SURVEY OF THE WESTERN SWAMP TORTOISE AND ITS HABITAT AT THE PERTH AIRPORT

Report to the **FEDERAL AIRPORTS CORPORATION** and the **AUSTRALIAN NATURE CONSERVATION AGENCY**

by

Dr Gerald Kuchling, Chelonia Enterprises.
Principal Investigator, Western Swamp Tortoise Recovery Team

and

Dr Andrew A. Burbidge, Director, Western Australian Threatened Species and Communities Unit, W. A. Department of Conservation and Land Management.
Chairman, Western Swamp Tortoise Recovery Team

for the **Western Swamp Tortoise Recovery Team**

Includes the study:

AQUATIC INVERTEBRATE SURVEYS AND WATER QUALITY OF PERTH AIRPORT SWAMPS

by

Dr Stuart A. Halse (CALM Science and Information Division) and
Dr Andrew W. Storey (Wetland Research & Management).

JANUARY 1996

CHELONIA ENTERPRISES
PO Box 1359, Subiaco
WESTERN AUSTRALIA 6008

CONTENTS

1. THE PURPOSE OF THIS REPORT

On 02 September 1970, a juvenile Western Swamp Tortoise *Pseudemydura umbrina* was found on airport property adjacent to Hardey Road. The occurrence of this juvenile, about 20 km south of the closest known Western Swamp Tortoise population at Ellen Brook Nature Reserve, demonstrated the existence of a reproducing population of the species at the airport land.

The Federal Airports Corporation (FAC) currently proposes the development of the Perth Airport Business & Recreational Park Stage 2, which will impact on the area where this Western Swamp Tortoise was most probably collected. Report No. 92/35 - *Perth Airport Business & Recreational Park Stage 2 Public Environmental Review* by Alan Tingay & Associates, dated October 1994, did not assess the impacts of the proposed development on the Western Swamp Tortoise and its habitat.

The Western Swamp Tortoise *Pseudemydura umbrina* is probably Australia's most endangered vertebrate species and listed as Endangered in the Commonwealth *Endangered Species Protection Act 1992 (ESP Act)*. A primary reason for the FAC and the Australian Nature Conservation Agency (ANCA) to instigate this survey was to determine the status of the Western Swamp Tortoise in the Perth Airport Business & Recreational Park area for the purpose of the Public Environmental Review. Under section 165.(2), the *ESP Act* prescribes that the ANCA must prepare inventories that identify, and state the abundance of, the listed native species and listed ecological communities in Commonwealth areas. This has yet to be done for the land at Perth Airport which is vested in the FAC on behalf of the Commonwealth of Australia.

A meeting took place at Perth Airport on 02 February 1995, attended by officials of the FAC, Alan Tingay & Associates, ANCA, the Commonwealth Environment Protection Agency (CEPA) and members of the Western Swamp Tortoise Recovery Team. A result of the discussions at the meeting was that the FAC and ANCA requested that the Western Swamp Tortoise Recovery Team conduct a survey of the Western Swamp Tortoise and its habitat over the whole area which is vested in the FAC on behalf of the Commonwealth of Australia, including and particularly focusing at the area which is proposed for development as Perth Airport Business & Recreational Park Stage 2.

The formal instrument for this survey is a consultancy agreement between the Federal Airports Corporation and Chelonia Enterprises.

2. BACKGROUND INFORMATION ON THE WESTERN SWAMP TORTOISE *PSEUDEMYDURA UMBRINA*

The Western Swamp Tortoise *Pseudemydura umbrina*, a small (15.5 cm maximum carapace length, 550 g maximum body mass) chelid freshwater tortoise, represents monotypically the subfamily Pseudemydurinae; all other living Chelidae belong to another subfamily. Western Swamp Tortoises are only found in the south-western corner of Western Australia, in seasonal swamps on clay or sand over clay soils in and near the Swan Valley on the Swan coastal plain near Perth. The climate is Mediterranean with cool, wet winters and hot, dry summers. During winter and spring, the tortoises are active in the shallow waters of ephemeral swamps and feed on live food (insect larvae, crustaceans and small tadpoles). During the dry summer months, the Swamp Tortoises lie dormant (aestivate) in naturally occurring holes or under leaf litter.

In late spring or early summer, near the time when the swamps dry out, the females lay three to five eggs in an underground nest. Hatchlings emerge the following autumn with a body mass of three to six grams. The hatchlings must grow to about twenty grams in their first winter and spring in order to have a chance of surviving the following summer. In most swamps, they only grow enough if rainfall is good in winter and spring. A high percentage of hatchlings do not survive beyond their first summer.

Western Swamp Tortoises take ten to twenty years to mature and have a life span similar to humans. Even females with an age of over sixty years lay eggs. This long reproductive life of individuals balances the heavy losses of eggs and hatchlings. Some native animals predate tortoise eggs and hatchlings, but no native predators harm adult Swamp Tortoises because of their hard, protective shell. However, the introduced European Red Fox, dogs and cats take a heavy toll of tortoises in Australia, including adult Western Swamp Tortoises. Pigs are also capable of predating tortoises.

Western Swamp Tortoises are not territorial, and seem to have large home ranges. At Ellen Brook Nature Reserve (30 ha inside the fox-proof fence) and Twin Swamps Nature Reserve (155 ha inside the fence) individuals seem to use the whole reserve area. Some try persistently (and some also manage) to get out of the fenced areas. Two marked individuals of the Twin Swamps population have been found in swamps about one kilometre from the reserve boundary. Radio-tracking has demonstrated that individuals can easily move over dry land and move more than 500 m in one day. Home range size and distance of movements may vary considerably between individuals and may also depend on habitat structure and availability, but it is evident that both may be of considerable magnitude for an animal of such a small size.

Pseudemydura umbrina is the most endangered chelonian (tortoise or turtle) species in the world. It is listed as "Endangered" in the IUCN Amphibia-Reptilia Red Data Book (IUCN 1982), is on Appendix I of CITES (Convention on International Trade in Endangered Species of Wild Flora and Fauna) and has been given a priority rating "1"

in the Action Plan for Tortoises and Freshwater Turtles (IUCN/SSC 1989). Under the new IUCN categories of threat of Critically Endangered, Endangered and Vulnerable (IUCN 1994), *Pseudemydura umbrina* clearly meets the criteria for the category "Critically Endangered", having suffered a greater than 80% population reduction over the last three generations (Criterion A1a), occupying an area of less than 10 km^2 (Criterion B1), having a population estimated to number less than 250 mature individuals and a continuing decline (Criteria C1 and C2, and having a population size of less than 50 mature individuals (Criterion D).

The Western Swamp Tortoise is one of Australia's most endangered vertebrate species. It has been declared as "likely to become extinct or is rare " under Section 14(2)(ba) of the Western Australian *Wildlife Conservation Act 1950*. In Western Australia, the species is recognised as "Critically Endangered" according to the 1994 IUCN Red List Categories. The Action Plan For Australian Reptiles (ANCA 1993) assigned *Pseudemydura umbrina* a higher score of threat (46.3 points) then any other Australian reptile. It was also the only Australian reptile assigned to the then draft IUCN category of 'Critical'. The species is listed under "Schedule 1 Part 1 - species that are endangered" of the *ESP Act*.

By 1987 the world population numbered less than 50 individuals: about 30 animals remained in the wild in two small nature reserves and 17 animals were in captivity, of which only three were adult females. Captive breeding success in the past had been poor and egg production in captivity had ceased between 1980 and 1987. A three-year crash project started in 1988 with the aim of establishing successful captive breeding techniques to increase the number of *P. umbrina* to a more secure level. This was a joint project of the Zoology Department of The University of Western Australia, Perth Zoo, and the Western Australian Department of Conservation and Land Management (CALM). It was funded by the World Wide Fund for Nature Australia, the then Australian National Parks and Wildlife Service (now ANCA), the Western Australian Nature Conservation and National Parks Trust Account, CALM and Perth Zoo. The success of this project generated a concerted follow up program for the recovery of the Western Swamp Tortoise.

To implement the necessary actions for the long-term recovery of the Western Swamp Tortoise, a species management program (with a term of ten years) was published as an official document of the Western Australian Department of Conservation and Land Management (Burbidge *et al.* 1990). A recovery team was formed in December 1990 which coordinates all work and which includes members from agencies involved in research, funding and management. Early in 1991, the *P. umbrina* population at Ellen Brook Nature Reserve was secured against introduced predators, mainly the European Red Fox, by a specially designed, electrified fence. In 1994 the population at Twin Swamps Nature Reserve was similarly fenced and reintroduction of captive bred tortoises to Twin Swamps started. During 1992/93 a Recovery Plan for *P. umbrina* was drafted which addressed the causes of the decline of the species and which prescribed necessary conservation actions until the year 2002. It was published by CALM as Wildlife Management Program No 11 (Burbidge and Kuchling 1994) and

endorsed for funding under ANCA's Endangered Species Program. During 1996 the Western Swamp Tortoise Recovery Plan will be reviewed and updated.

3. THE SURVEY

Western Swamp Tortoise populations are difficult to monitor and survey. The species is secretive, has a cryptic colouration, is hard to detect, does not enter baited traps, and spends six to eight months per year underground. Even regular (e.g., weekly) patrols of an area by experienced wildlife officers, including the monitoring of water depths and quality of swamps, does not necessarily lead to the detection of existing Western Swamp Tortoises. Twin Swamps Nature Reserve, for example, which is about 20 km north of Perth Airport, has been surveyed in this manner for many years, since monitoring of the tortoise population with terrestrial drift fences and pit falls was terminated there in the early 1980s. Between 1983 and July 1994, CALM's routine monitoring program of this Nature Reserve did not record any Western Swamp Tortoise individuals. At Twin Swamps Nature Reserve, the species was considered "effectively extinct" by 1985 (Burbidge and Kuchling 1994). Despite this assessment, the sudden increase of field research concomitant with the reintroduction of captive-bred *Pseudemydura umbrina* into Twin Swamps Nature Reserve during the winter of 1994 led to the detection of two resident adult females in the reserve. Both were reproductively active, which implies that at least one male may also be in the area. At Twin Swamps Nature Reserve, even a decade of regular monitoring by wildlife officers, including specific searches for tortoises, did not detect the persistence of a remnant Western Swamp Tortoise population, albeit at a very low population level.

Western Swamp Tortoises are not attracted to baited traps. The only successful method of trapping Western Swamp Tortoises are drift fences plus pitfalls or aquatic funnel traps. Terrestrial drift fences with pits along the margins of swamps have been successfully used by CALM during the 1960s and 1970s to monitor the Western Swamp Tortoise population at Twin Swamps Nature Reserve. This method catches tortoises when they move overland, mainly in autumn and late spring. A major concern and drawback of this method is the increased exposure of tortoises to predation, in particular by the European fox, while they are confined in the pits.

The use of an aquatic drift fence with intermittent traps was successful in trapping Western Swamp Tortoises during a trial at Ellen Brook Nature Reserve in September 1994. This method confines tortoises in water with access to air for breathing and protects them from predation. Tortoises are caught during their whole active period, in winter and spring. Other methods used to catch Western Swamp Tortoises include seine netting and cast netting in relatively open water, wading through shallow water with good visibility and visually spotting tortoises, and puddling (feeling) with the hands through shallow water to physically locate animals.

The aim of the present survey was to determine the status of Western Swamp Tortoises at Perth Airport and to assess the area's habitat and potential habitat. In

scientific terms, a survey can only prove the existence and measure the abundance, but not the non-existence or extinction, of a species in a given area. According to the guidelines and definitions provided by the *ESP Act*, "a species is presumed extinct at a particular time if: (a) it has not been definitely located in nature during the preceding 50 years; or (b) it has not been definitely located in nature during the preceding 10 years despite thorough searching during that period". Since the Western Swamp Tortoise was recorded on Perth Airport land in 1970, any survey of the species which, potentially, could satisfy the law that the species was extinct in a given area would have to extend over more than one season in more than one year. This is particularly imperative due to the longevity of individuals and the cryptic nature of the Western Swamp Tortoise. The present survey did not run over a sufficient time period to allow a conclusion of extinction as defined by the *ESP Act*.

The habitat of the Western Swamp Tortoise is ephemeral swamps with standing water from late autumn/winter to spring/early summer. Typically this swamp habitat is dry from mid-summer to early autumn. During the dry period of the year the tortoises move out of the swamp areas into adjacent bushland, including Banksia woodland, where they aestivate in underground holes or under leaf litter. Both the ephemeral swamps and the surrounding bush or woodlands are important as habitat. Western Swamp Tortoises are not normally found in permanent water bodies. They may, however, temporarily use artificial, permanent farm dams, particularly if swamp areas have been drained.

Important qualities of the swamp habitat are: depth of the water, duration of flooding, cover by shrubs and other plants, insolation, food availability (aquatic invertebrates and small tadpoles), and water quality. Important features of the terrestrial habitat are soil structure (e.g. natural holes and tunnels), the amount of bush and tree cover and leaf litter, abundance of introduced predators and, in some environments, the frequency and extent of fires.

According to the *ESP Act*, "habitat" means an area: (a) in which an organism, or a group of organisms, lives; or (b) in which an organism, or a group of organisms, has lived and into which the organism or group has the potential to be reintroduced. Under section 52.(1), the Act not only provides for the protection of species, ecological communities and habitats in Commonwealth areas, but also of "potential habitats". This survey assesses the extent and the condition of the habitat and evaluates potential habitat of the Western Swamp Tortoise on the Perth Airport land.

This study is composed of two major components: one is the trapping and searching effort to assess the presence and abundance of Western Swamp Tortoises, the second is the habitat assessment. The habitat assessment included the monitoring of swamp water levels, assessment of the swamp canopy structure, potential aestivation habitats, general observations of flora and fauna, a survey of invertebrate composition and biomass and water chemistry analyses. The invertebrate and water chemistry analyses were subcontracted to and compiled by Dr Stuart Halse (CALM Science and Information Division) and Dr Andrew Storey (wetlands consultant, Wetland Research

and Management). This study is presented here as a separate report, but its results are also discussed in the habitat evaluation section.

4. SURVEY METHODS

Maps and air-photos were used to determine the former extent and the changes over time of the swamps on the airport land. Thirty nine sites were designated for general habitat evaluation and searches (Fig. 1). Swamp areas were estimated by local inspections of swamps and planimetry from an 1:5 000 air-photo from 1986 (provided by Alan Tingay & Associates). The estimated areas are rough estimates of the free water surface areas in winter/ spring 1995. If those were considered significantly smaller than they would be in good rainfall years, a second estimate for good years is provided in parentheses.

Drift-fences and trap lines were built in 18 seasonal swamps out of the 39 sites identified for evaluation. The fences were build with black plastic mesh (10 mm gaps) which was dug into the ground and held upright with metal stakes. Whenever there was free water at a site, custom-built traps (design Gerald Kuchling) were set into the spaces in the drift fences. If trap sites became dry, pits were dug alongside the drift-fence. Since trap lines were only checked every 48 hours we did not want to confine any mammals in the pits and provided escape structures (small branches). This may be the main reason why we did not record any vertebrates in the pits except frogs.

The drift fences with traps and pits were inspected every 48 hours and all trapped animals removed and released. All captured vertebrates and freshwater crayfish were noted and the carapace length and sometimes the body mass of Long-necked Tortoises were measured.

Inspections and searches of swamp areas where no trapping occurred took place at various times during the survey, often in addition to the routine trap inspections. Specific additional searches took place on 23 and 24 September, 15 and 26 October, 09 and 29 November and 03 and 09 December 1995.

Data from earlier limited examinations, searches and trapping carried out at the airport by the Western Swamp Tortoise Recovery Team in 1994 are discussed where appropriate.

5. TIME FRAME OF FIELD WORK AND PROJECT PERSONNEL

The proposal for this survey stated that field work, in particular construction of drift fences, should start during May 1995 in order to cover the start of the wet season when Western Swamp Tortoises are usually on the move. Approval for the survey, however, was not received until late June 1995, limiting the effectiveness of the survey. During an inspection of the airport land by A.A. Burbidge, G. Kuchling, M. Price (Alan Tingay & Associates) and J. Davis (FAC) on 17 June 1995, the trapping sites were

determined. From 29 June to 15 December 1995, Mr Philip Boglio was contracted as field assistant and constructed most drift fences during July and early August. Due to the fact that many areas were already flooded the construction took slightly more time than it would have earlier in the season. The first traps were set on 14 August 1995. The trapping and searching field work was carried out by Philip Boglio, Gerald & Gundi Kuchling (Chelonia Enterprises) and Andrew A. Burbidge (CALM).

The duration of trapping depended on the water levels in the swamps. The last traps were removed on 03 January 1996.

6. RESULTS

A. History of the swamps at the airport land

A Perth map from 1919 (Commonwealth Department of Defence, Sheet South H.50, correct to December 1915, at the scale of 1:63 360) shows most of the airport land as undeveloped timber, scrub and swamp land. Mundays Swamp, Poison Gully, and the smaller swamps in the northern part of the airport land south of Kalamunda Road are shown at about the same extent that they have today. The area south of the former Belmont-Kalamunda Road (now Grogan Road), which is the southern portion of the land vested in the FAC on behalf of the Commonwealth of Australia, has the name Five Mile Swamp in the western, central and southern parts, while the eastern part is marked "Liable to Floods", and in the south east Cummings Swamp extends on to airport land (Fig. 2).

A map from 1942 (No. 398 Zone 1, Sheet South H 50, 1:63 360) still shows vast swamp areas on the airport land, although some further development of roads and building blocks has taken place around them. The map does not show an airport, although an air photo of 1940 does (copies of air photos provided by Alan Tingay & Associates). Airport facilities then, as well as on an air photo from 1959, were confined to the northern half of the present airport land (north of the former Belmont-Kalamunda Road). The 1959 photo also does not show any drain in the southern part of the airport land.

The vast swamp area south the Belmont-Kalamunda Road, named Five Mile Swamp on the 1919 map, does not show major development impacts until the 1969 photo on which the runway is extended into its area and the main Water Authority drain is being built. The drain on this photo goes from the runway to the west and then turns north. Hardey Road and other roads in the area, although visible as tracks on the 1940 and the 1959 photos, are only major structures built since the 1969 photo. The drain extents to the east of the runway in a photo from 1972, when it had practically the same dimensions as today.

On a photo from 1982, the runway is being extended over the drain further to the south and reaches its present dimension. Swamp areas to the east and south of this

development appear much drier than on an air photo of 1975. Obviously the drain had a major impact on the remaining areas of Five Mile Swamp and on the area to the east, which, on the 1919 map, was marked "Liable to Floods".

On 02 September 1970, a juvenile Western Swamp Tortoise *Pseudemydura umbrina* was "caught at airport swamps adjacent Hardey Road" (note by Andrew Burbidge on CALM Western Swamp Tortoise record card #126). Although the point of capture was not exactly defined, it is evident that this tortoise was found in the Five Mile Swamp area. This is a clear indication that, at the time, the Five Mile Swamp area sustained a Western Swamp Tortoise population.

The "low-lying areas" of the Perth Airport Business and Recreational Park Stage 2 (as indicated in PER Figure 6) and the "wet low woodlands, seasonally damp Melaleuca low woodlands, seasonally damp heaths, wet sedgelands and open water" (PER Figure 7) were all part of the former Five Mile Swamp which also extended further to the north and east than the development proposal. Due to drainage of the area over the last 25 years this land may now be much drier than it was in the past.

B. Anecdotal reports of Western Swamp Tortoise sightings at Perth Airport

City of Belmont Councillor Miss Knizek grew up in a house in Hope Street adjacent to the airport, about where Tonkin Highway now runs. Directly behind the house the airport bushland and swamps began and there was a drain on the corner which does not exist any more. Miss Knizek vividly remembers that, as child in the late 1960s / early 1970s, she regularly found two sorts of tortoises around her house during winter when it was wet and the land was flooded: one sort had a long neck and there were small and large individuals of this kind; the other sort had a short neck, a slightly more bumpy shell and never was large. The kids always discussed that one kind must be a turtle and the other kind a tortoise (information provided by Miss Knizek by telephone on 24 January 1996). These observations, obviously, concerned Long-necked Tortoises (*Chelodina oblonga*) and Western Swamp Tortoises (*Pseudemydura umbrina*) and were made at the western edge of the Five Mile Swamp area.

Mr Eric McCrum from the Herdsman Lake Wildlife Centre grew up in Bassendean and, as a child in the early 1940s, used to spend time at South Guildford in swamps in what is now the northern section of the Perth Airport land. These were swamps with stands of *Melaleuca* which were very similar to those in Ellen Brook and Twin Swamps Nature Reserves. There were definitely tortoises living there with short necks which were smaller than the Long-necked Tortoises. As kids they mainly found them when searching for Gilgies. Mr McCrum believes they were Western Swamp Tortoises (information provided by Mr McCrum by telephone on 25 January 1996).

Mr Len Lidlow has kept his horses for five years on airport land south of Grogan Road in the Poison Gully area. On 6 August 1995 Mr Lidlow showed one of us (GK) the place in swamp PG3 where, three years previously, during summer, he has found a dry tortoise shell near the deepest part of the swamp (Figs. 21, 22). He left the shell were it

was and did not keep it. It was relatively small and not the shell of a Long-necked Tortoise, which Mr Lidlow knows well. Mr Lidlow believes it was the shell of a Western Swamp Tortoise.

C. Description of swamp sites

The swamp areas given below are rough estimates of the free water surface areas in winter/ spring 1995. If those were considered significantly smaller than they would be in good rainfall years, a second estimate for good years is provided in parentheses. A dash indicates that no area >0.05 ha was flooded for a period of several days during winter/spring 1995. The following nomenclature and identification is used for the purpose of this study.

Table 1: Swamp identification and estimated water surface area in winter/spring 1995; in brackets estimated area for wet years. Swamp symbols are the same as in Figure 1.

