elands River and from those collected from the Buffeljags River. The separation of the specimens from the Elands River from those from the upper Riviersonderend River (e.g. at Site 0, also upstream of Theewaterskloof Dam) was unexpected, and needs further investigation.

10.3 HABITAT REQUIREMENTS OF *POTAMONAUTES PERLATUS*

Potamonautes perlatus is an omnivorous, hardy, common species that occurs in rivers with variable discharge regimes, and its distribution is unlikely thus to be directly affected by flow regulation caused by impoundments. These crabs prefer cobble and boulder strewn river bottoms, and usually avoid stagnant pools and backwaters. The encroachment of marginal vegetation into the river channel, or the alteration of substratum to a sandy bed, may reduce the habitat available for these animals.

10.4 SUMMARY

- All crab specimens collected from the Riviersonderend and Breede River were identified as the Cape river crab, *Potamonautes perlatus*, a species common to rivers in the western Cape.
- *Potamonautes perlatus* is a hardy species that occurs commonly in the western Cape, in rivers with variable discharge regimes, so this species is unlikely to be directly affected by regulation of flow as a result of Theewaterskloof Dam.
- The encroachment of vegetation into the river channel may, however, reduce the availability of cobble- and boulder-strewn biotopes, which the Cape river crab favours, but it will occur even on muddy bottoms of ponds.

11. MACROINVERTEBRATES

11.1 INTRODUCTION

The shallow rivers of the Western Cape support a macroinvertebrate (large invertebrates) fauna that includes the immature and often the adult stages of insects, crustaceans, arachnids and worms. Benthic (river bed) macroinvertebrates occur on or under stones, or in the finer sediments, in pools, runs and riffles. Other macroinvertebrates inhabit the instream and marginal vegetation. Many macroinvertebrates are primary consumers, near the base of the food chain, and are therefore essential in the functioning of riverine ecosystems (Davies and Day 1986).

Riverine fauna and their different life stages are adapted to narrow ranges of hydraulic and chemical conditions, and thus the often heterogeneous lotic environments of the Western Cape lead to a wide diversity of macroinvertebrates (Davies *et al.* 1993). The hydraulic and chemical characteristics of river waters are important determinants of macroinvertebrate community composition and may be important cues influencing various components of the life cycles, such as pupation or emergence, of riverine species. Alterations to these characteristics, such as changes in frequency and magnitude of base flows and flood events may lead to the loss of sensitive species, and an increase in numbers of individuals of those species that can tolerate, or even benefit, from these altered conditions.

The macroinvertebrate community composition at a particular site will reflect the immediate history of the physical and chemical conditions in the water at that point (Hawkes 1982). Changes in water chemistry often accompany alterations to the natural flow regime of a river, and sensitive species will react rapidly to these alterations to their environments (e.g. Cairns and Dickson 1971); thus the macroinvertebrate assemblages can be expected to reflect the extent to which a river has deteriorated from its natural state. Riverine macroinvertebrates are increasingly being used in biological monitoring and in the assessment of the ecological state of rivers (Cairns and Pratt 1993).

The macroinvertebrate fauna of the Riviersonderend downstream of Theewaterskloof Dam, and of the Breede River near its confluence with the Riviersonderend, was sampled in late winter (September 1995) and summer (January 1996) using a rapid bioassessment technique. This method was chosen to provide an indication of the state (a range of natural to perturbed) of the two rivers, at the eight selected sites. A provisional species list for each site was also compiled to provide details of differences between the sites.

11.2 METHODS OF DATA COLLECTION AND ANALYSIS

11.2.1 Rapid bioassessment

The South African Scoring System, SASS (Chutter 1995), is a field-based rapid bioassessment method that uses information on benthic macroinvertebrates specifically to assess the impairment of water quality in rivers (Dallas *et al.* 1995). The implementation of the SASS method in the field has shown that it is also sensitive to other factors, such as alterations in the flow regime, and thus the method also provides a useful index of biotic integrity which can assist in evaluating the status of a riverine ecosystem. A detailed explanation of SASS, including the recognised sampling methods, is presented in Chutter (1995). The method used in this study is SASS4, the latest modification of SASS (Chutter 1995). The method is subject to continuous revision.

The standard SASS4 field sampling technique involves kick- and sweep-sampling of representative areas of all aquatic biotopes for a specified length of time, using a 900 µm-mesh collecting net. The aquatic invertebrates in each sample are visually identified in the field to the taxonomic level of family and are then returned to the river.

For the SASS4 method, each family of riverine animals has been allocated a sensitivity/tolerance score based on expert opinion, with respect to the water quality conditions which the various taxa are known to tolerate (Dallas *et al.* 1995). For instance, taxa that are recognised as highly tolerant of poor water quality conditions have been allocated scores of 1, whereas extremely sensitive ones have scores of 15. The total SASS4 score is calculated by summing the scores for each taxon present and the average score per taxon (ASPT) by dividing this total score by the number of taxa recorded. Table 11.1 lists the sensitivity scores allocated to the various taxa found in the present study.

11.2.2 Provisional species lists for the Riviersonderend and Breede River

A provisional macroinvertebrate species list was compiled for the Riviersonderend and Breede Rivers, from specimens collected from the SASS4 samples.

Specimens were preserved and returned to the laboratory for identification to species, or to the lowest taxonomic level possible. The taxonomy of many of the groups of freshwater macroinvertebrates in South Africa is inadequately documented, and is under continual revision (F.C. de Moor, Albany Museum, Grahamstown, pers. comm.). Identification below the level of family or genus is thus tentative for some taxa. Unconfirmed names are designated by question marks. These provisional species lists were compiled for both late winter/spring and summer. These lists should, however, be considered to be incomplete, as it is improbable that the complete summer and winter faunas were sampled during the two visits to the rivers.

Table 11.1 **SASS4 macroinvertebrate sensitivity scores used to determine total scores and the average score per taxon (ASPT) for Sites 1 to 6 on the Riviersonderend, and for Sites A and B on the Breede River.**

TAXON	SENSITIVITY SCORE
PLATYHELMINTHES	
Planaria (flatworms)	5
OLIGOCHAETA (worms)	1
HIRUDINEA (leeches)	3
DECAPODA	
Shrimps	8
Crabs	3
ACARINA	
Hydrachnellae (water mites)	8
EPHEMEROPTERA (mayfly nymphs)	
Leptophlebiidae	13
Baetidae (1 species)	4
(2 species)	6
(> 2 species)	12
Caenidae	6
Tricorythidae	9
Heptageniidae	10
Ephemerellidae	15
ODONATA (dragon- and damselfly nymphs)	
Coenagrionidae	4
Chlorocyphidae	10
Corduliidae	8
Libellulidae	4
Gomphidae	6
Aeshnidae	8
HEMIPTERA (bugs)	
Notonectidae	3
Naucoridae	7
Veliidae	5
Gerridae	5
Nepidae	3
Corixidae	3
TRICHOPTERA (caddisfly larvae)	
Hydropsychidae (1 species)	4
(2 species)	6
(>2 species)	12
Philopotamidae	10
Ecnomidae	8
Hydroptilidae	6
Other movable case larvae:	
(i.e. Leptoceridae; Glossosomatidae; Barbarochthonidae; Petrothrincidae)	
1 case type;	8
2 case types;	15
3 case types	20
COLEOPTERA (beetles: adults and larvae)	
Elmidae/Dryopidae (adults; larvae)	8
Limnichidae (larvae)	8
Dytiscidae (adults, larvae)	5
Gyrinidae (adults, larvae)	5
Hydraenidae (adults)	8
MEGALOPTERA	
Corydalidae	8

Table 11.1 continued **SASS4 macroinvertebrate sensitivity scores used to determine total scores and the average score per taxon (ASPT) for Sites 1 to 6 on the Riviersonderend, and for Sites A and B on the Breede River.**

GASTROPODA (snails and limpets)	
Ancylidae	6
Physidae	3
Lymnaeidae	3
Cyrenidae*	6
DIPTERA (fly larvae)	
Simuliidae	5
Chironomidae	2
Tabanidae	5
Psychodidae	1
Culicidae	1
Athericidae	13

* The Family Cyrenidae has not been allocated a sensitivity score in the current version of SASS, and thus a provisional score of 6 was allocated to this group on the advice of H Dallas, Freshwater Research Unit, University of Cape Town.

11.3 RESULTS

11.3.1 SASS4 results

SASS4 scores, number of taxa, and ASPTs for all sites on the Riviersonderend and Breede River are presented in Table 11.2. The total SASS4 score at a site provides a measure of the richness of invertebrate life present and, as it is the sum of individual (sensitivity) scores which are based on water quality conditions, the total score reflects the chemical conditions at that site. Natural variation in the nature and availability of different biotopes will also influence the total score: a lower diversity of biotopes has been linked to reductions in the total score at a site, particularly where riffle and/or marginal vegetation are absent (Chutter 1995; Dallas 1995). Thus, a high total score may be indicative of good water quality and diverse biotopes available to the biota, while a low score should not be interpreted as indicative of poor water quality alone.

The ASPT indicates whether the community is dominated by sensitive taxa (leading to a high ASPT) or resistant taxa (low ASPT). Further, Chutter (1995) states that the ASPT should not be affected by the absence of available biotope, in cases where the river is relatively unpolluted. Variation in the average score per taxon may be due both to longitudinal changes in characteristics of a river, as well as to anthropogenic perturbation. For example, the uppermost reaches of some rivers have greater numbers of higher-scoring than low-scoring taxa than are found in downstream reaches (Freshwater Research Unit, University of Cape Town, unpublished data). As a guideline for interpreting SASS results, Chutter (1994) recommends that more weight be placed on the ASPTs when ASPT and total scores are relatively high, whereas, when total scores are low, more weight should be placed on them than on ASPT values. Furthermore, where there is little variation in ASPT, but marked differences in the total scores, this may indicate the influence of factors other than water quality on the macroinvertebrate communities present.

With regard to the results for the Riviersonderend and the Breede River (Table 11.2), the sites nearest to Theewaterskloof Dam (Sites 1 and 2), and the sites on the Breede River in September 1995 had fairly low total scores, which may be interpreted as indicating poor to intermediate water. Based on total SASS scores recorded for a number of Western Cape rivers, Dallas (1995) suggests that scores below 85, such as those for Site 1 in both September and January, are indicative of poor water quality, while scores between 86 and 140 indicate intermediate water quality. Water quality investigations at Sites 1 and 2, and algal samples taken during both field visits to these sites, suggest, however, that the water quality is at least as good as the reaches downstream. ASPT values showed little overall variation between sites in both September and January, and this, compared with the marked changes in total scores, implies that the lower total scores are due to the dramatically altered flow regime, rather than poor water quality at these sites. For instance, during the September field visit, a range of biotopes was apparent at Sites 1 and 2, but discharges were very low, thus reducing the availability of this habitat to the biota. At Site 1 in January there was no riffle biotope as a result of high flows, and this had a drastic effect on the total score for this site. The highest ASPT scores, over 7, were recorded at Sites 3 and 6 in September, indicating good water quality at these sites.

