DRAFT DESKTOP REPORT:

THE ECOLOGIGICAL IMPORTANCE AND SENSITIVITY OF THE LOWER ORANGE RIVER DOWNSTREAM OF 20º LATITUDE TO THE ORANGE-FISH RIVER CONFLUENCE

1. FLOW AS ECOLOGICAL/ENVIRONMENTAL DRIVING FORCE

The Orange River System (ORS) has a catchment area exceeding 1 000 000km^2 (McKenzie & Schäfer, 1990), and is naturally divided into upper (origin to Orange-Vaal confluence), middle (Orange-Vaal confluence to Aughrabies Falls) and lower (Aughrabies Falls to river mouth) sections (Wellington, 1933). The ORS had recently been re-divided into upper (origin to Orange-Vaal confluence) and lower (Orange-Vaal confluence to Orange River Mouth) Orange River, with the Vaal River re-divided into upper, middle and lower Vaal (Department of Water Affairs and Forestry, 2002). Of the ORS's total catchment's average annual run-off of 11 900X10^{6}m^3, the present lower Orange River (the combined previous middle and lower river stretches) contri-butes 210X10^{6}m^3 (1,8%) of water (Kriel, 1972).

In an analysis of the median monthly flows in the previously termed middle Orange River, with Boegoeberg Dam as point of reference, Benade (1993), using data from 1914-01-01 to 1989-04-30, calculated that the ORS's natural flow patterns showed an 82% summer (October to May)/18% winter (May to October) distribution. Minimum flow occurred during August (Wellington, 1933; Chutter, 1973; Benade, 1993) and maximum flow during February (Tomasson & Allanson, 1983; Benade, 1993), showing erratic flow peaks coupled with high silt loads (Tomasson & Allanson, 1983).

Statistically the ORS appears to display a one in 10 to 15 year episodic flood cycle (Benade, 1988), but floods can also occur every five to 10 years (Department of Information, 1971). Annual flow as well as floods and flow cessations are totally unpredictable due to the fact that rainfall in the catchment is extremely erratic and can at times be restricted to only certain sections of the catchment (Benade, 1988). Flow records, dating back to November 1913, indicate the maximum run-off for any particular hydrographic year to be 19 431X10^{6}m^3 (163% of the mean) (Oct. 1924 to Sep. 1925), with a minimum of 1 275X10^{6}m^3 (11% of the mean) (Oct. 1948 to Sep. 1949) (Kriel, 1972). Despite such extremes, the ORS displays a natural flow pattern and resilience, which provided the framework within which its ecosystem evolved a seasonal status regarding its most important abiotic factors, ***i.e.*** flow, temperature, oxygen, turbidity (including suspended solid transport), mineral content and probably also pH (Benade, 1993). Episodic flood events serve as driving forces behind the ecological functioning of the system (Benade, 1988), as do minor to medium maintenance floods (Benade, 1993).

Since the Vanderkloof Dam became operational in 1977, the natural flow regime of the middle Orange River has become greatly damped, changing to a 59% summer/41% winter flow distribution (Benade, 1993). Together with the Gariep Dam, the Vanderkloof Dam also has a damping effect on floods in the lower Orange River as these two impoundments are capable of totally or partially absorbing the minor to medium floods required for ecological/environmental maintenance (Benade, 1993).

2. AN ECOLOGICAL DESCRIPTION OF THE ORANGE RIVER, WITH REFERENCE TO THE SECTION 20º LATITUDE TO ORANGE-FISH CONFLUENCE

2.1 PHYSICO-CHEMICAL COMPONENTS

2.1.1 ***Temperature***

Benade (1993) found a general downstream winter/summer convergence in the surface water temperatures in the Orange River stretch between Aughrabies Falls and the Orange River mouth. A downstream drop in summer temperature in this river stretch is probably due to cooling caused by progressive, extremely high, downstream evaporation, while a downstream winter temperature increase is probably due to an east/west increase in atmospheric temperature (Benade, 1993).

2.1.2 ***Oxygen***

The Aughrabies Falls, as well as the numerous rapids found in the study area have an extremely positive influence on the river's oxygen content, which, in turn, is needed by the aquatic biota (Benade, 1993).

2.1.3 ***pH***

Benade (1993) found the pH in the study area to be slightly alkaline, between 7,2 and 8,4. Higher pH values were particularly recorded where samples were taken at localities situated next to, or just downstream of intensively cultivated riparian stretches.

2.1.4 ***Turbidity***

Turbidity is an indication of water transparency/light penetration and is determined by the presence/absence of suspended silt and/or organic matter. The combination of low flows (a result of river regulatory structures, ***i.e.*** dams), high evaporation rates and high mineral content (agricultural and other pollution) usually results in suspended solid precipitation, which leads to riverbed degradation (Benade, 1993).