SYMBOL	SWAMP NAME	estimated area in ha
N1	North Swamp 1	0.3
N2	North Swamp 2	1.5
N3	North Swamp 3	2.3
N4	North Swamp 4	0.9
MN1	Munday North Swamp 1	0.6
MN2	Munday North Swamp 2	0.4
MW1	Munday West Swamp 1	0.7
MW2	Munday West Swamp 2	- (0.3)
MW3	Munday West Swamp 3	- (4.5)
PG1	Poison Gully Swamp 1	3.4
PG2	Poison Gully Swamp 2	3.5
PG3	Poison Gully Swamp 3	2.8
PG4	Poison Gully Swamp 4	1.6
PG5	Poison Gully Swamp 5	1.4
FMN1	Five Mile North Swamp 1	2.8 (4.2)
FMC1	Five Mile Centre Swamp 1	0.3 (3.3)
FMC2	Five Mile Centre Swamp 2	1.2
FMC3	Five Mile Centre Swamp 3	0.9
FMC4	Five Mile Centre Swamp 4	0.3 (1.8)
FMC5	Five Mile Centre Swamp 5	- (0.9)
FMC6	Five Mile Centre Swamp 6	0.3 (1.8)
FMC7	Five Mile Centre Swamp 7	- (0.8)
FMC8	Five Mile Centre Swamp 8	0.7
FMS1	Five Mile South Swamp 1 (Runway Swamp)	1.7
FMS2	Five Mile South Swamp 2	- (1.1)
FMS3	Five Mile South Swamp 3	- (1.8)

FMS4	Five Mile South Swamp 4 (Link Road Swamp)	0.3
FMS5	Five Mile South Swamp 5	- (0.5)
FMS6	Five Mile South Swamp 6	- (2.8)
FMS7	Five Mile South Swamp 7	- (1.2)
FME1	Five Mile East Swamp 1	4.4
FME2	Five Mile East Swamp 2	1.5
FME3	Five Mile East Swamp 3	6.4
FMW1	Five Mile West Swamp 1	- (5.0)
C1	Cummings Swamp 1	0.8
C2	Cummings Swamp 2	1.9
SE1	South East Swamp 1	0.7 (3.3)
SE2	South East Swamp 2	1.7
NW1	North West Swamp 1	1.0

The North Swamp Group

The four North Swamps all have sandy clay or sand over clay ground, clear but dark (tea-coloured) water and *Melaleuca* stands. All four swamps have populations of *Hydrocotyle lemnoides*, an aquatic plant listed as vulnerable (Schedule 1 Part 2) of the *ESP Act*. All swamps are surrounded by *Eucalyptus* and *Banksia* woodland. The extend of these swamps today seems to be similar to that on the map from 1919. The airport security fence and the boundary road now pass between N2 and N3 and separate these swamps. In the past, water may have drained from N3 into N2; this is now restricted. N3 was grazed by cattle until about a year ago. Apart from these impacts the swamps seem to be relatively undisturbed.

North Swamp 1 (N1)

North Swamp 1 is a relatively small swamp with dark but clear water and good stands of submerged and semi-submerged plants including *Hydrocotyle lemnoides* (Fig. 3). In 1995 there was water from about July until the middle of December, with a maximal depth of >50 cm. However, in 1994 this swamp did not contain much water.

North Swamp 2 (N2)

In 1995, N2 had water from July until 7 December, with a maximal water level of 49.5 cm. The water is less coloured than in the other three North Swamps and there is an extensive and dense stand of *Hydrocotyle. lemnoides* (Fig. 4). Before 1994 there was dense regrowth of *Melaleuca* (Fig. 5). In summer 1994/95 the area was burnt. The easternmost section of the swamp is more open with grass tussocks (Fig. 6).

North Swamp 3 (N3)

North Swamp 3 has a dense regrowth of *Melaleuca* and was burnt during summer 1994/95 (Fig. 7). Along the edges the *Melaleuca* canopy is higher (Fig. 8). The swamp fills early in winter, has up to 76 cm depth and is the swamp of the North Swamp group which has the longest period of flooding, until late December/early January

(Fig. 9). Until about a year ago this swamp was grazed by cattle, which are now excluded.

North Swamp 4 (N4)
North Swamp 4 is similar to North Swamp 2, but smaller and more shallow (Fig. 10). It has the shortest period of swamp life in the northern group.

The Munday Swamp Group

Munday Swamp itself is a deeper *Melaleuca raphiophylla* swamp (Fig. 11) with a peaty clay ground. Munday Swamp has been the subject of other studies and is not discussed here in depth. In most years the water is permanent. We do not consider it to offer good Western Swamp Tortoise habitat, although it could well be used by Western Swamp Tortoises during droughts or in early summer when surrounding swamp areas become dry. On 31 December 1995, we seine-netted with a 15 m long net three times for about 50 m through open water in the southern part of the swamp, but branches and snags prevented good netting results. The catch was one Yabby (*Cherax destructor*) and one feral Goldfish.

We consider several seasonal swamp areas adjacent to Munday Swamp potential Western Swamp Tortoise habitat and combine them for this study as Munday Swamp Group. All these swamps were degraded to some degree by either livestock grazing, clearing, or drainage.

Munday North Swamp 1 (MN1)
This swamp is basically a shallow (knee deep) extension of Munday Swamp to the north, with an open water surface area and some *Melaleuca* stands at the margins. A channel connects it with Munday swamp during winter and may also drain water out of it and into the outflow channel of Munday swamp. It is inside a horse and cattle paddock. In 1993 and 1995 it dried out during November, but in 1992 it had water until late December. Visual inspections revealed high invertebrate numbers and, generally, high numbers of ducks. The water is dark and rather muddy.

Munday North Swamp 2 (MN2)
This swamp also has a connecting channel to Munday Swamp, which is, however, dry for most of winter and spring. The water is about similar to MN1 in its western part which is part of a paddock (Fig. 12). The eastern part shows dense regrowth of a *Melaleuca* thicket. The period of swamp life is about similar to MN1.

Munday West Swamp 1 (MW1)
This is a shallow (about 20-25 cm) swamp area to the west of Munday Swamp, inside the airport security fence. It has obviously been cleared in the past (Fig. 13). Its western third is cut off by a gravel road and much drier than the eastern part. The water is clear. In 1993 and 1995 it was dry by early November, in 1994 by late October. There is an abundance of small crustaceans in this swamp (Fig. 14).

Munday West Swamp 2 (MW2)

This swamp area is downstream at the outflow channel of Munday Swamp and affected by drainage, clearance and earth moving operations. During the last four years it did not provide good swamp habitat.

Munday West Swamp 3 (MW3)

This swamp area is between Munday Swamp and the international terminal apron and is extensively drained by two artificial channels. The swamp may have been cleared in the past, is invaded by weeds and does not hold water for any length of time (Fig. 15).

The Poison Gully Swamp Group

Poison Gully is the southern water catchment area of Munday Swamp. Water drains in winter and spring from several swamp areas through the gully into Munday Swamp. The ground of the swamps is mainly clay or pebbly silt. The whole area is used for livestock grazing.

Poison Gully Swamp 1 (PG1)

Poison Gully Swamp 1 is directly south-west of the southern end of Munday swamp, with the drain crossing through it (Fig. 16). The northern part, towards Munday Swamp, is a cleared cattle pasture (Fig. 17). The south-eastern part, with its stand of *Melaleuca lateritia* and soil structure, is very similar to swamps at Ellen Brook Nature Reserve (Fig. 18). However, the whole PG1 is now obviously drier than in the past and heavily invaded by exotic grasses. The part west of the drain (Fig. 19) has water mainly at the firebreaks and in some depressions. In 1995 the swamp areas were effectively dry by late September, the drain by 19 October.

Poison Gully Swamp 2 (PG2)

Poison Gully Swamp 2 is to the west of the gully at both sides of Grogan Road. It is used for horse paddocks by a riding school and cleared except for its eastern margin (Fig. 20). South of Grogan Road there is an earth dam along its eastern margin which separates it from PG3. The deepest part of the swamp is along this dam where there was water until 19 December 1995. The water was dark coloured and slightly muddy, obviously due to the horses.

Poison Gully Swamp 3 (PG3)

Poison Gully Swamp 3 is east of PG2, separated from it by the gully and an earth dam. It consists of three parts. The part immediately to the south of Grogan Road has a dense stand of *Melaleuca raphiophylla*. Where Poison Gully bends to the east there is a small claypan to the north which is part of a cleared horse paddock, and a larger claypan to the south which is the main area of PG3. In the 1995 season the deepest part of this swamp contained water until early January 1996 (Fig. 21). The water is not dark stained and relatively clear in early winter when dense stands of submerged plants are growing. In late winter and spring the water has a light clay colour and is muddy (possibly due to the horses). The central part of the clay pan has a stand of *Melaleuca lateritia* (Fig. 22). Much of this area is up to knee deep in winter, there are

also extensive shallow parts. The swamp is used by many water birds, including Yellow-billed Spoonbill (Fig. 23), Straw-necked and Australian White Ibis, Wood Duck, Pink-eared Duck, Grey and Chestnut Teal, Australasian Grebe and Shoveler, Dusky Moorhen, Coot, Black-fronted Dotterel, Black-winged Stilt, Sacred Kingfisher and Splendid Fairy-wren. The swamp is part of a horse paddock (see Fig. 21).

Poison Gully Swamp 4 (PG4)
Poison Gully Swamp 4 is an elongate swamp east of PG3 with *Melaleuca* woodland (Fig. 24). The water is dark coloured (like black tea), partly clear and partly muddy due to horses. In spring 1995, the surface was covered with duck weed (*Lemna*). The northern part, towards the Poison Gully, is the deepest part (Fig. 25) and had water until end of December 1995.

Poison Gully Swamp 5 (PG5)
Poison Gully Swamp 5 is south of PG4 and has about the same appearance, with an open water area in its southern part.

The Five Mile Swamp Group

As discussed above (History of the swamps at the airport land), Five Mile Swamp was a large interconnected swamp area until the late 1960s when the construction of the main drain and the extension of the runway reduced it to remnant swamp patches. It is the area where Western Swamp Tortoises were observed until the late 1960s / early 1970s. For this study, the swamps are separated into a north, a south and an east group. The Five Mile North Swamp group is treated here as Five Mile North Swamp 1 and contains degraded swamp areas to the south of the International Terminal, between the runway and Horrie Miller Drive. The Five Mile Centre Swamp group comprises the swamps on both sides of the main drain, east of the runway and west of the Horrie Miller Drive. FMC7 and FMC8 are in the area which is now proposed for development as Perth Airport Business & Recreational Park Stage 2. The south group is south of the main runway and west of the Horrie Miller Drive and lies entirely in the proposed area for the Perth Airport Business & Recreational Park Stage 2. It is probably the area where the Western Swamp Tortoise was collected in 1970, but it may also have come from the Five Mile Centre Swamp group. The east group are the Five Mile Swamp remnants to the east of Horrie Miller Drive, and the west group consists only of Five Mile West Swamp 1 which is west of the main runway.

Five Mile North Swamp 1 (FMN1)
The security fence and the boundary road cut through Five Mile North Swamp 1. The part inside the security fence is now very dry and does not hold much water. Most of the water is now on the firebreak just east of the security fence and in the adjacent stands of *Melaleuca raphiophylla*. The water is clear and has a dark colour. Remnant swamp areas extend up to Horrie Miller Drive. Overall, the area is heavily degraded by tracks, drainage, clearance and weeds.

Five Mile Centre Swamp 1 (FMC1)
This swamp is directly north of the main drain, between the runway and the security fence. It is heavily affected by drainage and grasses and other weeds have invaded the *Melaleuca* woodland and heath. Soil has been extracted in the south-western part where there are now some shallow, seasonal pools with some submerged aquatic plants (Fig. 26). This part typically contains water until December.

Five Mile Centre Swamp 2 (FMC2)
This swamp is the extension of FMC1 to the east, at the other side of the security fence. It is heavily affected by drainage (Fig. 27), but contained clear, dark water in its northern part with *Melaleuca raphiophylla* until 19 November 1995. The southern part has obviously been cleared and is an area of dense grasses and other weeds.

Five Mile Centre Swamp 3 (FMC3)
Five Mile Centre Swamp 3 is east of FMC2 and west of Horrie Miller Drive its situation is very similar to FMC2, but is has a denser *Melaleuca* heath. FMC2 and FMC3 are separated by a gravel road on an earth bund.

Five Mile Centre Swamp 4 (FMC4)
This swamp is between the runway and the security fence directly south of the main drain which drains away most water: a channel in the form of a half-circle effectively keeps most of the *Melaleuca preissiana* and *Banksia litoralis* swamp area dry (Fig. 28). The main flooded area is adjacent to the runway, a disturbed area where soil movements occurred and with grass cover (Fig. 29). The water is dark coloured but clear.

Five Mile Centre Swamp 5 (FMC5)
This swamp is an extension of FMC4 to the east, at the other side of the security fence. Due to the adjacent drain, the area, a *Melaleuca teretifolia* and *Hakea varia* heath, is now effectively dry.

Five Mile Centre Swamp 6 (FMC6)
Five Mile Centre Swamp 6 is south of FMC4 directly east of the runway (Fig. 30). Apart from a relatively open section directly east of the runway it is a *Banksia litoralis* and *Melaleuca teretifolia* heath or woodland with an undergrowth of sedges. The water is dark coloured, the deepest point is close to the runway and had water until 15 December 1995. In 1994 it dried out in early November.

Five Mile Centre Swamp 7 (FMC7)
Five Mile Centre Swamp 7 is part of a former swamp band running east-west. The swamps FME2, FMC8, FMC7, and FMS1 were once interconnected and part of this band, which is now broken up into separate pieces by the main drain and a series of roads or tracks build on earth bunds. FMC7 is inside the area proposed for development as the Perth Airport Business & Recreational Park Stage 2. FMC7 has a relatively open *Melaleuca* stand, is heavily invaded by grasses and remained practically dry during 1995 (Fig. 31).

Five Mile Centre Swamp 8 (FMC8)
Five Mile Centre Swamp 8 is directly south of the carpark of the Perth Mint and west of Horrie Miller Drive. It is inside the area proposed for development as the Perth Airport Business & Recreational Park Stage 2. Most of the area has a dense *Melaleuca* heath with sedges and grasses (Figs. 32, 33). The water is dark coloured and clear (Fig. 34), the deepest part had water until 17 December 1995.

Five Mile South Swamp 1 (Runway Swamp, FMS1)
Runway Swamp has been artificially deepened, most of it is not an open water body. The shallow margin has stands of *Melaleuca* and *Typha domingensis*. The water is dark coloured, clear and permanent. Due to the modifications it is not typical Western Swamp Tortoise habitat, although it could be used by them as drought refuge during dry winters and springs. FMS1 is inside the area proposed for development as the Perth Airport Business & Recreational Park Stage 2.

Five Mile South Swamp 2 (FMS2)
Five Mile South Swamp 2 is inside the security fence. It once formed a single swamp area with FMS3, from which it is now separated by the security fence and the boundary road, but there is still a connection through pipes. It is inside the area proposed for development as the Perth Airport Business & Recreational Park Stage 2. During 1994 and 1995, most of the area remained virtually dry. Only a small depression (about 10 m x 2 m) held water from July until 21 November 1995. The water is very dark coloured. The whole swamp area was flooded, however, during winter 1991 when water birds were nesting there (Fig. 35). A shallow depression in the northern part was intermittently flooded to about 5 cm during September 1995 (Fig. 36). FMS2 has a *Melaleuca raphiophylla* woodland which is now invaded by grasses.

Five Mile South Swamp 3 (FMS3)
Five Mile South Swamp 3 is outside the security fence to the south-east of FMS2. It is inside the area proposed for development as the Perth Airport Business & Recreational Park Stage 2. It is very similar to FMS2 and, during 1994 and 1995, most of the area remained dry. A depression in its eastern part had water from July until the middle of October and, after rains, again from 20 October until the middle of November (Fig. 37). The water is dark coloured but clear.

Five Mile South Swamp 4 (Link Road Swamp, FMS4)
Link Road Swamp is a section of a former larger swamp which remains in the corner between the closed Hardey Road and the security fence. FMS5 is the part of this former larger swamp inside the security fence. Both are inside the area proposed for development as the Perth Airport Business & Recreational Park Stage 2. It is a *Banksia litoralis* woodland with a slightly peaty ground. It had water from early August 1995 until early January 1996. In 1994 it dried out in the middle of December. The water is dark coloured. This type of swamp is generally Long-necked Tortoise habitat rather than Western Swamp Tortoise habitat.

Five Mile South Swamp 5 (FMS5)
This *Banksia litoralis* woodland was ones part of Link Road Swamp and is now separated from it by the security fence and the boundary road. During 1995 it was not flooded for any length of time. It is inside the area proposed for development as the Perth Airport Business & Recreational Park Stage 2.

Five Mile South Swamp 6 (FMS6)
Five Mile South Swamp 6 is south-east of Link Road Swamp, between the former Hardey Road and Tonkin Highway. It has stands of *Melaleuca preissiana*, but most of it is low heath. During 1995 it remained practically dry, only a firebreak had water for short periods. It is inside the area proposed for development as the Perth Airport Business & Recreational Park Stage 2.

Five Mile South Swamp 7 (FMS7)
Five Mile South Swamp 7 is in the corner between Tonkin Highway, Horrie Miller Drive and the former Hardey Road. It is inside the area proposed for development as the Perth Airport Business & Recreational Park Stage 2. It has a stand of *Melaleuca raphiophylla* and drains into the road ditch of Tonkin Highway. During 1995 it remained practically dry, only the road ditch held water during winter and spring.

Five Mile East Swamp 1 (FME1)
Five Mile East Swamp 1 is in the north-eastern corner between ???? Phillips Road and the main drain. It has a large area of open water with sedges and grasses and stands of *Melaleuca preissiana* and partly dense heath (Figs. 38, 39, 40). There was water from late June until 23 November 1995, the water is dark coloured and clear. The ground is sandy clay. The swamp area also extends to the west of Phillips Road, where there is a flooded area directly adjacent to the road. The remainder of the western part is heavily affected by the main drain and remains dry for most of the time.

Five Mile East Swamp 2 (FME2)
Five Mile East Swamp 2 is south-east of FME1, to the north of the main drain. It is separated from FME1 by a sandy ridge and has a relatively similar vegetation (Fig. 41), but the ground is mainly clay. The swamp had water from July until 2 October 1995, the water is clear and only slightly dark coloured. In former times this swamp extended further to the south-west at the other side of the main drain, but this part now remains dry for most of the time.

Five Mile East Swamp 3 (FME3)
Five Mile East Swamp 3 is adjacent to Horrie Miller Drive, a *Melaleuca raphiophylla* woodland with adjacent low heath. It had water from August until 12 October 1995 and, after rains, again from 18 October to 19 November 1995. The ground is sandy and the water dark coloured. This swamp has a very dense population of Koonac *Cherax preissii*.

Five Mile West Swamp 1 (FMW1)
Five Mile West Swamp 1 is a *Melaleuca* heathland to the west of the north-south runway in the corner of the intersection with the other runway. A drain through its centre now keeps it more or less dry (Fig. 42). If more degraded areas with *Melaleuca* woodlands and heaths to the south and west are included, the former but now dry swamp area would be larger than 10 ha.

The Cumming Swamp Group

Most of the swamp area called Cummings Swamp on the map of 1919 is now part of the Forrestfield Marshalling Yard. Only its north-western end is on airport land and still exists as swampland. The eastern bend of Clayton Road now separates it into two small swamp areas.

Cummings Swamp 1 (C1)
Cummings Swamp 1 is a relatively open water inside a cattle paddock, with *Melaleuca raphiophylla* stands at its shores. It is about knee deep and has water until about the end of the year. The water is clear and lightly dark coloured.

Cummings Swamp 2 (C2)
The bend of Clayton Road cuts through Cummings Swamp 2, with a part inside the bend and a part directly north of it. The northern part is inside a paddock. C2 is a *Melaleuca raphiophylla* woodland with relatively dark coloured but clear water, typically until early December.

The South East Swamp Group

The South East Swamp group consists of two swamps which, on the 1919 map, were the northern parts of a large unnamed swamp area south-east of Five Mile Swamp. The main swamp areas have been developed for industry, housing and as Kewdale Freight Terminal.

South East Swamp 1 (SE1)
South East Swamp 1 is in the north-western corner of Newburn Road and Tonkin Highway. It is a *Melaleuca raphiophylla* woodland. In 1995 it had only water from 4 to 18 September and after rains from 18 to 22 October (Fig. 43). The water is dark coloured and clear. In 1994 it remained nearly dry, but in 1991 it had water well over knee deep and at least until January.

South East Swamp 2 (SE2)
South East Swamp 2 is in the north-western corner of Tonkin Highway and the Forrestfield Marshalling Yard. It is a *Melaleuca* woodland and heath (Figs. 44, 45, 46). The water is dark coloured and clear, it had water until 9 November 1995.

North West Swamp 1 (NW1)

North West Swamp 1 is in the north west corner of the airport land outside the security fence, south-east of the Great Eastern Highway bypass. It is a relatively open Melaleuca woodland on both sides of the drain which drains Munday Swamp and the northern part of the airport. The area is invaded by grasses and weeds. It has sandy clay soil and had some water until 24 September 1995 and again after the rains in the middle of October 1995. the swamp area is obviously affected by the drain and rather degraded.

D. Water levels

Table 2: Depth gauge readings in swamps. Empty cells indicate no readings taken or, at the end of columns, that the swamp remained dry for rest of observation period. The gauge of FMS2 was in a depression of about 10 x 2 m, the rest of the swamp remained more or less dry. The gauge of FMC4 was not in the deepest part of the swamp, elsewhere the water was slightly deeper. The other gauges were in the deepest parts of the swamps.

DATE	N2	N3	FMC2	FMC4	FMC6	FMC8	FMS2	FMS4	FME1	FME2	FME3	SE1	SE2
16.08.						480		310	385	240	140	dry	
17.08.	410			285			400					dry	
18.08.		760				485		330	385	240	140	dry	
19.08.	415			270		485	375	340	385	240	145	dry	
21.08.	425			285		495	400	365	390	250	150	dry	
23.08.	433			280		500	385	stolen	390	250	150	dry	
25.08.	450			285		505	425		390	250	160	dry	
27.08.	470			285		510	430		390	260	165	dry	
29.08.	475			250		505	380		385	250	160	dry	
31.08.	475	760		230		500	325		385	235	145	dry	
02.09.	470			200		495	290		370	220	130	dry	
04.09.	485			295		520	465		395	255	190	20	
06.09.	515			310		560	555		415	290	230	40	
08.09.	510			292		570	552			270	235	60	
10.09.	495			280		580	490		385	250	235	70	
12.09.	490			275		580	480		380	250	225	80	
14.09.	480			280		590	510		380	250	235	105	
16.09.	472			250		583	450		380	232	225	80	
18.09.	465	750		220	575	580	475		375	220	220	50	
20.09.	460			220	570	575	400		370	220	200	dry	
22.09.	450	735		185	560	565	350		365	195	200	dry	
24.09.	440	720		160	550	550	320		360	170	190	dry	
26.09.	430	705		135	535	535	290		350	155	175	dry	
28.09.	420	705		130	530	525	280		350	135	165	dry	200
30.09.	413			110	515	512	250		340	90	148	dry	190
02.10.	400	680		80	500	500	220		330	10	130	dry	170
04.10.	390	665		80	490	490	215		325	dry	120	dry	165
06.10.	385	660		70	480	475	210		320	dry	100	dry	155
08.10.	375	650		50	470	460	190		310	dry	80	dry	140
10.10.	365	640		30	455	450	170		300	dry	60	dry	120
12.10.	365	635		40	445	440	165		300	dry	45	dry	110
14.10.	350	620		dry	430	415	140		280	dry	dry	dry	80
16.10.	340	610		dry	415	400	130		270	dry	dry	dry	50
18.10.	450	745		285	565	530	565		400	210	240	140	250

20.10.	440	745		265	570	550	540		380	190	295	140	240
22.10.	426	730		220	555	575	445		365		282	90	226
24.10.	410	715		170	540	570	380		350	125	270	dry	210
26.10.	400	700		132	527	560	342			dry	250		192
28.10.	385	685	320	90	510	550	295		325		230		170
30.10.	370	670	310	100	510	545	340		310		220		160
01.11.	375	675	310	125	515	550	400		320		235		165
03.11.	365	660	295	100	500	545	365		315		225		160
05.11.	350	640	270	55	485	525	280		290		200		125
07.11.	335	640	250	10	465	510	250		285		185		110
09.11.	350	640	269	115	486	520	332		295		196		112
13.11.	320	605	150	dry	450	485	195		265		145		50
15.11.	300	595	135		430	460	170		245		110		dry
17.11.	285	580	100		405	450	135		225		65		
19.11.	267	560	dry		372	420	93		195		dry		
21.11.	250	540			340	400	60		165				
23.11.	230	525			300	380	dry		60				
25.11.	210	505			250	330			dry				
27.11.	195	55			250	315							
29.11.	180	480			220	295							
01.12.	170	470			210	285							
03.12.	150	450			175	260							
05.12.	20	430			150	240							
07.12.	dry	410			110	220							
09.12.		386			85	190							
11.12.		370			60	150		310					
13.12.		350			60	125		305					
15.12.		340			40	120		290					
17.12.		320			dry			275					
19.12.						dry		260					
22.12.		280						240					
25.12.		253						215					
27.12.		230						194					
31.12.								154					
03.01		100						130					

Table 3: Depth gauge readings for some swamps where readings started during December 1995. These swamps had water throughout winter and spring, but were not monitored with gauges during that time.