Table 11.2 SASS4 total scores, number of taxa, and ASPTs for Sites 1 to 6 on the Riviersonderend, and Sites A and B on the Breede River

SITE	TOTAL SCORE		NO. OF TAXA		ASPT	
	SEP	JAN	SEP	JAN	SEP	JAN
RIVIERSONDEREND						
SITE 1	72	37	12	6	6.0	6.2
SITE 2	104	133	18	23	5.8	5.8
SITE 3	169	154	23	24	7.3	6.4
SITE 4	126	141	19	24	6.6	5.9
SITE 5	171	168	25	25	6.8	6.7
SITE 6	110	83	15	13	7.3	6.4
BREEDE RIVER						
SITE A	103	107	16	19	6.4	5.6
SITE B	108	93	17	15	6.4	6.2

The total scores recorded at Site 3 were greater than the two sites upstream, in both September and January, and fall within the 'good water quality' category of Dallas (1995), in which scores exceed 140. While there were no marked improvements in water quality at this site, compared with Sites 1 and 2, there was a diverse range of biotopes at this site which could support a greater number of macroinvertebrate taxa. The Gobos River, which has its source in the Riviersonderend Mountains and flows partly through the Municipal Nature Reserve at Greyton, joins the Riviersonderend just upstream of this site. Its contribution, of naturally-timed flows, pure water, and possibly invertebrate drift, may play a large role in the fairly natural state of the river fauna. Although the total scores and ASPTs were lower in January than in September, the results of water quality analyses did not show any marked differences between the two visits. However, in January, the river bed in some of the slower-flowing parts was covered with a layer of silt and bacterial growths. It may be that the absence of good winter scouring flows allows for a build-up of this benthic matter, exacerbated by agricultural activities in summer, thus shifting the invertebrate assemblage to one characterised by more tolerant taxa.

Further downstream at Site 4, the total scores and ASPTs were lower than at Site 3, in both September and January, suggesting intermediate water quality (Dallas 1995). Further, the effects of infilling of the river channel in this reach and loss of habitat have been described in Section 4, and this physical alteration to the avilable biotope may have lowered the total scores at this site. Total scores and ASPTs were higher at Site 5 than at Site 4 in both months, indicating good water quality.

The total score at Site 6 was lower than those at Sites 2 to 5 in September, and dropped further in January. Sites 4 and 6 were also characterised by reductions in ASPT in January, but these decreased ASPTs were not lower than other values in this month. The low total score in January at Site 6 may thus have been affected by factors other than water quality. However, the presence of sewage fungus at Sites 4 and 6 in January is an indication of a deterioration in water quality in summer, probably as a result of agricultural pollution (see Section 5.4), with the result that more tolerant taxa comprise the instream fauna.

Scores in the Breede River were fairly low, compared with those recorded for the Riviersonderend, and did not change markedly from September to January.

Dallas (1995) used the SASS4 method to sample the macroinvertebrate faunas of several Western Cape rivers, and a comparison with scores recorded from similar geomorphological zones, is useful here. Sites on the Berg River, within the upper river zone, had a range of total scores between approximately 45 and 95, and ASPTs ranging from 5 to 10, while the lower river total scores ranged from 50 to 70, and ASPTs from 3.5 to 5.5. The Berg River does, however, suffer from severe water quality perturbations in places. Thus, most of the sites on the Riviersonderend, which, broadly speaking, changes from an upper to lower river within the study area, had total scores which far exceeded the Berg River scores, while some of the lower Riviersonderend scores, such as those from Site 1, fell within these ranges.

11.3.2 Provisional species list for the study area

In SASS, the scores assigned to macroinvertebrate families are based on the water quality conditions in which these families can be expected to occur. Interpretation of SASS scores should thus be restricted to assessments of water quality conditions. The list of benthic macroinvertebrates that were collected from the Riviersonderend and Breede Rivers during the field surveys (Table 11.3) allows for a better understanding of the overall state of the river at each site, as individual taxa present, or absent, from a site may indicate aspects of the ecosystem, in addition to water quality, that have changed from the natural condition, for example the flow regime. The taxa collected during the field visits are compared with the list recorded by Coetzer (1986) for the Breede River system.

A total of 58 taxa was recorded in the Riviersonderend below Theewaterskloof Dam during the September field study, and 59 in January. Insect groups dominated at all sites on both rivers, a feature characteristic of western Cape rivers (King 1981). Organic pollution of rivers can lead to this dominance altering in favour of non-insect taxa such as oligochaete worms, flatworms, molluscs and leeches. That this was not the case indicates that the Riviersonderend is not noticeably affected by large loads of organic pollution. The numbers of taxa (identified to species where possible) ranged from between 8 and 14 at Site 1 to 33 at Site 3. With the exceptions of Sites 1 and 6, where less than 20 taxa were recorded during both months, most sites supported a fairly high diversity of tolerant, cosmopolitan species, as well as some more sensitive ones. However, even at Site 6 in January, four baetid species and four trichopteran species were present, including the fairly sensitive philopotamid family (see Table 11.1).

During the September 1995 field visit, the discharges at Sites 1 and 2 were very low. In fact, the DWAF flow data indicate that winter discharges in the vicinity of Site 1 drop lower than 0.1 $m^3 s^{-1}$ for long periods. Thus it is probable that the low diversity of macroinvertebrates at Sites 1 and 2 is due to the dramatically altered flow regime, rather than poor water quality. In January 1996, even fewer species were recorded at Site 1, probably as a result of unnaturally high flows there as a result of irrigation releases. This high discharge, flowing through a narrow gorge as it did at Site 1, resulted in severe physical conditions (i.e. extreme velocities) to which most summer communities in western Cape rivers are not adapted. Taxa, such as the gyrinid coleopterans, that were recorded at Site 1 in January, are those that can tolerate high flows. At Site 2, however, the increased discharge in January made available a wider wetted area and a greater range of biotopes, with the result that macroinvertebrate diversity increased slightly from 21 to 27 taxa.

Many of the taxa recorded in the Riviersonderend were present in both September and January, and the list in Table 11.4 suggests that there was no strong seasonality in invertebrate community structure. This apparent lack of seasonality, particularly in the upper parts of the river closer to the dam, is undoubtedly influenced by the alteration in the flow regime of the river. The presence of the Ephemerellidae (Ephemeroptera) at Sites 3 and 6 in September suggests a degree of seasonality, whilst a number of Baetidae (Ephemeroptera) and hemipteran taxa were collected only in January.

The Riviersonderend is characterised by a large number of mayfly species, including the cosmopolitan *Baetis harrisoni*, and also probably the rarer *Centroptiloides* sp. In 1975 and 1976, Coetzer (1986) recorded similarly large numbers of ephemeropteran species, mostly of the family Baetidae, from the Breede River. Only two species of leptophlebiid mayfly were recorded in this study, and both of these are prevalent in still or slow-flowing waters (Barnard 1932). Eight species of Trichoptera were recorded in the Riviersonderend, while the sensitive *Ecnomus* sp., was restricted to one site on the Breede River. Of the trichopterans that occurred in the Riviersonderend, the Leptoceridae are most sensitive to changes in water quality and quantity (de Moor 1992); and whilst they occur on most substratum types, they prefer fast-flowing water (Scott 1958). Leptocerids were most abundant at Sites 3 and 5, where, as previously noted, a diverse array of biotopes was available in both September and January. The most abundant trichopterans were the Hydropsychidae, especially *Cheumatopsyche afra*, which is tolerant of variable water quality (Dallas and Day 1993).

A few coleopteran taxa such as the gyrinids and limnichids were common in the Riviersonderend. Gyrinid adults are surface swimmers occurring in pools and runs in most river zones, and also in rapid mountain rivers, and are thus tolerant of a wide range in flow conditions. Interestingly, the genus *Orectogyrus* has been thought of as largely restricted to the Highveld, although at least one other record of this group exists from the Breede River system (Molenaars River). Limnichid coleopterans are a littoral group often associated with muddy or sandy water edges (pers. obs.), and these were prevalent in the Riviersonderend, although absent from the Breede River. The coleopteran family Helodidae was absent from both rivers; this family is particularly sensitive to water quality conditions (Freshwater Research Unit, unpublished data).

Species in the dipterans families Simuliidae and Chironomidae are frequently associated with poor water quality, especially in conditions of nutrient enrichment in the case of the chironomids, and where there is an increase in suspended particles, in the case of the simuliids. The chironomids were, however, comparatively poorly represented in all samples, reinforcing the conclusions in Section 5 with regard to concentrations of nutrients in the Riviersonderend. The Simuliidae were abundant only at Site 6 in January. The low abundance of chironomids and simuliids also supports the observationthat the macroinvertebrate community composition in the Riviersonderend has been affected more by flow perturbations than deteriorations in water quality.

Dobsonflies (Megaloptera) and dragonflies (Odonata) comprise the main invertebrate predators in Western Cape rivers, the former dominating the fast-flowing waters of mountain streams and stony foothill rivers and the latter being more prevalent in pools and on aquatic vegetation. Dobsonflies were present only at Site A on the Breede River, but a number of species of odonates were recorded at all sites. The most common of these were the families Coenagrionidae and Aeshnidae, which are climbers on emergent vegetation and prefer pools and slow-flowing waters, and Libellulidae, which prefer very fast-flowing waters (Davies and Day In press.). Coetzer (1986) recorded the presence of two species of odonate in the Breede River, but none in the Riviersonderend.

Leeches were recorded at Sites 1, 2 and 3 on the Riviersonderend, and flatworms of the genus *Dugesia* sp. were found in both the Breede River and the Riviersonderend. The ancylid limpet, *Burnupia* sp., was recorded at all sites, while, of the snails, *Lymnaea* sp. was sampled only at Site 3, and *Physa acuta* only on the Breede River in January. The family Ancylidae was also sampled by Coetzer (1986) in 1975 and 1976 in both the Riviersonderend and Breede Rivers. The mussel of the family Cyrenidae, probably *Corbicula africana*, was found at both sites on the Breede River, and at Site 5 on the Riviersonderend in January. These non-insect taxa are common and generally tolerant of wide ranges of conditions, and do not require water of pristine quality. Most of the snail and limpet groups prefer pools and slower-flowing water, and these were the dominant biotopes downstream of Theewaterskloof Dam, and in the Breede River.