2.1.5 ***Conductivity***

Conductivity is an indication of the total mineral content of a water body. Benade (1993) found a gradual increase in downstream conductivity, with peaks within and/or just downstream of riparian irrigation sections.

2.2 BIOLOGICAL COMPONENTS

2.2.1 Vegetation

2.2.1.1 ***Floodplain vegetation***

For the purpose of this report, the term floodplain vegetation focuses on the terrestrial type shoreline and island vegetation occurring within the study area's floodplain. Because of the inaccessibility of the floodplain along various stretches of the study area's main river channel as a result of its mountainous character, the author had observed quite a number of technically pristine stretches of shoreline and island vegetation during aerial surveys in the past.

2.2.1.3 ***Aquatic microphytes and aquatic and semi-aquatic macrophytes***

Filamentous Phycophyta (***e.g. Spirogyra*** spp.) are fairly abundant in the side streams of the lower Orange River, and the blue-green alga (Cyanophyceae), ***Gloeotrichia natans***, occurs in the lower stretches of this river section (Benade, 1993).

The American floating water fern, ***Azolla filiculoides***, related to the pest species ***Salvinia molesta*** (Kariba Weed), grows at its best in sheltered, lightly shaded places (Jubb, 1972; Ashton, 1974). Like ***Salvinia***, it is capable of rapidly colonizing open water surfaces (Ashton, 1974). This species is particularly noticeable in the lower Orange River downstream of Boegoeberg Dam, where it commensalistically obtains shelter from ***Phragmites*** reeds (Benade, 1993).

Benade (1993) observed the presence of the Broad-leaved Pondweed, ***Potamogeton schweinfurthii***, the Fennel-leaved Pondweed, ***P. pectinatus***, the Curled Pondweed, ***P.***

crispus, and the Willow-herb, ***Ludwigia stolonifera*** in the study area. Of possible concern is the presence of ***P. crispus***, which has been described as a plant providing habitat for the snail intermediate hosts of ***Schistosoma*** spp. (bilharzia) (Botanical Research Institute, 1980).

The river reed, ***Phragmites australis***, is the dominant semi-aquatic macrophyte along the whole of the Orange River, flourishing relatively short distances downstream of the start of irrigation areas (Benade, 1993). However, reed communities are less abundant along the watercourse of the study area than in the Orange River section between Boegoeberg Dam and Aughrabies Falls (Benade, 1993) because of much less riparian agricultural activities along the study area river stretch as a result of the mountainous nature and inaccessibility of large sections thereof.

The smoother flow in the lower reaches of the lower Orange River, with resulting precipitation of suspended matter, enhances light penetration and a consequent increase in the diversity of aquatic and semi-aquatic macrophytes. According to Jacot-Guillarmod (deceased, Botanical Research Institute, Grahamstown: pers. comm.) the appearance, settlement and expansion of a variety of aquatic and semi-aquatic plant species in the regulated Orange River is a natural consequence of flow stabilisation.

2.2.2 Freshwater invertebrates

Except for pioneering expeditions, where species' classification and identification were the major objectives, no proper studies/surveys have been undertaken on the freshwater invertebrates of the ORS prior to river regulation (1884) (Benade, 1993). Biological information, however little, on the main streams of the Orange and Vaal Rivers started accumulating in the 1950's and, in respect of freshwater invertebrates, mostly involved fish parasites and/or economically important organisms, such as the Simuliidae (Blackflies) and the snail intermediate hosts of ***Schistosoma*** (Bilharzia) and ***Fasciola*** (Fluke) spp. (Benade, 1993). Agnew (1965) undertook a once-off survey of the invertebrates of the Orange River as a whole. Dr Rob Palmer documented some recent studies on ORS invertebrates whilst doing Blackfly control research and the Namibian National Museum compiled a checklist of freshwater invertebrates found within the Namibian borders.

During investigations of possible dam sites in the lower Orange River (Boegoeberg Dam to Orange-Fish confluence) by the Orange River Environmental Task Group in 1996, Dr Mark Chutter (Afridev) conducted SASS sampling at the different identified sites and found that the invertebrate populations appear to be rather homogenous throughout the entire length of the Orange River. This he ascribed to the unpredictable, erratic nature of the ORS.

Apart from recording presence of the Freshwater Shrimp, ***Caradina nilotica***, and the Freshwater Mussel, ***Corbicula africana***, a gradual downstream increase in the occurrence of freshwater fish being infested by parasites, as well as an increase in fish parasite diversity, in the study area had been observed during fish surveys between 1985 and 1989 (Benade, unpublished data). This phenomenon is indicative of water quality deterioration.