DATE	PG2	PG3	PG4 north	PG4 south
05.12.	395			
07.12.	340			505
09.12.	270			465
11.12.	220	510		430
13.12.	165	455		370
15.12.	120	410	275	330
17.12.	55	350	137	260
19.12.	dry	300	205	187
22.12.		224	155	83
25.12.		150	90	dry
27.12.		110	45	
31.12.		50	dry	

Most of FMS2 remained dry during the survey, there was however a small depression in a grassy area that contained water during winter and spring. No depth gauge readings were taken in this depression, but invertebrates were sampled in it. This depression contained water from at least 28 July until 10 October when it dried out, and after rains again from 18 October until about 15 November.

A further depth gauge was in Poison Gully (the drain) itself in the area of Poison Gully Swamp 1. The data are not presented here, but the drain was dry by 19 November 1995.

E. Trapping

Table 4: 1995 Trapping success for individual swamps: percent of trap days at which one specimen of Long-necked Tortoise (*Chelodina oblonga*), Koonac (*Cherax preissii*), Gilgie (*Cherax quinquecarinatus*), and Yabby (*Cherax destructor*) was caught.

Swamp	number of trap days	*Chelodina oblonga*	*Cherax preissii*	*Cherax quinquecarinatus*	*Cherax destructor*
N2	574	0.52%	12.54%	-	-
N3	277	1.08%	13.36%	-	-
PG1 (drain)	57	50.88%	-	15.79%	5.26%
PG2	23	-	-	-	-
PG3	18	-	-	-	5.55%
PG4	32	-	-	3.13%	-
FMC2	43	-	16.28%	-	-
FMC4	134	-	74.63%	-	-
FMC6	330	-	0.61%	-	-
FMC8	220	1.82%	48.18%	-	-
FMS2 (pool)	122	-	-	-	-
FMS4	30	10.00%	-	-	-
FME1	98	3.06%	19.39%	-	-
FME2	150	-	-	-	-
FME3	293	-	76.45%	-	-
SE1	32	-	9.38%	-	-
SE2	88	3.41%	70.45%	-	-

Trapping with drift fences and traps or pits took place over different time periods according to water levels. One of the 18 swamps with drift fences, FMS3, never had enough water to set traps; only pits were used at this site. The other 17 sites had traps

for various periods, depending on the water levels. Since pits did not trap any vertebrates apart from a few frogs we only present the results of trapping with aquatic funnel traps. Various numbers of traps were used at different swamp sites. The trapping effort is presented as trap days, which combines the number of days any traps were set at a particular swamp site.

The low trapping result of FMC6 with only two Koonacs (trapping success 0.61%) and nothing else caught in 330 trap days is surprising, because the same trapline was used in 1994 with much better trapping results: in 334 trap days between 16 August and 25 October 1994, 13 Long-necked Tortoises and at least 30 Koonacs (number estimated, no hard data available) were caught. Link Road Swamp (FMS4) was also trapped in 1994, with 32 trap days from 05 November until 07 December 1994, when 12 Long-necked Tortoises and no crayfish were caught.

Table 5: 1994 Trapping success for FMC6 and FMS4 (Link Road Swamp):

Swamp	number of trap days	*Chelodina oblonga*	*Cherax preissii*	*Cherax quinquecarinatus*	*Cherax destructor*
FMC6	334	3.89%	≈ 9%	-	-
FMS4	32	37.5%	-	-	-

The trapping success of FMC6 in 1994 was comparable to the 1995 trapping result of FME1. In 1994, all Koonacs have been released back into FMC6, whereas the tortoises were released into Runway Swamp (FMS1) which is close by. This may explain the lack of Long-necked Tortoises in FMC6 in 1995, but not the low catch rate of Koonacs. All Long-necked Tortoises caught in FMS4 in 1994 were released back into FMS4. Most of the FMS4 tortoises in 1994 were juveniles (carapace lengths: 184.9, 131.8, 75.5, 70.7, 68,9, 66.8, 65.6, 64.3, 62.2, 59.6, 39.7, 39.0 mm), which indicates that FMS4 is a good breeding habitat for Long-necked Tortoises.

The data in Table 4 and 5 indicate that high densities of Long-necked tortoises (≥10% trapping success) may exclude Koonacs from swamps. High densities of Long-necked Tortoises were found in Link Road Swamp (FMS4) and the Poison Gully drain (PG1 - the only trap was not set in the swamp area, but in the drain). The relationship of the density of Koonacs to swamp quality for Western Swamp Tortoises has not been investigated. Koonacs occur in some swamps at Twin Swamp Nature Reserve, but have not been observed or trapped in the swamps at Ellen Brook Nature Reserve. The absence of Koonacs in some swamps (e.g., Ellen Brook Nature Reserve, Airport swamps PG2, PG3, FME2) may be related to their clay soils with very little sand. Koonacs may favour sandy clay or sand over clay soils.

The occurrence of the Yabby *Cherax destructor* in Munday Swamp, the Poison Gully drain and Poison Gully Swamp 3 should be a matter of concern, since the Yabby is not native to South-western Australia.

The overall trapping results for individual swamps in 1995 were:

North Swamp 2 (N2): trapping occurred from 15 August until 03 December 1995, with a total of 574 trap days. 72 Koonac (*Cherax preissii*), 3 Long-necked Tortoises *Chelodina oblonga* (carapace lengths: 213, 218, 240 mm), 2 *Limnodynastes dorsalis*, 2 *Litoria moorei* and 2 Australasian Grebes were caught and released.

North Swamp 3 (N3): trapping occurred from 21 September 1995 until 03 January 1996, with a total of 277 trap days. 37 Koonac, 3 Long-necked Tortoises (carapace lengths: 212, 231, 232 mm), 2 juvenile Australian Grey Teal, 1 juvenile Pacific Black Duck, and 1 juvenile Australasian Grebe were caught and released.

Poison Gully Swamp 1 (PG1): trapping occurred from 25 September until 21 November 1995, a total of 57 trap days. 29 Long-necked Tortoises (carapace lengths: 250.5, 221.8, 234.4, 208.3, 214.3, 195.1, 237.6, 249.1, 202.6, 223.9, 231.3, 240.5, 244.6, 179.1, 231.7, 237.2, 222.2, 237.0, 179.4, 178.9, 241.8, 175.1, 208.0, 170.3, 180.1, 252.0, 234.1, 235.0 mm, plus one dead juvenile), 9 Gilgies, 3 Yabbies, 2 *Litoria moorei*, 1 duckling (*Anas superciliosa*) were caught and released.

Poison Gully Swamp 2 (PG2): trapping occurred from 04 December until 22 December 1995, a total of 23 trap days. Nothing was trapped.

Poison Gully Swamp 3 (PG3): trapping occurred from 04 December until 22 December 1995, a total of 18 trap days. 1 Yabby was caught and kept as voucher specimen.

Poison Gully Swamp 4 (PG4); trapping occurred from 06 December until 27 December 1995, a total of 32 trap days. 1 Gilgie was caught and released.

Five Mile Centre Swamp 2 (FMC2): trapping occurred from 25 October until 19 November 1995, a total of 43 trap days. 7 Koonacs were caught and released.

Five Mile Centre Swamp 4 (FMC4): trapping occurred from 15 August until 14 November 1995, a total of 134 trap days. 100 Koonacs and 1 Buff-banded Rail were caught and released.

Five Mile Centre Swamp 6 (FMC6): trapping occurred from 20 September until 15 December 1995, a total of 330 trap days. 2 Koonacs were caught and released.

Five Mile Centre Swamp 8 (FMC8): trapping occurred from 15 August until 13 December 1995, a total of 220 trap days. 106 Koonacs and 4 Long-necked Tortoises (carapace lengths: 181.3 [caught three times], 177.3 [caught twice], 174.6, 136.4 mm) were caught and released.

Five Mile South Swamp 2 (FMS2): trapping occurred from 14 August until 14 November 1995, a total of 122 trap days. 5 *Limnodynastes dorsalis* were caught and released.

Five Mile South Swamp 4 (FMS4) (Link Road Swamp): trapping occurred from 14-19 August 1995 (when the trap was stolen) and again from 08 December 1995 until 03 January 1996, a total of 30 trap days. 3 Long-necked Tortoises (carapace lengths: 123, 125, 128 mm) were caught and released.

Five Mile East Swamp 1 (FME1): trapping occurred from 15 August until 21 November 1995, a total of 98 trap days. 3 Long-necked Tortoises (carapace lengths: 171.8, 145, 164.8 mm) and 19 Koonacs were caught and released.

Five Mile East Swamp 2 (FME2): trapping occurred from 16 August until 06 October 1995, a total of 150 trap days. 6 ducks (a mother *Anas superciliosa* with 5 ducklings) and 1 Bobtail (*Tiliqua rugosa*) were caught and released.

Five Mile East Swamp 3 (FME3): trapping occurred from 16 August until 19 November 1995, a total of 293 trap days. 224 Koonacs and 3 Bobtails (*Tiliqua rugosa*) were caught and released.

South East Swamp 1 (SE1): trapping occurred from 10-18 September and from 18-26 October 1995, a total of 32 trap days. 3 Koonacs and 1 Bobtail (*Tiliqua rugosa*) were caught and released, 1 Quenda (the western subspecies of the Southern Brown Bandicoot, *Isodoon obesulus*) was found dead in a trap.

South East Swamp 2 (SE2): trapping occurred from 28 September until 11 November 1995, a total of 88 trap days. 62 Koonacs and 3 Long-necked Tortoises (carapace lengths: 198.5 [caught twice], 173.6, 161.6 mm) were caught and released.

F. Searches

Searches involved all 39 swamp sites plus some drains at the airport land. Long-necked Tortoises were frequently observed, in particular in drains. Four Long-necked Tortoises were found dead in or near FME1: two adults which were obviously trodden on and cracked open by horses in shallow water (Figs. 48-51), one juvenile which may have been predated and another one which was floating dead in a puddle on a firebreak close to FME1. At the time this track was heavily used by off road vehicles.

Commonly observed frogs in many swamps included *Litoria adelaidensis*, *Litoria moorei*, *Ranidella glauerti* and *insignifera*, *Crinia georgiana*, and *Limnodynastes dorsalis*. *Pseudophryne guentheri* was found in FME2 and *Heleioporus eyrei* in FMS4.

7. DISCUSSION

A. Presence of the Western Swamp Tortoise

No Western Swamp Tortoises were captured during the survey. Noting that the area recently supported the species and the difficulty of detecting these tortoises when at low density, it seems likely that if the species still exists in the area it would be represented by a few scattered individuals. Additional survey effort in future years may detect some remaining individuals. Continued trapping, perhaps at lower levels than in 1995 may detect some animals. Any animals found would be extremely valuable as founders for translocated populations (see below) and could also provide a wider genetic base from which to captive-breed tortoises for future translocations (the present captive and known wild animals have limited genetic diversity).

The Oblong (or Long-necked) Tortoise *Chelodina oblonga* was captured in many swamps at the Airport. The presence of this species does not mean that these swamps are not suitable for Western Swamp Tortoises; both species occur together in some types of ephemeral swamps. Both are found at Twin Swamps Nature Reserve and, before the fox-proof fence was built, at Ellen Brook Nature Reserve.

B. Suitability of Perth Airport as "habitat" for the Western Swamp Tortoise

Suitability of habitat (within the meaning of the *ESP Act*) for the Western Swamp Tortoise has been judged in terms of

(i) water depth and duration during 1995,
(ii) water chemistry of samples taken from ten swamps,
(iii) invertebrate species diversity and biomass sampled in nine of the ten swamps for which water chemistry data are available, and
(iv) our experience gained during many years of researching and managing Western Swamp Tortoises.

In addition, we have provided information on management issues relating to each area discussed.

The proposed business park

With the exception of FMC8, the suitability of swamps in the area proposed as Business Park is at present low because most of the swamps in this area are too highly modified and/or drained. FMS2, FMS3, FMS5, FMS6 and FMS7 did not retain any significant quantities of water during 1995. FMC8, which is situated at the northern edge of the proposed Business Park, had sufficient water during 1995 and in the invertebrate study clustered with South West Swamp at Twin Swamp Nature Reserve.

South West Swamp was known to harbour tortoises during the 1960s and during 1995, translocated tortoises released there survived and grew satisfactorily.

Halse and Storey, when discussing the results from aquatic invertebrate and water quality surveys, stated that FMS3 (their A12) had the most similar water quality and also a similar invertebrate community composition to swamps in Ellen Brook and Twin Swamps Nature Reserves and that it must be viewed as potential habitat for the Western Swamp Tortoise. During 1995 this swamp was dry (except for a small pool) during most of the survey; however, during 1991 it did contain water. The swamp has a healthy overstory of *Melaleuca* similar in structure to other swamps that flood well in most years. However, it is now heavily overgrown by exotic grasses, suggesting that it has been fairly dry for some time. Why it is now dry is not clear since there is no obvious drain. It could be affected by drainage northwards into Runway Swamp, or it could be affected by broader scale changes to water tables due to drainage and groundwater pumping.

Investigations into flooding regimes and groundwater levels would be needed before a clear statement could be made that the swamp could be rehabilitated as habitat for the Western Swamp Tortoise. Should rehabilitation be possible, FMS3 and FMS2 (originally the same swamp, but now divided by Link Road and its bund) could together provide about 3 ha of swamp habitat. These two swamps are proposed to be filled and developed in the Business and Recreation Park proposal. If they were rehabilitated and conserved they could be linked to our proposed Five Mile Swamp centre group conservation area (see below).

FMS1 (Runway Swamp) has a small semi-permanent core and a dry perimeter, having been excavated, and is not good Western Swamp Tortoise habitat. FMS4 (Link Road Swamp) is small and relatively deep and retains water until early- to mid-summer. It, also, is not good Western Swamp Tortoise habitat. Both the latter swamps are suitable *Chelodina oblonga* habitat and should be retained and managed as swamp habitat as part of any future development.

Swamp FMC8 is in good condition and provides suitable Western Swamp Tortoise habitat and in 1995 had good water depths and invertebrate species diversity and biomass. However, it is small and isolated and would support very few Western Swamp Tortoises on its own. This problem could be overcome if FMC8 was included in the larger Five Mile Swamp Centre group of swamps rehabilitated for Western Swamp Tortoises (see below).

Other areas

Some other swamps within land owned by the Federal Airports Corporation provide or could provide suitable Western Swamp Tortoise habitat.

The most suitable groups of swamps, in priority order, are

1. North Group

These swamps, totalling about 5 ha are in good condition. Most have suitable invertebrate species diversity and biomass. Halse and Storey considered that N3 (their A3) must be considered to be potential habitat because of the similarity of its community composition to North West Swamp at Twin Swamps Nature Reserve. Suitable aestivation habitat exists around North group swamps, but improved fire management is needed. Reasonable quality Banksia woodland surrounds some of the swamps. Two of these swamps are inside the security fence and two outside. A relatively small amount of extra fencing would be required to enclose the whole area within the security fence. However, the present security fence is not "fox-proof" and needs modification to prevent foxes climbing or burrowing beneath it.

Translocation of captive-bred Western Swamp Tortoises into this area would be possible once it is secure and managed (see below).

2. Five Mile Swamp centre group

FMC1, FMC2, FMC3, FMC4, FMC5 and FMC6 appear to have provided excellent Western Swamp Tortoise habitat, but at present are greatly affected by the Main Drain and retain little water during winter and spring. Bunding and other suitable management could probably lead to rehabilitation of these swamps and make them again suitable for Western Swamp Tortoises. To these should be added FMC8 (see above) and FMC7. Halse and Storey considered that FMC6 (their A10) must be considered to be potential habitat because of the similarity of its community composition to North West Swamp at Twin Swamps Nature Reserve. Some of these swamps are inside the security fence and some are outside. The Airport Link Road bisects the area as does the Main Drain.

Before this area could be made suitable for the Western Swamp Tortoise the following actions are needed:

(I) To prevent drainage of the swamps the Main Drain would need to be run underground through pipes. Overflow drainage from some swamps would probably be required to ensure no flooding of airport runways.

(ii) A fox-proof fence would need to be constructed around the area.

(iii) Problems associated with Link Road need to be addressed. Tunnels could be built beneath it to allow tortoise movements and a low fence built either side to prevent tortoise access onto the road.

3. Five Mile Swamp east group

FME1 has the highest invertebrate species diversity of any swamp examined. Halse and Storey considered that FME1 (their A33) must be considered to be likely habitat

because of the similarity of its community composition to swamps at Twin Swamps and Ellen Brook Nature Reserves. FME2 appears suitable but in 1995 held little water, presumably because of drainage. FME3 is in good condition and has a fairly large area of swamp, but appears to be significantly affected by drainage.

The whole area is affected by drains which would need modification. It is also heavily used by horse riders and off-road vehicles.

4. Poison Gully group

Swamps in this area have suitable depth and duration. Invertebrate species diversity and biomass were suitable in the one swamp sampled.

Most of the area, especially outside the swamps themselves, are very degraded. The land is leased and used for a variety of purposes, including horse agistment and riding. Before this area could be made suitable for Western Swamp Tortoises it would need extensive long term rehabilitation. At FME1 two *Chelodina oblonga* were found with severe injuries, presumed to be caused by horses hooves (Figs. 48-51). Similar injuries would be sustained by Western Swamp Tortoises in this area unless horses and stock were excluded.

5. South East group

The area including SE1 and SE2 has some areas of good quality *Banksia* woodland vegetation and would make an high quality nature conservation reserve. The swamps, however, are not deep and would probably not provide good Western Swamp Tortoise habitat in dry years unless a deeper swamp was created as a drought refuge.

6. Munday group

Munday Swamp itself is not Western Swamp Tortoise habitat; it does, however, support a population of *Chelodina oblonga*. Swamps to the west of Munday Swamp are all affected by drainage, clearance and/or weed invasion. The best is MW1, which had breeding Black-headed Stilts in 1995.

The area does not provide adequate Western Swamp Tortoise habitat at present. However, as most swamps are within the security fence their rehabilitation should be examined.

C. Translocations of the Western Swamp Tortoise

The Western Swamp Tortoise Recovery Plan for the period 1993 to 2002 provides for translocation of captive-bred Western Swamp Tortoises from Perth Zoo to Twin Swamps Nature Reserve. No other translocation sites are prescribed.

In 1995, the Western Swamp Tortoise Recovery Team decided to review the Recovery Plan for the second five period of its operation. One reason for the review was that captive breeding had been more successful than anticipated, leading to the conclusion that extra translocation sites could be supported. The Recovery Team is concerned that the existing nature reserves for the Western Swamp Tortoise, Ellen Brook and Twin Swamps Nature Reserves, are small in area and may not be able to support large enough populations of the Western Swamp Tortoise for the species to be downgraded from Critically Endangered.

The review has not been completed. Few translocation sites are available since the vast majority of the area once inhabited by the species has been greatly modified since European settlement. However, a list of possible translocation sites has been prepared and preliminary inspections have been made of them: in Drummond Nature Reserve near Toodyay, near Peel Inlet, at Dobaderry Swamp in the Darling Range as well as at Perth Airport. Of these, Perth Airport is the only site examined that is within the known geographic range of the species. The Peel Inlet sites are the only other prospective area on the Swan coastal plain, but the preliminary inspection suggested that they are primarily Long-necked Tortoise habitat rather than Western Swamp Tortoise habitat. The other two sites, while appearing suitable in some ways, are east of the Darling Scarp in an area where the species has never been recorded and where climatic conditions are different and may be unsuitable.

Based on current information, Perth Airport appears to provide the best available translocation sites for the Western Swamp Tortoise. Before translocation can be firmly recommended the review of the Recovery Plan must be completed and adopted by both the Western Australian and Commonwealth Governments. Resources for the implementation of recovery actions, including any translocations to Perth Airport and the conservation management of airport land, must be identified.

Translocation to Perth Airport can only take place if some of the areas identified in this report are given long term protection from development (possibly as National Nature Reserves) and are made suitable for the establishment of Western Swamp Tortoise populations. Required management actions will include the exclusion of foxes and other feral predators, maintenance of suitable water levels by drainage modification and habitat management, water quality monitoring, and fire management. Translocations, if approved, must be closely monitored by radio-tracking translocated animals and monitoring of population status over many years.

8. CONCLUSIONS

1. The Western Swamp Tortoise has inhabited swamps and associated vegetation at Perth Airport within the past few decades, which equates to only one or two generations of this long-lived, slow-growing species.

2. No Western Swamp Tortoises were detected during the 1995 survey. However, the species is very difficult to detect when it is in low numbers. Based on the present level of information the species can not be considered to be locally extinct at the airport.

3. Some swamps within Perth Airport land provide suitable habitat for the Western Swamp Tortoise, a Critically Endangered Species specially protected under Commonwealth and Western Australian legislation. Western Swamp Tortoises could survive and breed in these swamps with minor changes to land management practices (mainly the exclusion of foxes) and constitute 'habitat', as defined in the ESP Act.

4. Additional swamps and adjacent areas could be made suitable as Western Swamp Tortoise habitat with modifications to the drainage system and current land management practices. These areas, also, are 'habitat' as defined in the ESP Act.

5. Areas within Perth Airport proposed as a Business Park do not contain swamps currently suitable as habitat for the Western Swamp Tortoise, with the exception of one swamp, FMC8, which should be excluded from the Business Park and added to the proposed Five Mile Swamp centre group conservation area. It may be possible to rehabilitate Swamps FMS2 and FMS3 so they become suitable habitat for the Western Swamp Tortoise (see Discussion), but further investigations of the flooding regime and groundwater levels are required.

9. RECOMMENDATIONS

1. Attempts to capture Western Swamp Tortoises on Perth Airport land should continue, but at a lower level of intensity than in 1995.