Table 11.3 **Provisional list of benthic macroinvertebrate taxa for the sites sampled on the Riviersonderend (Sites 1 to 6) and on the Breede River (Sites A and B), in September 1995 (denoted by "S") and in January 1996 (denoted by "J").**

		SITE							
		1	2	3	4	5	6	A	B
ANNELIDA									
Oligochaeta		J	J	J	S/J	S	S	S	S
ACARINA									
Hydrachnellae			S		J	S/J			
COLEOPTERA									
Dytiscidae (adults)			J			S			
Dryopidae (adults)				J	J				
Elmidae (adults)				S/J	J	J		J	J
Elmidae (larvae)	sp. A		J	S				J	S/J
	sp. C			J		J		S/J	S/J
Gyrinidae (larvae/adults)	*Aulonogyrus* sp.	S/J	S/J	S/J	S	S/J	S	S	
	Orectogyrus sp.				J	J	J	J	J
Hydraenidae (adults)	*Hydraena* sp.	S		J	S				
Limnichidae (larvae)		S/J	S/J	S/J	S/J	S/J	S		
DECAPODA									
Brachyura	*Potamonautes perlatus*	S/J	S/J	S/J	S/J	S/J	S	S/J	S/J
Palaemonidae									
Palaemoninae	*Palaemon capensis*					S			S/J
DIPTERA									
Athericidae					S	S			
Chironomidae (larvae)									
Tanypodinae		S	S	J					
Chironominae:									
Chironomini	*Chironomus* sp.		J						
Tanytarsini	*Rheotanytarsus* sp.		S	J		J			
Orthocladiinae:	*Polypedalum* sp.		S			S	J		J
	Tvetenia sp.			S					
	Orthocladiinae sp. A								J
	Orthocladiinae sp. AB			S	J	S		S	S/J
Culicidae						J		J	
Psychodidae								J	
Simuliidae (larvae)	*Simulium* spp.	S	S/J	S/J	S/J	S/J	S/J	S/J	S/J
Tabanidae				S	S/J	S		J	

Table 11.3 continued **Provisional list of benthic macroinvertebrate taxa for the sites sampled on the Riviersonderend (Sites 1 to 6) and on the Breede River (Sites A and B), in September 1995 (denoted by "S") and in January 1996 (denoted by "J").**

		SITE							
		1	2	3	4	5	6	A	B
EPHEMEROPTERA									
Baetidae	?*Afroptilum* sp.			J					
	Baetis sp. 1 (*harrisoni*)	S/J	S/J	S/J	S/J	S/J	S/J	S/J	S/J
	Baetis sp. 2			S/J	S/J	S/J	J	S/J	S/J
	Baetis sp. 3	S/J	S/J	S/J		S/J	S		
	Baetis sp. 4		J	J	J		J	S/J	S
	Baetis sp. 5							S	
	Baetis sp. 6			J	J				
	?*Centroptiloides* sp.				J	J	J		
	Cloeon sp.		J						
	Pseodopannota ?*maculosa*					S	S	J	
	Demoulinia sp.	S/J	J		J			S/J	S/J
Caenidae	*Caenis* sp.		S/J	S/J	S/J	S/J	S/J	S	S
Ephemerellidae	*Ephemerellina* sp.						S		
	Lithogloea ?*harrisoni*			S					
	Lestagella ?*penicillata*			S					
Heptageniidae	*Afronurus* ?*harrisoni*		S	S/J		S/J	S		
Leptophlebiidae	*Adenophlebia* ?*dislocans*				S				
	Euthralus ?*elegans*			S/J	S/J	S/J	S	S/J	S/J
Tricorythidae	*Tricorythus* sp.			S/J	J	S/J	J		S/J
HEMIPTERA									
Corixidae			J		S/J	J		J	
Gerridae			J	J		S			
Naucoridae			S/J		S/J			S	
Nepidae	sp. 1		S	S					
	sp. 2					S			
Notonectidae			J						
Veliidae			J	J	J	J	J	J	
HIRUDINEA									
Branchiobdellidae		S	S	S					
MEGALOTERA									
Corydalidae	*Chloriniella peringueyi*							J	
MOLLUSCA									
Ancylidae	*Burnupia* sp.	S	S/J	S/J	S/J	S/J	S/J	S/J	S/J
Cyrenidae	*Corbicula* ?*africana*					J		S/J	S/J
Lymnaeidae	*Lymnaea* sp.		J	S/J	J				
Physidae	*Physa acuta*							J	J

Table 11.3 continued **Provisional list of benthic macroinvertebrate taxa for the sites sampled on the Riviersonderend (Sites 1 to 6) and on the Breede River (Sites A and B), in September 1995 (denoted by "S") and in January 1996 (denoted by "J").**

					SITE			
		1	2	3	4	5	6	A	B
ODONATA									
Coenagrionidae	?*Pseudagrion* sp.		S/J	S/J	J	S/J		S/J	
Chlorocyphidae	*Platycypha* sp.				S	S/J			
Aeshnidae	*Aeschna* spp.	S/J	S/J	S/J	S/J	S/J		S	
Corduliidae	?*Macromia* sp.	S	S/J	J	J	J			
Gomphidae	?*Paragomphus* sp.						S		
Libellulidae	*Zygonyx* sp.	S		S			S/J		S/J
PLATYHELMINTHES	*Dugesia* sp.		J	S/J	S		J	S/J	S/J
TRICHOPTERA									
Ecnomidae	*Ecnomus* sp.								S
Hydropsychidae									
Hydropsychinae	*Cheumatopsyche ?afra*		S	S/J	S/J	S/J	S/J	S/J	
	Cheumatopsyche thomasseti			S/J				S/J	S/J
Macronematinae: Macronematini	*Macrostemum ?capense*			S/J			S/J	S/J	S
Hydroptilidae	*Hydroptila ?capensis*		J			J			S
Leptoceridae									
Leptocerini	sp.		S	S					
	Athripsodes ?bergensis			S					
	Oecetis sp.		J	S/J	J	S/J	J		
Philopotamidae	?*Chimarra* sp.				S	S/J	S/J		

The freshwater shrimp, *Palaemon capensis*, occurred, somewhat surprisingly, at Site 5 on the Riviersonderend, as well as in the Breede River. This is usually found in lower rivers near to their estuaries, and may represent a new distribution record.

11.4 SUMMARY

- The macroinvertebrate faunas of the Riviersonderend downstream of Theewaterskloof Dam, and of the Breede River near its confluence with the Riviersonderend, were sampled in late winter (September 1995) and summer (January 1996) using SASS4, a rapid bioassessment technique.
- Total SASS4 scores for the sites on the Riviersonderend ranged from very low at Site 1, immediately downstream of Theewaterskloof Dam, to good scores further downstream, as far as the Riviersonderend gorge, near the town of Riviersonderend.

- It is likely that the low numbers of macroinvertebrate taxa recorded at Site 1 during both September and January, and at Site 2 in September, were caused by the altered flow regime as a result of the dam, rather than poor water quality, as suggested by the low SASS4 total scores but moderate ASPT values.

- SASS4 total scores were highest at Sites 3 and 5, where water quality was good. Further, all types of biotope were available to the biota at these sites. The Gobos River enters the main channel upstream of Site 3, contributing naturally-timed flows, pure water, and possibly invertebrate drift, which may play a large role in maintaining the fairly natural state of the river fauna, particularly during the wet season. Site 5 is situated close to the gorge near the town of Riviersonderend and is relatively undisturbed.

- The total scores at Sites 4 and 6 during summer conditions indicate a deterioration in water quality compared with winter, probably as a reuslt of agricultural pollution. The ASPTs at these sites, however, changed little compared to other sites, indicating that other factors, such as infilling of the river channel in these reaches, which affect the biotic integrity of the river may be having a greater influence on the macroinvertebrates than water quality.

- A total of 58 taxa was recorded in the Riviersonderend and Breede Rivers during the September field study, and 59 in January. With the exception of Site 1 and, to some extent Site 6, most sites supported a fairly high diversity of both tolerant, cosmopolitan taxa, and some more sensitive species.

- The composition of the macroinvertebrate communities sampled in the Riviersonderend, in many cases, supports the observation that the biota are influenced more by alterations to the flow regime, than by changes in water quality. For example, the chironomid dipterans, which occur in large numbers where there is organic pollution, were not recorded in abundance in the Riviersonderend.

- Many of the taxa recorded in the Riviersonderend were present in both September and January, suggesting a lack of strong seasonality in invertebrate community structure. This apparent lack of seasonality, particularly in the upper parts of the river closer to the dam, is undoubtedly influenced by the alteration in the flow regime of the river.

12. RIVER CONSERVATION STATUS AND IMPORTANCE

12.1 CONSERVATION STATUS

The term *conservation status*, as it is used in this section, refers to the number and severity of anthropogenic perturbations on a river (e.g. Kleynhans *et al.* 1988) and the damage they inflict on the system. These disturbances include abiotic factors, such as water abstractions, weirs, dams, pollution and dumping of rubble, and biotic factors, such as the presence of alien plants and animals.

12.1.1 Methods for determining conservation status

No single method for determining conservation status is presently available for Western Cape rivers, although various methods are being investigated and adapted for use in the region (B.A. Gale, Cape Nature Conservation, pers. comm.). The assessment of conservation status used here is an adaptation of the assessment method proposed by Kleynhans *et al.* (1988) for rivers in the Transvaal. It is based on those abiotic and biotic perturbations (Table 12.1) regarded as primary causes of degradation of a river ecosystem (King 1992). The approaches used at present to assess the conservation 'status' of river ecosystems are continually being updated.

Table 12.1 Abiotic and biotic perturbations regarded as primary causes of degradation of a river ecosystem (King 1992).

ABIOTIC	BIOTIC
Water abstraction	Removal of indigenous riparian vegetation
Extent and impact of weirs	Encroachment of exotic riparian vegetation
Extent and impact of impoundments	Presence of plantations, orchards and cultivated lands along river bank
Impact of roads and bridges on river and riparian zone	Presence of exotic aquatic macrophytes
Litter and rubble	Presence of exotic aquatic fauna
Modifications to river bed and channel	
Erosion of river bank	
Extent and characteristics of flow regulation	
Altered water quality	

Central to the determination of conservation status is an assessment of the degree to which a river is perceived to have been modified from its natural (i.e. undisturbed) state. Other assessments include an assessment of the " habitat integrity" of a river. Habitat integrity is defined as " ... the extent to which a river can maintain a balanced, integrated composition of physico-chemical and habitat characteristics over time and on a spatial scale, compared to the natural ecosystems of the same region ... " (Kleynhans and Engelbrecht 1994). An assessment of habitat integrity of the Riviersonderend was undertaken by Dr Kleynhans as part of this study but forms a separate report. The assessment of both conservation status and habitat integrity allows comparison between the two methods since the former is an adaptation of the latter method, which is intended for assessments of an entire river system, using a helicopter (C.J. Kleynhans, Institute for Water Quality Studies, pers. comm.). Assessments of conservation status, on the other hand, are assessments of anthropogenic disturbance conducted during visits to specific sites on the river. As such, assessments of conservation status have additional value as a form of ground-truthing for the assessment of habitat integrity.