2.2.3 Freshwater fish species

Because of the harsh aquatic environment, ***i.e.*** unpredictable erratic flows, droughts and episodic floods, the ORS as a whole is relatively poor in indigenous freshwater fish species diversity. The fishes of the ORS have, over long periods of natural selection (Gaigher ***et al***., 1980), adapted to a riverine environment (Du Plessis & Le Roux, 1965) and are mainly bottom feeders or predators (Du Plessis & Le Roux, 1965). Because of these adaptations, they can benefit from the natural seasonal changes in environmental factors such as flow, temperature and turbidity (Tomasson & Allanson, 1983). They generally spawn from the onset of spring through to autumn, when the river is in its annual high flow period, utilizing the flooded river banks and floodplains, conditions conducive to growth and survival of the young (Tomasson & Allanson, 1983).

Presently, eight fish families are represented by 22 species in the ORS. Of these, three families, represented by five species are alien to Southern Africa, one species of an indigenous family is also alien and one species, indigenous to the subregion, of another family had been introduced to the ORS. The ORS thus only contains 15 indigenous freshwater fish species, representing five families – compare with KwaZulu-Natal's ±85 species.

Of the 15 indigenous fish species, six are endemic to the ORS with four of them Red Data listed. Of the remaining nine indigenous species, two are becoming threatened within the system, while the possibility exists that one could be an endemic subspecies.

The freshwater fish species occurring in the study area are listed in TABLE 1.

TABLE 1: Checklist of the freshwater fish species found between Aughrabies Falls and the Orange River Mouth
(Classification and common names according to Skelton [1993], and status according to Benade [1993]).
(L=Large; M=Medium; S=Small; E=Endemic; I=Indigenous; V=Vulnerable; R=Red Data; In=Introduced; A=Alien)

FAMILY	SPECIES			STATUS					
	Scientific Name	**Common Name**		**E**	**I**	**V**	**R**	**In**	**A**
ANGUILLIDAE	***Anguilla mossambica***	Longfin Eel	L		X				
CYPRINIDAE	***Mesobola brevianalis***	River Sardine	S		X				
	Barbus trimaculatus	Threespot Barb	S		X	X			
	B. hospes	Namaqua Barb	S	X			X		
	B. paludinosus	Straightfin Barb	S		X	X			
	B. kimberleyensis	Largemouth Yellowfish	L	X			X		
	B. aeneus	Smallmouth Yellowfish	L	X					
	L. capensis	Orange River Mudfish	L	X					
	Cyprinus carpio	Carp	L						X
AUSTROGLANIDIDAE	***Austroglanis sclateri***	Rock Catfish	M	X			X		
CLARIIDAE	***Clarias gariepinus***	Sharptooth Catfish	L		X				
CICHLIDAE	***Psedocrenilabrus philander***	Southern Mouthbrooder	S		X				
	Tilapia sparrmanii	Banded Tilapia	S		X				
	Oreochromis mossambicus	Mozambique Tilapia	M					X	

2.3.1 ***Anguilla mossambica***

Anguilla mossambica (Longfin Eel) is the most numerous anguillid in southern Africa (Bruton, Bok & Davies, 1987), with its distribution mainly restricted to the eastward flowing river systems draining into the Indian Ocean (Bruton ***et al***., 1987). Scientific records indicate that it is **rare in the ORS**, although anglers claim more frequent catches (Jubb, 1959). Observations of eels (life history stage and size unknown) entering the Orange River mouth during the 1988 floods (about mid-February to April) had been reported (M Dodders, Public Relations Officer, Consolidated Diamond Mines Ltd, Oranjemund).

2.3.2 ***Mesobola brevanalis***

Mesobola brevanalis (River Sardine) has a wide, discontinuous distribution in southern Africa (Jubb, 1967). **In the ORS**, it is **restricted to** Orange River **stretch between Aughrabies Falls and the Orange River Mouth** (Jubb, 1967**) where it is the most common and abundant fish species** (Skelton & Cambray, 1981; Cambray, 1984b; Benade, 1993) found in the open water habitats of the mainstream, quiet backwaters as well as flowing channels and rapids (Skelton & Cambray, 1981; Benade, 1993), preferring quiet open and/or backwater habitats (Benade, 1993). Its abundance and habitat preference suggest that it benefits from river regulation. Its external morphology suggests it to be an active open water feeder (Skelton & Cambray, 1981), which feeds on planktonic crustaceans, aquatic insects from the bottom or mid-water, algae and terrestrial insects (Pienaar, 1978). Skelton and Cabray (1981) reported emerging and semi-emerged Simuliidae from some individuals' gut contents, suggesting it to be a possible predator of this pest (Benade, 1993). Breeding starts during spring (Pienaar, 1978; Skelton & Cambray, 1981; Cambray, 1984b; Benade, 1993), and continues until early (Benade, 1993) to late (Cambray, 1984b) summer.