2. Areas within Perth Airport land should be set aside for the conservation of the Western Swamp Tortoise (possibly as National Nature Reserves) and rehabilitated and managed as habitat for the Western Swamp Tortoise so the species can be translocated from the captive-bred population at Perth Zoo. This will require significant changes in land use outside the airport security fence and changes to drainage patterns both within and outside the security fence.

   Proposed Western Swamp Tortoise conservation areas, in order of priority, are:

   North group conservation area,
   Five Mile Swamp centre group conservation area,
   Five Mile Swamp east group conservation area,
   Poison Gully group conservation area,
   South East group conservation area, and
   Munday group conservation area.

3. Swamp FMC8 should be excluded from the proposed Business Park development and included in Five Mile Swamp centre group conservation area.

4. Further investigations of the flooding regime and groundwater levels at and surrounding Swamps FMS2 and FMS3 be made to find out whether they can be rehabilitated to become suitable habitat for the Western Swamp Tortoise. These swamps on their own are probably too small to become a conservation area; they would need to be combined with Five Mile Swamp centre group conservation area if rehabilitated. Although it may be possible to rehabilitate these two swamps in the Business Park area, we believe that concentrating on the rehabilitation and conservation management of swamps elsewhere on Airport land has a higher priority, particularly our first two priorities for conservation areas, provided above.

10. ACKNOWLEDGEMENTS

We thank Dr Brenton Knott for help with the identification of the freshwater crayfish.

11. REFERENCES

ANCA (1993).The Action Plan for Australian Reptiles. ANCA, Canberra.

Burbidge, A.A., Kuchling, G., Fuller, P.J., Graham, G. and Miller, D. (1990). The Western Swamp Tortoise. Western Australian Wildlife Management Program No. 6, CALM, Perth.

Burbidge, A.A. and Kuchling, G. (1994). Western Swamp Tortoise Recovery Plan. Western Australian Wildlife Management Program No. 11, CALM, Perth, 29pp.

IUCN (1982). Red data book Amphibia-Reptilia, Part 2. IUCN, Morges, Suisse.

IUCN (1994). IUCN Red List categories. Prepared by the IUCN Species Survival Commission. As approved by the 40th meeting of the IUCN Council, Gland, Switzerland, 30 November 1994. IUCN, Gland.

IUCN/SSC Tortoise and Freshwater Turtle Specialist Group (1989). Tortoises and freshwater turtles: an action plan for their conservation. IUCN/SSC Tortoise and Freshwater Turtle Specialist Group, Gland, Switzerland, 48 pp.

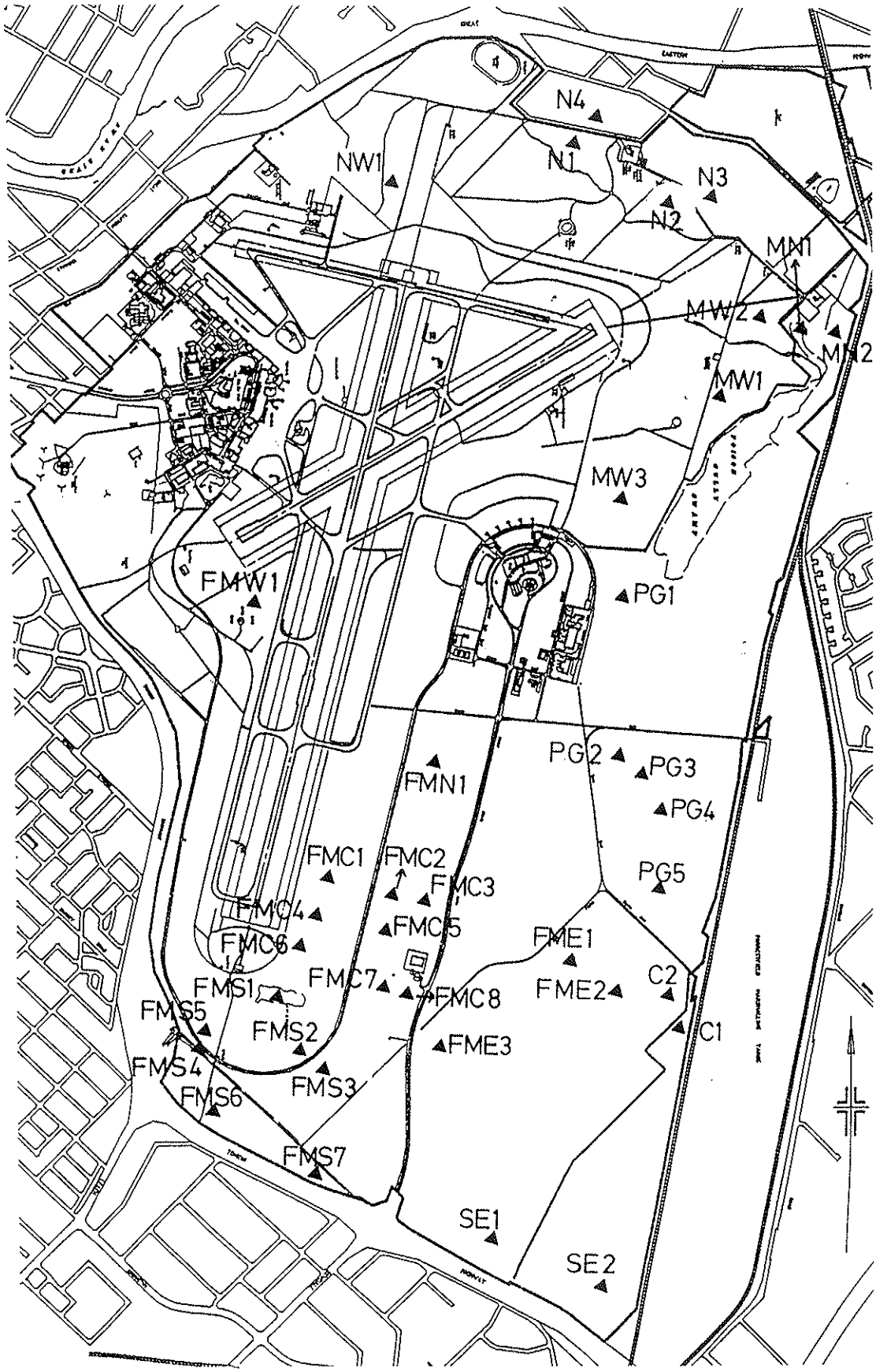

Figure 1 Map of Perth Airport land with location of the 39 swamp sites (triangles). Symbols as in Table 1.

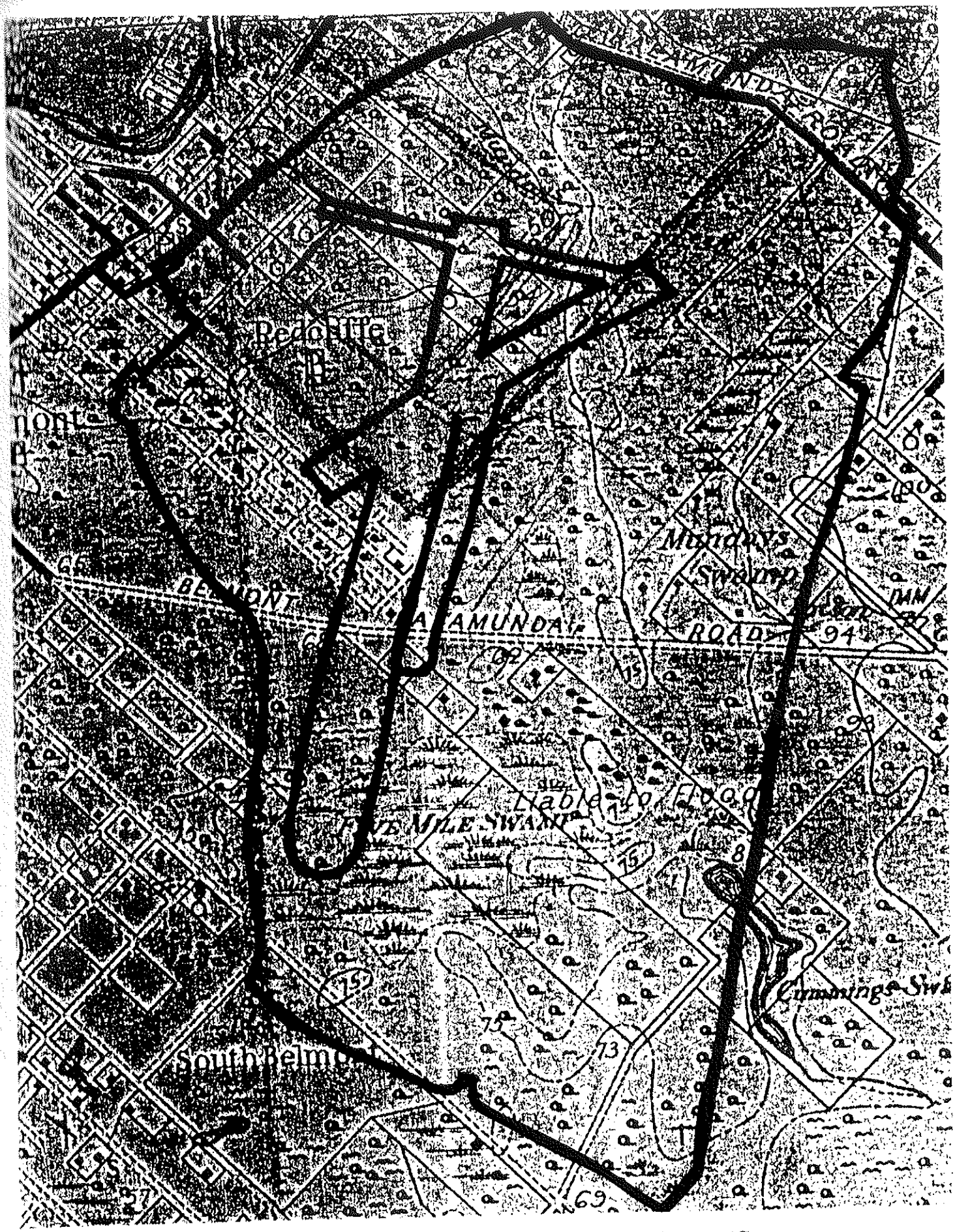

Figure 2: Enlarged copy (to about 1:20000) of the 1919 Perth map (Commonwealth Department of Defence, Sheet South H.50, 1:63 360, correct to December 1915) with Perth Airport land overprinted.

Figure 3: North Swamp 1 (N1), 26.10.1995

Figure 4: North Swamp 2 (N2), *Hydrocotyle lemnoides*, 16.09.1994

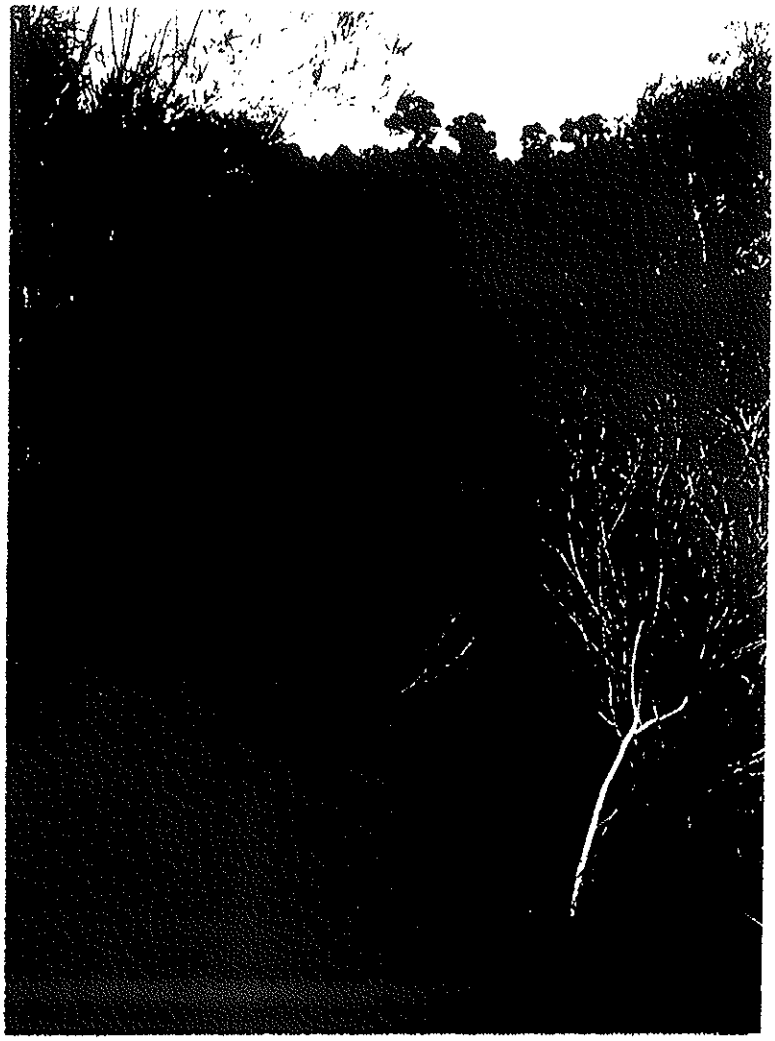

Figure 5: North Swamp 2 (N2) main area, 29.08.1991.

Figure 6: North Swamp 2 (N2) eastern part, 16.07.1994.

Figure 7: North Swamp 3 (N3) main central part, 30.09.1995.

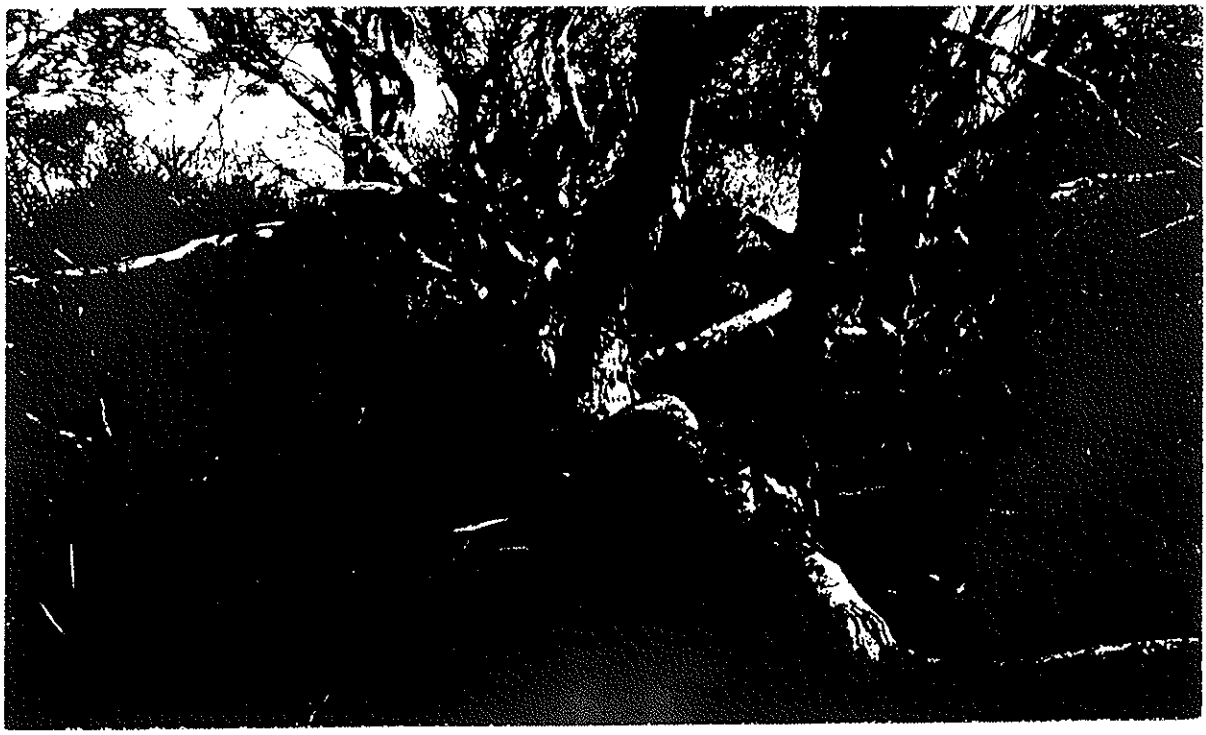

Figure 8: North Swamp 3 (N3) western margin,08.10.1994.

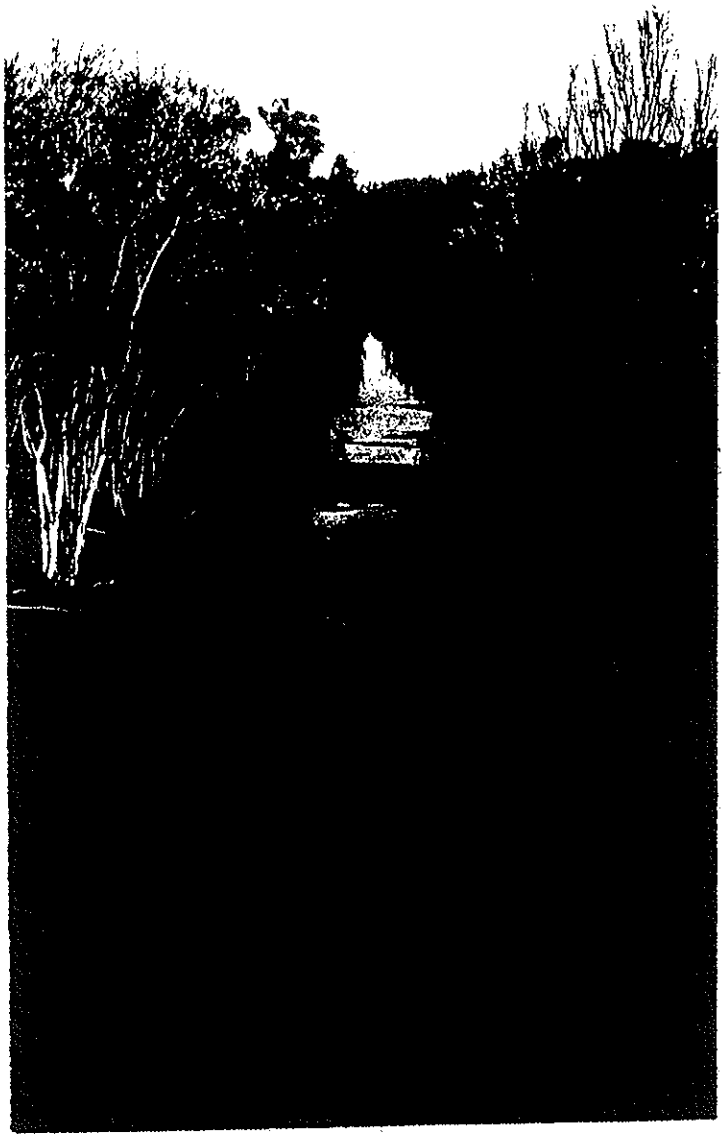

Figure 9: North Swamp 3 (N3), firebreak in southern part, 03.01.1996.

Figure 10: North Swamp 4 (N4), 23.09.1995.

Figure 11: Munday Swamp (main swamp area), 03.01.1996.

Figure 12: Munday North Swamp 2 (MN2), 23.09.1995.

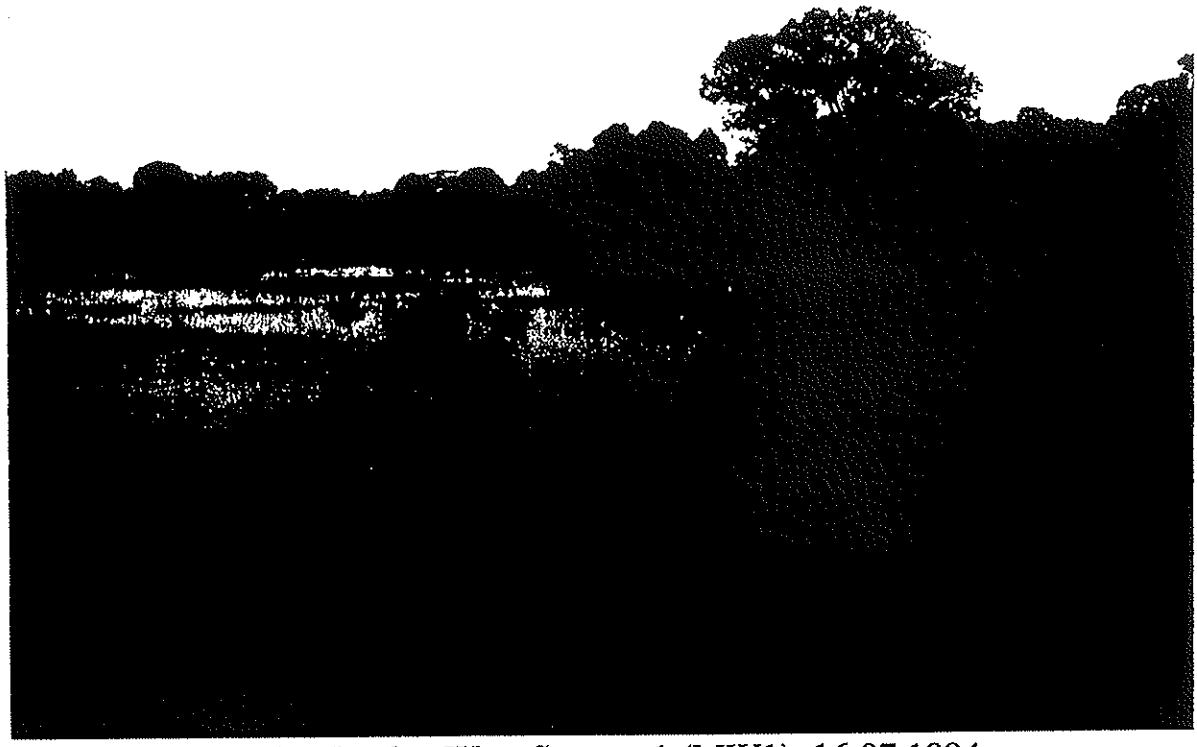

Figure 13: Munday West Swamp 1 (MW1), 16.07.1994.

Figure 14: Munday West Swamp 1 (MW1), just after falling dry, 18.10.1994.
Shells of crustaceans (Conchostraca) on the ground.

Figure 15: Munday West Swamp 3 (MW3) + drainage channel, 27.11.1993.

Figure 16: Poison Gully Swamp 1 (PG1), drain, 30.09.1995.