The assessment of conservation status also allows comparison between the results of this study and other similar studies on rivers in the south-western Cape, where only conservation status has been assessed. The methods used here are identical to those used to assess the conservation status of the Wit River, Bain's Kloof (Brown and Tharme 1994), the Du Toit's River, Franschhoek (Tharme and Brown 1994), the Molenaars River, Du Toit's Kloof (Ractliffe and Brown 1994), the Koekoedou and Dwars Rivers, Ceres (Ractliffe and Brown 1995), and the Eerste River, Stellenbosch (Brown and Dallas 1995), and, as such, allow comparison between these rivers.

It is emphasised that the assessments of conservation status of the different reaches of the Riviersonderend presented in this report are preliminary and should be reviewed once methods for the assessment of conservation status and importance, and associated policy issues pertaining to local rivers, have been formalised.

For the current study, and following the methods devised by Kleynhans *et al.* (1988), a **visual** assessment was made of the severity of each of a series of impacts (on a six-point (0-5) scale with 0 indicating no impact, and 5 an extremely severe impact (Table 12.2)), and a score was assigned to each impact. Thus, from Table 12.2, a serious impact would have a scale of 4, and might be allocated a score of 7 or 8. Each impact carries a weighting, depending on its relative importance as a threat to habitat integrity (devised by Kleynhans *et al.* 1988). Thus the total score for each impact is equal to the assigned score multiplied by the weight (see Table 12.4) of that impact.

Scores for biotic and abiotic parameters are summed separately and are expressed as a percentage of the maximum possible value (100%). The resultant scores for biotic and abiotic conservation status, and the overall conservation status score (calculated as the average of the biotic and abiotic scoes) are then used to place the conservation status into a specific descriptive conservation-status class (Table 12.3). Thus, the result of the assessment is descriptive and not quantitative. The general descriptive procedures listed in Table 12.2 were used to score the level of the impact of the variables listed in Table 12.1 for each of the conservation status assessment sites visited during the first field visit in September 1995.

Table 12.2 Summary of the scoring procedures used to determine conservation status.

SCALE OF IMPACT	RATING	DESCRIPTION	SCORE
0	None	no discernible impact, or the factor is located in such a way that it has no impact	0
1	Small	the factor is limited to a few localities and the impact is also very small	1-2
2	Moderate	the factor is present at a small number of localities and the impact is limited	3-4
3	Large	the factor is generally present with a clearly detrimental impact; large areas are, however, not influenced	5-6
4	Serious	the factor is frequently present and almost the whole of the defined section is impacted; only small areas are not influenced	7-8
5	Critical	the factor is present overall with a high intensity; the whole of the defined section is detrimentally influenced	9-10

The final value assigned to each variable was thus calculated as follows:

$$\frac{\text{score}}{\text{maximum value}} \text{ x weight (\%)}$$

where the maximum value in this case = 10.

The respective values for the abiotic and biotic parameters are considered to be an indication of the degree to which the abiotic and biotic conservation status of the river has been modified. These totals are subtracted from 100 to arrive at values which indicate the extent to which the river is still natural. The resultant numbers indicate the abiotic and biotic conservation status.

Finally, these two values were used to place the conservation status into specific **Conservation-Status Classes** (after King 1992, Table 12.3). It should be noted that a reach that scores within 1% of an entirely natural condition, will nevertheless be allocated in a Class 2 status.

Table 12.3 Conservation-Status Classes (after King 1992).

STATUS CLASS	DESCRIPTION
Class 1	100% of potential value; unmodified, natural.
Class 2	80-99% of potential value; largely natural with few modifications. A small change in natural habitats and biota may have taken place, but the assumption is that ecosystem functioning is essentially unchanged.
Class 3	60-79% of potential value, moderately modified. A loss and change of natural habitat and biota has occurred, but basic ecosystem functioning appears to be predominantly unchanged.
Class 4	40-59% of potential value, largely modified. A loss of natural habitat, and taxa and a reduction in basic ecosystem functioning has occurred.
Class 5	20-39% of potential value, seriously modified. The loss of natural habitat, taxa and ecosystem functioning is extensive.
Class 6	0-19% of potential value, modifications have reached a critical level and there has been an almost complete loss of natural habitat and biota. In the worst cases, the basic ecosystem functioning has been destroyed.

12.1.2 Results

O'Keeffe *et al.* (1985), at a workshop on the conservation status of South African rivers, described the Riviersonderend as a river where " ... substantial changes are apparent, such as locally severe pollution, dominant alien species, major water regulations ... ".

The abiotic and biotic factors (definitions of each are available in Kleynhans *et al.* 1988) considered in the current assessment of conservation status, the scores assigned to each, and the present conservation status calculated for each conservation status assessment site (CS1 to CS19) within the geomorphological reaches (as defined in Section 2.2) are provided in Table 12.4, and are plotted in Figure 12.1.

The effects of Theewaterskloof Dam are noticeable along the entire length of the Riviersonderend downstream of the dam. The major effects appear to be two-fold:

1. Retraction of the river channel (particularly the braided sections of the channel) and expansion of palmiet beds, probably as a result of the reduced frequency and reduced size of flood events since construction of the dam, which have been aggravated in the past two years. A consequence of the reduced risk of flooding is that farmers have extended their fields into the river channel, closed secondary channels by bulldozing them and/or utilised the in-channel islands for grazing or crop production.
2. Releases made from the dam for irrigation in the downstream farming areas. This has resulted in a shift in, and possibly even a reversal of, the natural hydrological regime in the river (see Section 3), which can have serious consequences for the river biota.

Apart from the effects of the dam, several types of anthropogenic disturbance were visually identified. These included (in order of decreasing frequency of occurrence):

1. Removal of indigenous riparian vegetation/invasion of the riparian strip by alien trees.
2. Infilling of the river channel to extend cultivated fields.
3. Water abstraction.
4. Closure of small braided channels.
5. Dumping of litter and rubble.

A detailed description of the assessment of the conservation status of each site follows.

A) Upstream of Theewaterskloof Dam

A.1 Geomorphological Reach No. 4: river and wetland section to influence of the dam (Plate 1a and 1b; Table 12.4a)

Although the study area was confined to the Riviersonderend downstream of Theewaterskloof Dam, the conservation status of a site immediately upstream of the dam, in geomorphological reach 4, was also assessed.

CS1. The Riviersonderend upstream of Theewaterskloof Dam and SAFCOL forestry activities

Abiotic Conservation Status = 96 %

Biotic Conservation Status = 95 %

Overall Conservation Status = 96 %

Upstream of the dam, a Department of Water Affairs (H6H008) gauging weir slightly affected its conservation status. Forestry activity downstream of the site appears to have had little effect on the conservation status of the main river. The reasons are two-fold, because the riparian belt is largely undisturbed, and much of the river length in this section is upstream of the forestry activities. The same cannot be said for some of the smaller tributaries, which have been bulldozed or otherwise damaged by forestry activities. The only other disturbance is a hiking trail in the upper reaches of the catchment.

B) Downstream of Theewaterskloof Dam

B.1 Geomorphological Reach 7: lateral confinement through Donkerhoekberge (Figure 2.2a; Plates 2a and 2b; Table 12.4a)

CS2. The Riviersonderend River immediately upstream of the Department of Water Affairs pump at Fisantekraal (including main sampling Site 1)

Abiotic Conservation Status = 64 %

Biotic Conservation Status = 90 %

Overall Conservaton Status = 77 %

Abiotic Conservation Status

The water leaving Theewaterskloof Dam flows through the Keeromspoort, which is largely inaccessible and, probably as a result, the site is relatively undisturbed. There was, however, a reduction in water quality at Site 1 compared to the upstream site, as evidenced by a thin coating of black algae on the rocks and a reduction in water clarity. This was probably an indication of the quality of water released from Theewaterskloof Dam. Also, irrigation releases from the dam, are made throughout the summer (A. Roux, DWAF Western Cape, pers.comm.) and are likely to have major effects on the fauna and flora in the river (see Sections 6 and 11).

- ***Biotic Conservation Status***

The Biotic Conservation Status is affected by the presence of some alien trees on the northern slopes of the gorge, although there was some evidence of attempts to clear this vegetation by hacking. The southern slopes of the gorge, and the riparian belt, appeared to be largely free of alien vegetation.

B.2 *Geomorphological Reach 8: wide, poorly-defined channel through wetlands (Figure 2.2a, b; Plates 3 and 4; Table 12.4a)*

CS3. The Riviersonderend at Helderstroom Prison

Abiotic Conservation Status = 41 %

Biotic Conservation Status = 40 %

Overall Conservation Status = 40 %

Abiotic Conservation Status

This site was assessed from the bridge where the road crosses the river. As was the case at the upstream site, the Abiotic Conservation Status of this reach has been reduced by the presence of Theewaterskloof Dam. In addition, the road bridge impacts on the river, and the banks have been modified by infilling in places, presumably to extend the cultivated fields as far into the floodplain as possible. Although evident at this site in a comparatively limited way, the practice of infilling was evident from this point down the entire length of the river, and has probably become more common since the construction of Theewaterskloof Dam, which has reduced the likelihood of the fields being inundated or washed away by winter flooding. The water quality at the bridge appeared to be poor, as evidenced by the large amount of sewage fungus present where the bridge blocked the flow of water, creating stagnant pools.

Biotic Conservation Status

The dam, and probably also the road bridge, have created hydraulic conditions that have encouraged the spread of palmiet (*Prionium serratum*), which choked much of the channel. Normally, the spread of the palmiet would have been controlled by winter flooding, which would wash away part of the growth and clear the river channels.

There was wholesale removal of indigenous riparian trees, and the cultivated lands extended to the water's edge. These have been replaced in sections by large bands of alien trees, primarily black wattle (*Acacia mearnsii*). The macrophyte growth consisted predominantly of *Aponogeton distachyos*, and there appeared to be very few alien macrophytes in the river. Several exotic fish species, reportedl to occur downstream of the dam, are addressed in more detail in Section 7.

CS4. The Riviersonderend at Middelplaas (including Site 2)

Abiotic Conservation Status = 44 %
Biotic Conservation Status = 29 %
Overall Conservation Status = 37 %

Abiotic Conservation Status

The Abiotic Conservation Status assigned to this reach was slightly lower to that assigned to the previous reach. The effects of the dam remain the same and, as was the case upstream, a road bridge crosses the river. The position and size of the bridge, and the shape of the river banks, suggest that the river has, in the past, experienced large floods. At the time of the winter visit, however, a dirt track ran along the river bank in what used to be the channel, and the dry parts of the river bank were colonised by terrestrial vegetation, predominantly alien trees and shrubs such as *Acacia mearnsii*, *A. saligna*, *A. longifolia*, *A. melonoxylon*, *Sesbania punicea* and *Populus canescens.* As at CS3, the river banks have been filled in to increase the size of the cultivated fields which lined the river. Associated with these fields were loads of rocks that had been cleared from the fields and dumped into or near the river. At the sampling site, part of the right-hand bank had been used as a tip for rubbish, consisting primarily of building rubble and scrap iron. Some of the iron had been thrown into the river. The water appeared turbid, and the rocks were coated with a thin layer of epilithon

Biotic Conservation Status

Much of the indigenous riparian vegetation had been removed, although some patches containing *Salix mucronata* subsp. *capensis*, *Brabejum stellatifolium*, *Rhus angustifolia*, *Cliffortia strobilifera* and *Metrosideros angustifolia* remained. A considerable amount of alien vegetation lined the banks of the river.