2.3.3 ***Barbus trimaculatus***

Barbus trimaculatus (Threespot Barb) is a widespread tropical African freshwater fish species (Skelton & Cambray, 1981). In the Orange River System, its distribution includes the

Vaal River catchment, as well as the Orange River below the Orange-Vaal confluence (Skelton and Cambray, 1981). Its **habitat preference is rapid areas** (Benade, 1993). Its **gonad development is triggered by photoperiod and/or temperature, and breeding by flow** (Benade, 1993).

2.3.4 ***Barbus hospes***

Barbus hospes (Namaqua Barb) is **endemic to the Orange River stretch between Aughrabies Falls and the Orange River Mouth** (Jubb, 1967), being **most abundant downstream from Goodhouse** (Cambray, 1984b; Benade, 1993) and is **Red Data listed** (Skelton, 1987). It occurs in a variety of habitats, from quiet pools near rapids to fast-flowing sections, **favouring open flowing water, a sandy substrate and little vegetation** (Cambray, 1984b) **in and around rapids** (Benade, 1993). This species' general biology is practically unknown, and, together with its restricted distribution, it is thus highly vulnerable to ill-considered human interference and/or mismanagement in the upstream catchment (Benade, 1993). It appears to be a stream spawner, which breeds between mid-spring and autumn, spawning in rapids and utilizing the pools in and around rapids as nursing sites for the young (Benade, 1993). It also appears that **this species' juvenile survival is not satisfactory under regulated flow conditions**. **Flow** therefore **appears to be a most important component of this species' basic habitat requirements**.

2.3.5 ***Barbus paludinosus***

Barbus paludinosus (Straightfin Barb) is an extremely widespread tropical fish species in Africa, with its distribution in the ORS similar to that of ***B. trimaculatus*** and its numbers rather low (Skelton and Cambray, 1981). It prefers quiet to slow flowing, moderately vegetated bays, shores, backwaters, pools and impounded areas, the habitat type where its young is probably also bred and nursed (Benade, 1993). Occasional flood/high flow appears to be a vital component of its life history strategy, however, flow appears not to be this species' major breeding stimulus. Other environmental factors, such as temperature and/or photoperiod could be the important breeding stimuli for this species. Spawning occurs between mid-spring to late summer (Cambray, 1984b: Benade, 1993).

2.3.6 ***Barbus kimberleyensis***

Barbus kimberleyensis (Largemouth Yellowfish) is **endemic to**, and widely distributed in **the ORS**, except for its absence from the Lesotho catchment (Jubb, 1967). It is, however, **not abundant in the regulated Orange River between Vanderkloof Dam and the Orange River Mouth** (Benade, 1993). **It is a predator** (Jubb & Farquharson, 1965; Mulder, 1973), and thus essentially a **visual feeder** which **prefers clear, fast-flowing water with a sandy to gravel substrate** (Mulder, 1973). **It takes approximately seven years to mature sexually**, reaching sexual maturity at extreme minimum lengths of 35 (male) and 36 cm (female) (Benade, 1993) and **breeds in and below rapids** (Skelton & Cambray, 1981) during the first post-winter floods (Tomasson & Allanson, 1983) from early spring to summer (Benade, 1993). Under regulated conditions, temperature probably became its determinant breeding factor (Tomasson & Allanson, 1983; Benade, 1993), with low temperatures (hypolimnetic water) retarding breeding, initial growth rates and juvenile survival (Tomasson & Allanson, 1983). Although predators generally occur at lower densities than prey species, Benade (1993) ascribes this species' extremely low numbers in the regulated Orange River to river regulation and increasing catchment utilization adversely affecting its reproduction, recruitment and dependence on visibility for feeding, and suggests that it is **Red Data** listed.

2.3.7 ***Barbus aeneus***

Barbus aeneus (Smallmouth Yellowfish) is **endemic to**, and widely distributed throughout **the ORS** (Jubb, 1967) and is presently the most abundant large fish species in the Orange River (Benade, 1993). It is an opportunistic omnivore (Tomasson, 1983), which **prefers clear, fast-flowing water and a sandy to gravel substrate** (Mulder, 1973; Skelton & Cambray, 1981). It breeds during the first post-winter floods (Tomasson & Allanson, 1983) from late spring to early summer (Benade, 1993), migrating upstream to spawn on gravel beds (Jubb, 1967). Under regulated conditions, temperature most probably determines breeding time, with low temperatures (hypolimnetic water) retarding breeding as well as initial growth rates, and also leading to high mortalities (Tomasson & Allanson, 1983). Flow and/or temperature should rather be considered as spawning stimuli and important factors in successful juvenile growth and species recruitment.