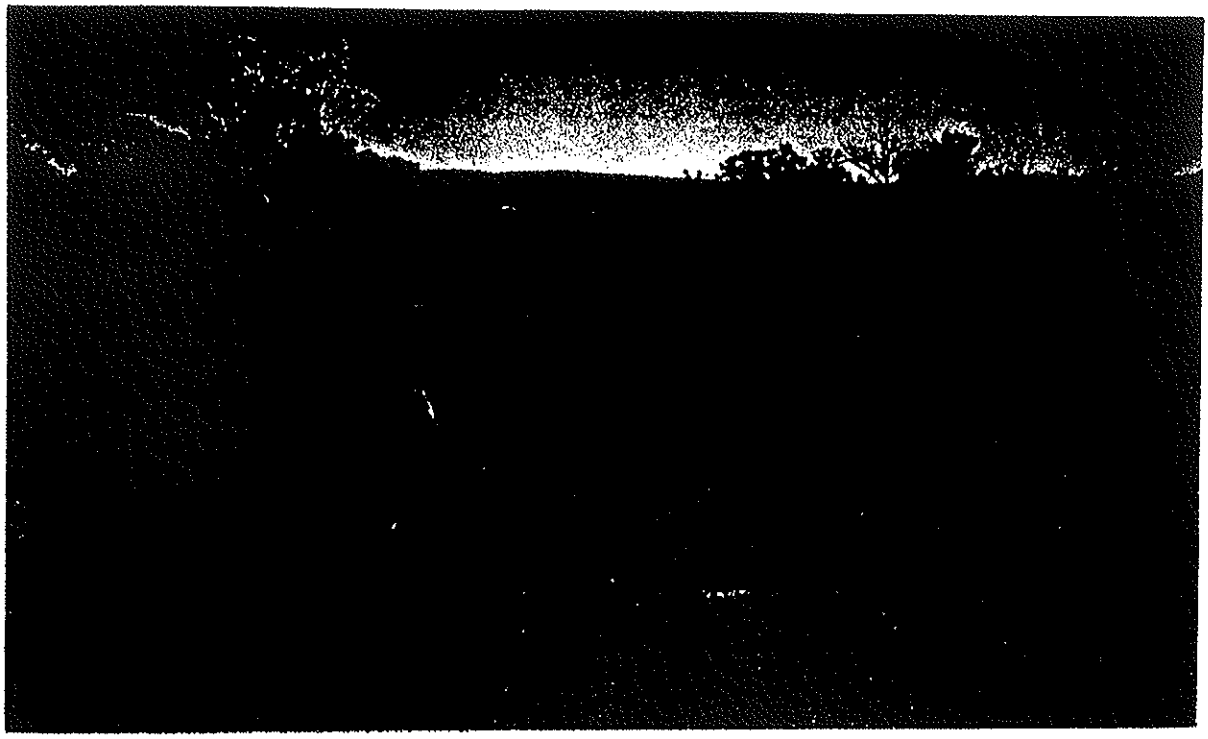

Figure 17: Poison Gully Swamp 1 (PG1), northern part towards Munday Swamp, 24.09.1995.

Figure 18: Poison Gully Swamp 1 (PG1), south-eastern part, 24.09.1995. Puddling for tortoises in the last water puddles.

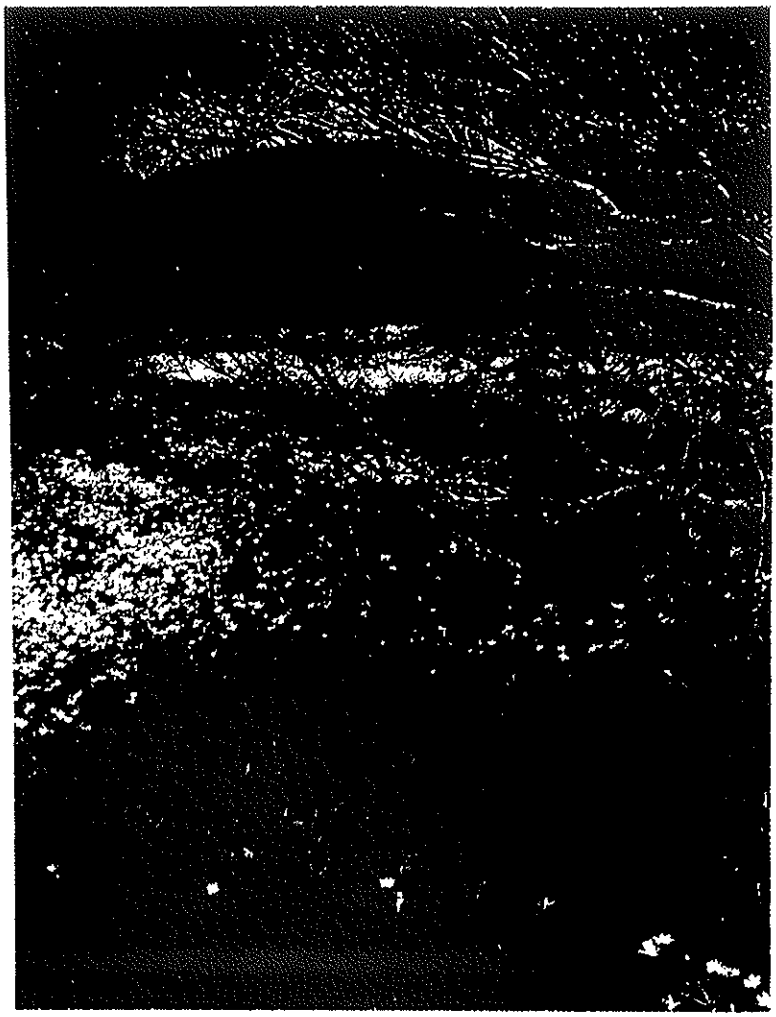

Figure 19: Poison Gully Swamp 1 (PG1), part west of drain, 24.09.1995.

Figure 20: Poison Gully Swamp 2 (PG2), eastern margin with last water, 17.12.1995

Figure 21: Poison Gully Swamp 3 (PG3), deepest part with the last water (15 cm at gauge) and horse. In foreground *Melaleuca lateritia*. 25.12.1995.

Figure 22: Poison Gully Swamp 3 (PG3), 06.08.1995. Mr Lidlow points out the place near the *Melaleuca lateritia* stand where, three years ago in summer, he allegedly found a dry Western Swamp Tortoise shell.

Figure 23: Poison Gully Swamp 3 (PG3), 29.11.1995. Yellow Billed Spoonbills.

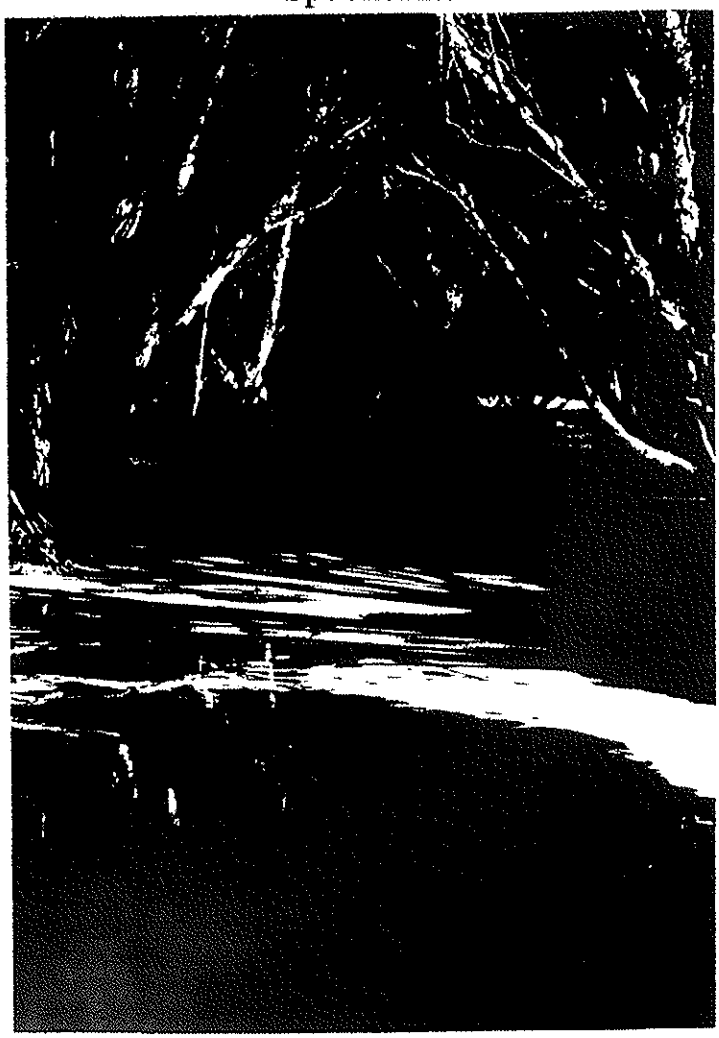

Figure 24: Poison Gully Swamp 4 (PG4), 29.11.1995.

Figure 25: Poison Gully Swamp 4 (PG4), northern part, 19.12.1995.

Figure 26: Five Mile Centre Swamp 1 (FMC1), excavated area in south-west corner, 27.11.1993

Figure 27: Five Mile Centre Swamp 2 (FMC2) and main drain with pipes draining the swamp areas. 03.12.1995.

Figure 28: Five Mile Centre Swamp 4 (FMC4), southern end of half-circle drain which drains the water into the main drain. 16.09.1995

Figure 29: Five Mile Centre Swamp 4 (FMC4), area adjacent to runway, 16.07.1994.

Figure 30: Five Mile Centre Swamp 6 (FMC6), 05.10.1994.

Figure 31: Five Mile Centre Swamp 7 (FMC7), drift fence and pit (water on ground of pit), 16.09.1995.

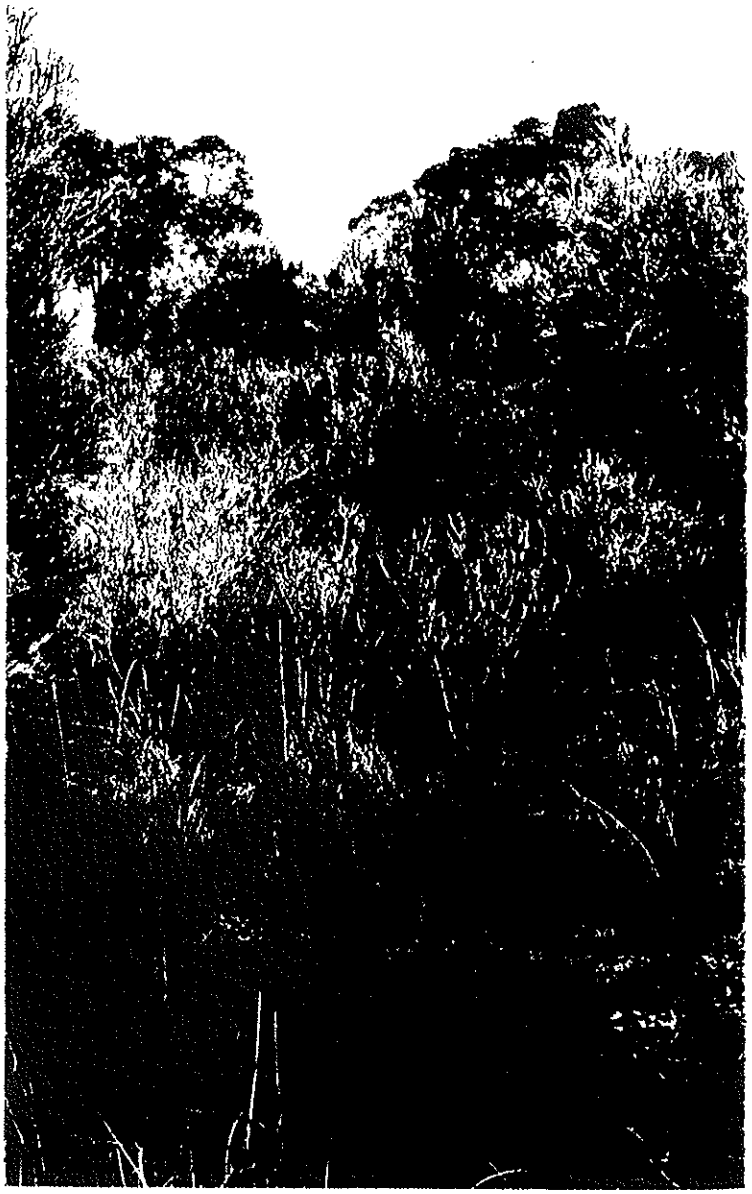

Figure 32: Five Mile Centre Swamp 8 (FMC8), western part, 15.10.1995.

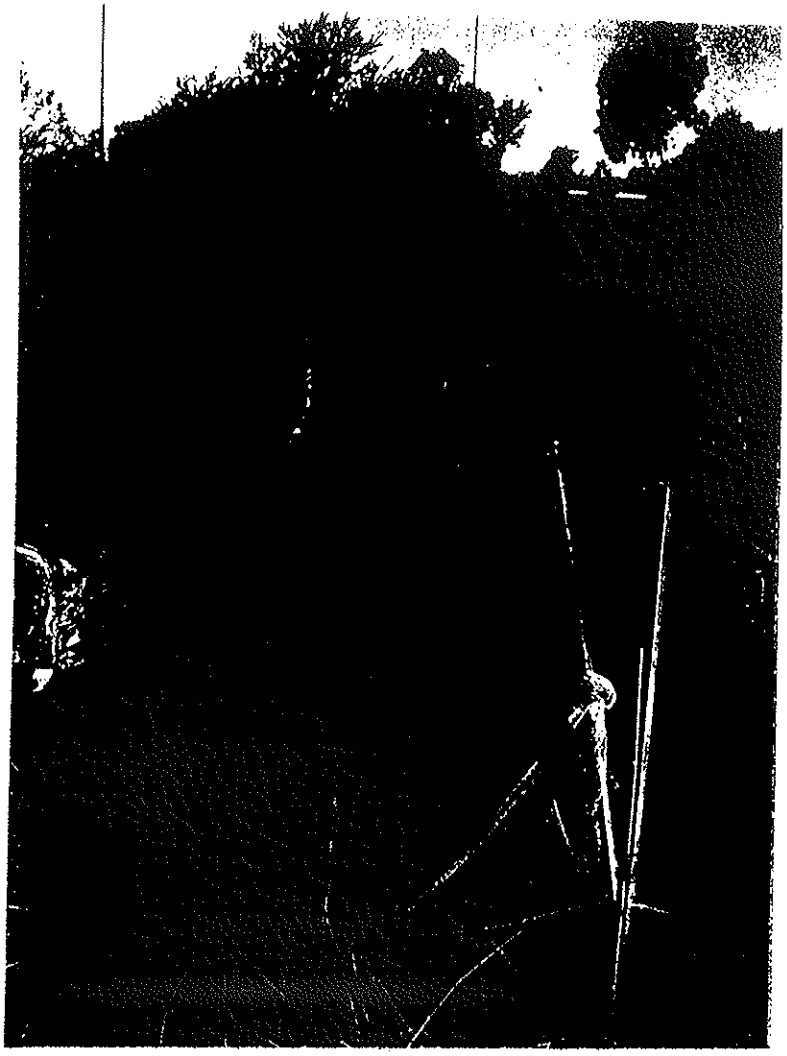

Figure 33: Five Mile Centre Swamp 8 (FMC8), eastern part, 09.12.1995.

Figure 34: Five Mile Centre Swamp 8 (FMC8), western part, 15.10.1995.

Figure 35: Five Mile South Swamp 2 (FMS2), 29.08.1991, young scoots.

Figure 36: Five Mile South Swamp 2 (FMS2), trap in area which was intermittendly flooded during September. 30.09.1995.

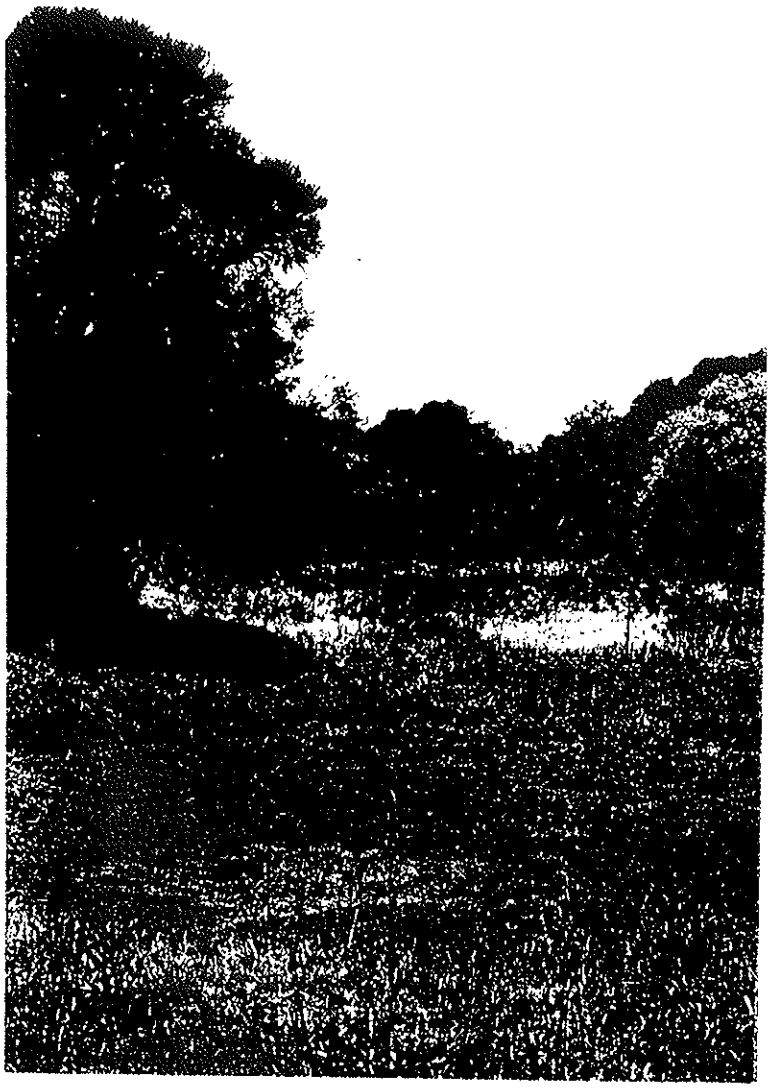

Figure 37: Five Mile South Swamp 3 (FMS3), depression in eastern part, 15.10.1995.

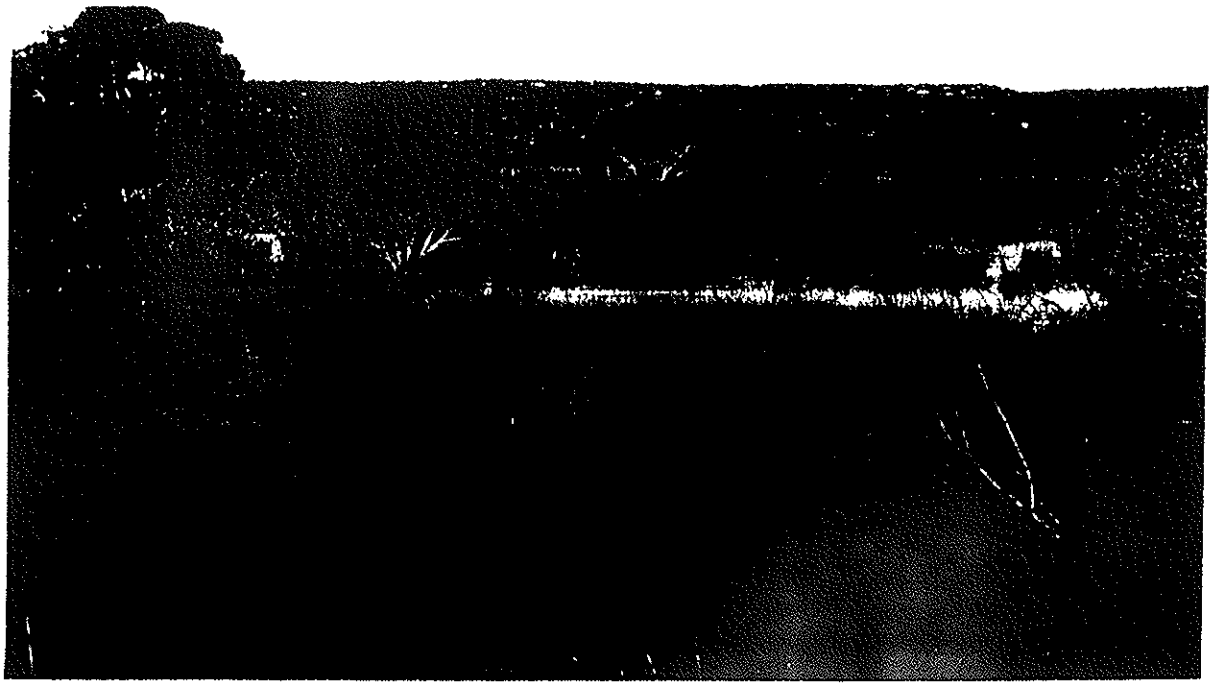

Figure 38: Five Mile East Swamp 1 (FME1), western part, 21.07.1994

Figure 39: Five Mile East Swamp 1 (FME1), central part,21.07.1994.

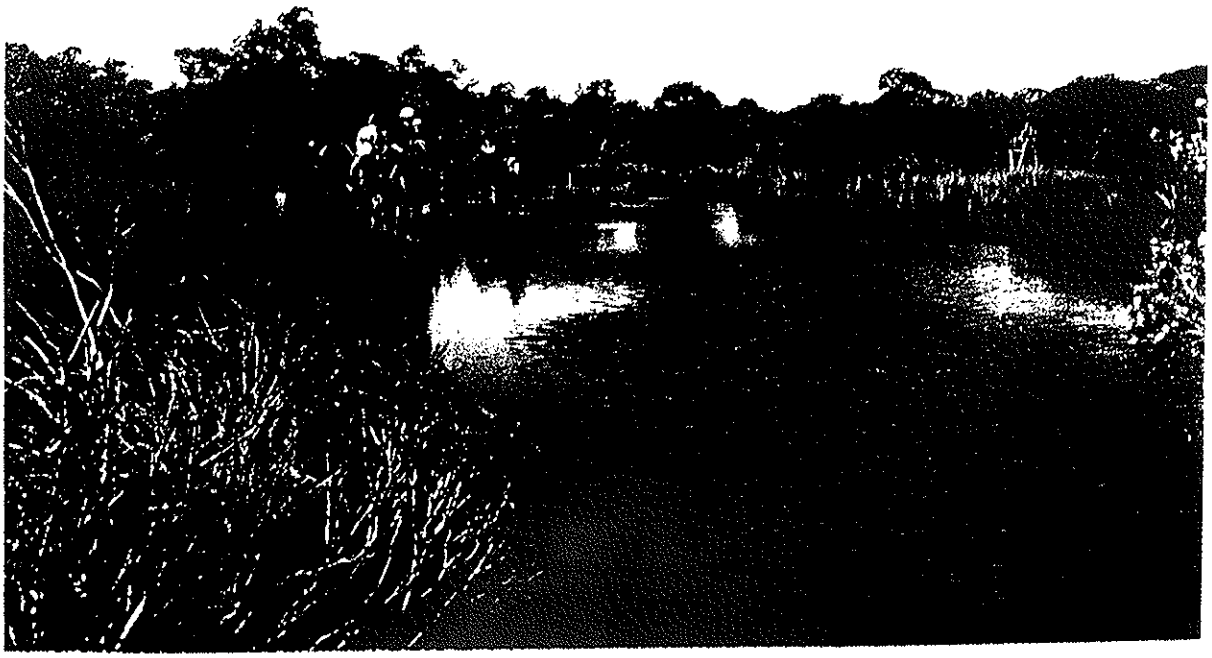

Figure 40: Five Mile East Swamp 1 (FME1), eastern part , 22.10.1995.