CS5. The Riviersonderend immediately upstream of the town of Greyton near Natuskloof

Abiotic Conservation Status = 50 %
Biotic Conservation Status = 43 %
Overall Conservation Status = 47 %

Abiotic Conservation Status

This site was assessed from a point on a farm immediately upstream of Greyton. At the time of the study, at the site where the assessment was done, the left-hand bank of the river had recently been excavated to create a well-point, situated on the edge of the main channel about 0.5 metres from the winter base-flow level of the water. Litter, mostly cigarette packs and beer tins, was strewn along the banks.

Biotic Conservation Status

Some indigenous vegetation remained along the banks at the site, although this was infested with, *inter alia*, *Acacia mearnsii* and *A. longifolia*. In terms of removal of indigenous riparian vegetation, this site did not appear to be as badly degraded as some of the other sites visited during the study, as reflected by the slightly higher biotic conservation status accorded this reach. There were cultivated lands close to the river (farming proteas), but in most cases these were separated from the river channel by riparian vegetation. The presence of this riparian belt of trees is important because it acts as a buffer between the river and the activities in the surrounding catchment. Notwithstanding the degradation of the banks and the alien infestation of the riparian belt, this particular site had considerable rehabilitation potential. The presence of established indigenous riparian vegetation, consisting primarily of *Prionium serratum*, *Metrosideros angustifolia*, *Cliffortia strobilifera* and *Salix mucronata*, is particularly encouraging, since it enhances the rehabilitation potential of this stretch of the river. The river was inhabited by several alien species of fish. At the time of the winter visit, some fisherman visiting the site informed us that they regularly caught largemouthed bass (*Micropterus salmoides*) in the river and that catfish (*Clarias* sp.; probably *C. gariepinus*) of 5 kg were not uncommon.

B.3) Geomorphological Reach 9: well defined channel in wide valley bottom (Figure 2.2b,c; Plates 5 and 6; Table 12.4b)

CS6. The Riviersonderend at Greyton campsite (including Site 3)

Abiotic Conservation Status = 55 %
Biotic Conservation Status = 44 %
Overall Conservation Status = 49 %

Abiotic Conservation Status

This site was situated at the Greyton campsite, where a bridge crossed the river. Upstream of the bridge, the channel was deep and braided with palmiet islands, and downstream of the bridge, the channel was a wide, shallow cobble channel which extended for approximately 50 m downstream before the braided channels continued. The river channel was impacted by the road bridge, and there were clear signs of a reduction in channel width. This is probably the result of a reduction in the size and frequency of channel maintenance floods, as well as upstream abstraction for irrigation, which affected the abiotic status assigned to the river at this site. At the same time, encroachment of alien riparian species into the macro-channel was more limited than at other sites, which may be the result of runoff from tributaries like the Gobos River, which enters the Riviersonderend just upstream of this site. The main channel was evident and, importantly, farming activities had not encroached on the river. Litter was scattered around the site, and in the river, and an old rusted fence hung across the river immediately downstream of the bridge. Nevertheless, the clarity of the water was higher than at other sites visited. In January, however, orange/brown growths were noted on the bed in slow-flowing areas.

Table 12.4a **RIVIERSONDEREND: Abiotic and biotic variables used in the calculation of Conservation Status, and the weighting and score applicable to each variable, for reaches 4, 7 and 8.**

VARIABLE	WEIGHT	REACH 4		REACH 7		REACH 8					
		UPSTREAM OF DAM CS1		KEEROMSPOORT CS2 (=Site 1)		HELDERSTROOM CS3		MIDDELPLAAS CS4 (=Site 2)		NATUSKLOOF CS5	
		Assigned score	Weighted score	Assigned score	Weighted score	Assigned score	Weighted score	Assigned score	Weighted score	Assigned score	Weighted score
ABIOTIC											
Water abstraction	14	0	0	5	7	6	8.4	7	9.8	7	9.8
Extent and impact of weirs	9	4	3.6	0	0	0	0	0	0	0	0
Extent and impact of impoundments	11	0	0	10	11	10	11	9	9.9	9	9.9
Impacts of roads and bridges on river and riparian zone	9	0	0	0	0	8	7.2	9	8.1	0	0
Litter and rubble	5	0	0	0	0	3	1.5	8	4	0	0
Riverbed and channel modifications	12	0	0	0	0	5	6	5	6	6	7.2
River bank erosion	12	0	0	0	0	1	1.2	0	0	5	6
Extent and characteristics of flow regulation	14	0	0	10	14	10	14	8	11.2	7	9.8
Water quality	14	0	0	3	4.2	7	9.8	5	7	5	7
TOTAL			**3.6**		**36.2**		**59.1**		**56.0**		**49.7**
BIOTIC											
Removal of indigenous vegetation	25	0	0	0	0	7	17.5	8	20	6	15
Encroachment of exotic vegetation	23	2	4.6	3	6.9	5	11.5	8	18.4	7	16.1
Presence of plantations, orchards and cultivated lands along river bank	26	0	0	0	0	10	26	10	26	7	18.2
Presence of exotic macrophytes	15	0	0	0	0	0	0	1	1.5	1	1.5
Presence of exotic aquatic fauna	11	0	0	3	3.3	5	5.5	5	5.5	6	6.6
TOTAL			**4.6**		**10.2**		**60.5**		**71.4**		**57.4**

Table 12.4b **RIVIERSONDEREND: Abiotic and biotic variables used in the calculation of present Conservation Status, and the weighting and score applicable to each variable, for reaches 9 and 10.**

		REACH 9						REACH 10					
VARIABLE	WEIGHT	GREYTON CAMPSITE CS6 - Site 3		SANDVLAKTE CS7		SOETKRAAL CS8		HET ZIEKENHUIS CS9		VREDE CS10		LEEUWKRAAL CS11 - Site 4	
ABIOTIC													
Water abstraction	14	7	9.9	8	11.2	8	11.2	8	11.2	7	9.9	8	11.2
Extent and impact of weirs	9	0	0	0	0	0	0	0	0	0	0	0	0
Extent and impact of impoundments	11	8	8.8	8	8.8	8	8.8	8	8.8	8	8.8	8	8.8
Impacts of roads and bridges on river and riparian zone	9	6	5.4	0	0	6	5.4	7	6.3	0	0	6	5.4
Litter and rubble	5	2	1	0	0	0	0	3	1.5	0	0	0	0
Riverbed and channel modifications	12	3	3.6	0	0	9	10.8	9	10.8	0	0	9	10.8
River bank erosion	12	0	0	0	0	6	7.2	6	7.2	4	4.8	6	7.2
Extent and characteristics of flow regulation	14	7	9.8	7	9.8	7	9.8	7	9.8	8	11.2	8	11.2
Water quality	14	5	7	6	8.4	7	9.8	7	9.8	7	9.8	7	9.8
TOTAL			**45.5**		**38.9**		**63**		**65.4**		**44.5**		**64.4**
BIOTIC													
Removal of indigenous vegetation	25	10	25	8	20	8	20	8	20	10	25	10	25
Encroachment of exotic vegetation	23	10	23	10	23	10	23	8	18.4	8	18.4	10	23
Presence of plantations, orchards and cultivated lands along river bank	26	0	0	2	5.2	8	20.8	9	23.4	8	20.8	9	23.4
Presence of exotic macrophytes	15	1	1.5	2	3	0	0	1	1.5	1	1.5	0	0
Presence of exotic aquatic fauna	11	6	6.6	6	6.6	6	6.6	6	6.6	6	6.6	6	6.6
TOTAL			**56.1**		**57.8**		**70.4**		**69.9**		**72.3**		**78.0**

Table 12.4c RIVIERSONDEREND: Abiotic and biotic variables used in the calculation of present Conservation Status, and the weighting and score applicable to each variable, for reaches 11 and 12

		REACH 11						REACH 12					
VARIABLE	WEIGHT	TIYGERHOEK CS12 - SITE 5		RIVIERSONDEREND CS13		GOLF COURSE CS14		AVONTUUR CS15 - SITE 6		KLIPFONTEIN CS16		VANDRIGSDRIF CS17	
ABIOTIC													
Water abstraction	14	7	9.8	9	12.6	9	12.6	8	11.2	10	14	10	14
Extent and impact of weirs	9	0	0	0	0	0	0	10	9	10	9	10	9
Extent and impact of impoundments	11	7	7.7	7	7.7	7	7.7	7	7.7	7	7.7	7	7.7
Impacts of roads and bridges on river and riparian zone	9	5	4.5	4	3.6	0	0	0	0	0	0	7	6.3
Litter and rubble	5	0	0	3	1.5	3	1.5	6	3	0	0	0	0
Riverbed and channel modifications	12	0	0	0	0	0	0	10	12	0	0	8	9.6
River bank erosion	12	0	0	6	7.2	2	2.4	9	10.8	6	7.2	2	2.4
Extent and characteristics of flow regulation	14	7	9.8	7	9.8	7	9.8	7	9.8	8	11.2	9	12.6
Water quality	14	4	5.6	5	7	6	8.4	7	9.8	7	9.8	7	9.8
TOTAL			**37.4**		**49.4**		**42.4**		**73.3**		**58.9**		**71.5**
BIOTIC													
Removal of indigenous vegetation	25	5	12.5	6	15	5	12.5	4	10	10	25	10	25
Encroachment of exotic vegetation	23	7	16.1	9	20.7	9	20.7	8	18.4	10	23	10	23
Presence of plantations, orchards and cultivated lands along river bank	26	4	10.4	0	0	0	0	2	5.2	7	26	6	15.6
Presence of exotic macrophytes	15	0	0	0	0	0	0	0	0	2	3	0	0
Presence of exotic aquatic fauna	11	6	6.6	6	6.6	6	6.6	6	6.6	6	6.6	6	6.6
TOTAL			**45.6**		**42.3**		**39.8**		**40.2**		**60**		**70.2**

Biotic Conservation Status

The indigenous riparian belt had been removed in places, particularly in the vicinity of the campsite, and the existing riparian vegetation consisted primarily of alien trees. This stretch of the river was inhabited by a number of alien species of fish (Section 6), and fishermen at the site reported that they had caught several largemouthed bass, including a gravid female.