2.3.8 ***Labeo capensis***

Labeo capensis (Orange River Mudfish) is **endemic to**, distributed throughout **the ORS** (Jubb, 1967), **and the dominant large ORS fish species** (Mulder, 1973b: Vaal River; Skelton & Cambray, 1981: Orange River). **However, its numbers decline towards the lower Orange River stretch between Aughrabies Falls and the Orange River Mouth** (Benade, 1993). It is a detritivore (Groenewald, 1957; Jubb, 1967) appearing to be utilizing all aquatic habitat types in the Orange River System (ORS) (Mulder, 1973b; Cambray, 1984), from quiet, weedy backwaters to rapids (Cambray, 1985). Its breeding is naturally triggered by local rains throughout summer (Cambray, 1985), and spawning occurs in floodplains, main streams and rapids (Cambray, 1985) between mid-spring and late summer/early autumn (Benade, 1993). Flow is a major stimulus for ***L. capensis***' breeding (Cambray, 1985; Benade, 1993). Regulated river conditions offer a longer spawning season, with this species now depending on a suitable combination of water temperature, photoperiod and regulated flow to trigger spawning (Cambray, 1985).

2.3.9 ***Cyprinus carpio***

Cyprinus carpio (Carp) is an **alien freshwater fish species**, which had been introduced to the former Cape Province in 1896 and has, due to its ability to adapt to a wide spectrum of habitat conditions, the widest distribution range of all alien fish species in southern Africa (Jubb, 1972). **In the ORS, its distribution ranges from below the trout waters in the upper catchment** (Jubb, 1967) **to the Orange River Mouth** (Benade, 1993). It follows varied diet, from vegetable matter to aquatic animals, and its habit of dredging its environment's bottom mud, enables it to find food almost anywhere (Jubb, 1978).

2.3.10 ***Austroglanis sclateri***

Austroglanis sclateri (Rock Catfish) is **endemic to** and widely distributed in **the ORS** in both warm and cold waters (Jubb, 1967), but is, however, **not common**, even in its preferred habitat (Skelton & Cambray, 1981) and is therefore **Red Data** (Skelton, 1987). It is an omnivore, feeding primarily on aquatic insects, larvae and nymphs, with large specimens taking small fish (Jubb, 1967). Predation (visual feeding) thus also forms a major part of its feeding habits. It appears to be highly specialised regarding its habitat requirements, consisting basically of a rock/sand/gravel substrate and ranging from bedrock with/without scattered rocks and sandy to gravel substrates, to rocky pools, rapids (Skelton & Cambray, 1981; Cambray 1984b; Benade, 1993) and riffles, with the surrounding aquatic environment adhering to specific water quality standards (Benade, 1993). Benade (1993) reported its populations to show a "patchy" distribution downstream of Vanderkloof Dam, suggesting that river regulation and catchment utilization, together with the resulting constant turbidity levels, fragmented it populations in the regulated Orange River, restricting it to clearer slow flowing to stagnant water (Benade, 1993).

2.3.11 ***Clarias gariepinus***

Clarias gariepinus (Sharptooth Catfish) has a wide distribution range in southern Africa (Jubb, 1967), with the ORS its southern-most natural distribution (Cambray, 1979; Hamman, 1981) and does not occur in large quantities under riverine conditions (Skelton & Cambray, 1981; Cambray, 1984b; Benade, 1993). It is an omnivorous scavenger, usually feeding at the bottom or in thickly weeded areas (Jubb, 1967). Large members of this species are also known to be cannibalistic (Bruton, 1978). Its habitat ranges from deep profundal to shallow littoral areas (Bruton, 1978). Equipped with suprabranchial organs (pseudo lungs), it can be found in water of low oxygen content and because of this air breathing capability, it can succumb easily to pesticide sprays (Jubb, 1967). Spawning occurs from mid-to late spring until mid-autumn (Benade, 1993) in grassy places inundated by floodwaters of high oxygen content (Jubb, 1967). Oranjemund inhabitants reported large numbers of dead ***C. gariepinus***, washed up on the Atlantic Ocean shores during and after the 1988-flood, indicating that this species could be vulnerable during extreme flood conditions (Benade, 1993).

2.3.12 ***Pseudocrenilabrus philander***

Pseudocrenilabrus philander (Southern Mouthbrooder) has a wide distribution range (Skelton & Cambray, 1981), occurring from the Vaal, Orange (below Orange-Vaal confluence) (Skelton & Cambray, 1981) and Uvongo (KwaZulu-Natal) Rivers, northwards (Jubb, 1967). It is a predator, with its young feeding on zooplankton while the adults feed on small fish, crustaceans, aquatic insect larvae and hovering insects at the surface (Jubb, 1967). Its habitat ranges from rocky rapids, through rocky shores, sandy open water and backwaters, to flowing channels, with preference given to sheltered vegetated areas (Skelton & Cambray, 1981; Benade, 1993). It is a mouth brooder, which mainly breeds in slow flowing sheltered pools and backwaters during mid-spring to mid-autumn (Benade, 1993). This species has benefited from river regulation because of its commonness in the extensive reed beds in the lower Orange River (Cambray, 1984b).