Figure 41: Five Mile East Swamp 2 (FME2), 21.07.1994.

Figure 42: Five Mile West Swamp 1 (FMW1), drain through its centre, 27.11.1993.

Figure 43: South East Swamp 1 (SE1), 22.10.1995.

Figure 44: South East Swamp 2 (SE2), 30.09.1995.

Figure 45: South East Swamp 2 (SE2), 23.09.1995.

Figure 46: South East Swamp 2 (SE2), 23.09.1995.

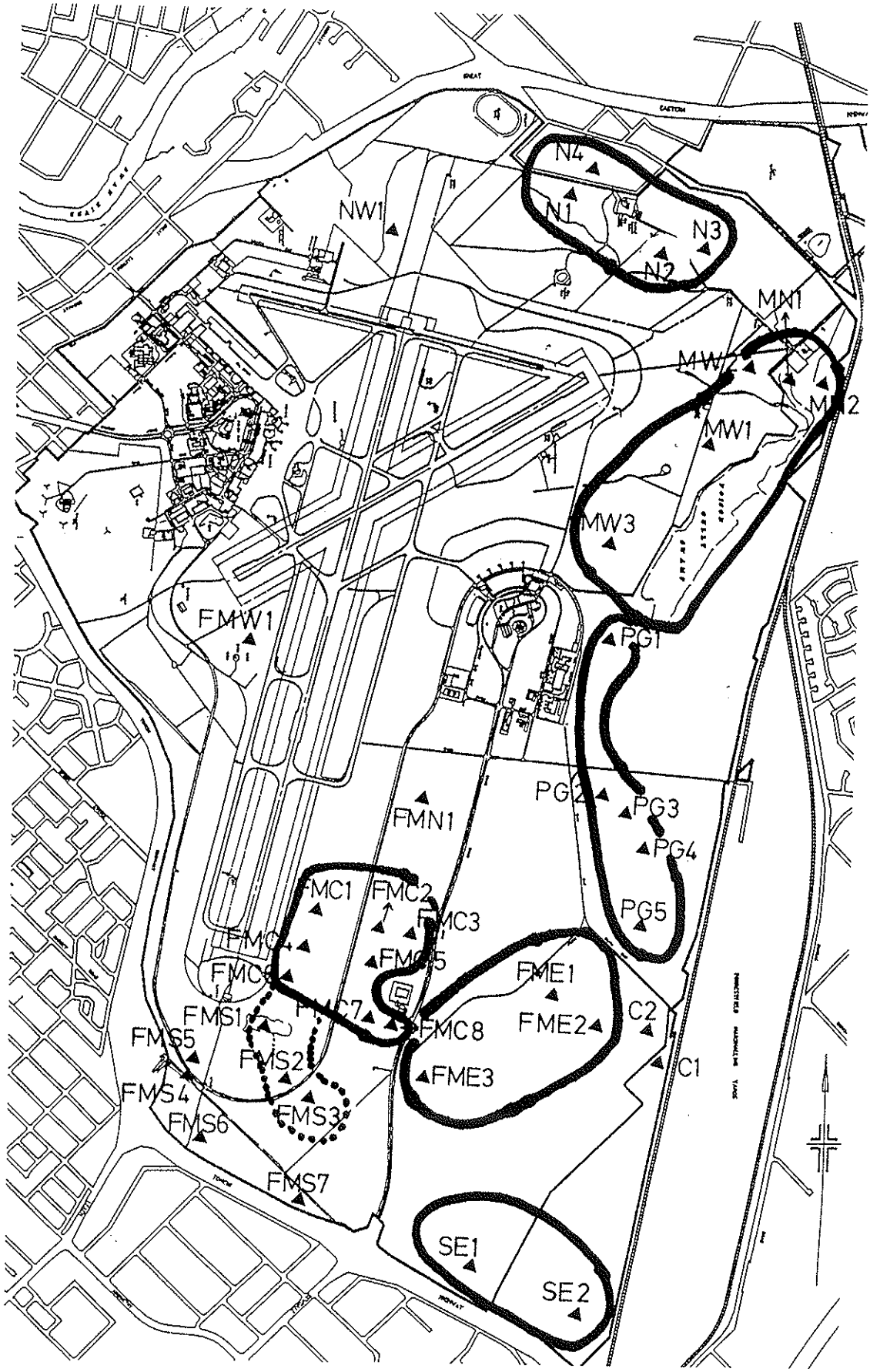

Figure 47: Map of Perth Airport with the groups of swamps proposed for Western Swamp Tortoise habitat conservation and rehabilitation.

Figure 48: *Chelodina oblonga* female with crushed shell, possibly caused by a horse. 29.09.1995, found floating in FME1.

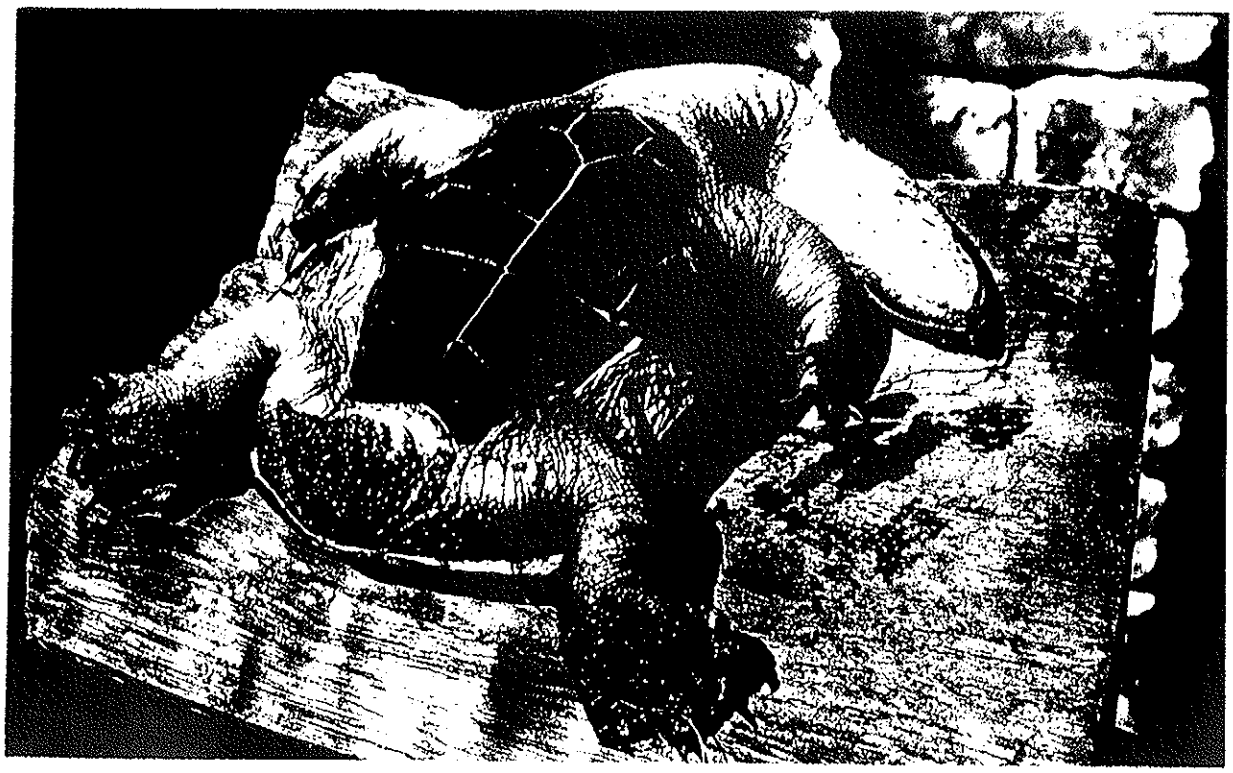

Figure 49: *Chelodina oblonga* female with crushed shell, same animal as in Fig. 48. Left plastral bridge broken. 29.09.1995.

Figure 50: *Chelodina oblonga* male with crushed shell and extruded intestines, possibly caused by a horse. 28.10.1995, found floating in FME1.

Figure 51: *Chelodina oblonga* male with crushed shell, same animal as in Fig. 50. Right and left plastral bridge broken. 28.10.1995.

Aquatic Invertebrate Surveys and Water Quality of Perth Airport Swamps

S.A. Halse[1] and A.W. Storey[2]

[1]*Department of Conservation and Land Management, Science and Information Division, PO Box 51, Wanneroo 6065*
[2]*Wetland Research and Management, 93 King Street, East Fremantle 6158*

Introduction

The Western Swamp Tortoise, *Pseudemydura umbrina*, is listed as endangered under Schedule 1, Part 1 of the Commonwealth Endangered Species Protection Act 1992 and there are legal obligations on landholders and developers to provide information about likely impacts of proposed developments on the tortoise. A business and recreational park is proposed at the southern end of Perth Airport, subject to environmental review. Because a Western Swamp Tortoise was captured in the vicinity in 1970 and the species may still occur in the area, the Western Swamp Tortoise Recovery Team was commissioned to evaluate (1) the abundance of tortoises on Airport land and (2) the suitability of swamps on Airport land as habitat for tortoises. The information will be used to assess likely impacts of proposed developments on the Western Swamp Tortoise.

This report focuses on the suitability of the swamps on land at Perth Airport for Western Swamp Tortoises, as judged by water quality, the abundance of potential food items and similarity with other swamps where tortoises are known to occur. In addition, the conservation value of the airport swamps for aquatic invertebrates is examined briefly. Information on abundance of tortoises and a more comprehensive evaluation of the potential of the Airport swamps as tortoise habitat are provided in a larger document, of which this report forms part.

Methods

Wetlands sampled

Nine of the ten wetlands selected for measurement of water quality and collection of invertebrates contained water and were sampled on 12 September and 8 November 1995 (Swamps A2, A3, A10, A12, A14, A33, A34, A37, A42) (Fig. 1). Swamp A13 was dry on both occasions. The codes used as wetland names in this report differ from those in the main document (Table 1).

Water quality measurements

Measurements and water samples were taken from a representative site in each wetland for all parameters except depth, which was estimated in the deepest part of the wetland. The parameters and methods of measurement are listed in Table 2.

Invertebrate sampling

A single invertebrate sample consisting of a 50 m sweep with an FBA-type pond net was taken from each site on each sampling date. A mesh size of 110 μm was used.

The net was kept just above the substrate to reduce the amount of detritus collected, meaning that invertebrates in the water column and on submerged aquatic vegetation were sampled better than truly benthic species. The 50 m sweep was not continuous so that as many micro-habitats as possible were sampled. Most swamps contained large quantities of submerged macrophytes and leaf litter so that plant material accumulated rapidly in the net and reduced the efficiency of sampling. Therefore, the net was cleaned of detritus every 15 m or so. Tadpoles were collected as well as invertebrates, and, because they were potential food items, they were included in all analyses of biomass.

Invertebrate samples were preserved in the field with 70 % alcohol. In the laboratory, plant material and organic matter were removed and the animals were sorted into commonly recognized invertebrate categories (usually the taxonomic level of Order or Family) (Table 3). When keys were available, the species present in each category were identified (sometimes animals were sent to a specialist taxonomist). The biomass of each invertebrate category and tadpoles was then determined by oven-drying at 60 ^{o}C to estimate (1) abundance of each category and its relative importance in terms of community structure and (2) the amount of potential food that each category could provide to tortoises.

Comparison with Nature Reserves swamps

The existing population of Western Swamp Tortoises is centred on the Ellen Brook Nature Reserve, but low numbers persist in Twin Swamps Nature Reserve. Both reserves are in the Upper Swan Valley and are referred to herein as the Nature Reserves.

As part of the Western Swamp Tortoise Recovery Plan, extensive measurements of water quality and biomass of aquatic invertebrates were made from 1991 to 1994 at Ellen Brook and in three swamps at Twin Swamps - namely East, North-West and South-West. Invertebrates were identified to species level where possible in 1992. The methodology was the same as used at the Perth Airport swamps except that replicate samples were collected - three sets of water quality measurements and five invertebrate sweeps at each site on each sampling occasion. To help evaluate the suitability of the Airport swamps as habitat for Western Swamp Tortoises, unpublished results for September from the Nature Reserves were compared with results from the Airport swamps. Mean values of the replicate were used for Nature Reserves swamps.

Analyses

The analyses of water quality and invertebrate data were divided into four sections.

1. Tabulation and examination of data, including assembling a list of invertebrate species present.
2. Multivariate comparison of water quality in Airport and Nature Reserves.
3. Multivariate comparison between Airport swamps in terms of (1) biomass of different invertebrate groups and (2) species composition. Biomass values were $\log(x.10^{4}+1)$ transformed
4. Multivariate comparison of Airport and Nature Reserves swamps in terms of (1) biomass of different invertebrate groups and (2) species composition.

The PATN computer package (Belbin 1992) was used for multivariate analyses, which consisted firstly of classifying the swamps into groups of sites with similar attributes using an agglomerative hierarchical fusion technique (flexible UPGMA), the Bray-Curtis association measure and a β-value of -0.1. This produced a dendrogram indicating relationships between sites. Usually an ordination was also performed to show how discrete the groups were in terms of the parameters used in the classification (it is common to find groups overlap in many parameters). Ordinations were performed using SSH with a cut level of 0.9 and 10 random starts. In some cases gradients in water quality data were superimposed on ordinations using Principal Axis Correlation.

Results

A total of 120-130 invertebrate taxa were collected in the Airport swamps (Appendix lists 130 taxa but some of these are probably redundant because many young animals could be identified only to genus). The number of taxa listed for different swamps varied from 56 at A33 in September to 17 in the same swamp in November. Swamps usually had 20-40 taxa, with fewer species in November than September although the reduction at A33 was much more pronounced than elsewhere (Appendix).

The species richness at the Airport swamps fell into the range observed for wetlands on the coastal plain near Perth by Davis *et al.* (1993), although A33 was at the upper end. However, there were some interesting records. The endemic copepod *Boeckella geniculata*, collected from A34, is known from only six other sites, all temporary pools in south-western Australia (Bayly 1992). Similarly *Boeckella bispinosa*, which occurred at A37, is restricted to the Perth area and a single location in Tasmania. The species was not recorded in Perth wetlands by Davis *et al.* (1993), although it is moderately common in the Nature Reserves swamps. Another copepod, *Hemiboeckella andersonae*, which occurred in A3, A10, A33 and A34, was previously known from only 10 pools and swamps in south-western Australia, including some Nature Reserves swamps. Several of the ostracod species collected from the Airport swamps were undescribed and *Cypretta* sp. 441 has not been collected anywhere previously.

Total biomass of invertebrates and tadpoles varied considerably between swamps and between sampling dates (Fig. 2). The highest biomass recorded in a 50 m sweep was approximately 4.5 g dry weight at A12 in September; the lowest was <0.01g dry weight at A10 in November. Biomass values at all swamps in September were equivalent to or, usually, much greater than the September biomass values of 0.2-0.5 g dry weight recorded from Ellen Brook between 1991 and 1994.

In terms of water quality in September, all Airport swamps were fresh with <400 mg/L Total dissolved solids (Table 4). pH varied from 5.8 to 7.4 and levels of turbidity were low. Nutrient levels were low in all swamps except A12, which had high levels of phosphorus. Water varied from moderately coloured to dark but some swamps, especially A14, contained significant levels of chlorophyll, indicating that planktonic algae were present. Dissolved oxygen levels varied from 49 % saturation at A37 to 102 % at A2. Silica levels were high in A42.

In terms of ionic composition, bicarbonate was the dominant anion in A2, A12 and A14 whereas chloride dominated in A10 and A34. A14 was the only swamp where cations were not dominated by sodium. Most Australian waters are sodium chloride dominated but bicarbonate dominance is moderately common in very fresh water.

Water quality at Airport and Nature Reserves swamps

Five groups of swamps were recognized in a multivariate analysis of water quality data from the Airport swamps and Nature Reserve swamps in September (the number of groups chosen is arbitrary but should usually be close to the square root of the number of sites) (Fig. 3). For the Nature Reserves swamps, which had been sampled four times, water quality was fairly consistent across years so samples from Ellen Brook, South-West and North-West formed separate groups. East was an exception; its water quality varied between years. All Airport swamps clustered together, except for A12, which was grouped with North-West. Because we sampled only one year we could not examine constancy of water quality for the Airport swamps.

The ordination based on the water quality data showed that Ellen Brook and South-West had distinctive water quality, while differences between North-West, East and the Airport swamps were small (Fig. 4).

Community structure at Airport swamps

In the absence of good information about dietary preferences of the Western Swamp Tortoise, suitability of a swamp as tortoise habitat for feeding is probably best judged by comparing its overall community structure to that of known tortoise habitat. In an initial comparison of the different Airport swamps, we used biomass of each of the major invertebrate categories and tadpoles as a measure of community structure but found that the swamps clustered into two groups according to sampling date (A42 was an exception in that its November sample fell in with the September samples from other swamps) (Figs 5 and 6). The most likely reason for the strong seasonality in groupings was the large decline in biomass at Airport swamps between September and November. Within the September cluster, A2, A3, A10, A14 and A37 formed one sub-group, while A12, A33, A42 and A37 formed another.

As the basis for a a second comparison of the Airport swamps, we used species composition. Once again, swamps fell into two groups according to time of sampling although the September sample from A37 clustered among the November samples (Fig. 7). There was little similarity in relationships between swamps across sampling dates. Nor were the sub-groups based on biomass similar to those based on species composition (Figs 5 and 7).

Biomass of invertebrates in swamps around Perth usually increases between September and November; the decline in the Airport swamps, together with other evidence that several swamps had dried and re-flooded between sampling occasions and the inconsistent relationships between swamps across the two sampling dates, suggested that community structure in November may have been aberrant. Therefore, we concentrated our analyses on September samples.

Comparison of community structure at Airport and Nature Reserves swamps

When biomass of the major invertebrate categories was used to compare Airport and Nature Reserve swamps, six groups were recognized. Samples from Ellen Brook and North-West and three of the East samples fell into one cluster, together with A3, A10, A12 and A33 (Fig. 8). Samples from the same swamp in different years grouped together, showing that community structure as measured by biomass of invertebrate categories was usually stable across time and characteristic of each swamp. Samples from South-West occurred in another cluster, together with A42. Samples from A37, A2 and A34 fell into single sample groups, while A14 was lumped with the East sample from 1993. Ordination once again showed the consistency of consecutive samples from Nature Reserves, except for East Swamp in 1993 (Fig. 9). Of the Airport swamps, only A14, A34 and A37 were well separated from the Nature Reserves swamps.

When environmental gradients were laid over the ordination in Figure 9, the strongest correlations between community structure and water quality were with Dissolved oxygen ($r = 0.75$), Total dissolved solids ($r = 0.70$), Colour ($r = 0.65$), Total nitrogen ($r = 0.65$), Silica ($r = 0.60$) and Chlorophyll ($r = 0.59$).

A comparison of the Airport and Nature Reserves swamps based on species composition produced rather different relationships (Fig. 10). At the three-group level all the Nature Reserves swamps clustered together in one group. At the four-group level, Ellen Brook split off. The Airport swamps exhibited the same relationships as they did in the earlier classification of Airport swamps only (Fig. 7), except that A37 clustered with A2, A3 and A14 as an outlier, instead of being grouped with November samples. Ordination reinforced that the major division was between the Airport and the Nature Reserves. This may be partly owing to greater sampling intensity at Nature Reserves swamps (five sweeps instead of one), which produced more species per site . On the other hand, there were some obvious differences in species composition between the Airport swamps and those in the Nature Reserves.

Overlaying water quality data on the species composition ordination produced strong correlations with Chlorophyll ($r = 0.85$), Turbidity ($r = 0.74$), Total nitrogen ($r = 0.71$), Alkalinity ($r = 0.63$), Colour ($r = 0.63$), Dissolved oxygen ($r = 0.62$), pH ($r = 0.54$) and Total dissolved solids ($r = 0.48$).

Discussion

In assessing the suitability of the Airport swamps as tortoise habitat, we used water quality data, total biomass of invertebrates and tadpoles, and invertebrate community structure as indicators. We used two measures of community structure: biomass of major invertebrate categories and species composition. The biomass data, which combined information about productivity, swamp type and location, appeared to give better results than the species data, which was probably sensitive to small-scale environmental changes and random events.

Issues such as the duration of inundation, availability of nesting areas and likelihood of predation, which will be dealt with in the main document, may often have greater impact on the suitability of swamps for the Western Swamp Tortoise than water quality and the availability of food. Therefore, our conclusions about the suitability of

swamps for tortoises need to be read in conjunction with recommendations in the main document.

Another caveat is that little is known about the limits of tolerance of the Western Swamp Tortoise. We detected differences between the Airport swamps and the Nature Reserves swamps, which presumably represent the best habitat for the species. However, multivariate analyses are designed to find differences; we cannot judge whether the differences were large enough to render any swamp unsuitable for tortoises without including sites that are just outside the habitat range of the tortoise in the analyses.

Based on water quality data, A12 is most similar to the Nature Reserve swamps, being part of the North-West cluster (Fig. 3). However, the ordination in Figure 4 showed that differences between all Airport swamps, North-West and East are small. North-West and East are both regarded as prime tortoise habitat.

Total biomass of invertebrates at all Airport swamps in September was high enough to support tortoises, if the biomass in Ellen Brook is taken to represent adequate food levels. The same was not true of November, however, when all swamps, except A2, had dramatically reduced biomass and A10, A14, A33, A34 and A37 may not have had enough food to support tortoises. However, we doubt whether November 1995 represented typical conditions in the swamps and tentatively suggest that total biomass in the Airport swamps is adequate to support Western Swamp Tortoises.

Community composition based on biomass suggested that A12, A33 and, especially A3 and A10, were similar to North-West. A42 was similar to South-West , where tortoises also occur. A14, A34, A37, and, to a lesser extent A2, differed in some aspects of community composition from the Nature Reserve swamps.

Conclusions and recommendations

Given that A12 had the most similar water quality to the Nature Reserve swamps and had similar community composition to North-West, it must be viewed as suitable habitat for Western Swamp Tortoises. A3 and A10 must also be considered to be suitable because of the similarity of their community composition to that of North-West. A33 had high biomass and similar community composition to the Nature Reserve swamps; therefore, it should also be viewed as likely tortoise habitat. Other swamps may also provide suitable habitat and, as stated above, none can be excluded as tortoise habitat without better information about the biology of the Western Swamp Tortoise.

A14, A34 and A33 have claim to conservation importance for reasons other than the Western Swamp Tortoise. The undescribed ostracod, *Cypretta* sp. 441, has been found only at A14. A34 is one of only seven sites where the copepod, *Boeckella geniculata*, has been collected. Fifty-six invertebrate taxa were collected from A33 in September, which is a high species richness for a swamp on the Swan Coastal Plain (see Davis *et al.* 1993) and makes it worthy of conservation.