CS7. The Riviersonderend at Sandvlakte

Abiotic Conservation Status = 61 %
Biotic Conservation Status = 42 %
Overall Conservation Status = 52 %

Abiotic Conservation Status

This site was assessed from a site on the farm Sandvlakte. The river channel did not appear to have been mechanically modified at this site. There were two small water pumps and one large, solar-powered water pump on the banks of the river, suggesting that water is abstracted, and thus adversely affecting the abiotic conservation status of the site. The water was turbid and water quality appeared to be poor

Biotic Conservation Status

A considerable number of alien species was present in the riparian belt, although some indigenous shrubs, such as *Rhus angustifolia*, *Senecio halimifolius* and *Salix mucronata* remained, as well as some indigenous sedges and herbs. In places, such as near the pumps, the riparian belt had been completely removed. Cultivated fields were not evident immediately adjacent to the river banks, but the area around the pumps appeared to be heavily utilised as a drinking spot for cows. Numerous in-channel islands of palmiet were present slightly upstream of the pump points, in addition to two indigenous macrophytes, *Aponogeton distachyos* and *Nymphaea nouchali*, in the water.

CS8. The Riviersonderend at Soetkraal

Abiotic Conservation Status = 37 %
Biotic Conservation Status = 30 %
Overall Conservation Status = 33 %

Abiotic Conservation Status

This site was assessed from the road adjacent to the Soetkraal. The public road running along the south bank abuts directly on the river at this site, and infilling for the road has probably resulted in some impact on the river. The present channel curves sharply at this point, and the river appears, in the past, to have been braided at this point. At the time of sampling, however, some of the braids had been bulldozed and the remnants of in-channel islands had been cultivated. The water was turbid and slow flowing.

Biotic Conservation Status

The site was accorded a low biotic conservation status because, many sections of the riparian vegetation had been removed, and the remainder was heavily infested with alien trees, such as *Acacia mearnsii* and *A. melanoxylon* and the alien shrub, *Sesbania punicea.*

B.4) Geomorphological Reach 10: multiple channels (Figure 2.2d,e; Plates 7, 8 and 9; Table 12.4b)

CS9. The Riviersonderend at Het Ziekenhuis

Abiotic Conservation Status = 35 %

Biotic Conservation Status = 30 %

Overall Conservation Status = 32 %

Abiotic Conservation Status

This site was assessed from the road which crosses the river, *via* a series of bridges and culverts, near Het Ziekenhuis. The contraction of the river channel was noticeable at this site, and, at the time of sampling, the original floodplain was being used to grow crops and graze cattle. The flow of water in the secondary channels was extremely low and in some instances the channels had been blocked off completely by an expansion of farming activities into the river. What little water there was in these channels was turbid. Even in the main channel (Plate 9a) there had been some infilling of the banks, probably to prevent flooding, and a dense growth of palmiet lined the steeply-sided channel.

Biotic Conservation Status

Compared with some of the previous sites, a relatively high percentage of the riparian belt upstream of the bridge consisted of indigenous vegetation, including milkwoods (*Sideroxylon inerme*), *Rapanea melanophloeos* (Cape beach or boekenhout), yellowwoods (*Podocarpus elongatus*) and wild almond (*Brabejum stellatifolium*). However, on the downstream site of the bridge, there was a greater number of alien trees (*Acacia mearnsii, A. melanoxylon, A. longifolia* and *Sesbania punicea*) in the riparian vegetation, and signs of removal of the riparian vegetation as a result of infilling for cultivated fields.

CS10. The Riviersonderend at Vrede

Abiotic Conservation Status = 56 %

Biotic Conservation Status = 28 %

Overall Conservation Status = 42 %

Abiotic Conservation Status

This site was assessed from the Ponthuis on the farm Vrede. The river consisted of a single wide channel. Some water abstraction was evident in the form of a water pump on the left-hand bank and two windmills on the right-hand bank. There was an oily film on the water surface, but the water was less turbid relative to some of the other sites visited. The presence of the macrophyte, *Triglochin striata*, suggested, however, that salinities were high

Biotic Conservation Status

The biotic status of the river had been compromised by the removal of much of the riparian vegetation and the presence of cultivated fields extending virtually into the river on both sides. Where a riparian belt was present, it consisted of alien invasives, such as *Acacia mearnsii*, *A. saligna*, *A. melonoxylon*, *Quercus robur* and *Sesbania punicea*. The invasion of alien vegetation into the riparian belt had occurred in the last four decades, as evidenced by an aerial photograph of the farm taken in the vicinity of the Ponthuis in 1953 (Plate 10a), in which very few alien trees are visible. The marginal vegetation consisted of palmiet, which was only mildly disturbed in places. The indigenous herbaceous flora was relatively complete.

CS11. The Riviersonderend at Leeuwkraal (including Site 4)

Abiotic Conservation Status = 36 %
Biotic Conservation Status = 22%
Overall Conservation Status = 29 %

Abiotic Conservation Status

The river channel upstream and downstream of this site was slightly braided, with a few in-channel palmiet islands. However, the multiple channels had for the most part been closed for the creation of cultivated fields, or bulldozed, such as the channel immediately upstream of this site (Plates 9e and f) and, at the sampling site, the river formed a single channel bordered on the left bank by a wide belt of palmiet, with a steep right bank that had been raised and filled in to create fields. The resultant narrowing of the channel provided only a pool-run sequence of biotopes. The river channel at this site was sinuous, with evidence of erosion of the right bank, which was probably the result of modifications to the river upstream, such as the road bridge. Water abstraction occurred at the site, as there were two pumps on the right-hand bank. The water was turbid.

Biotic Conservation Status

The indigenous riparian vegetation had been completely removed at this site, and, particularly along the left bank of the river, the riparian belt was heavily invaded by alien trees, such as *Acacia mearnsii*, to the extent that fallen trees often blocked the river channel. Extensive invasions of exotic herbaceous flora, such as Kikuyu grass (*Pennisetum clandestinum*), were evident.

B.5) Geomorphological Reach 11: laterally confined around Riviersonderend town (Figure 2.2e; Plates 10 and 11; Table 12.4c)

CS12. The Riviersonderend at Tygerhoek/Oliphantskloof (including Site 5)

Abiotic Conservation Status = 63 %

Biotic Conservation Status = 54 %

Overall Conservation Status = 59 %

Abiotic Conservation Status

An old road bridge crosses the river at the site. The river in this stretch was cobble-bottomed and formed a single channel. Generally, the river appeared to be less disturbed than at many of the other sites. Some cultivated fields alongside the river were separated from the river by a belt of riparian vegetation. The Olifantskloof, which forms part of the Groot Tygerberge, lies to the north, just upstream of this site, and streams flowing from these mountains contribute runoff to the river at this site. The water was fairly clear.

Biotic Conservation Status

A large number of alien trees (e.g. *A. mearnsii*, *A. melonoxylon*, *A. longifolia*, *Pittosporum undulatum*, *Populus canescens* and *Eucalyptus* sp.) were present at the site, but, encouragingly, also a few indigenous trees (e.g. *Rapanea melanophloeos*, *Ilex mitis* and *Kiggelaria africana*). The marginal vegetation consisted mainly of indigenous sedges of the families Cyperaceae (e.g. *Isolepis prolifer*, *Cyperus texilis* and *C. denudatus*) and Juncaceae (e.g. *Juncus lomatophyllus* and *Prionium serratum*).

CS13. The Riviersonderend in the Riversonderend Gorge

Abiotic Conservation Status = 51 %

Biotic Conservation Status = 58 %

Overall Conservation Status = 54 %

Abiotic Conservation Status

The conservation status of this site was assessed from a fishing spot, opposite to the Olifantsrivier tributary in the Riviersonderend Gorge. No farming activities occurs immediately adjacent to the river, and the area appears to be used primarily for recreational activities. A considerable amount of 'picnic' litter (cigarette boxes, beer cans, etc.) was present at the site. Water clarity was poor.

Biotic Conservation Status

The entire right-hand bank of the river was heavily infested with *Acacia mearnsii* and *Eucalyptus* sp., but slopes of the catchment on the left-hand side of the river, with the exception of the riparian belt, appeared to be largely free of alien plants. A narrow band of *Prionium serratum* and *Salix mucronata* was present. The lack of channel-scouring floods was evident at this site, where a small tributary has deposited a large quantity of fine alluvium in the channel. This has resulted in the main channel being slightly diverted, and some undercutting of the right-hand bank has occurred. Before the construction of Theewaterskloof, this material would, presumably, have been redistributed during large flood-events.

CS14. The Riviersonderend upstream of the Riviersonderend golfcourse

Abiotic Conservation Status = 58 %
Biotic Conservation Status = 60 %
Overall Conservation Status = 59 %

Abiotic Conservation Status

This site was assessed from a picnic site on the river near the Riviersonderend Golf Course. Judging from the number of people (*ca* 70) at the site at the time of sampling, it is a popular recreation spot, despite its inaccessibility. There were no ablution facilities available at the site, with the result that, apart from the area immediately adjacent to the river, the entire area smelt of human excreta. The water was fairly clear, probably benefitting from the relatively pure water of the Tierkloof tributary, which enters the main river at this point. The banks were rocky and relatively undisturbed.

Biotic Conservation Status

There was a considerable amount of alien vegetation (e.g. *Acacia mearnsii* and *A. longifolia*) at the site, although a number of indigenous species, such as *Brabejum stellatifolium*, *Halleria elliptica*, *Prionium serratum* and *Diospyros glabra* were present.

B.6) Geomorphological Reach 12: wide, poorly-defined channel through flat wetlands (Figure 2.2 e,f,g; Plates 12, 13 and 14; Table 12.4c)

CS15. The Riviersonderend at Avontuur (Stormsvlei; including Site 6)

Abiotic Conservation Status = 27 %
Biotic Conservation Status = 60 %
Overall Conservation Status = 43 %

Abiotic Conservation Status

A 1.75 m-high weir completely blocked the main river channel at this site, and the river was diverted, through a sharp bend, over an old cobble road to the weir and into a secondary channel before rejoining the main channel *ca* 100 m downstream. The result was evidenced by the fact that, at the time of sampling, extensive erosion was occurring to the outward bank of the bend in the secondary channel. The water was fairly clear in September, but moderately turbid in January, and there was a considerable number of fallen dead trees in the water, probably as a result of the erosion.

Biotic Conservation Status

The riparian vegetation along the left-hand bank consisted predominately of alien vegetation (*A. mearnsii*) whilst extensive stands of palmiet (*Prionium serratum*) and reeds (*Phragmites australis*), together with *Cliffortia strobilifera*, occurred within the old channel. The old channels along the left-hand bank still supported a fairly rich mixture of indigenous species, despite the area being heavily grazed. Typical species included *Rhus laevigata*, *Putterlichia pyracantha*, *Senecio iraefolia*, *Leonotis leonurus* and *Pennisetum macrourum*.

CS16. The Riviersonderend at Klipfontein

Abiotic Conservation Status = 41 %
Biotic Conservation Status = 40 %
Overall Conservation Status = 41 %

Abiotic Conservation Status

The conservation status of this site was assessed from the farm Klipfontein, where the river channel was wide, deep, and slow-flowing as a result of backflooding from an abstraction weir situated *ca* 500 m downstream of the site. The river banks were disturbed, with areas of bare sand in places, particularly under the gum trees, and some rubble had been dumped along the river's edge. Cultivated fields extended to the water's edge on the left-hand bank. A large pump, with multiple offtakes, was situated just downstream of the site, at the weir. The water was fairly turbid.