2.3.13 ***Tilapia sparrmanii***

Tilapia sparrmanii (Banded Tilapia) has a natural distribution from the ORS northwards to the Kunene, Limpopo and Zambezi River Systems, and, from the Limpopo southwards, to the Tugela River in KwaZulu-Natal (Jubb, 1967). It is widespread, but not abundant, in the lower Orange River (Skelton & Cambray, 1981; Cambray, 1984b). It is an omnivore, feeding on aquatic vegetation, zooplankton, small crustaceans, insect larvae, nymphs and worms (Jubb, 1967). It prefers well vegetated, silted shores, pools and backwaters in slow flowing riverine areas (Benade, 1993). It is a substrate spawner, with monogamous habits, which breeds from spring (Jubb, 1967) to late autumn (Benade, 1993). Spawning and fertilization takes place in a hollow, and eggs and fry are guarded by both adults (Jubb, 1967). Occasionally, eggs and fry are picked up in the mouth to be moved to other sites, but no mouth brooding occurs (Jubb, 1967). This species seems to benefit from river regulation and catchment utilisation as river regulation and catchment utilisation stimulate the development of ***Phragmites*** reed beds, which, in turn provide shelter and enhance flow stabilisation and silt deposition, thus creating habitat for this fish species (Benade, 1993).

2.3.14 ***Oreochromis mossambicus***

Oreochromis mossambicus (Mozambique Tilapia) is widely distributed in the African east coast rivers, from Beira to as far south as the Brak River, south of Port Alfred (South Africa) (Jubb, 1967). It is the only known **indigenous** freshwater fish species **introduced to** the ORS, and specifically the **lower Orange River section between Aughrabies Falls and the Orange River Mouth** (Benade, 1993). This euryhaline mouth brooder (Jubb, 1967) was originally imported to the Hardap Dam (Fish River: Namibia), from where it made its way to the mentioned lower Orange River stretch (Skelton and Cambray, 1981). When last recorded, its distribution ranged between downstream of Goodhouse to the Orange River Mouth (Cambray, 1984b; Benade, 1993). It is being expected that this species will eventually extend its distribution range to include the whole of the Orange River section between Aughrabies Falls and the Orange River Mouth (Benade, 1993).

3. ISSUES OF CONCERN IN RESPECT OF DAM CONSTRUCTION IN THE ORANGE RIVER STRETCH 20º LATITUDE TO THE ORANGE-FISH CONFLUENCE

3.1 PHYSICO-CHEMICAL EFFECTS OF AN IMPOUNDMENT ON A RIVER

Medium to large impoundments normally display thermal stratification during summer, ***e.g.*** an epilimnion (warm, productive, upper water layer), a thermocline (transitional layer) and a hypolimnion (cold, mainly unproductive bottom water layer). During winter thermal stratification is much less pronounced to completely absent in such an impoundment. The depth and productivity of the epilimnion depends to a large extent on the transparency/turbidity of the water in the impoundment. Being the impoundment's productive layer, a lot of physico-chemical (temperature, oxygen content, pH, etc.) and biological (plankton production) modifications to the incoming river water occur in the impoundment's epilimnion. This can result in major differences in the epilimnetic layer's physico-chemical and biological character in comparison with the downstream river water. This situation is aggravated by mineral accumulation in the impoundment, which, in combination with the extreme evaporation rates along the study area route, can lead to serious deterioration in water quality (impoundment and downstream river) and even to eutrophication. On the other hand, the impoundment's hypolimnetic water is usually much colder, and also poorer in oxygen content than the downstream river water. Water releases, whether epi- or hypolimnetic, from such an impoundment to the downstream river during summer can therefore send a host of physico-chemical and biological shocks through the river stretch, which will negatively impact on the downstream biota.

Waterfalls and rapids are extremely important in replenishing the oxygen lost from the riverine environment by water abstraction and the high temperatures characteristic of the entire study area. This should definitely receive serious attention during dam site selection, as inundation of such river phenomena will have detrimental effects on the riverine biota.

Dam construction and river regulation usually lead to increases in riparian agricultural activities, especially irrigation (catchment utilisation). This, in turn, will inevitably lead to agricultural pollution resulting in changes to the river oxygen content, pH, turbidity and conductivity.