Conditions at the Airport swamps in November 1995 appeared to be unusual, so that the information presented here is based on September samples. Additional monitoring

of water quality and community structure based on biomass, in November as well as September, would enable the swamps to be characterized better. Future monitoring should include sites where tortoises are unlikely to occur, as well as some of the Nature Reserves swamps.

Acknowledgments
The following helped with identifications: Russel Shiel (Cladocera), Don Edward (Chironomidae), Sue Harrington (Culicidae), Mark Harvey (Hydracarina) and Shirley Slack-Smith (Mollusca).

References

Bayly, I.A.E. (1992). The non-marine Centropagidae (Copepoda:Calanoida) of the world. SPB Academic Publishing, The Hague.

Belbin, L. (1992). PATN: pattern analysis package. CSIRO Division of Wildlife and Ecology, Canberra.

Davis, J.A., Rosich, R.S., Bradley, J.S., Growns, J.E., Schmidt, L.G. and Cheal, F. (1993). Wetlands of the Swan Coastal Plain, vol.7: wetland classification on the basis of water quality and invertebrate community data. Water Authority of Western Australia, Perth.

Table 1. Codes used in this report and wetland names used in main document.

Code	Wetland
A2	North Swamp 2
A3	North Swamp 3
A10	Five Mile Centre Swamp 6
A12	Five Mile South Swamp 3
A13	Five Mile South Swamp 2
A14	Five Mile South Swamp 4
A33	Five Mile East Swamp 1
A34	Five Mile East Swamp 3
A37	Poison Gully Swamp 3
A42	Five Mile Centre Swamp 8

Table 2. Water quality parameters measured at the Perth Airport swamps. Measurements made by the Chemistry Centre of Western Australia are marked *.

Parameter	Units	Method of measurement
Depth	m	Estimated
Conductivity	mS/m	Conductivity meter
Total dissolved solids	mg/L	Gravimetry
Alkalinity	mg/L	Titration, expressed as $CaCO_3$
Ionic composition	mg/L	Atomic emission spectrometry or autoanalyser
pH		Meter
Colour *	TCU	Absorbance at 465 nm
Turbidity *	NTU	Nephelometric turbity meter
Total soluble persulphate nitrogen *	mg/L	Persulphate digestion and colorimetric determination
Total soluble persulphate phosphorus *	mg/L	Persulphate digestion and colorimetric determination
Total chlorophyll *	mg/L	Acetone extraction, spectrophotomic determination with HCl acidification (includes *a*,*b*,*c*)
Phaeophytin *	mg/L	Acetone extraction, spectrophotomic determination with HCl acidification
Silica	mg/L	autoanalyser
Dissolved oxygen	%	Meter

Table 3. Invertebrate categories used for measurement of biomass.

Category	General description
Tadpoles	
Molluscs	Snails
Annelids	Worms
Hydracarina	Water mites
Anostracans	Fairy shrimps
Conchostracans	Clam shrimps
Cladocera - Daphnia	Water fleas
Cladocera - others	
Ostracods	Seed shrimps
Copepods	
Decapods	Gilgies etc
Amphipods	Scuds
Isopods	Slaters
Culicids	Mosquitoes
Chironomids	Midges
Stratiomyids	Soldier flies
Other Diptera	
Zygopterans	Damselflies
Anisopterans	Dragonflies
Ephemeropterans	Mayflies
Notonectids	Backswimmers
Corixids	Water boatmen
Coleopterans	Beetles
Trichopterans	Caddisflies
Lepidopterans	Moth larvae

Table 4. Water quality data from the Airport swamps in September 1995.

	Depth	Conduc	TDS	Alkal	Ca	Mg	Na	K	CO3	HCO3	Cl	SO4	NO3	pH	Colour	Turbid	N	P	Chloro	Phaeo	SIO2	DO
	m	tivity	mg/L	inity	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L		TCU	ity	mg/L	mg/L	phyll	phytin	mg/L	%
A2	0.4	28.7	180	50	19	7	34	2	1	61	44	11	0.02	7.31	200	1.4	1.5	0.02	0.016	0	1.2	102
A3	0.5	35.2	230	53	19	7	45	3	1	65	59	14	0.01	7.37	300	1.5	1.8	0.02	0.013	0.012	2	92
A10	0.8	36.9	310	13	7	11	55	3	1	15	82	23	0.02	5.78	600	3.7	2	0.02	0.001	0.006	15	60
A12	0.5	24.5	300	78	14	12	26	13	1	95	24	10	0.03	6.93	960	1.5	3.9	5.1	0.005	0.006	8.4	75
A14	0.9	35.9	250	50	30	14	25	6	1	61	31	73	0.01	6.68	190	0.6	1.2	0.09	0.024	0.004	5.5	81
A33	0.8	52.5	360	63	18	12	78	6	1	76	100	17	0.01	7.2	410	2.6	1.8	0.03	0.001	0.004	2.9	82
A34	0.3	27.8	200	23	6	5	45	4	1	27	60	9	0.02	6.67	420	14	1.4	0.02	0.004	0.003	4	67
A37	0.8	36.6	300	45	11	7	58	3	1	55	70	12	0.01	6.56	610	42	2.8	0.29	0.007	0	6.6	49
A42	0.4	47.4	380	70	17	12	70	6	1	85	82	21	0.02	6.86	600	8.8	2	0.05	0.002	0	16	51

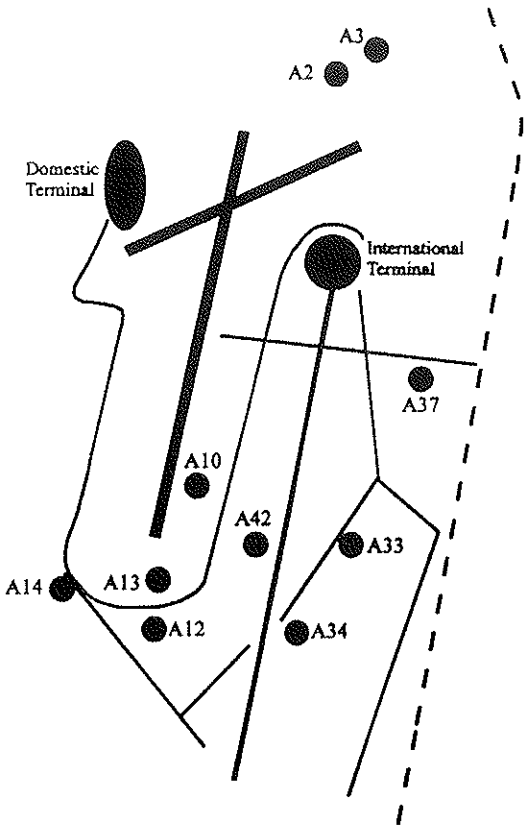

Figure 1. Location of swamps sampled for water quality parameters and aquatic invertebrates near Perth Airport.

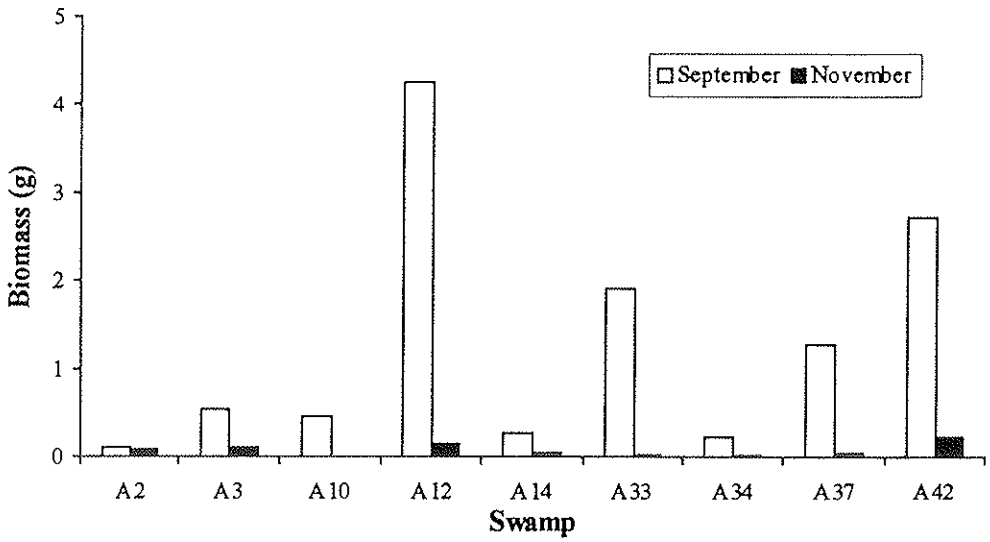

Figure 2. Total biomass of invertebrates and tadpoles (g dry weight) in 50 m sweeps of Airport swamps in September and November.

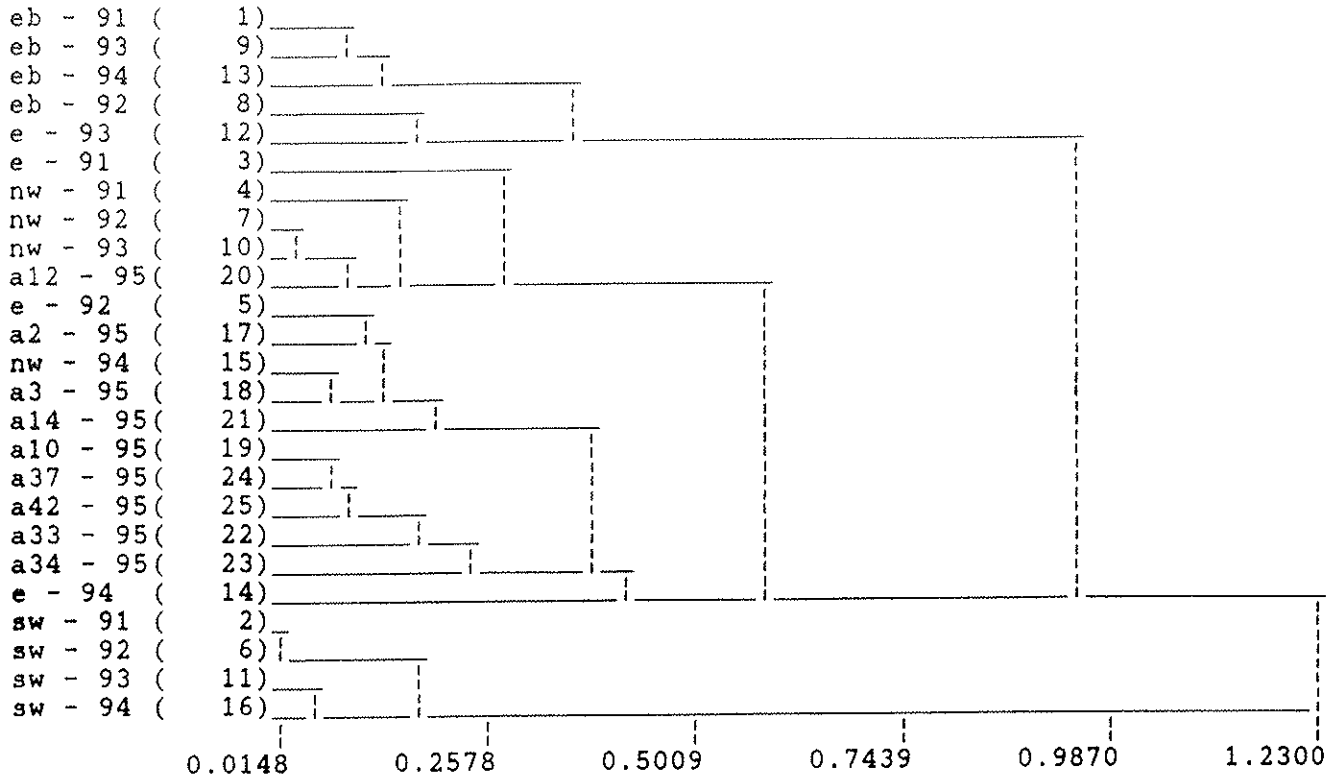

Figure 3. Classification of Perth Airport Swamps with Twin Swamps and Ellen Bk using environmental data for each year (September samples only:- Ellen Brook = eb; Twin Swamps: e = East, nw = North West, sw = South West; Perth Airport: a2, a3, a10, a12, a14, a33, a34, a37 & a42).

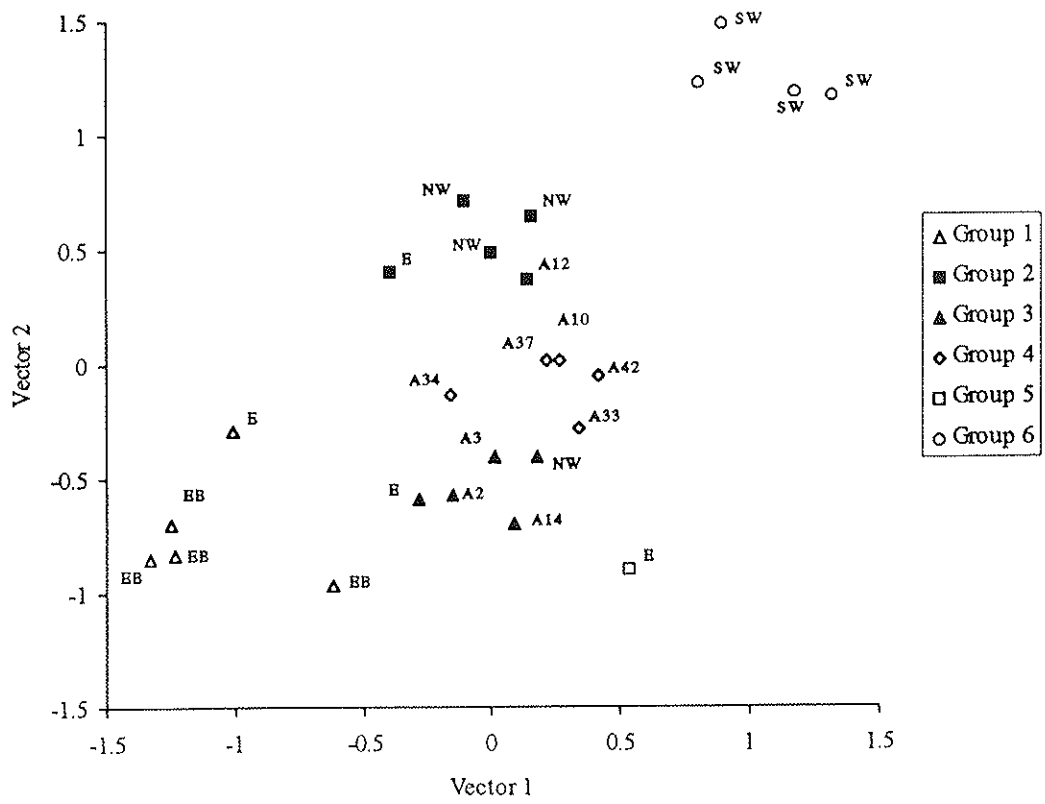

Figure 4. Ordination of Airport and Nature Reserves swamps based on environmental data showing the discreteness of groups recognized in Fig. 3.

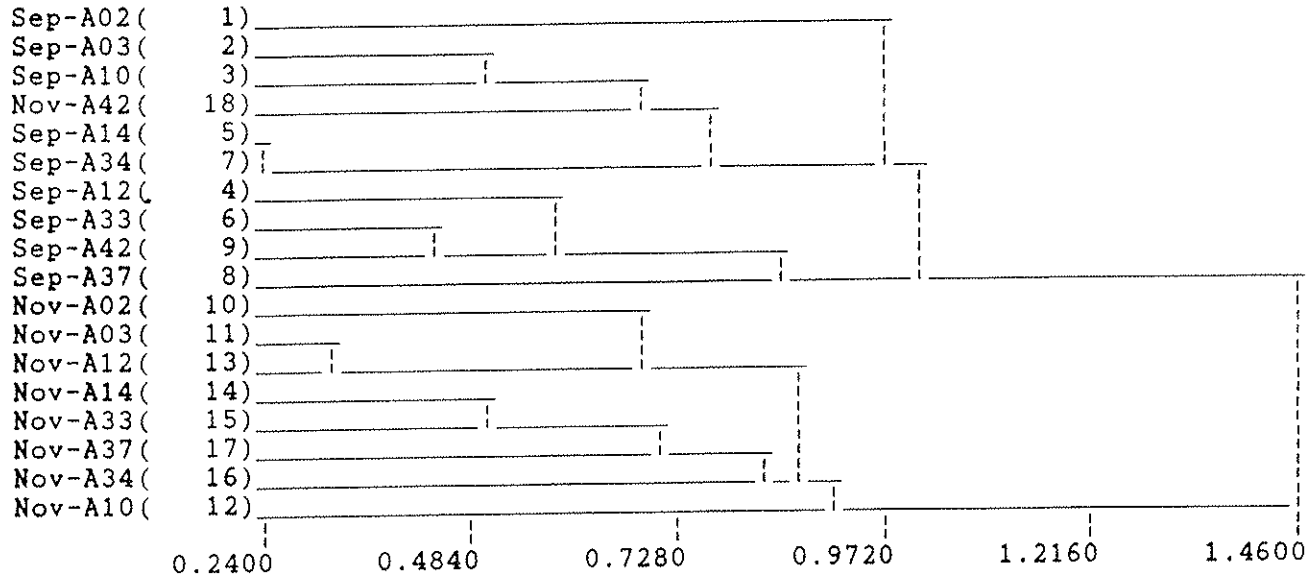

Figure 5. Classification of Perth Airport Swamps (September & November 1995) using biomass of invertebrates (mg) in each category (swamps identified by month sampled and swamp number).

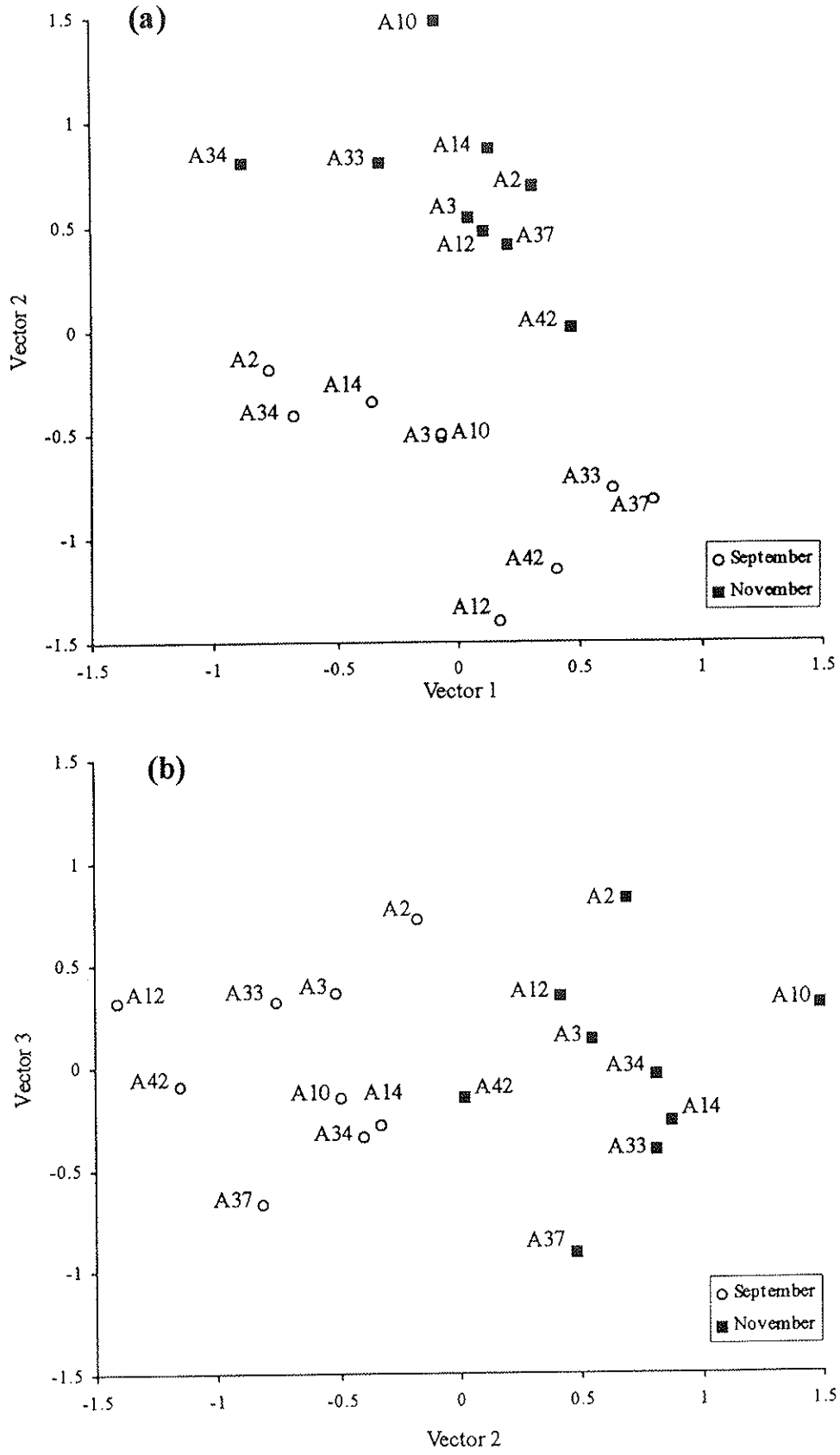

Figure 6. Ordination of Airport swamps using biomass data from September and November.

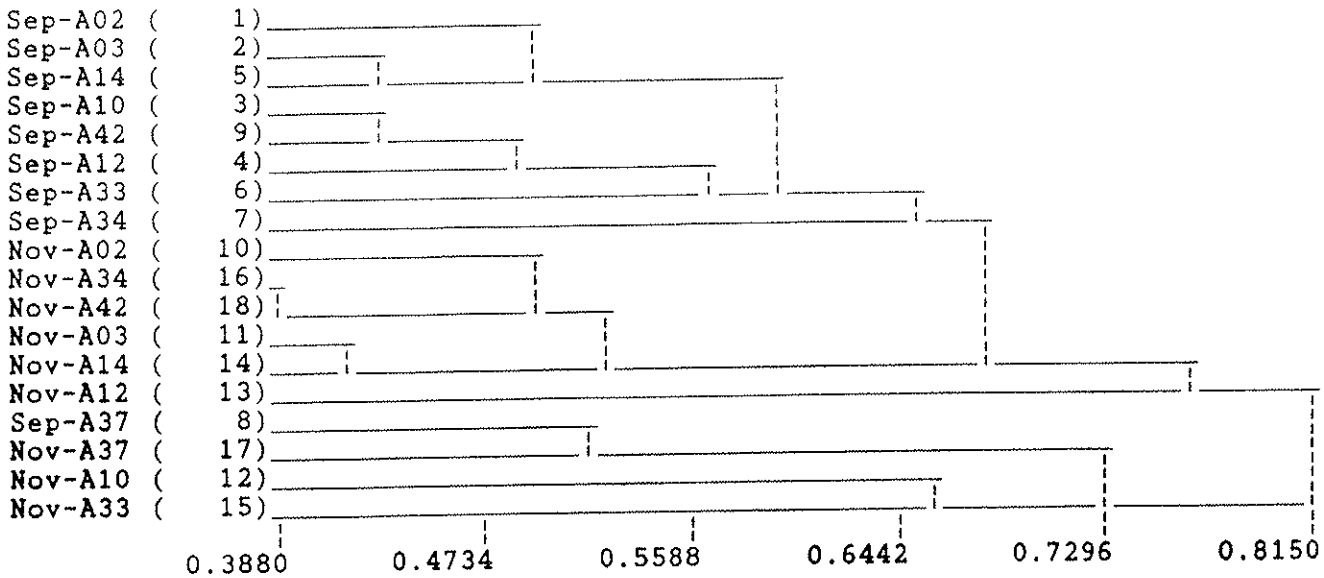

Figure 7. Classification of Perth Airport Swamps (September & November 1995) using invertebrate community structure.