Biotic Conservation Status

The aquatic *Nymphaea nouchali* grew in the water along the margins of the river, and the stand of *Prionium serratum* was largely submerged at the time of sampling as a result of the above-mentioned backflooding. The riparian vegetation consisted primarily of *Eucalyptus* spp. with bare soil beneath the trees. At the time of sampling, the entire portion of the catchment adjacent to the right-hand bank had just been planted with *ca* 500 000 pine, gum, blackwood and Australian chestnut trees (Klipfontein owner, pers comm.).

CS17. The Riviersonderend at Vaandrigsdrif

Abiotic Conservation Status = 29 %
Biotic Conservation Status = 30 %
Overall Conservation Status = 29 %

Abiotic Conservation Status

The conservation status was assessed from a bridge crossing the river at Vaandrigsdrif. This site used to be a braided section of the Riviersonderend but in September was confined to a single channel. All the secondary channels had either been cut off from the river or empty because there was insufficient water left in the river to fill them. It appeared that any high flows reaching this far downstream had insufficient force to maintain the braided nature of the river, but were contained in a single channel. The impact of reduced winter flows, as a result of Theewaterskloof Dam, combined with upstream abstraction of water, was marked at this site in September, the river having been reduced to a small stream with a width of *ca* 7 m and a flow rate of *ca* 0.3 m s^{-1}, less than a fifth of that measured at Site 6. There was also an old, disused irrigation ditch running parallel with a dry secondary channel. Presumably this used to transport water from an upstream weir. The islands that would have occurred between the braided sections of the river showed signs of having been used for farming activities, but were now abandoned.

Biotic Conservation Status

Alien vegetation, especially *Eucalyptus* spp., predominated across the entire stretch of what used to be the braided section of the river,. The marginal vegetation in the remaining channel consisted of palmiet (*Prionium serratum*) but even this was, literally, being left high and dry in the winter as a result of reduced baseflows.

Figure 12.1 summarises the overall conservation status for each geomorphological reach of the Riviersonderend. Upstream of the dam, the river is in good condition, with the exception of some forestry activities. The status of the river deteriorates downstream of Theewaterskloof Dam, as a

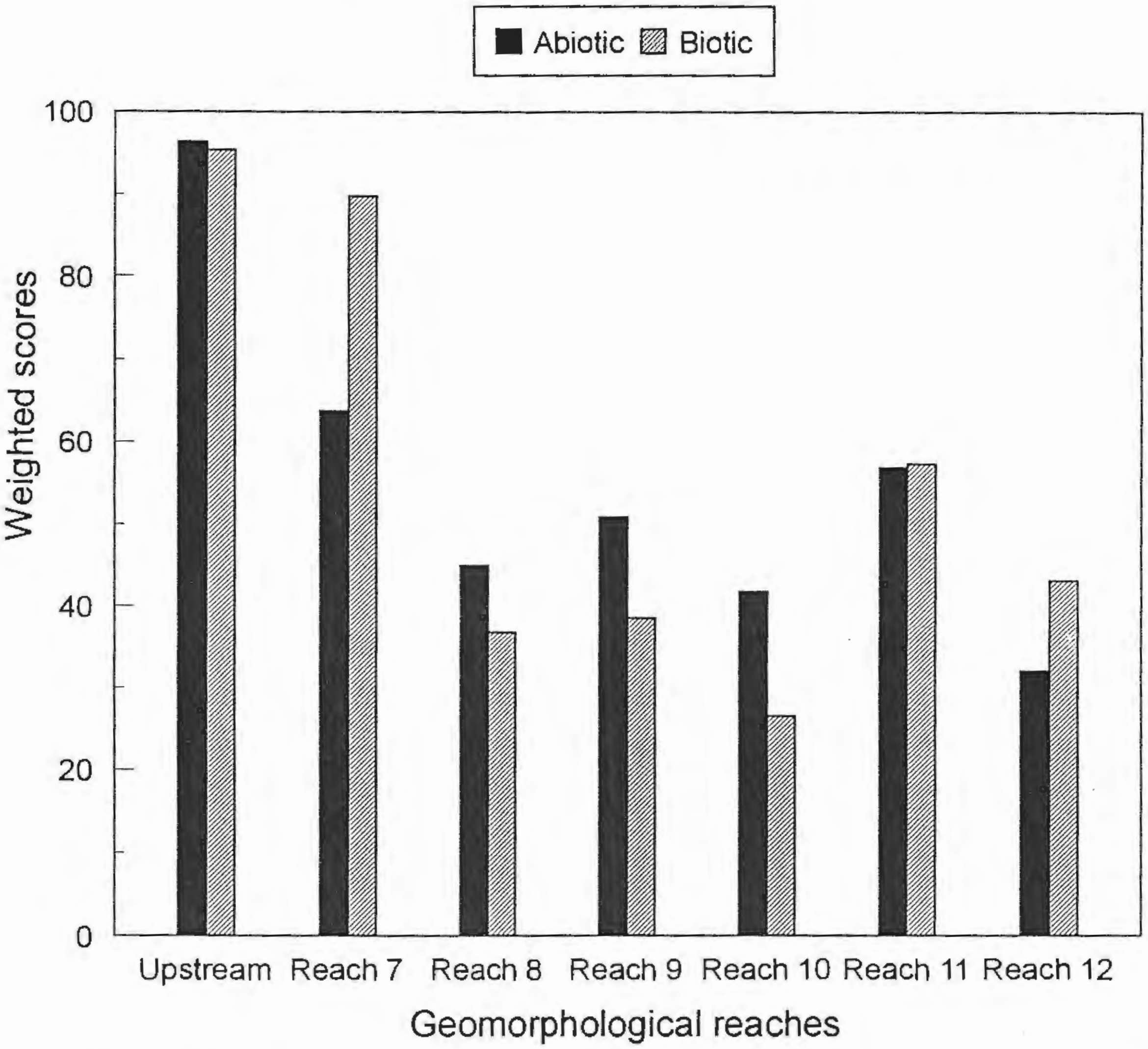

Figure 12.1 **The Abiotic and Biotic Conservation Status for the Riviersonderend upstream of Theewaterskloof Dam, for Reach 4, and downstream of the dam, for Reaches 7 to 12.**

direct result of the dam, in particular of its extreme alteration to the hydrological regime. The fact that the river flows through a narrow gorge just downstream of the dam, protects it from the additional impacts of farming activities, which make their presence felt from Reach 8, where the overall conservation status is only 41 %. Downstream, as the influence of the Riviersonderend Mountains ameliorates the extreme flow patterns, the condition of the river improves somewhat (Reach 9: overall conservation status of 44.7 %), although the accumulative effect of farming activities become dominant (Reach 10: overall conservation status of 34.3 %). The Riviersonderend Gorge provides some relief to this degradation, as a result of the undeveloped areas to the north of the river (Reach 11: overall conservation status of 57.2 %), but from here the river deteriorates steadily (Reach 12: overall conservation status of 37.7 %) to its confluence with the Breede River.

BREEDE RIVER

CS18. The Breede River at "The Abbey" upstream of its confluence with the Riviersonderend (including Site A; Plate 15; Table 12.4d)

Abiotic Conservation Status = 48.7

Biotic Conservation Status = 61.9

Overall Conservation Status = 55.3

Abiotic Conservation Status

The road has affected the river both at the bridge and in places along its right-hand bank. In addition, an old, disused causeway was evident across the river on the downstream side of the bridge. Dead trees were caught against the bridge and rubble had been dumped on both banks. The left bank had been filled in to extend cultivated fields, and the right bank filled in for the road. Both banks were very disturbed, the left bank particularly so. The banks were sandy, with some erosion evident in places. The water was was fairly clear. Some of the algae recorded at the site are, however, associated with high nutrient levels and elevated conductivities.

Biotic Conservation Status

Large patches of *Potamogeton pectinatus* were present. *Salix mucronata* lined the banks and patches of *Phragmites australis* were also present. Much of the riparian vegetation had been removed from the banks, and this had been replaced by alien invasives such as *Acacia mearnsii*, *A. saligna* and *Sesbania punicea*. A few *Olea europaeae* (wild olive) trees were present on the banks. At the time of sampling, bluegill sunfish and largemouth bass were seen in the water.

CS19. The Breede River at the DWAF gauging weir H7H006 - downstream of its confluence with the Riviersonderend (including Site B; Plate 16; Table 12.4d)

Abiotic Conservation Status = 48.2

Biotic Conservation Status = 58.1

Overall Conservation Status = 53.2

***Abiotic Conservation Status*:**

The river was affected by the DWAF gauging weir, which severely altered the natural flow of the river by forcing the water through two small channels. This resulted in a change in the direction of the river and armouring of the river bed immediately downsteam of the weir. In addition, cultivated fields extended down to the water on the left-hand bank.

Table 12.4d BREEDE RIVER: Abiotic and biotic variables used in the calculation of present Conservation Status, and the weighting and score applicable to each variable - Sites CS 18 - CS 19.

		SITE A THE ABBEY		SITE B DWAF GAUGING WEIR H7H006	
VARIABLE	WEIGHT	CS18		CS19	
ABIOTIC					
Water abstraction	14	7	9.8	8	11.2
Extent and impact of weirs	9	0	0	8	7.2
Impacts of roads and bridges on river and riparian zone	11	7	7.7	3	3.3
Litter and rubble	9	5	4.5	0	0
Riverbed and channel modifications	5	5	2.5	7	3.5
River bank erosion	12	5	6	4	4.8
Extent and characteristics of flow regulation	12	7	8.4	7	8.4
Water quality	14	7	9.8	7	98
TOTAL			**48.7**		**48.2**
BIOTIC					
Removal of indigenous vegetation	25	9	20.7	9	20.7
Encroachment of exotic vegetation	23	5	11.5	4	9.2
Presence of plantations, orchards and cultivated lands along river bank	26	5	13	5	13
Presence of exotic macrophytes	15	6	9	5	7.5
Presence of exotic aquatic fauna	11	7	7.7	7	7.7
TOTAL			**61.9**		**58.1**

***Biotic Conservation Status*:**

A considerable amount of the submerged macrophytes, *Ruppia* sp. and *Myriophyllum* sp., and water hyacinth (*Eichornia crassipes*), were growing in the backwater areas, suggesting slight eutrophication of the river at this site and low current speeds. The riparian vegetation, where present, was invaded by alien species (e.g. *Sesbania punicea* and *Acacia saligna*) although some indigenous plants, particularly *Acacia karoo*, *Salix mucronata* and *Prionium serratum*, were present.

***Biotic Conservation Status*:**

A considerable amount of the submerged macrophytes, *Ruppia* sp. and *Myriophyllum* sp., and water hyacinth (*Eichornia crassipes*), were growing in the backwater areas, suggesting slight eutrophication of the river at this site and low current speeds. The riparian vegetation, where present, was invaded by alien species (e.g. *Sesbania punicea* and *Acacia saligna*) although some indigenous plants, particularly *Acacia karoo*, *Salix mucronata* and *Prionium serratum*, were present.