Riverbed degradation resulting from suspended solid precipitation caused by the combination of low flows (river regulation), high evaporation rates and high mineral content (agricultural and other pollution) leads to aquatic habitat degradation, which could be detrimental to the survival of certain indigenous, including endemic, organisms, while being promotive to the unwanted establishment of other indigenous, as well as alien, organisms.

3.2 EFFECTS OF AN IMPOUNDMENT ON THE RIVERINE BIOTA

3.2.1 Vegetation

The technically pristine inland deltas and shoreline and island vegetation along the inaccessible floodplain stretches of the study area's main river channel will be threatened by dam construction as these stretches' mountainous character provides ideal dam sites. This will result in their being inundated. These river stretches should rather be considered for conservation because of their value as vegetation benchmarks and habitat for stream preferring aquatic organisms. On the other hand, lower, stabilised water flow volumes will negatively affect natural shoreline and island vegetation communities downstream of a major dam. This, in turn, will result in riverbank destabilisation.

Increasing river regulation and catchment utilisation will result in increases in filamentous Phycophytes and blue-green alga (algal blooms), and will also promote habitat changes suitable for the encroachment and colonisation of plant species such as the American floating water fern (***Azolla filiculoides***), water weeds (***Potamogeton schweinfurthii***, ***P. pectinatus***, ***P. crispus,*** and ***Ludwigia stolonifera***) and the river reed (***Phragmites australis***). This, in turn, will promote the habitat possibilities and further artificial distribution of certain economically important invertebrate pest species, as well as Red Billed Quelea (***Quelea quelea***) of which individuals had already been observed as far downstream as the Orange River Mouth (M Anderson, Northern Cape Nature Conservation, pers. comm.). It will also create habitat advantageous to certain fish species (indigenous and alien), while negatively affecting others (certain endemic and indigenous ones).

3.2.2 Freshwater invertebrates

It can be expected that further river regulation will enhance habitat possibilities for economically important invertebrates such as Blackflies, the snail intermediate hosts of Bilharzia and Fluke spp., mosquito's, etc. Certain free-living aquatic invertebrates might also gradually make their appearance. Together with increasing parasite infestations amongst the fish populations, they can serve as indicators of water quality deterioration. It will therefore be absolutely necessary to involve aquatic invertebrate specialists in possible further river regulation investigations.

3.2.3 Freshwater fish species

The key freshwater fish species of major concern in respect of dam construction in the lower Orange River stretch between 20º latitude and the Orange-Fish confluence, are listed in TABLE 2.

TABLE 2: Key freshwater fish species expected to be affected by dam construction in the lower Orange River stretch between 20º latitude and the Orange-Fish confluence
(E=Endemic; I=Indigenous; V=Vulnerable; R=Red Data)

KEY FRESHWATER FISH SPECIES		STATUS			
Scientific Name	**Common Name**	**E**	**I**	**V**	**R**
Barbus hospes	Namaqua Barb	X			X
B. kimberleyensis	Largemouth Yellowfish	X			X
Austroglanis sclateri	Rock Catfish	X			X
Barbus aeneus	Smallmouth Yellowfish	X			
Labeo capensis	Orange River Mudfish	X			
Barbus trimaculatus	Threespot Barb		X	X	
B. paludinosus	Straightfin Barb		X	X	

Five of the six endemic ORS fish species occur in this river section, of which one, ***Barbus hospes***, is unique to the Orange River section between Aughrabies Falls and the Orange River Mouth. Three of the five endemic species, ***B. hospes***, ***B. kimberleyensis*** and ***Austroglanis sclateri*** are Red Data listed. Although the other two endemics, ***B. aeneus*** and ***Labeo capensis***, are fairly abundant and thus appear not to be threatened, they remain of concern because of their endemic status. For instance, in the Orange River stretch between Vanderkloof Dam and the Orange-Vaal confluence, it appears that ***L. capensis***' populations are approaching "bottle-neck" situations as a result of the extreme effects of river regulation in this river section (Benade, 1993). On the other hand, in the over-extended lower Vaal River (Vaalharts Weir to Orange-Vaal confluence) ***B. aeneus***' populations also appear to be approaching "bottle-neck" situations (Benade, 1993).

Although ***Barbus trimaculatus*** and ***B. paludinosus*** are not endemic species, their relatively low numbers thus far recorded from the Orange River section between Aughrabies Falls and the Orange River Mouth make them vulnerable to changes in the main river channel. Their indigenous status in the river section makes it important biotic components of the river section's total ecology (Benade, 1993). As in the case of endemic species, any threat to an indigenous species is indicative of negative impacts on the ecosystem (Benade, 1993). For instance, siltation of rapids in the lower Vaal River (Vaalharts Weir to Orange-Vaal confluence) resulted in ***B. trimaculatus*** nearing extinction in this river section (Benade, 1993).