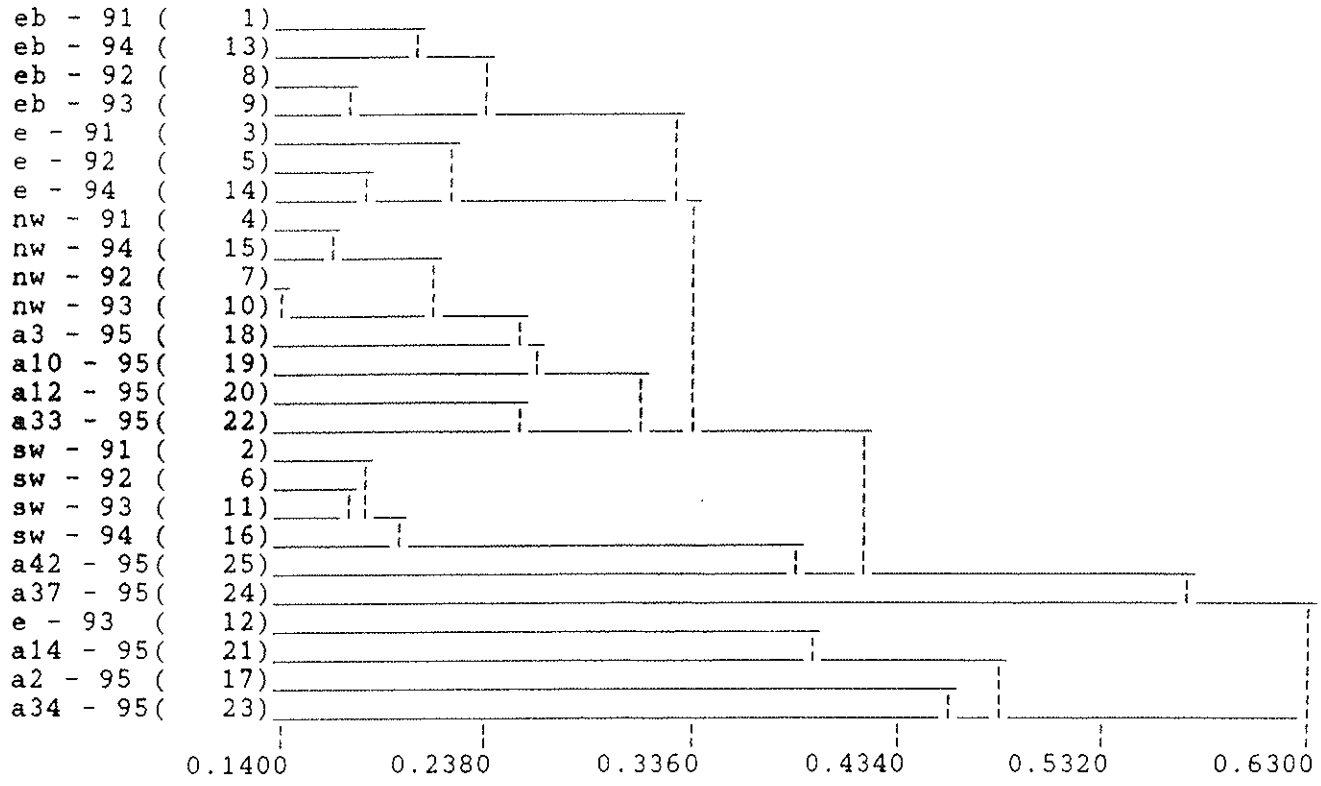

Figure 8. Classification of Perth Airport Swamps with Twin Swamps and Ellen Bk on biomass of invertebrates in each category for each year (September samples only:- Ellen Brook = eb; Twin Swamps: e = East, nw = North West, sw = South West; Perth Airport: a2, a3, a10, a12, a14, a33, a34, a37 & a42).

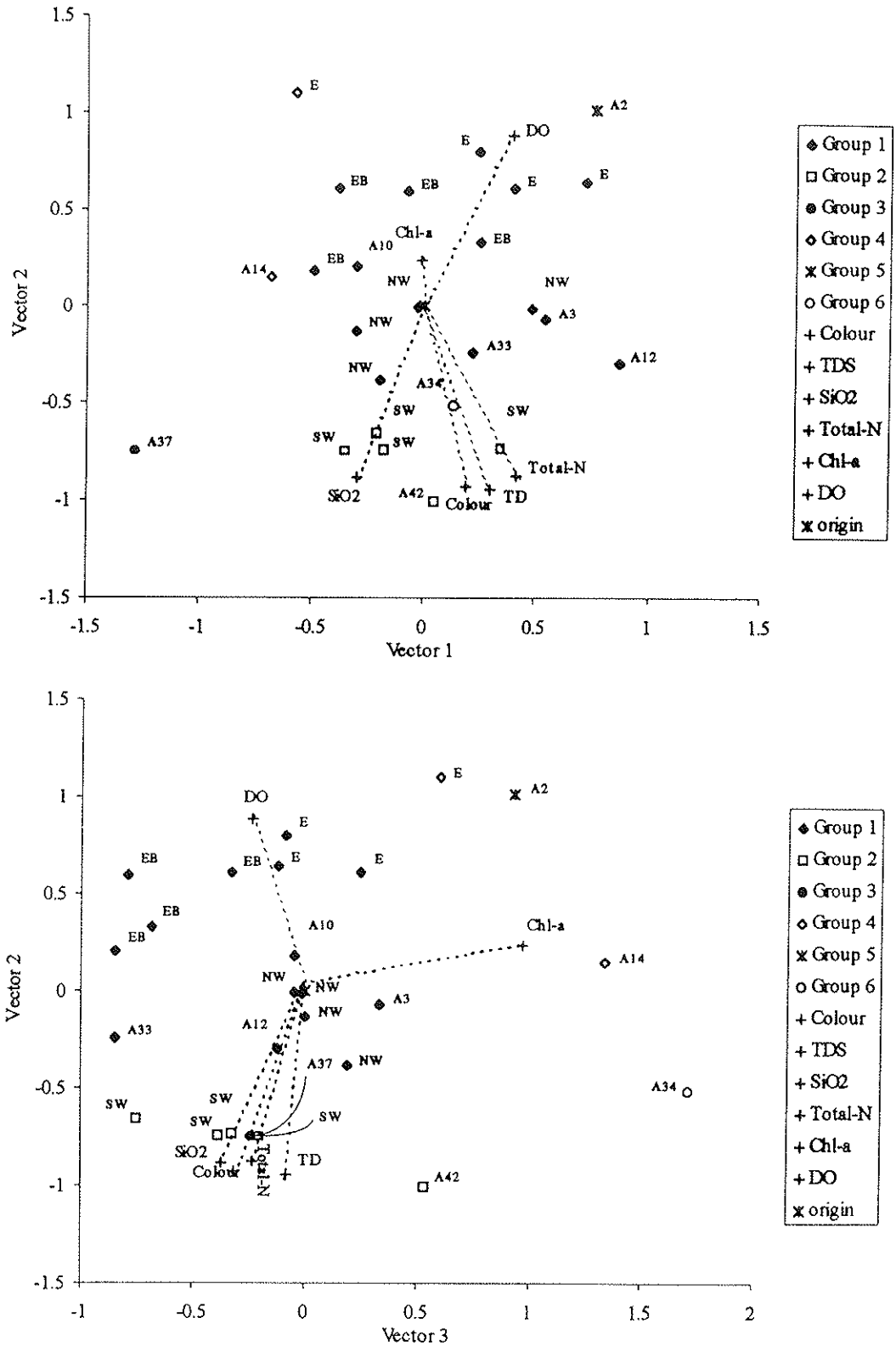

Figure 9. Ordination of Airport and Nature Reserves swamps based on biomass data from September.

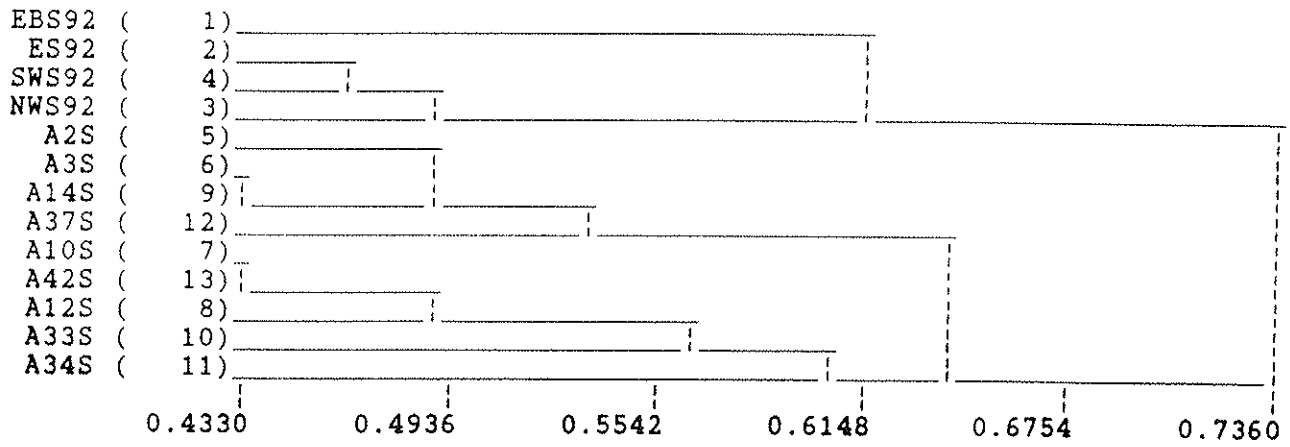

Figure 10. Classification of Perth Airport Swamps (September 1995) with Ellen Brook (EB) and Twin Swamps (E, east; SW, South west; NW, north west) (September 1992) using invertebrate community structure.

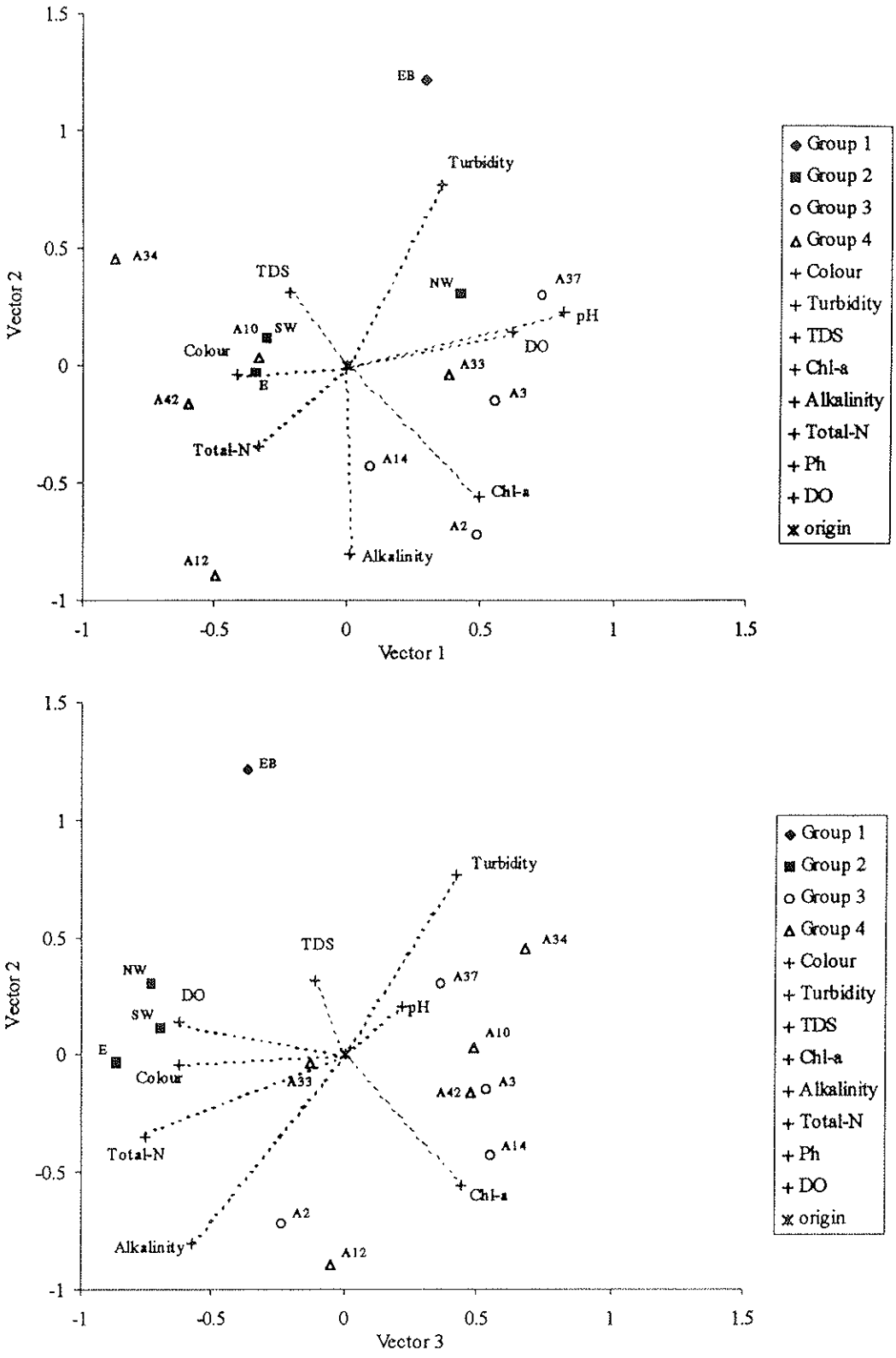

Figure 11. Ordination of Airport and Nature Reserve swamps based on species composition data.

Appendix. Aquatic invertebrate taxa collected at the Airport Swamps in September and November 1995.

ORDER	FAMILY	SPECIES	2 Sept	2 Nov	3 Sept	3 Nov	10 Sept	10 Nov	12 Sept	12 Nov	14 Sept	14 Nov	33 Sept	33 Nov	34 Sept	34 Nov	37 Sept	37 Nov	42 Sep
Cnidaria	Hydridae	*Hydra sp.*		1	1	1		1				1		1		1	1		
Mollusca-Gastropoda	Succineidae	*Succinea sp*												1					
	Ancylidae	*Ferrisia petterdi*						1					1			1	1	1	
	Planorbidae	*Physastra sp.*					1						1				1	1	1
Turbellaria		*Turbellaria spp*			1										1				
Annelida - Oligochaeta		*Oligochaeta sp.*											1						
Oribatida		*Oribatida spp.*		1			1	1	1			1	1		1	1			1
Hydracarina	Eylaidae	*Eylais sp. A*					1						1						
	Pionidae	*Acercella falcipes*	1		1		1				1	1					1		
		Piona murleyi			1		1		1	1	1	1				1		1	
		Pionidae sp.				1													
	Limnesiidae	*Limnesia sp. A*			1	1					1	1	1				1	1	
	Arrenuridae	*Arrenurus sp. A*			1	1													
Mesostigmata		*Mesostigmata sp.*					1								1				
Concostraca	Limnadiidae	*Eulimnadia sp.*					1						1						1
	Lynceidae	*Lynceus sp.*	1		1		1		1										1
Cladocera	Chydoridae	*Archepleuroxus baylyi*													1				
		Chydorus sp		1															
		Biapertura sp					1												
		Biapertura aff affinis											1						
		Biapertura aff setigera													1				1
		Dunhevedia aff crassa		1									1						
		Gen nov sp nov											1		1				
		Pleuroxus sp	1	1	1	1	1		1	1	1	1			1		1	1	1
		Aff Pseudochydorus sp				1													
		Alona aff diaphana		1															
	Macrothricidae	*Macrothrix sp*	1										1				1		
	Daphniidae	*Ceriodaphnia sp*	1		1		1		1		1	1			1	1			1
		Daphnia carinata	1		1		1		1		1		1		1	1			1
		Simocephalus sp A		1	1	1					1		1				1	1	
		Scapholegeris kingi					1							1	1	1			
		Daphniopsis sp													1				
		Simocephalus sp B		1						1				1					
	Moinidae	*Moina sp*						1											
Ostracoda	Cyprididae	*Alboa worooa*									1				1				1
		Cypretta sp. 272	1	1				1	1	1	1	1	1		1	1	1	1	1
		Cypretta baylyi					1			1				1					
		Cypretta aff globulosa										1		1	1	1			1
		Cypretta sp. 441									1	1							
		Cypericercus sp. 442	1					1					1						
		Bennelongia australis		1	1	1	1	1	1	1	1	1	1	1			1	1	1

		Bennelongia sp. 277					1	1					1		1				
		Candonocypris novaezelandiae								1									
		Ilyodromus sp. 255								1									
		Sarscypridopsis aculeata								1									
		Strandesia sp. 436		1	1	1	1									1			
		Eucypris virens															1		
Copepoda	Centropagidae	*Boeckella robusta*	1				1				1		1				1		
		Boeckella bispinosa															1	1	
		Boeckella geniculata													1	1			
		Boeckella sp.					1												
		Calamoecia attenuata	1		1	1					1	1							
		Calamoecia tasmanica	1	1	1	1	1	1	1		1	1		1			1	1	
		Hemiboeckella andersonae			1			1					1		1				
	Cyclopoidae	*Microcyclops sp. EB1*															1	1	
		Mesocyclops sp. EB1	1	1	1				1	1	1	1				1	1		1
		Paracyclops chiltoni								1									
	Canthocamptidae	*Canthocamptus australicus*									1								1
Decapoda	Parastacidae	*Cherax tenuimanus*													1				1
Amphipoda	Ceinidae	*Austrochiltonia subtenuis*					1		1				1						
Isopoda	Phreatoicidea	*Paramphisopus palustris*			1		1						1		1		1		1
	Tanypodiinae	*? Parachironomus sp.*	1			1							1						
		Ablabesmyia ?notabilis	1			1		1					1	1					
		Chironomus aff. alternans	1	1			1		1	1	1	1				1			
		Chironomus tepperi							1										
	Orthocladiinae	*Corynoneura scutellata*	1	1	1	1	1		1		1	1	1		1	1	1		1
		Cricotopus sp.	1	1	1	1		1					1	1				1	
		Dicrotendipes ?conjunctus	1	1	1	1							1						
		Larsia ?albiceps	1	1															
		Limnophyes pullulus	1		1		1		1		1	1	1		1	1	1		1
	Chironominae	*Orthocladiinae ?sp.V44*													1				1
		Orthocladiinae sp.			1				1		1		1		1				1
		Paramerina levidensis	1			1						1	1				1		
		Procladius paludicola											1						
	Tanytarsini	*Tanytarsus sp.*		1	1						1		1	1	1	1			
	Culicinae	*Aedes macintoshi*					1						1		1				1
		Anopheles annulipes	1	1	1	1						1	1	1		1			
		Culex australicus	1						1	1	1				1	1			
		Aedes alboannulatus	1						1	1									
	Chaoborinae	*Promochlonyx australiensis*					1						1		1				
	Stratiomyidae	*Stratiomyidae spp.*		1		1			1			1		1					
	Ceratopogonidae	*Ceratopogonidae spp.*		1		1		1	1				1	1	1	1	1	1	1
	Ephydridae	*Ephydridae sp.*		1	1			1		1	1					1			
	Muscidae	*Muscidae sp.*	1										1						
Lepidoptera	Pyralidae	*Pyralidae sp*		1		1		1	1	1		1				1			
Odonata - Zygoptera	Coenagrionidae	*Ischnura aurora/heterosticta*				1				1				1					
		Ischnura sp.		1														1	

	Lestidae	*Austrolestes io*						1										
		Austrolestes analis						1										
		Austrolestes annulosos		1														
Odonata - Anisoptera	Aeschnidae	*Aeschnidae sp.*	1		1		1	1					1					
		Anax papuensis		1					1									
	Libellulidae	*Libellulidae sp.*							1									
		Diplacodes bipunctata		1														
Ephemeroptera	Baetidae	*Cloeon sp.*				1		1										
Hemiptera	Notonectidae	*Anisops hyperion*							1		1							
		Anisops thienemanni							1									
		Anisops sp.	1	1	1	1		1					1	1			1	1
	Corixidae	*Agraptocorixa sp.*			1		1		1				1	1				1
		Micronect robusta			1	1	1	1			1		1					1
Coleoptera	Dytiscidae	*Allodessus bistrigatus*	1						1	1			1					1
		Antiporus femoralis	1		1		1		1				1					1
		Bidessus sp.	1							1								
		Homeodytes scutelaris			1	1	1						1					
		Hyphydrus sp.							1									
		Liodessus ?inornatus			1													
		Megaporus sp (l)	1										1				1	
		Paracymus pygmaeus	1						1	1		1						
		Rhantus sp. A larva									1							
		Rhantus sp. B larva								1								
		Rhantus suturalis	1						1				1				1	
		Sternopriscus browni							1	1			1					
		Sternopriscus sp. (l)												1				
		Dytiscidae sp. ?(SAHV020)																1
	Haliplidae	*Haliplus gibbus/fuscatus*			1			1					1					
	Hydrophilidae	*Hydrophilidae sp. (l)*	1	1	1			1	1	1	1		1				1	1
		Berosus approximans				1			1				1					1
		Berosus sp (l)		1									1				1	
		Enochrus sp. (SAHV23)				1												
		Hydrochus sp. (SAHV34)				1												
	Helodidae	*Helodidae sp.*	1	1	1		1				1		1		1		1	1
	Scirtidae	*Scirtes sp.*																
	Curculionidae	*Curculionidae sp.*											1					1
	Carabidae	*Carabidae sp.*			1													
	Limnichidae	*Limnichus sp.*															1	
		Coleoptera sp(l)							1									
Trichoptera	Leptoceridae	*Triplectides australis*		1		1	1		1	1		1	1			1		1
		Leptoceridae sp.H									1	1	1					
	Hydroptilidae	*Hellyethira malleoforma*		1		1	1		1	1		1	1			1		1
		Hellyethira ?simplex		1		1	1		1	1		1	1			1		1
		No. Taxa	35	34	36	31	36	21	34	31	27	27	56	17	29	23	26	18	36