12.2 CONSERVATION IMPORTANCE

Conservation importance refers to the importance of conserving a particular ecosystem based on its naturalness and uniqueness, and the diversity of its fauna and flora. Other criteria may also apply if, or example, rare or endangered species are present, or if the ecosystem has been the focus of considerable scientific endeavour (J.M. King, Freshwater Research Unit, University of Cape Town, pers. comm.). The term should not be confused with *conservation status* as defined in Section 12.1.

At present there are few formalised methods for determining conservation importance (Kleynhans *et al.* 1988) and those that do exist are somewhat controversial. Moreover, the assignment of a conservation-importance rating to a river is highly dependent on the *stated conservation objectives* for the river concerned.

Factors affecting the conservation importance of the Riviersonderend might include its size and length, since there are only a few other rivers of a similar size in the south-western Cape. Its proximity to the towns of Genadendal, Greyton and Riviersonderend means that it should have both educational and recreational value for those towns.

12.3 SUMMARY

- Upstream of the dam, the Riviersonderend is in good condition, except in limited stretches where forestry activities have degraded the riparian belt, and the river was assigned a high conservation status.
- Downstream of the dam, in geomorphological reach 7, the riparian zone on the river channel are relatively undisturbed. Theewaterskloof Dam has, however, had considerable impact on the flow regime.

- Downstream of Keeromspoort the river is subjected to considerable anthropogenic pressure. The effects of Theewaterskloof Dam are noticeable along the entire length of the Riviersonderend downstream of the dam. Contraction of the river channel (particularly the braided sections of the channel) and expansion of palmiet beds are evident, and probably result from the reduced frequency and size of flood events in the river since the construction of the dam.
- Because of the reduced risk of flooding resulting from the presence of Theewaterskloof Dam, farmers have extended their fields into the river channel, have bulldozed secondary channels and/or are utilising the in-channel islands for grazing or crop production. Furthermore, releases made from the dam for irrigation in the downstream farming areas have resulted in a shift in, and possibly even a reversal of, the natural hydrological regime in the river, which can have serious consequences for the river biota.
- Several other types of direct and indirect anthropogenic disturbance were identified. These included removal of indigenous riparian vegetation, invasion of the riparian strip by alien trees, infilling of the river channel to extend cultivated fields, run-of-river abstraction, closure of small braided channels, and dumping of litter and rubble.
- Consequently, the lower reaches of the Riviersonderend were assigned low conservation status values.
- Nowhere below Keeromspoort (Site 1) was the riparian vegetation in a reasonable state. It was all highly disturbed and invaded.
- Factors affecting the conservation importance of the Riviersonderend might include its size and length, since there are only a few other rivers in the south-western Cape of similar size. Its proximity to the towns of Genadendal, Greyton and Riviersonderend means that it should have both educational and recreational value for those towns. As such, the river might be accorded a high conservation importance.

13. SYNTHESIS

13.1 GENERAL CHARACTERISTICS OF THE RIVIERSONDEREND

The Riviersonderend is a perennial river that rises in the Hottentots-Holland Mountains before flowing into Theewaterskloof Dam. Downstream of the dam, and for some 120 km, the river flows through a wide valley below the foothills of the Riviersonderend Mountains. It then joins the Breede River near Swellendam. Downstream of Theewaterskloof Dam, the Riviersonderend can be divided into six distinct geomorphological reaches. Each reach exhibits a distinctive channel morphology, substratum type and proportions of different biotopes.

Immediately downstream of the dam, the river flows through the Donkerhoekberge, and the channel becomes laterally confined between quartzitic sandstone cliffs. Although the presence of Theewaterskloof Dam appears to have had a considerable impact on the flow regime of the river in this reach, it is largely inaccessible and thus has the highest conservation status along the river, in terms of its natural channel morphology and riparian vegetation and, to some extent, its water quality.

Downstream of this reach, the valley opens out and the river channel is poorly defined as it flows though flat wetlands for some 16 km. Flow regulation, particularly in winter, has considerably affected this reach, as has its locality agricultural lands. The overall conservation status of the river in this reach is lower than that of the reaches immediately downstream of the dam because of a deterioration in water quality and the invasion of the riparian belt by alien plants.

In the next reach, near Genadendal, the river changes again, and is characterised by a well-defined river channel, flowing along a wide, predominantly sandstone and shale, valley floor. There is an improvement in water quality and some indigenous riparian species persist along this reach. Runoff from the Gobos River, which enters the Riviersonderend within the reach, balances, to some extent, the effects of water abstraction for irrigation and flow regulation, leading to a marked increase in the abiotic conservation status.

Still further downstream, the river enters a zone which is characterised by multiple channels, with in-stream palmiet islands and long runs and pools. Many of the channels have been filled in for agricultural purposes, and the riparian zone is heavily infested with alien trees. Hence, this reach achieved the lowest overall conservation status.

The state of the river improves, in terms of biotic and abiotic components, as the river enters the gorge near the town of Riviersonderend. Bankside activities are limited because of the narrowing of the valley through the gorge. Deposition of alluvial material from the Riviersonderend Mountains, which form the northern slopes of the river in the gorge, has led to a heterogeneous river bed and, thus, to an array of biotopes available for the river biota. Consequently, the conservation status of this laterally-confined reach is higher than that in the two reaches upstream.

The final reach, before the Riviersonderend joins the Breede River is once again characterised by a wide, poorly-defined channel flowing through flat wetlands. The river in this reach has become largely confined to a channel flowing through a band of eucalyptus and acacia trees, as a result of encroachment of agricultural activities into the macro-channel, and the conservation status is fairly low.

Along the entire length of the river, deep, slow-flowing runs form the dominant biotope; limited stretches of riffle biotope are available to the riverine biota, particularly in the reaches where infilling has created a much narrower and deeper channel.

Various anthropogenic disturbances are noted in the Riviersonderend catchment. Wheat-farming is the dominant agricultural activity in the area, although some stock-farming is also practised. In many places these activities are encroaching into the river channel, and cultivated fields extend right up to the river margins, which are often altered to allow for the creation of fields. This physical interference with the riparian zone of the river has allowed the invasion of alien trees and shrubs, which are evident along the length of the river, but especially in the lower reaches and where the river braids into multiple channels.

Notwithstanding the fact that the river flows through agricultural lands for much of its length, water quality in the Riviersonderend is relatively good. There are signs of occasionally high salinities in the lower reaches of the river, but this is far less of a problem than in the Breede River.

13.2 THE IMPACTS ON THE RIVIERSONDEREND AS A RESULT OF THEEWATERSKLOOF DAM

Theewaterskloof Dam has had a major effect on the flow regime of the river, especially in the reaches closest to the dam. Several components of the natural flow regime have been altered or removed. For example, the seasonality of flow has been changed, leading to flood-flows at inappropriate times of the year (e.g. at the end of the wet season when the dam spills). The magnitude and number of floods are now insufficient for the maintenance of the channel morphology and prevention the encroachment of of marginal vegetation. Furthermore, baseflows are too low in winter and, in some cases, too high in summer, to sustain many of the invertebrates that should be present in the river, and the transitional periods between the dry and wet season have been removed completely from the flow regime.

These alterations are particularly evident in the upper reaches of the river during the winter months, when baseflows are low and the contributions from winter rainfall are evident only in the lower reaches. In summer, releases for irrigation are gradually balanced by abstraction with increasing distance downstream of the dam, and, near the confluence with the Breede River, over-abstraction is compensated for by summer rainfall, or at least this appeared to be the case during the period in which this study was conducted.

As an inevitable consequence of lower flows and the lack of scouring floods, the width of the river has been reduced considerably relative to its undisturbed state. This has, in turn, allowed farmers to cultivate the river banks, which are now unlikely to flood with any regularity. In addition, the permanently-dry and often physically-altered banks of the river are ideal habitat for invasion by alien plants, such as *Acacia mearnsii* and *Sesbania punicea*.

The invertebrate communities sampled at the sites nearest the dam reflect the poor biotic status of the river. The fact that the water quality in these reaches is more dilute than in downstream reaches, and appears to be natural, indicates that these communities have been affected by the dramatic alteration of the flow regime rather than by decreases in water quality. Further downstream, flows tend to be less affected by the presence of the dam, partly as a result of contributions to runoff from the Riviersonderend Mountains. The invertebrate communities in these reaches also tend to be more diverse, consisting of typical western Cape fauna, including sensitive taxa such as some mayflies, beetles and caddisflies. In the lower reaches, close to the confluence of the Riviersonderend and Breede River, however, agricultural activities result in considerable degradation of the riverine biota.

13.3 POTENTIAL IMPACTS OF RAISING THEEWATERSKLOOF DAM ON THE RIVIERSONDEREND

The continued ecological integrity or level of naturalness of the Riviersonderend is not guaranteed. At present, the river shows a some recovery downstream of the dam, if only in the middle reaches. An increase in irrigation demand and releases, however, coupled with increased use of Theewaterskloof Dam for municipal water supply would almost certainly extend the impacts of the dam further downstream. Also, further development of the water resources of the tributaries draining the Riviersonderend Mountains, should occur, would remove the single most important factor that allows the river to maintain its present state.

Maintenance of the current state of the Riviersonderend should be the minimum objective of sound river management, but further degradation can be mitigated against by the provision of water to simulate the natural flow regime, with its wet, dry and transitional periods, and scouring flows in winter. Furthermore, irrigation demands need to be re-evaluated, along with an investigation of alternatives to spray irrigation. Finally, removal of aliens would not only help to restore the natural vegetation of the riparian belt, but would considerably increase runoff in the river during summer, which would mitigate against the effects of increased run-of-river abstraction of water from the lower reaches of the river.

The Department of Water Affairs and Forestry (DWAF) has stated that it is committed to the management of rivers as resources (DWAF White Paper, 1994c), and this implies that the river should retain its basic natural ecological functioning. An appropriate flow regime is central to sound management of a river as an ecosystem, and it is our recommendation that the Instream Flow Requirements (IFR) of the river should be determined, and the attainment of this IFR included in the management objectives for the river, as outlined by Ninham Shand Inc. (NSI). If DWAF has the intention of implementing a policy of ecologically sound management of rivers, then an IFR would be a necessary action irrespective of whether the raising of Theewaterskloof Dam is investigated further.

The future scenario in terms of water supply in the Western Cape has been outlined by Ninham Shand Inc. (Mr K de Smidt, NSI, Cape Town), and includes increased releases of irrigation water into the Riviersonderend during summer, in addition to maximum annual yields from dams in the region, through minimising winter spillage. If management to maintain the river as a functioning riverine ecosystem is undertaken, and appropriate releases made throughout the year for the river, it would probably be unnecessary to increase the current storage capacity of Theewaterskloof Dam.

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