3.2.4 Impacts of dams/large weirs on the aquatic biota of rivers

- Dams/large weirs form major migration barriers resulting in genetic compartmentalisation and inbreeding of aquatic populations. This enhances the manifestation of poor genetic characteristics, weakening populations and sometimes leading to extinctions.

  It is therefore extremely important to consider fishways as integral parts of dam/weir construction in river courses in order to maintain genetic diversity within aquatic populations. It must be kept in mind that there is more in a fishway than only providing for aquatic organisms to cross the artificial barrier.
- Because thermal stratification is rather characteristic of large dams, structures for downstream water releases should be designed to allow for mixing in order to minimise physico-chemical shocks in the downstream river section.

- The height of a dam wall determines the length of the resulting inundated river stretch as well as the size of the impoundment's surface area, which includes peripheral land and tributary stretches to be submerged. Because the ORS is poor in indigenous freshwater fish species diversity, and 12 out of the 15 indigenous ORS freshwater fish species, including one unique Red Data listed endemic (***Barbus hospes***), one unique indigenous (***Mesobola brevianalis***), two endemic Red Data listed (***B. kimberleyensis*** and ***Austroglanis sclateri***) and two vulnerable indigenous (***B trimaculatus*** and ***B. paludinosus***) fish species occur in the river stretch between Aughrabies Falls and the Orange River Mouth, it is important that this diversity is maintained. It is therefore important the fish species' habitat, and especially instream habitat, requirements are considered when dam sites are selected. From an environmental impact and management point of view, two or more properly sited smaller dams/weirs are preferred to one large dam.

4. THE ECOLOGICAL IMPORTANCE AND SENSITIVITY OF DIFFERENT RIVER REACHES IN THE ORANGE RIVER STRETCH 20º LATITUDE TO THE ORANGE-FISH CONFLUENCE

The co-ordinates of river reaches in the Orange River stretch 20º latitude to the Orange-Fish confluence considered to be of ecological importance are presented in TABLE 3 and indicated on the accompanying map. These reaches were identified by using the 1:50 000 maps listed in TABLE 4.

TABLE 3: River reaches in the Orange River stretch 20º latitude to the Orange-Fish confluence considered to be of ecological importance.

	RIVER REACH		REASON
	FROM	TO	
1.	29º39'00"S; 19º29'40"E	28º50'15"S; 19º15'00"E	Inland delta
2.	28º57'20"S; 19º04'20"E	28º53'30"S; 18º30'30"E	Inland delta
3.	28º42'20"S; 17º28'30"E	28º27'30"S; 17º20'20"E	Unique riverbed
4.	28º19'30"S; 17º22'30"E	28º06'00"S; 17º10'40"E	Unique riverbed

TABLE 4: Maps (1:50 000) used to identify rivere reaches of ecological importance in the Orange River strech 20º latitude to the Orange-Fish confluence.

MAP		NAME	EDITION
1.	2819BD	Oranje-kom	1ST 1973
2.	2819DB	Narries	1ST 1972
3.	2819BC	Blydeverwacht	1ST 1975
4.	2819DA	Skuitdrif	1ST 1972
5.	2819CB	Oseepkans	1ST 1975
6.	2819CD	Oupvlakte	1ST 1972
7.	2819CC	Pelladrif	1ST 1972
8.	2818DD	Kambreek	1ST 1972
9.	2818DC	Dabenoris	1ST 1972
10.	2818CD	Ramansdrif	2ND 1978
11.	2818CC	Goodhouse	2ND 1978
12.	2817DB	Haib	1ST 1971
13.	2817DD	Nous	2ND 1978
14.	2817DA	Noordoewer	1ST 1971
15.	2817DC	Vioolsdrif	2ND 1978
16.	2817CB	Modderdrif-Suid	1ST 1971
17.	2817AD	AUSSENKEHR	1ST 1971
18.	2817AB	Gamkab	1ST 1971
19.	2817AC	Vandersterrberg	1ST 1971
20.	2817AA	De Hoop	1ST 1971

In TABLE 3 it will be noted that river reaches numbers 3 and 4 both indicate "Unique riverbed" as reason ecological importance. The reason is that the author observed a unique riverbed section, consisting of a solid rock bank lining a narrow channel through which the river runs, during an aerial survey. Unfortunately it was not recorded exactly where this phenomenon was observed – it was, however, observed in the northerly flowing river stretch downstream of Vioolsdrif. Only two of these unique riverbed stretches occur in the entire Orange River – the other one being at Hopetown. It is suggested that the four river reaches indicated in TABLE 3 and on the map are further investigated for their ecological importance by an in-depth aerial photograph study and/or an aerial survey.

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